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Insight



# SEMICONDUCTOR SUPPLY AND PRICING WORLDWIDE

*Dataquest's Semiconductor Supply and Pricing Worldwide program responds to the quick information needs of semiconductor users. Clients of this program receive indispensable information needed to make solid, intelligent, and timely procurement and design-in decisions.*

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- Semiconductor cost models
- Market/product/life cycle analyses
- Semiconductor inventory levels
- Capital spending overview
- Semiconductor user surveys on technologies, products, packaging
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**Worldwide Semiconductor Consumption and Shipment Forecast:** Five-year revenue forecasts for the global semiconductor market by region.

***Available Second and Fourth Quarters 1997***

**Worldwide Semiconductor Market Share:** Market share by company for total semiconductors; total ICs; bipolar digital, memories, and logic; MOS digital, memories, microcomponents, and logic; analog ICs; discrete semiconductors; and optoelectronic semiconductors.

***Available Second Quarter 1997***



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***Available First Quarter 1997***

**Semiconductor Application Directions Focus Report:** Offers a user perspective on what types of semiconductors and technologies the major application markets are using now and in the future.

***Available First Quarter 1997***

**Printed Circuit Board Focus Report:** Includes market demographics, user trends, and forecasts for the PCB market.

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**Semiconductor Procurement User Wants and Needs Report:** Analyzes a new survey of top North American semiconductor users on topics such as technology, product, packaging, and supplier likes/dislikes.

***Available Fourth Quarter 1997***

**Dataquest**
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**Corporate Headquarters**
251 River Oaks Parkway
San Jose, CA 95134-1913
United States
Phone: 1-408-468-8000
Fax: 1-408-954-1780
Fax-Back: 1-800-328-2954 and press 4

**Boston Area**
Nine Technology Drive
P.O. Box 5093
Westborough, MA 01581-5093
United States
Phone: 1-508-871-5555
Fax: 1-508-871-6262

**United Kingdom**
Tamesis
The Glanty
Egham
Surrey TW20 9AW
United Kingdom
Phone: +44 1784 43 1611
Fax: +44 1784 48 8980

**Asia/Pacific**
Suite 5904-7, Central Plaza
18 Harbour Road
Wan Chai
Hong Kong
Phone: 852-2824-6168
Fax: 852-2824-6138

**Japan**
Aobadai Hills 4-7-7
Aobadai
Meguro-ku
Tokyo 153
Japan
Phone: 813-3481-3670
Fax: 813-3481-3644


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**Dataquest**
A Gartner Group Company

251 River Oaks Parkway, San Jose, CA 95134-1913
(408) 468-8000 Fax (408) 954-1780

May 12, 1997

Dear Semiconductor Supply and Pricing Worldwide Client,

I have recently learned of a client database error that could impact the delivery of Dataquest Perspectives for the ***Semiconductor Supply and Pricing Worldwide*** program. Because of this error, you may not have received all of the Dataquest Perspective documents published in 1997 by this service.

Just to be sure that your program binder is up to date, I am resending all of the Perspectives published this year by Semiconductor Supply and Pricing Worldwide. Please file them in your binder behind the Perspective tab divider.

We have corrected the database, and from this point forward all documents should arrive on a timely basis. Please accept my apologies for any inconvenience this error has caused you.

Sincerely,

R. Andrew Holtvedt

R. Andrew Holtvedt
Senior VP and President of Dataquest

encl:
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Perspective



Semiconductor Supply and Pricing Worldwide

# Market Analysis

# Second Quarter 1997 Procurement Pulse: Order Rates Flatten, Lead Times and Inventories Rise, and Spot Prices Exceed Contract Prices

**Abstract:** *The* Procurement Pulse *is a quarterly update (with interval updates, if events warrant) of critical issues and market trends based on surveys of semiconductor procurement managers in the North American region. Besides order rate, lead time, and inventory information, this survey also notes price status by semiconductor product family and package type, as well as key problems facing semiconductor users.*
*By Mark Giudici*

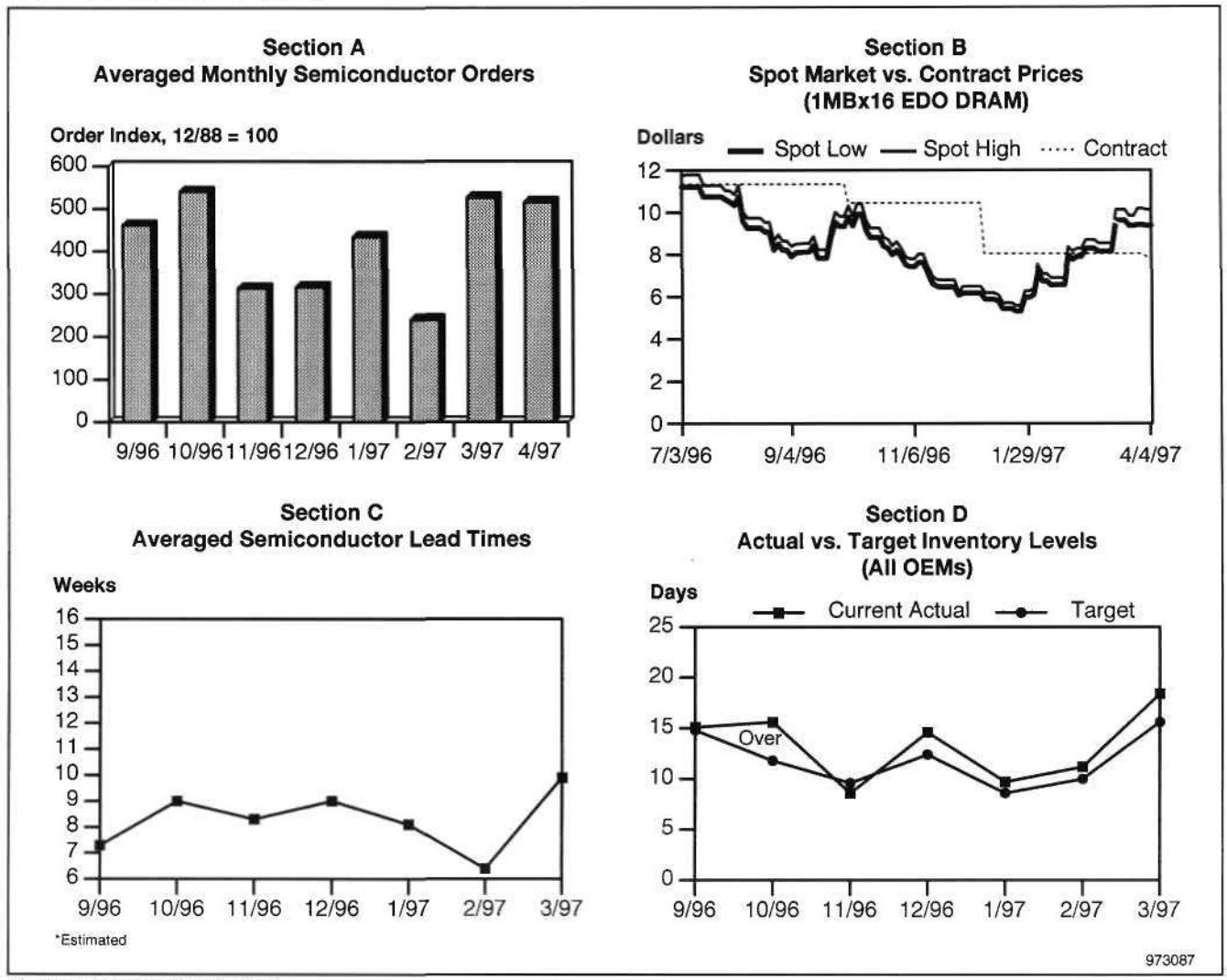
## Semiconductor Order Rate Expected to Bounce Back after Two Months of Cautious Forecasts

As seen in Section A of Figure 1, the outlook for semiconductor order activity has picked up since our last report and is expected to level off in the near term. While flat with March's forecast index, the outlook for April has historically shown where the market heads for the rest of the year, as order rates and inventory levels generally stabilize. This flattening of the order rate may in part be because of some short-term upturns in DRAM pricing noted for the first time in over 16 months. The overall sample continues to see price cuts for larger-volume contracts in all areas tracked in this survey—microprocessors (MPUs), logic, flash memory, and SRAM (except for some DRAMs). DRAM pricing for the overall sample actually rose an average of 4.4 percent in March after an unchanged price picture in February. The computer subset of the respondents saw a smaller rise of 2.8 percent in DRAM prices after unchanged prices noted in February. While overall prices continue to decline, except for DRAM, in the near term, thin small-outline

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packages (TSOPs) and ball grid arrays (BGAs) continue to earn premiums of 5 to 10 percent over more standard package offerings.

**Figure 1**
**Semiconductor Supply**




Source: Dataquest (April 1997)

## Spot Market and Contract Prices Cross Paths

In response to client requests, we have added a new graph to the *Procurement Pulse*. In addition to the spot market prices provided every week in Dataquest's *Semiconductor DQ Monday Report*, we provide Section B to highlight how contract 1Mbx16 DRAM prices compare with spot prices. Although overall demand for semiconductors remains strong, it appears that selected DRAM suppliers have curtailed production or shipments (or both) to stay the tide of DRAM price decline. In the near term, the spot market has reacted with higher prices, while contractual buyers have not noticed this managed market tactic. As noted over the past year, we expect continued volatility, with spot market prices vacillating around declining contract

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prices, causing uncertainty for some buyers. The overall trend, however, is for continued good availability, consistently declining contract prices, and low (eight- to 10-week) lead times for the next six to nine months for contract buyers.

## Lead Times for Semiconductors Near the 10-Week Mark

Section C highlights that the average lead time for respondents in March jumped to 9.9 weeks, compared with a 6.4 week average noted in February. The relative instability of lead times is in part because of the perceived uncertainty of DRAM supplies despite overall good availability of every other semiconductor product segment. The acknowledgment by both buyers and suppliers that 1996-style price cuts and availability are now history is encouraging some prudence among overzealous spot buyers, making contracted deliveries increasingly attractive. Good service levels combined with slowly declining prices are cementing many long-term supplier relationships. Of the entire sample, over 40 percent noted some problem with DRAM, but that was the only product area. The other semiconductor products enjoy good availability and reasonable pricing. Last quarter, over half of the respondents noted price fluctuations/inventory adjustments and end-of-life ordering as the key issues. This month, close to half of the respondents noted only DRAM availability as the main issue.

## Semiconductor Inventories Back to Historical Levels

Section D highlights how inventories continue to overshoot targeted levels and closely track target direction. As respondents forecast semiconductor order rates to flatten, as noted earlier, we see a corresponding slight increase in inventory levels—primarily in DRAMs to offset any near-term real or perceived price increases. The overall targeted and actual semiconductor inventory levels for March were 15.6 days and 18.4 days, respectively, compared with February's 10.0-day and 11.2-day inventory levels. While not shown, the computer subset again appears more aggressive than the average, with current target and actual inventory levels of 12.0 days and 16.3 days. We continue to expect to see stabilized inventory levels in the future in line with system sales levels.

## Dataquest Perspective

Availability of semiconductors remains very good to excellent (despite DRAM market manipulations) and we expect it to remain this way for the rest of 1997. Contract prices continue to decline, despite the efforts of some memory suppliers to curtail output, and lead times have stabilized to meet customer demand. Even with the current increases in the DRAM spot market, the volume of business through this channel remains surprisingly low. This reflects the continued user focus on total cost, not price alone, when determining a component buy. Dataquest continues to forecast steady 1997 growth rates for PCs and other electronics relative to 1996, with the overall trend following an upward growth slope. User semiconductor

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inventory levels are now in line with user demand, and we expect to see continual balance in these indexes in the near future. Real allocations are not a problem, but the near-term DRAM issue may well play itself out, forcing a quicker shift to 64Mb DRAMs if enough suppliers can come up with parts. At this time, this scenario is possible but not highly probable. Dataquest expects to see excellent semiconductor availability through the end of 1997. DRAM and MPU price elasticity to date have not propped up contract prices. While DRAM spot market prices have crossed contract prices on the upward path, the overall DRAM capacity situation will force suppliers sooner or later to release inventory or wafer starts because of economic necessity. The good news for users is that overall declining contract prices will continue to be with us for the rest of this year.

**For More Information...**

Mark Giudici, Director and Principal Analyst ..... (408) 468-8258
Internet address ..... mark.giudici@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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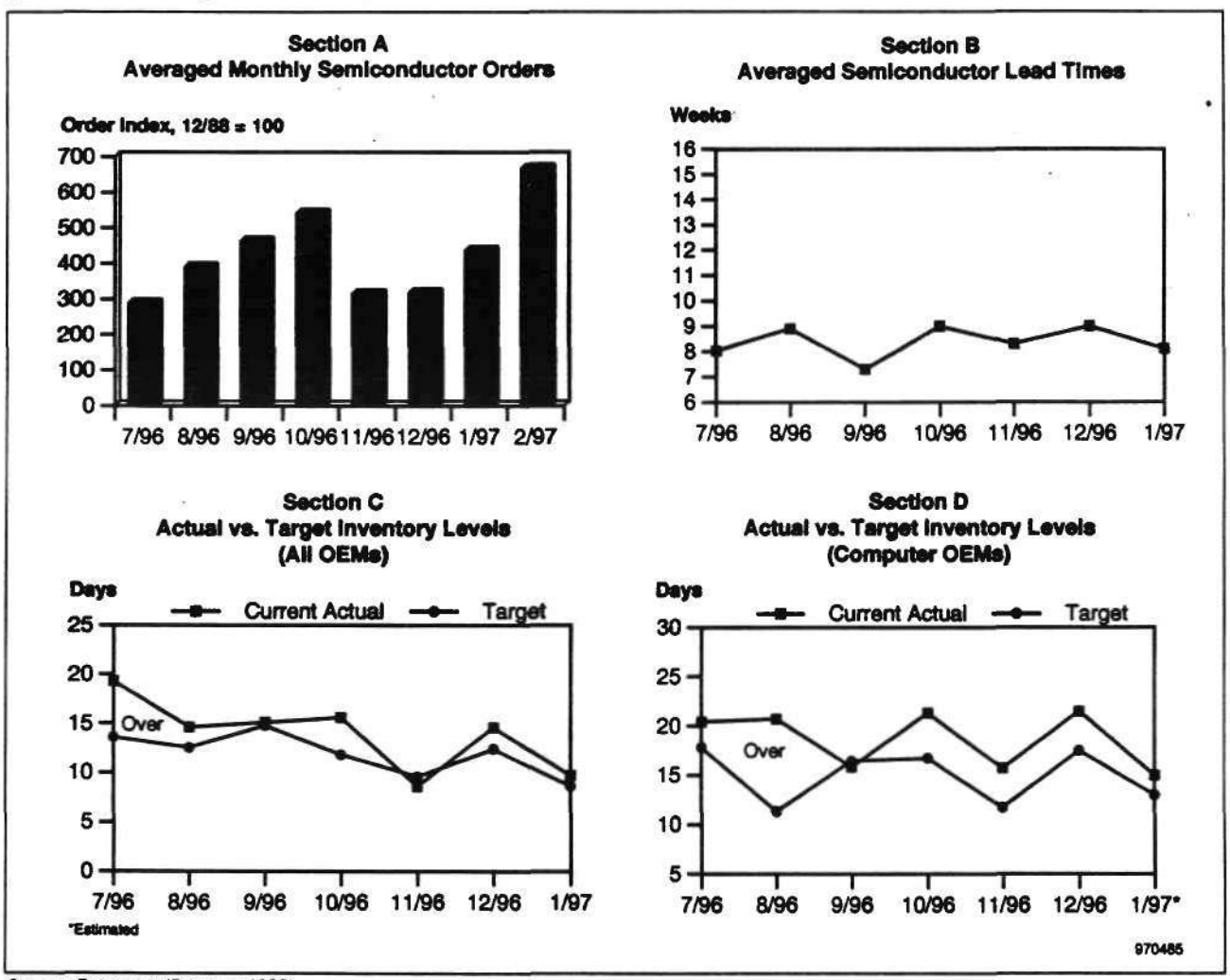
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# February Procurement Pulse: Order Rates Climb Higher while Lead Times and Inventories Decline

The *Procurement Pulse* is a quarterly update (with interval updates, if events warrant) of critical issues and market trends based on surveys of semiconductor procurement managers in the North American region. Besides order rate, lead time, and inventory information, this survey also notes price status by semiconductor product family and package type, as well as key problems facing semiconductor users.




Source: Dataquest (February 1996)


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# First Quarter 1997 Procurement Pulse: Order Rates Rebound while Lead Times and Inventories Stabilize

The *Procurement Pulse* is a quarterly update (with interval updates, if events warrant) of critical issues and market trends based on surveys of semiconductor procurement managers in the North American region. Besides order rate, lead time, and inventory information, this survey also notes price status by semiconductor product family and package type, as well as key problems facing semiconductor users.

**Figure 1**
**Averaged Monthly Semiconductor Orders**

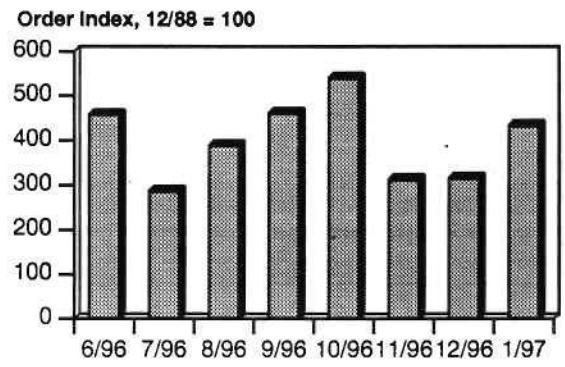



**Figure 2**
**Averaged Semiconductor Lead Times**

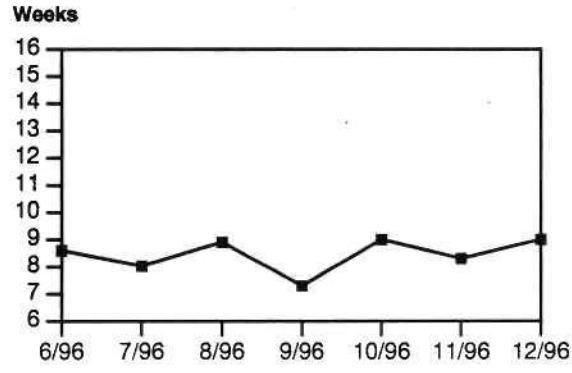



**Figure 3**
**Actual vs. Target Inventory Levels (All OEMs)**

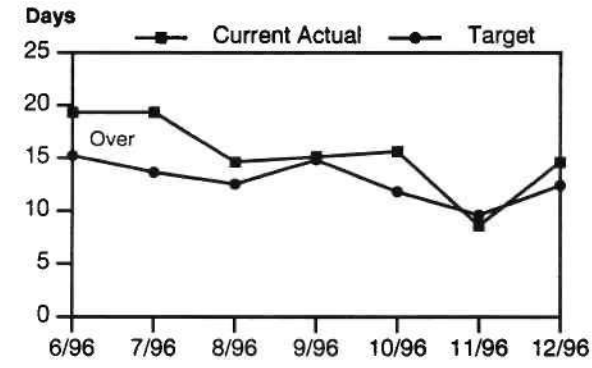
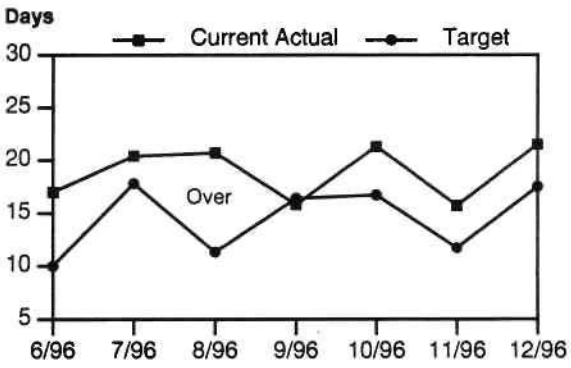



**Figure 4**
**Actual vs. Target Inventory Levels (Computer OEMs)**




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Source: Dataquest (January 1996)


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## Semiconductor Order Rate Expected to Bounce Back after Two Months of Cautious Forecasts

As seen in Figure 1, the outlook for semiconductor order activity is expected to pick up after the slowdown of forecast expectations over the past two months. Although 37 percent higher than last December's forecast index, the outlook for January has historically increased over the inventory rundown-influenced year-end low order outlook. This increase in order activity is expected despite lower overall prices of semiconductors. The continued buoyancy of the electronics market continues to benefit from these price declines where steady unit volumes are being ordered at lower dollar outlays. The overall sample continues to see price cuts for larger-volume contracts in all areas tracked in this survey—DRAM, MPUs, logic, flash memory, and SRAM (especially in DRAM and MPUs). DRAM pricing for the overall sample fell, on average, 1.6 percent in December after a 1.1 percent average drop noted in November. The computer subset of the respondents saw a more aggressive DRAM price cut of 4 percent in December after a 4 percent average drop noted in November. Although overall prices continue to decline, pricing for different semiconductor packaging (except for two respondents using TSOP) has reached parity.

## Lead Times for Semiconductors Hover around Nine Weeks

Figure 2 shows that the average lead time for respondents in December inched up to 9.0 weeks, compared with an 8.6-week average noted in November. The relative stability of lead times around nine weeks over the past three quarters reflects the excellent availability and pricing of parts that has kept customer-required delivery schedules the norm. Now, well over a year into a buyer's market, many procurement managers continue to balance price cuts with supply base relations. Good service levels combined with ever-lower prices are cementing many long-term supplier relations. Out of the entire sample, only two respondents noted problems with products, those being ASICs and some older standard logic parts. For the vast majority of the respondents and the overall market, however, there are no problems regarding product availability or pricing. Like last quarter, over half of this month's respondents noted price fluctuations or inventory adjustments and end-of-life ordering as the key issues now taking precedence. As noted over the past year, we expect the volatility of the spot market to continue to vacillate around declining contract prices, causing uncertainty for some buyers. The overall trend, however, is for continued good availability, consistently declining prices, and low lead times (eight to 10 weeks) for the next six to nine months.

## Semiconductor Inventories Back to Historical Levels

Figures 3 and 4 highlight how inventories have stabilized over the past three quarters and are in synchrony with system unit demand. Even with semiconductor order rates forecast to rise as noted above, we do not expect semiconductor inventories to rise, as availability is good and prices are expected to continue their decline. The overall targeted and actual semiconductor inventory levels for December were 12.4 days and 14.6 days, respectively, compared with November's 9.6-day and 8.6-day inventory levels. The computer subset now appears less aggressive than the average, possibly realigning increases in inventory with anticipated higher first quarter 1997 sales. The current target and actual inventory levels of 17.5 days and 21.5

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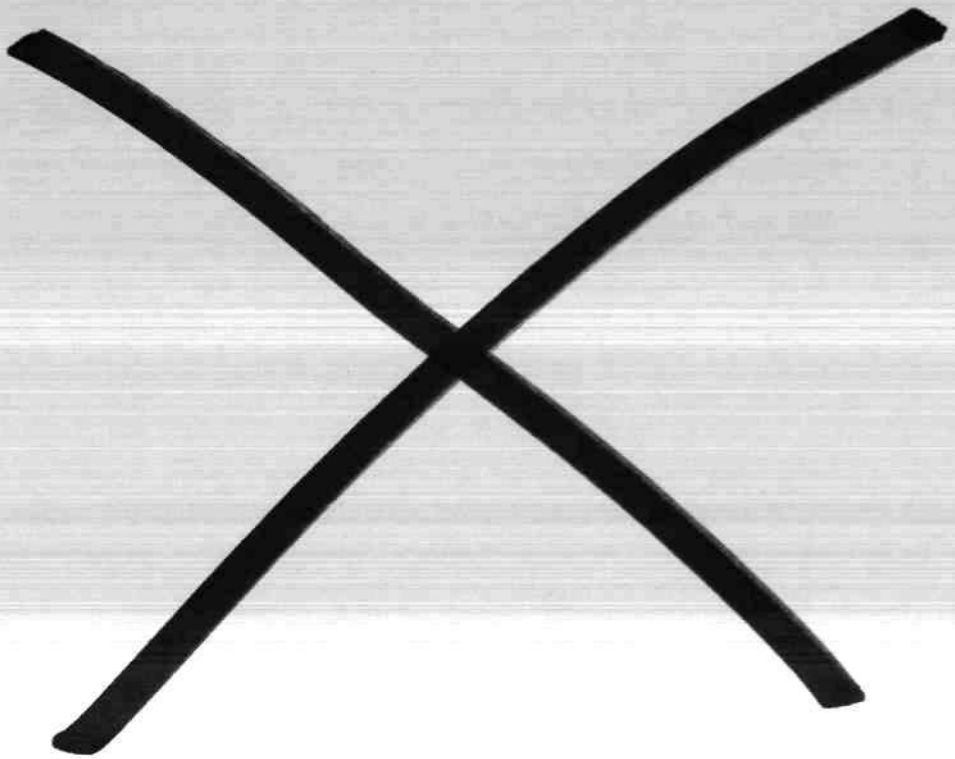
days compare with November levels of 11.7 and 15.3 days on hand for the computer subset. We continue to expect to see stabilized inventory levels in line with system sales levels.

## Dataquest Perspective

Availability of semiconductors remains very good to excellent, and we expect it to remain this way for the rest of 1997. Prices continue to decline, despite the efforts of some memory suppliers to curtail output, and lead times have stabilized to meet customer demand. Even with relentlessly low prices on the DRAM spot market, the volume of business through this channel is surprisingly low. This reflects the focus of users on total cost, not price alone, when determining a component buy. Although Dataquest forecasts steady 1997 growth rates for PCs and other electronics relative to 1996, the overall trend follows an upward growth slope. User semiconductor inventory levels are now in line with user demand, and we expect to see continual balance in these indexes in the near future. Allocations are not a problem, as obsolescence now has users' attention. Dataquest expects to see excellent semiconductor availability through the end of 1997. DRAM and MPU price elasticity to date have not propped up prices. Although the spot market continues to lead contract pricing lower, cost barriers will continue to moderate steep price cuts in this area. The good news for users is that declining prices will continue to be with us for the remainder of this year.

*By Mark A. Giudici*


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Perspective



Semiconductor Supply and Pricing Worldwide

# Market Analysis

# Fourth Quarter 1997 Procurement Pulse: Order Rates Mixed, Lead Times Up, Inventories Jump, and Spot Prices Continue to Lead Contracts Down

**Abstract:** *The* **Procurement Pulse** *is a quarterly update (with interval updates, if events warrant) of critical issues and market trends based on surveys of semiconductor procurement managers in the North American region. Besides order rate, lead time, and inventory information, this survey also notes price status by semiconductor product family and package type, as well as key problems facing semiconductor users.*
*By Mark A. Giudici*

## Semiconductor Order Rate Expected to Bounce Back after Two Months of Cautious Forecasts

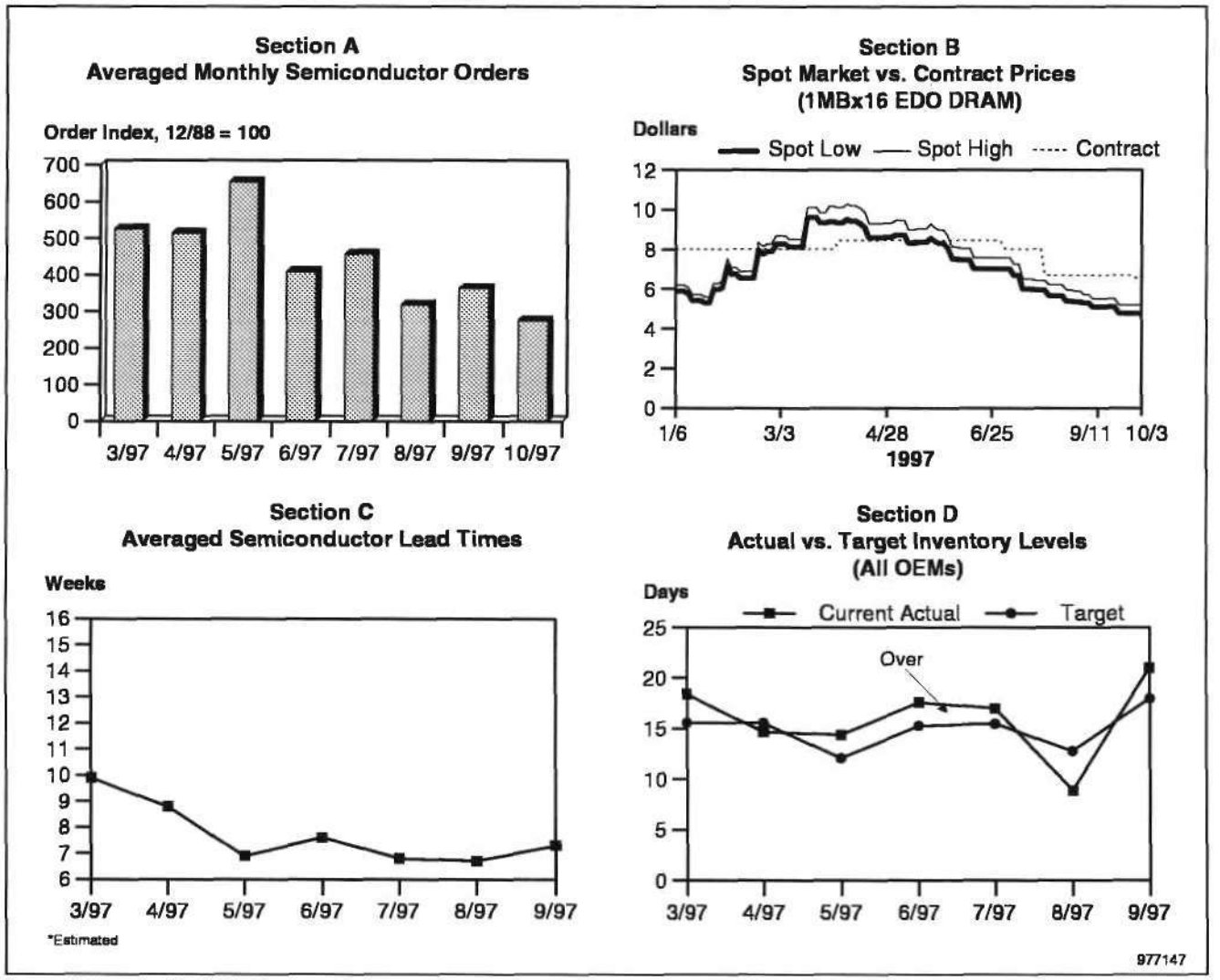
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MARIA VALENZUELA

As seen in Section A of Figure 1, the outlook for semiconductor order activity has gone down and up and now down again since Dataquest's last report. While slightly lower than September's forecast index, the outlook for October has historically been up; the start of the fourth quarter holiday ramp. This year definitely had the "summer slows," and it appears that order activity has not picked up appreciably as the market moves into the fourth quarter. The overall sample continues to see price cuts for larger-volume contracts in all areas tracked in this survey—MPUs, DRAM, SRAM, and, especially, flash memory. Highlighting the resumption of actual supply versus demand, DRAM pricing for the overall sample again declined by 2.3 percent, on average, after a relatively soft 3.9 percent decline in August. The computer subset of the respondents saw a slower decline of 2 percent in DRAM prices after a very abrupt 5 percent cut in August. While overall

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prices continue to fall, TSOP and BGA packages continue to earn (albeit smaller) premiums of 1 to 2 percent over more standard package offerings.

**Figure 1**
**Semiconductor Supply and Pricing**




Source: Dataquest (April 1997)

## Spot Market Pricing Again Leads Contract Pricing—Down

As a popular bellwether, DRAM spot pricing continues to nose-dive, highlighting the oversupply of memory, as shown in Section B. The second quarter scheme to control prices succeeded only in the volatile and low-volume spot market, as shown in the figure. The shift to the 64Mb DRAM device is now in full swing; although Dataquest still foresees a market crossover from the 16Mb part in the second or third quarter of 1998, some individual suppliers may already be there (using their own pricing as a crossover benchmark). As noted over the past year, Dataquest expects spot market prices to continue to vacillate around declining contract prices, causing uncertainty for some buyers. The overall trend, however, is for

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continued good availability, consistently declining contract prices, and low lead times (six to nine weeks) for the next six to nine months for contract buyers.

## Lead Times for Semiconductors Remain Manageable: Under Eight Weeks

Section C shows that the average lead time for respondents in September edged up slightly, to 7.3 weeks, compared with a 6.7-week average noted in August. The current stability of lead times is due in part to the removal of uncertainty over DRAM supplies and the perception of good availability for the near future. Even though spot prices are at all-time lows, most buyers are satisfied with the current low contract pricing and the stability those deliveries provide. Good service levels and slowly declining prices are cementing many long-term supplier relationships. Although there were no supply problems noted in this month's survey, it should be remembered that good communication with suppliers often averts problems. With general availability good and improving, there now appear to be few supply problems to complain about.

## Semiconductor Inventories Back to Historical Levels

Section D shows that inventories continue to overshoot targeted levels after a sharp dip in August. As respondents forecast semiconductor order rates to modulate, there is a corresponding slight increase in inventory levels, more in line with historical levels. The overall targeted and actual semiconductor inventory levels for September were 18.2 days and 20.8 days, respectively, compared with August's 12.8-day and 8.9-day inventory levels. Although not shown, the computer subset again appears more conservative than the average, with current target and actual inventory levels of 22.5 days and 17.5 days, respectively. Dataquest continues to expect to see stabilized inventory levels in the future, in line with steady systems sales levels.

## Dataquest Perspective

Availability of semiconductors remains very good and is expected to remain this way for the rest of 1997 and into early 1998. As Dataquest has noted since last March, contract prices continue to decline despite the efforts of some memory suppliers to curtail output, as noted earlier this year. Lead times have stabilized to meet customer demand, in line with the moderate price declines. Dataquest continues to forecast steady 1997 growth rates for PCs and other electronics relative to 1996, with the overall trend following an upward growth slope. User semiconductor inventory levels are now in line with demand, and continual balance in these indexes is expected in the near future. Real allocations are not a problem, but the attempted quick shift of some suppliers to the 64Mb DRAM density appears to be causing the non-64Mb suppliers with abundant capacity to lower prices faster, resulting in a push-out of planned crossover time frames. Dataquest expects to see excellent semiconductor availability through the second and third quarters of

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1998. DRAM and MPU price elasticity to date have not propped up contract prices. The good news for users is that overall declining contract prices will continue for the remainder of this year and into the next.

**For More Information...**

Mark Giudici, Director and Principal Analyst ..... (408) 468-8258
Internet address ..... mark.giudici@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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Perspective



Semiconductor Supply and Pricing Worldwide

# Market Analysis

## Fourth Quarter 1997 Quarterly Price Survey Highlights

**Abstract:** ***Dataquest has completed its fourth quarter 1997 North American contract pricing survey for the semiconductors tracked. This Perspective analyzes the main signals seen, both overall and by main family type, and their impact on contract buyers worldwide.***
***By Evelyn Cronin***

## General Market Characteristics

For most device families, price reductions are set to continue but at a controlled and stable pace. However, although asynchronous DRAM is still getting over its pricing free fall in the third quarter, Dataquest is still forecasting price reductions for the next 18 months.

Most devices in the growth and maturity phase of their life cycle curve can continue to expect controlled price reductions. Devices ramping up in volume are still showing good price reduction potential. The forecast continued good availability allows buyers to play suppliers off against each other on standard devices to get the best deal.

As of the date of this writing, no supplier has gone public with DRAM production cutback announcements. This may well change if suppliers are faced with the choice of losing money in order to sell products or cutting back production to break even. Often, this decision results in accelerating the migration to newer products and product methods rather than just cutting production.

It would be highly unusual for a supplier to vastly scale back DRAM production in the fourth quarter, which is widely viewed as the busiest quarter for shipments and sales. Production plans may be tweaked to match

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(For Cross-Technology, file in the Semiconductor Devices and User Issues binder)

changing demand patterns, but few vendors will significantly cut production. Most will not amiably surrender market share position; however, some will be forced to walk away from unprofitable orders.

There are many technology changes occurring in the DRAM market. These include 16Mb-to-64Mb density migrations, single in-line memory module (SIMM) to dual in-line memory module (DIMM) changes, and asynchronous to synchronous technology. These changes, coupled with the increased activity anticipated for the fourth quarter, mean that there may be some short-term demand and supply issues on newer products.

In general, lead times have not changed much from the last survey. Availability remains good on most devices, although there may be supplier-specific issues on certain older and newer devices. However, these problems are nothing new.

The following key points are based on the trends seen in Dataquest's *North American Semiconductor Price Outlook—Fourth Quarter 1997* (SSPS-WW-MS-9704, September 1997).

## DRAM

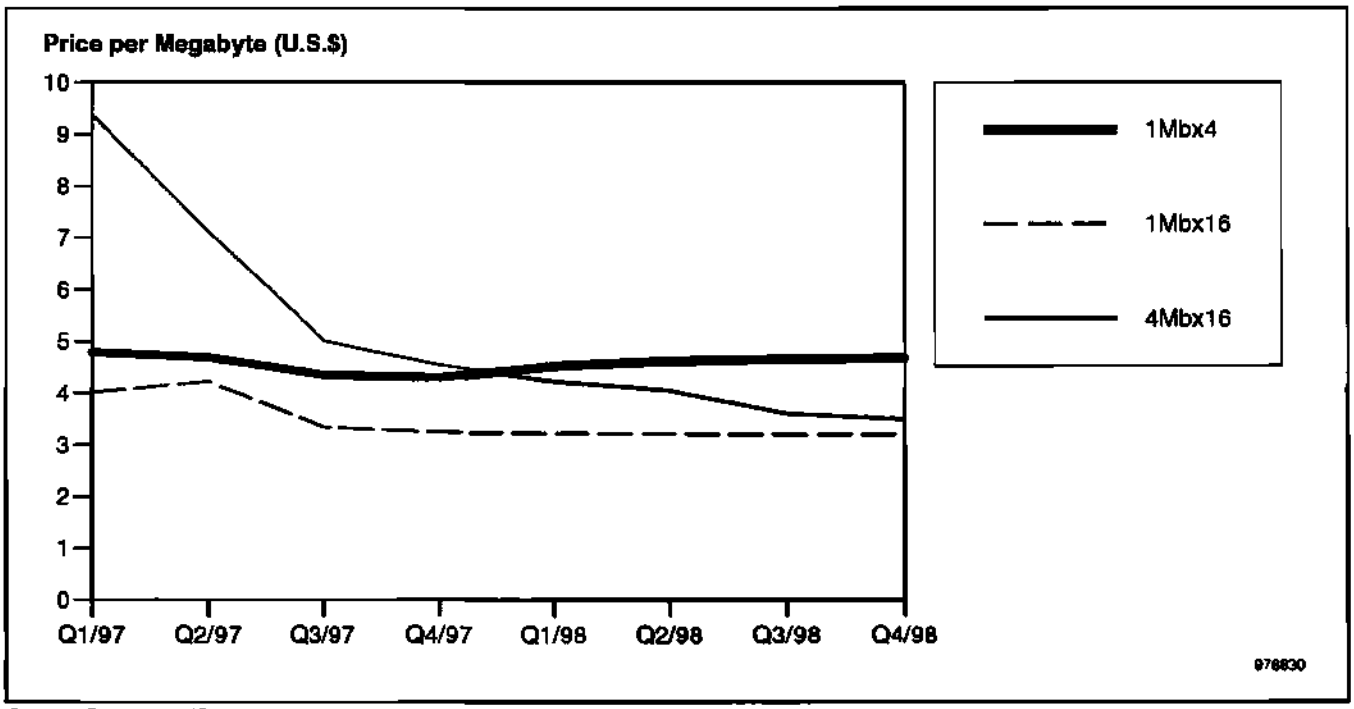
Figure 1 shows the forecast price per megabyte for extended data out (EDO) devices based on Dataquest's fourth quarter 1997 survey. The 16Mb device is the least expensive on a per-megabyte basis for 1997 and 1998. The 4Mb device will start to increase in 1998. User demand has shifted to the 16Mb and 64Mb densities, and suppliers have reduced 4Mb production. Dataquest expects the price to begin to increase. The 64Mb shows the most price volatility over the eight quarters, falling in large steps quarter on quarter. On a per-megabyte basis, the 64Mb will become less expensive than the 4Mb by the beginning of 1998, and, by the end of 1998, the 64Mb will be almost the same price as the 16Mb.

The key points about DRAM are:

- EDO and fast page mode (FPM) 16Mb devices fell dramatically compared to July and August.
- Prices for 4Mb asynchronous devices remained more stable from the second quarter to the third quarter and are forecast to experience controlled price reductions throughout 1998.
- FPM product is more expensive than its EDO equivalent. Survey participants expect that FPM pricing will start to increase in the second half of 1998.
- Price parity remains and is forecast to remain on SIMMs and DIMMs of the same megabyte density and technology.
- SDRAM is more expensive on a price-per-megabyte basis than the EDO equivalent. This holds for both devices and modules, and this difference is forecast to remain throughout 1998.
- Unlike pricing, lead times have not changed from last quarter and run from 3 to 8 weeks.

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**Figure 1**
**Price-per-Megabyte Forecast for EDO DRAM Devices, Fourth Quarter of 1997**




Source: Dataquest (September 1997)

## SRAM

The key SRAM points are:

- The pricing forecast is more aggressive this quarter than last, with pricing estimates lower now than in the third quarter of 1997. Overall pricing is down in this quarter's forecast, especially for the higher-density devices.
- The end-of-life trend that began last quarter is continuing for the lower-density devices tracked (x4 and x8 128Kb and x4 256Kb), and prices are forecast to start rising in 2000.
- For the x8 256Kb cache SRAM, the survey participants are still confident about price reductions.
- For pipeline burst synchronous cache SRAM devices, the 2Mb continues to be priced lower on a per-megabyte basis than the 1Mb at 8ns.
- On the fast x8 1Mb SRAMs, the 15ns is still less expensive than the 20ns and 25ns equivalents. Also, the 20ns and 25ns are showing price parity. However, although the 15ns is the least expensive fast x8 1Mb, the slow 70-100ns version is still lower in price.
- On 4Mb devices, the x8 versions remain less expensive than the x16 versions at equivalent speeds for the duration of the forecast. Also, the 15ns is more expensive than the 70ns version throughout the forecast, based on current respondents' reports. This may change, though.

- By and large, lead times are unchanged, ranging from two to four weeks for sub-1Mb and from three to six weeks for 1Mb. The single exception is the 4Mb family, which actually experienced an increase in delivery lead time. The 4Mb lead times rose from between three and six weeks in last quarter's forecast to between three and eight weeks this quarter.

## Flash

The key points about flash are:

- As with the other memory devices, prices are down again this quarter for the flash devices tracked.
- Also, pricing on lower-voltage devices remains very competitive, and in many cases, the lower the voltage, the less expensive the device long term.
- The x8 1Mb is least expensive in the PLCC/PDIP package. However, the 12V TSOP is less expensive than the 5V TSOP for the entire forecast at this density.
- At the x8 2Mb flash density, the 5V device has been less expensive than the 12V device for all of 1997 and is forecast to remain less expensive in the future, based on the survey inputs.
- On the x8 4Mb SOP flash devices, the 3V has been less expensive than the 5V and 12V since second quarter 1997 and should remain the least expensive of the three for the rest of the forecast.
- However, the PDIP/PLCC x8 4Mb remains less expensive than the least expensive SOP (that is the 3V) for the entire forecast.
- By third quarter 1997, buyers are predicting that the 3V will cost less than the 5V, which will cost less than the 12V on the 8Mb (1Mbx8 TSOP) devices for the same speed. According to survey participants, this will remain true until the end of the forecast period.
- For 16Mb (2Mbx8 TSOP) devices, buyers forecast that 3V will be less expensive than the 5V, which in turn will be less expensive than the 12V by the first quarter of 1998 at the same speed.
- Lead times remain unchanged from last quarter on all flash devices tracked. On average, the 512Kb devices have five-week lead times, the PLCC/PDIP 1Mb is at three weeks, and all other tracked devices are at four weeks.

## Microprocessors

The key points about MPUs are:

- Intel continues its campaign to migrate the market to faster microprocessors with more multimedia capability and is dropping the price of its selected devices appropriately.
- Intel has ceased production of all non-MMX Pentiums and is selling only the products left in inventory. So even though Intel has ended the

production life of these processors, their actual market life will end when Intel sells out.

- The MMX family has experienced very aggressive price reductions and currently is very attractively priced. These devices are gaining momentum, and Intel has high hopes for fourth quarter volumes.
- The Pentium II MPU family is coming down in price but at a less determined rate than the Pentium MMX family. Although the Pentium II is not the high-volume player for 1997, Intel has positioned it to take off next year.
- The Apple clone market is no more, and PowerPC processors are sold only to Apple. Thus, there is less incentive for Motorola Incorporated and IBM to lower prices aggressively.
- Lead times have increased slightly at the low end of the supply window, up from two to three weeks. Thus, this quarter's lead-time range is three to eight weeks.

## Dataquest Perspective

The third quarter was particularly slow from a DRAM demand perspective. There was a particularly large excess of DRAM, and prices fell dramatically. The DRAM spot market was on a downward price spiral throughout the quarter, and, although DRAM was plentiful there, customer orders were few. The DRAM contract market also experienced strong, sharp price reductions, and availability is excellent. Also, because buyers were not holding excess inventory, it is clear that the suppliers had to take the excess inventory risk.

Going into the fourth quarter, survey participants remain fairly bullish about availability and pricing on most device families. Although demand is forecast to be strong, all respondents were sure that supply would still exceed it. Not surprisingly, the survey participants expect good price reductions across the board. Also, lead times remain good, and those surveyed foresaw no major lead-time increases on the horizon.

Intel has taken the pricing bull by the horns, and compute microprocessors have seen some really aggressive price reductions from last quarter. This is particularly true on the Pentium MMX product family, which is attractively priced to hit the volume PC sweet spot for the fourth quarter.

Flash and SRAM continue to exhibit solid price reductions on high-density devices. Availability is good, and buyers do not see any supply problems on the horizon. Lead times have remained largely unchanged from the last quarter for the SRAM and flash devices tracked.

DRAM remains a tricky area. There should be an oversupply on a per-megabyte basis, but there may well be some product transition issues, which may cause instability. The instability may result in an excess of 16Mb EDO product and a pricing bloodbath or temporary shortages of certain synchronous devices. Currently, price parity between EDO and synchronous

DRAM (SDRAM) is not forecast by most respondents for 1997 or 1998. There are a few notable exceptions, though.

The excess of EDO 16Mb product resulted in a dramatic price shift down in the third quarter. All survey participants forecast that this price reduction will continue, albeit at a less stellar rate. The SDRAM product did not experience this sudden drop and so is more costly to buy on a per-megabyte basis, on average.

On all device families, two-way communication between buyer and supplier remains vital. This is particularly so in the fourth quarter, which is the busiest for many semiconductor end applications. Thus, keeping the channels of communication clear and candid helps limit any potential infeed risk.

**For More Information...**

Evelyn Cronin, Senior Industry Analyst ..... (408) 468-8075
Internet address ..... evelyn.cronin@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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Perspective



Semiconductor Supply and Pricing Worldwide

# Market Analysis

# Compute Microprocessor Supplier and Product Update: Intel Dominates Despite Increased Competition

**Abstract:** *This article analyzes the events in the compute microprocessor market from a user's perspective, focusing on products, suppliers, and the near-term direction of this critical market. We examine major CISC and RISC architecture and supply bases in this annual update based on 1996 shipment data.*
*By Mark Giudici and Nathan Brookwood*

## Introduction

This document analyzes developments of the compute microprocessor market from a product-base and supply-base perspective. Dataquest defines compute microprocessors as those using 16/32-bit, 32-bit, 32/64-bit, and 64-bit input/output (I/O) and using both CISC and RISC processors—this group is labeled "computational microprocessors." This category consists primarily of the x86/Pentium families, K5/6 families, and to a lesser extent, open-system RISC processors (Alpha, MIPS, PA-RISC, PowerPC, and SPARC). Because of the level of interest indicated, we have included a review of the PC core logic market in this update. This market continues to change dramatically as suppliers play the game of price/performance one-upmanship at the hardware level while application software support grows in importance as a user decision factor. These factors and others accelerate the rate of change to higher-performance systems while reducing the system life cycles of many leading-edge products.

This document is divided into three sections. The first serves as a guide to the current state of microprocessor families relative to their position in the overall microprocessor product life cycle curve, based on the latest shipment

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data available. The second section examines the strategies of the top suppliers of advanced MPU products,. The third section analyzes the current and future supply base for core logic and technology. Combining individual user company system data with this analysis provides good insight on the current and future supply base.

## MOS Microprocessor Product Life Cycles

This section uses life cycle information as a guide to assist users in adjusting to the forces that continue to reshape the worldwide MPU marketplace.

### Life Cycles for MPU Products Again Stretch Because of Competition Slip

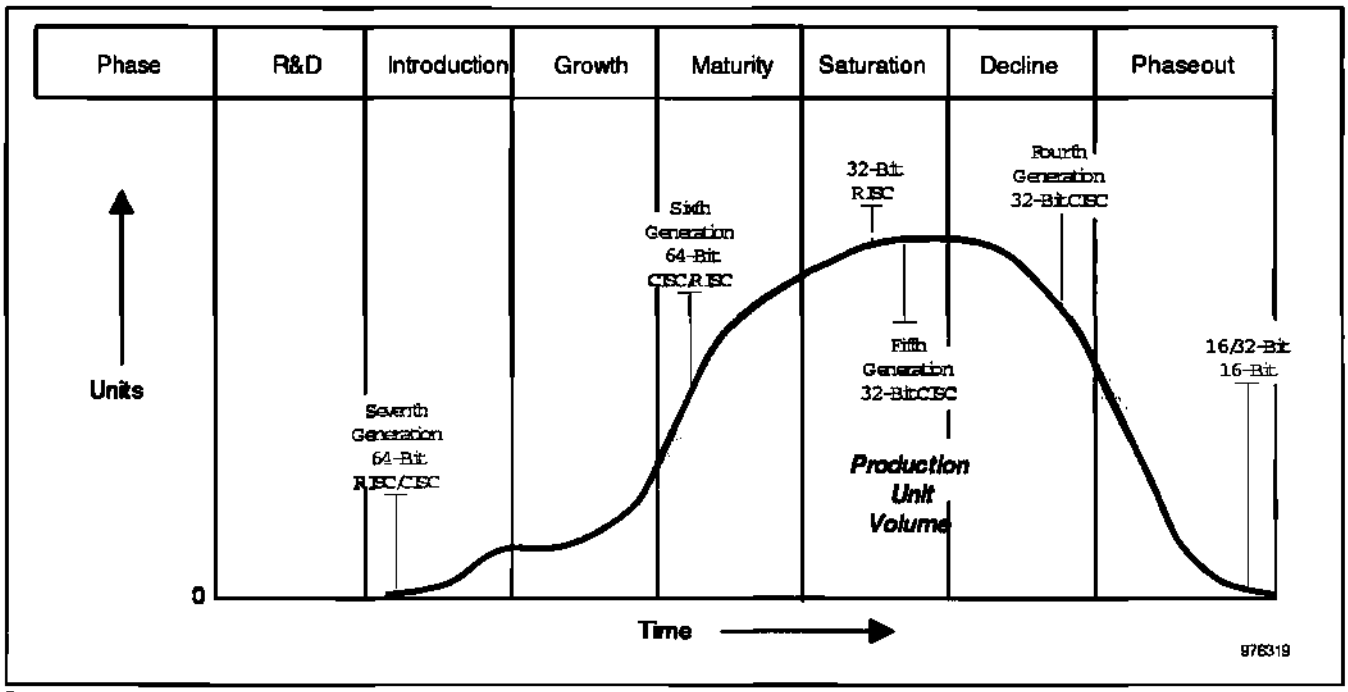
Figure 1 highlights the major change in microprocessor family life cycles, with the rapid acceptance of the fifth-generation processors (Pentium, K5, and 586). Intel Corporation's introductions of its Pentium and Pentium Pro products have slowed from the torrid pace of 1994 and 1995 to the intervals of earlier product releases. This is because of an effective level of competition with Intel's earlier product introductions. This has resulted in an increase in life cycle from the pre-1995 range of between 10 and 20 years to the current range of 12 to 22 years from initial research and development through obsolescence (phaseout). The typical MPU life cycle that involves production volumes (growth through decline) now generally exceeds eight years.

The lengthy R&D phase provides users a valuable opportunity to monitor a supplier's (or prospective supplier's) pace of technical achievement and legal standing, where applicable, as well as the supplier's timetable for bringing a new, state-of-the-art device to market. The somewhat competitive fifth-generation market continues to afford some price and availability relief as Advanced Micro Devices Inc. and, to a lesser extent, Cyrix Corporation legally compete with Intel in this area. The 486 market has declined rapidly almost to nonexistence, with the main supplier remaining—AMD. The 8-bit and 16-bit processor market remains solely with embedded applications. The 32-bit and up market remains fragmented. While a number of competitors vie for a piece of the Intel money pie, Motorola Incorporated has shifted its complete compute microprocessor focus to the PowerPC and has shifted its aging 68020/030/040 products to the embedded core market. The quickly accepted Pentium/MMX and other 32-bit and up RISC products are currently on the high end of the price/performance spectrum and are expected to come down the learning curve quickly over the next one to three years.

## Microprocessor Supplier Analysis

This section analyzes the product and market strategies of the leading suppliers of advanced microprocessors. Because of the interest expressed by Semiconductor Supply and Pricing program clients, this section focuses on suppliers that strongly serve the European and Americas markets.

**Figure 1**
**Microprocessor Product Life Cycle as of September 1997**




Source: Dataquest (September 1997)

Table 1 summarizes the 32-bit CISC computational microprocessor market in terms of revenue over the past two years. For all intents and purposes, the 32-bit CISC market and the x86 market now are one and the same, following the completion of the conversion of the Macintosh line from its earlier 68K base to the PowerPC. The market in 1996 grew 34 percent in revenue and 18 percent in terms of units, as average selling prices (ASPs) increased. The ASP increase is all the more impressive given the rapid rate at which Intel lowered microprocessor prices to spur personal computer system demand in a year with little technological innovation.

Intel, from a large base, and IBM, from a small base, grew faster in 1996 than the overall market, while other vendors grew more slowly and lost share. AMD saw both unit volumes and prices fall, driving revenue down 60 percent from the prior year. Cyrix's unit volume dropped by 44 percent, but revenue decreased at only half that rate, because the prices the company could charge for its fast 6x86 vastly exceeded what it charged for me-too 486 technology in the prior year. Cyrix initially set prices for its 6x86 at parity with those charged by Intel for devices with similar performance but quickly retreated from this position after its partner, IBM, adopted a more aggressive pricing strategy. Even then, Cyrix was unable to win any designs with major ("tier 1") vendors and had to sell its products at lower prices to less well-known vendors.

Table 2 summarizes the 32/64-bit RISC computational microprocessor market in terms of revenue and unit shipments over the past two years. This market grew 32 percent as measured by dollars but only 12 percent in terms of unit shipments. Unlike the much larger and highly concentrated CISC

market, the RISC market remains fragmented in terms of both architectures and vendors. In 1996, PowerPC, PA-RISC, and Alpha all outgrew the market in terms of units, while SPARC held its own. The Silicon Graphics Inc./MIPS architecture dramatically lost share in computational markets while dramatically gaining share in the embedded arena, where it dominates. Comparisons in year-to-year revenue changes in this segment are complicated by the lack of data for Digital Equipment Corporation in 1995 and Hewlett-Packard Company in both years. With the partial data available, Dataquest concludes that SPARC and MIPS revenue increased, driven by dramatic ASP growth, while PowerPC revenue decreased, driven by rapidly eroding ASPs, as Apple played off Motorola and IBM against each other.

**Table 1**
**32-Bit CISC Computational Microprocessor Vendors by Revenue (Millions of Dollars)**

| 1995 Rank | 1996 Rank | Company | 1995 Revenue ($M) | 1996 Revenue ($M) | 1995-1996 Growth (%) | 1995 Market Share (%) | 1996 Market Share (%) |
|---|---|---|---|---|---|---|---|
| 1 | 1 | Intel | 10,365 | 14,675 | 42 | 90 | 96 |
| 2 | 2 | Advanced Micro Devices | 743 | 300 | -60 | 6 | 2 |
| 4 | 3 | IBM | 67 | 174 | 160 | 1 | 1 |
| 3 | 4 | Cyrix | 205 | 160 | -22 | 2 | 1 |
| 6 | 5 | Texas Instruments | 16 | 18 | 13 | 0 | 0 |
| 8 | 6 | SGS-Thomson | 0 | 8 | NA | 0 | 0 |
| 5 | 7 | Motorola | 45 | 0 | -100 | 0 | 0 |
| 7 | 8 | United Microelectronics | 15 | 0 | -100 | 0 | 0 |
| | | **Total Market** | **11,456** | **15,335** | **34** | **100** | **100** |

NA = Not available
Source: Dataquest (August 1997)

**Table 2**
**32/64-Bit RISC Computational Microprocessor Vendors by Revenue (Millions of Dollars)**

| 1995 Rank | 996 Rank | Company | 1995 Revenue ($M) | 1996 Revenue ($M) | 1995-1996 Growth (%) | 1995 Market Share (%) | 1996 Market Share (%) |
|---|---|---|---|---|---|---|---|
| 1 | 1 | IBM | 525 | 439 | -16 | 52 | 33 |
| 7 | 2 | Digital | 0 | 235 | NA | 0 | 18 |
| 3 | 3 | Motorola | 176 | 209 | 19 | 18 | 16 |
| 2 | 4 | Texas Instruments | 180 | 195 | 8 | 18 | 15 |
| 8 | 5 | Sun Microsystems | 0 | 170 | NA | 0 | 13 |
| 5 | 6 | NEC | 39 | 40 | 3 | 4 | 3 |
| 6 | 7 | Toshiba | 32 | 32 | 0 | 3 | 2 |
| 9 | 8 | Integrated Device Technology | 0 | 3 | NA | 0 | 0 |
| 4 | 9 | Fujitsu | 51 | 0 | -100 | 5 | 0 |
| 10 | 10 | Hewlett-Packard | 0 | 0 | NA | 0 | 0 |
| | | **Total Market** | **1,003** | **1,323** | **32** | **100** | **100** |

NA = Not available
Source: Dataquest (August 1997)

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## Analysis of Computational Microprocessor Vendor Performance and Strategy

The advanced microprocessor market in some ways became more competitive in 1996 as AMD, Cyrix, and IBM kept competitively priced parts dangling in front of users. This did not prevent the high end of the market from becoming even more monopolistic, however. The result is an increased challenge for procurement managers, component engineers, and system designers at system companies concerning the choice of high-end and, to a lesser extent, midrange products, let alone suppliers.

Table 3 shows the estimated 1996 worldwide top MPU process technology and fab capability by geographic location for the following major MPU suppliers: AMD, Digital Equipment Corporation, IBM, Intel, Motorola, and Texas Instruments Inc. The process technology of these fabs is between 0.18 micron and 1.0 micron.

**Table 3**
**Estimated Top MPU Process Technology and Production Fab Capacity (Facilities in 1996 Production)**

| | Intel | Motorola | AMD | TI | IBM | Digital |
|---|---|---|---|---|---|---|
| **Number of Fab Lines** | | | | | | |
| Americas | 9 | 4 | 2 | 1 | 2 | 3 |
| Europe | 3* | 1 | 1 | | 1 | |
| Japan | | | | 1 | 1 | |
| Asia/Pacific | | | | | | |
| **Total** | **12** | **4** | **3** | **3** | **4** | **3** |
| **Clean Room (Sq. Ft.)** | | | | | | |
| Americas | 722,000 | 172,000 | 108,000 | 71,000 | 65,000 | 102,000 |
| Europe | 167,000* | 36,000 | 90,000 | - | 20,000 | - |
| Japan | - | - | - | 36,000 | 30,000 | - |
| Asia/Pacific | - | - | - | - | - | - |

*Includes Intel Israel
Source: Dataquest (September 1997)

### Intel

Intel described itself as "hitting on all cylinders" as its processor sales grew 42 percent to $14.7 billion, on a 28 percent increase in unit shipments, to 65 million processors. Along the way, it managed to collect $0.96 out of every dollar customers spent for personal computer microprocessors in 1996, up from $0.90 in the prior year. The company slowly ramped its Pentium Pro line, and by the fourth quarter found itself production constrained for these expensive parts. Given the dearth of new technology to excite buyers, Intel aggressively drove price and performance parameters, moving the 133-MHz Pentium processor from the high end of its line at the end of 1995 to the entry level just 12 months later. This performance increase, when combined with price decreases for DRAM and CD-ROM, maintained a 17 percent unit growth in the market and made PC vendors very successful, as long as they

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could manage the logistics and their expenses well. Dataquest expects that 1997 will prove a more challenging year for Intel as it begins the massive shift to Pentium II and faces revitalized competition from AMD and Cyrix later in the year.

### AMD

AMD watched as the 486 market evaporated before its K5 microprocessor could take up the slack, and it lost market share, unit share, and real money as a consequence. The company provided an all-too-realistic display of the impact an 18-month schedule slip can have in a world of 36-month product cycles. The company wisely placed its emphasis on integrating its NexGen acquisition and readying the K6 for market, a task that required close cooperation between its development and manufacturing organizations. By year's end, the company had achieved competitive low-end performance with its K5 and could demonstrate K6 devices with impressive clock speeds. AMD needs to continue executing in this new, more precise manner if it is to avoid a repetition of the disastrous year it experienced in 1996.

### Cyrix

Like AMD, Cyrix had a bad year, as it sought first to stabilize and then to sell its 6x86 microprocessor. Cyrix flirted briefly with the notion of charging Intel-style prices for Intel-style performance but discovered it had to give prospective purchasers a strong incentive to stray from "Intel Inside." Following the laws of classic economics, volume picked up as prices fell, and by year's end, Cyrix was selling almost as many chips as it (or, more accurately, IBM) could manufacture. The loss of momentum proved fatal to CEO Jerry Rogers' tenure and almost sank the company, as inventory built while cash shrank. Newly arrived CFO and acting CEO Jay Swent managed to stanch the flow of red ink and get the company prepared to launch its low-cost MediaGX processor and 6x86MX processor early in 1997. The recent announcement that Compaq Computer Corporation will market low-cost MediaGX-based systems may usher in a new and more profitable era for the company.

### IBM

IBM, the only vendor to participate in both the 32-bit RISC and the 32-bit CISC arenas, had vastly different experiences in each segment. Its PowerPC continued to lead the RISC market in terms of revenue and units, but the company saw revenue decrease in response to declining ASPs. In the CISC segment, where IBM manufactures most of the Cyrix-designed chips that are sold under the IBM and Cyrix brands, IBM's revenue grew rapidly on flat unit volumes; selling prices increased dramatically for the 6x86 over the 486-based products offered in the prior year. The IBM PC Company was one of the few major system vendors to include some non-Intel processors in its products, although such products tended to be destined for offshore markets where Intel's branding programs present less of a sales issue for a system vendor.

### Motorola

Until 1996, Motorola derived computational microprocessor revenue from both its 68K CISC line and its PowerPC RISC offerings. In 1996, Motorola's

68K was sold only into embedded markets and had no presence whatsoever in the computational segment. In its PowerPC business, Motorola maintained a consistent ASP on a year-to-year basis and managed to grow both unit volumes and revenue by about 20 percent.

### Sun

With its UltraSPARC offering, unveiled late in 1995, Sun Microsystems Inc. once again regained a measure of respectability with regard to microprocessor (and workstation) performance. UltraSPARC also enabled Sun to collect a reasonable tariff for its products, which translated into a 58 percent increase in SPARC revenue, to $365 million, on a 12 percent increase in unit volume to 804,000 units. Because of the previously mentioned problem in matching SPARC computational revenue with the appropriate vendors in 1995 and 1996, Dataquest bases these comparisons on the total RISC revenue and shipments for Sun, Fujitsu Ltd., and Texas Instruments.

## Other Computational Microprocessor Architectures/Suppliers

### PowerPC

The recent announcement that Microsoft will no longer enhance the PowerPC version of its Windows NT operating system restricts the computational market for PowerPC to the Apple Macintosh and IBM AIX environments, neither of which is likely to experience dramatic growth over the foreseeable future. Dataquest forecasts that the Macintosh market will grow more slowly than the overall PC market, thus restricting opportunities for PowerPC vendors. Dataquest anticipates that IBM and Motorola will both dedicate increasing portions of their marketing activities toward embedded PowerPC opportunities and products.

### SPARC

Although the unit growth of RISC-based workstations has slowed to a crawl, Dataquest anticipates that Sun still has ample growth opportunities in the midrange and high-end server market, where it has achieved credibility with the IS departments of major corporations and which the Windows NT/Pentium II juggernaut cannot easily serve.

### Alpha

Alone among the RISC microprocessors that emerged in the late 1980s, Alpha attempts to address compatibility with the huge installed base of x86 software applications. This feature, incorporated late in 1996 in Digital's version of Windows NT 4.0 and referred to as FX!32, has yet to make its presence fully felt. Dataquest remains hopeful that with its clear performance advantages, x86 compatibility story, and increasing price aggressiveness, Alpha may yet find its niche in the market.

### MIPS

The MIPS architecture once presented a major threat to x86 desktop domination, but that threat continues to fade with the passing of Windows NT for this architecture. Although the MIPS design continues to excel in embedded applications (every Nintendo 64 includes two processors, and every Sony PlayStation, one), it struggles in computational applications.

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### PA-RISC

Although Hewlett-Packard has been visibly working with Intel on its next-generation "Merced" program, HP continues to enhance its PA-RISC product line and plans a smooth transition to the 64-bit Intel environment beginning late in this decade. The recently announced PA-8500 incorporates an extremely large on-chip cache (the first ever for an HP processor) that should increase performance and substantially decrease system cost.

## Review of the 1996 Personal Computer Core Logic Market

A popular rumor holds that following Intel's serious entry into the core logic market in 1993, all other participants abandoned that market. As seen in Table 4, Intel in 1996 increased its share of the core logic market measured in dollars from 32 to 62 percent and measured in units from 22 to 52 percent. This still leaves lots of opportunities, especially when compared with the x86 microprocessor market, where Intel captured more than 90 percent of revenue. During the same period, VIA Technologies Inc. and Silicon Integrated Systems Corporation, both Taiwan-based, traded the No. 2 and No. 3 positions, while a greatly weakened OPTi Inc. retained the fourth position against a rapidly growing Acer Labs entry that ranked fifth overall.

Intel entered the largely moribund core logic arena in order to drive its own technology initiatives, including the high-speed Peripheral Component Interconnect bus (PCI) and the newer Universal Serial Bus (USB). Along the way, it discovered that it could produce core logic chipsets using recently decommissioned, fully depreciated microprocessor production equipment and thus gain an economic advantage. This equipment reuse strategy has allowed it to increase the pace at which it delivers new microprocessor technology, and it is this pace that in turn serves to stimulate market growth, a key Intel concern.

The vendors that have survived Intel's onslaught have had to learn how to design their products more quickly and how to achieve higher levels of system performance. Although they generally price their products at a discount from Intel's, the absolute cost savings (Intel's average chipset sells for less than $25) do not allow them to sell products that seriously compromise system-level performance.

As silicon densities have increased, core logic vendors have moved to expand product features as a means to preserve average selling prices, and Dataquest expects this trend to continue. Two years ago, the core logic absorbed the typical PC disk controller. Last year, keyboard controllers and real-time clocks were popular integration candidates. This year, parallel and serial port controllers, along with USB and IEEE 1394 (Firewire) support, are moving on-chip. Some vendors offer versions that integrate audio capabilities, while others integrate graphics accelerators. Core logic vendors serve as miniature vacuum cleaners, sucking up miscellaneous system functions as Moore's law permits vendors to integrate more and more function on each chip.

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**Table 4**
**x86 Core Logic Vendors, Ranked by 1996 Total Revenue (Millions of Dollars)**

| 1995 Rank | 1996 Rank | Vendor | 1995 Desktop | 1996 Desktop | 1995 Mobile | 1996 Mobile | 1995 Total | 1996 Total | 1996 Market Share (%) | 1995-1996 Growth (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Intel | 445.5 | 922.0 | - | 50.0 | 445.5 | 972.0 | 66 | 118 |
| 2 | 2 | SIS | 178.0 | 124.2 | 1.8 | 5.1 | 179.8 | 129.3 | 9 | -28 |
| 4 | 3 | OPTi | 116.3 | 33.6 | 8.8 | 50.4 | 125.1 | 84.0 | 6 | -33 |
| 7 | 4 | ALI | 52.8 | 70.7 | 4.0 | 7.4 | 56.8 | 78.1 | 5 | 38 |
| 5 | 5 | ITE(UMC) | 108.0 | 48.0 | 3.2 | 19.0 | 111.2 | 67.0 | 5 | -40 |
| 3 | 6 | VIA | 138.0 | 59.0 | 2.0 | 5.0 | 140.0 | 64.0 | 4 | -54 |
| 8 | 7 | National | - | - | - | 39.2 | - | 39.2 | 3 | NA |
| 6 | 8 | Cirrus | - | - | 58.5 | 28.0 | 58.5 | 28.0 | 2 | -52 |
| | | Others | 200.2 | - | 59.2 | | 259.4 | - | 0 | -100 |
| | | Total | 1,238.8 | 1,257.5 | 137.5 | 204.2 | 1,376.3 | 1,461.7 | 100 | 6 |

NA = Not available
Source: Dataquest (August 1997)

## Major Core Logic Supplier Strategies

### Intel

Intel more than doubled its desktop core logic shipments, paced by the introduction of the high-performance Triton II chipset (430HX) and the lower-cost Triton VX (430VX) model originally intended to support the ill-fated uniform memory architecture (UMA) concept. Intel began deliveries of its "Mobile Triton" (430MX) logic, specifically optimized for power-sensitive mobile environments and delivered almost 2 million sets of this logic. This was an impressive achievement, given that the major vendors of mobile systems still prefer to roll their own core logic instead of using any vendor's off-the-shelf products. Intel also launched its 440FX chipset that significantly lowered the cost of building desktop Pentium Pro-based systems. Dataquest anticipates that Intel will introduce its 440LX chipset, optimized for the Pentium II environment with the Accelerated Graphics Port (AGP), late in 1997. It will attempt to use the AGP feature to induce users to upgrade from older Pentium-based systems lacking AGP.

### VIA

VIA Technologies maintained its share in the desktop arena, primarily by catering to vendors designing products offshore for offshore markets. VIA has been quick to match Intel in adding system features and improving performance, and its latest products support a wide range of memory and cache technologies, along with key PC bus interfaces. While Intel intends to use the AGP features in its next version of Pentium II core logic to drive the market toward Pentium II, VIA has worked with AMD to add AGP features to its Pentium-style core logic devices. Such x86 clone vendors as AMD and Cyrix will require AGP support in Socket 7 motherboards in order to offer competitive system-level features in 1998, and these vendors will need at least one of the Intel-alternative chipsets to support this capability at a competitive performance level.

### Silicon Integrated Systems

SIS lost share in 1996 as its sales of desktop-oriented core logic fell almost 30 percent with no increase in mobile units or ASP to make up the difference.

Like VIA, SIS hopes to service the Socket 7 infrastructure that Intel is leaving behind in its migration to Pentium II.

### OPTi

Like SIS, OPTi saw sales fall by over 30 percent. OPTi moved to strengthen its mobile offering, but its gains in mobile failed to offset substantial losses in the desktop portion of its business. Like SIS, OPTi hopes to service the Socket 7 infrastructure that Intel is leaving behind in its migration to Pentium II.

## Dataquest Perspective

At the start of 1996, Dataquest asked, "Can any vendor compete with Intel in 1996?" By the end of the year, it became obvious that none could, at least in 1996. Using the narrowest of market definitions, Intel laid claim to $0.96 out of every dollar spent on x86 microprocessors used in computational applications, leaving just $0.04 for other x86 vendors to fight over. Alternative x86 vendors struggled first to release their products and then to find customers for them. AMD completed its K5 development, but lagged Intel's Pentium woefully with regard to operating frequency and performance. It was forced to discount the already low prices it charged for its products and watched its average selling prices erode dramatically. Cyrix finally squeezed its design onto a die it could manufacture at reasonable cost, only to encounter a variety of subtle thermal problems that restricted its operating frequencies. Both vendors watched as red ink gushed from their books, and both hoped to stanch their losses with new products in 1997.

The news from the RISC camp was no more encouraging. Microsoft pulled the plug on future support of the PowerPC in Windows NT, leaving the PowerPC's ultimate fate in computational applications resting solely on the long-term success of the Macintosh platform, a precarious position at best. Vendors of RISC-based workstations and servers began to feel the heat from the combination of Intel's Pentium Pro microprocessor and Microsoft's Windows NT 4.0 release. NeTpower Inc. and NEC Corporation converted their MIPS-based Windows NT products to Pentium Pro, leading Microsoft to discontinue support for that platform as well. By the end of the year, the architecturally neutral Windows NT environment supported only two architectures—Intel and Alpha.

Popular rumor holds that all other participants abandoned the core logic market that after Intel's serious entry into that market in 1993. According to Dataquest, Intel in 1996 increased its share of the core logic market measured in dollars from 32 to 62 percent and its share measured in units from 22 to 52 percent. This still leaves lots of opportunities, especially when compared with the x86 microprocessor market, where Intel captured more than 90 percent of revenue. During the same period, Taiwan-based VIA Technologies and Silicon Integrated Systems traded the No. 2 and No. 3 positions, with a greatly weakened OPTi retaining the fourth position and a rapidly growing Acer Labs ranked fifth overall.

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Add to all of this turmoil AMD's successful breach of the Intel technology wall in 1997, providing some competitive relief with its K6 products. How long this will last and whether capacity will be a constraint are the big questions this year. The computational MPU market continues to consolidate, with the Wintel solution becoming ubiquitous.


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**For More Information...**
Mark Giudici, Director and Principal Analyst ..... (408) 468-8258
Internet address ..... mark.giudici@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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251 River Oaks Parkway, San Jose, CA 95134-1913
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September 11, 1997

Dear Client:

The enclosed copy of "The Nonvolatile Memory Picture Becomes Clearer as Users Choose Long-Term Solutions," product code SSPS-WW-DP-9711, replaces the copy previously mailed to you. Because of a PostScript printing problem, the titles for Figure 1 and Figure 2 on the version previously mailed to you did not appear on the same pages as the figures themselves. This problem has been corrected. Please discard the copy you previously received and replace it with the enclosed one. We apologize for any inconvenience this may have caused.

Sincerely,

Gordon Riley
Production Manager

Perspective



Semiconductor Supply and Pricing Worldwide

# Market Analysis

# The Nonvolatile Memory Picture Becomes Clearer as Users Choose Long-Term Solutions

**Abstract:** *The nonvolatile memory market (ROM, EPROM, EEPROM, and flash) continues to grow, but some family members are starting to dominate. This Perspective focuses on the life cycles and technology trends within the nonvolatile market and analyzes 1996 market share data by geographical region and device family.*
*By Evelyn Cronin*

## Nonvolatile Devices

The nonvolatile market comprises four distinct devices: flash memory, EPROM, EEPROM, and mask ROM. Following are the Dataquest definitions for these devices, along with some typical applications:

- Flash memory: Includes nonvolatile products designed as flash EPROM/EEPROM that incorporate either 3V, 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 erase data only by bulk/chip, not by byte.
- Flash memory is now used on Pentium-based PC motherboards for BIOS and plug-and-play applications. Non-PC flash applications include wireless communications (digital cellular and personal handyphone) and consumer electronics (digital cameras and digital voice recorders).
- EPROM: Erasable programmable read-only memory. This product classification includes ultraviolet EPROM (UV EPROM) and one-time-programmable read-only memory (OTP ROM). EPROMs have memory cells consisting of a single transistor and do not require any memory cell

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refreshes. EPROMs are used to store code in applications both in embedded systems and in computers as the bootstrap or basic input/output subsystem (BIOS) in PCs.

- EEPROM: Electronically erasable programmable read-only memory. Included are serial EEPROM (S-EEPROM), parallel EEPROM (P-EEPROM) and electronically alterable read-only memory (EAROM). EEPROMs have memory cells consisting of a minimum of two transistors and do not require memory cell refreshes. This product classification also includes nonvolatile RAM (NV-RAM), also known as shadow RAM. These latter semiconductor products are a combination of static RAM (SRAM) and EEPROM technologies in each memory cell. The EEPROM functions as a shadow backup for the SRAM when power is lost. EEPROMs are usually used in specialized applications where the minimal storage capability is acceptable and byte erase is required. One such application is code storage in printers.
- Mask ROM: Mask-programmable read-only memory. Mask ROM is a form of memory that is programmed by the manufacturer to a user's specification using a mask step. Mask ROM is programmed in hardware rather than software. Mask ROMs are heavily used in the game industry and to hold font software in printers. Also, Apple Computer Inc. uses mask ROMs to hold BIOS software.

## Life Cycle Curves

Examining the life cycle curves for flash, EPROM, EEPROM, and mask ROM gives a useful perspective These life cycle curves are based on unit shipments per technology density.

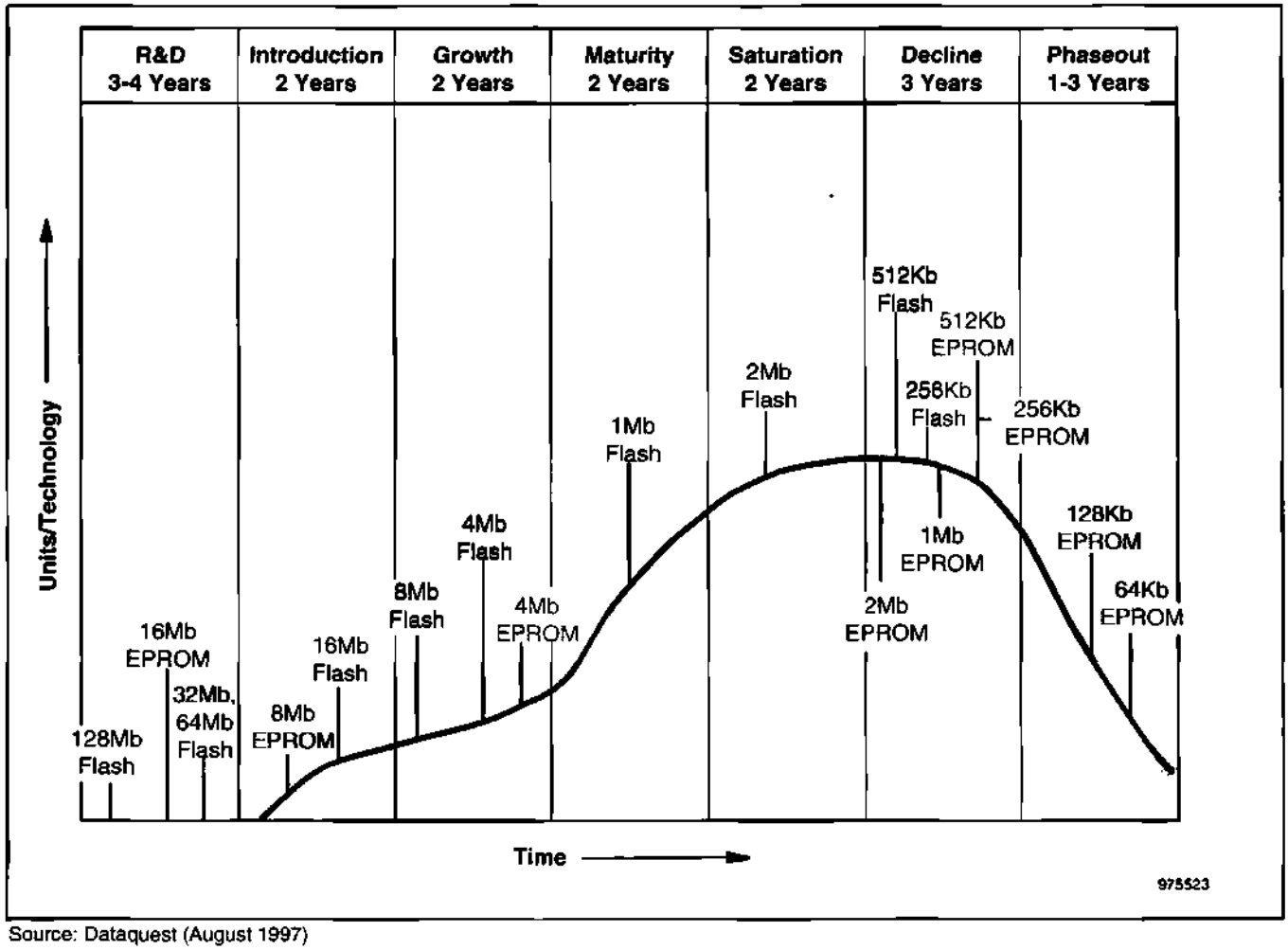
Figure 1 shows the life cycle curves for flash and EPROM at various densities. What is immediately obvious is that EPROMs are stronger in the lower-density parts, while flash will dominate densities above 8Mb. Also, at the same densities, flash and EPROM are usually in different stages, except at the 256Kb and 512Kb densities. Both flash and EPROM are in the decline stage at these densities, although EPROM is further along in that stage than is flash.

For flash, 1Mb is solidly in the maturity stage, while the 2Mb has already reached the saturation stage. The 4Mb and 8Mb flash are both still in the growth stage, with the 4Mb further into this stage. The 16Mb flash sits in the introduction stage. Flash at higher densities (32Mb, 64Mb, and 128Mb) is in the R&D stage.

With EPROM, the story is rather different. The 64Kb and 128Kb are both in the phaseout stage of their life cycle curve based on unit shipments. EPROM from 256Kb to 2Mb are sitting in the decline stage. Thus, the majority of EPROM sits in the final stages of its life cycle curve. The 4Mb EPROM is in its growth stage, with the 8Mb in the introduction stage of its life cycle. EPROM at 16Mb is still at the R&D stage.

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**Figure 1**
**Flash and EPROM Life Cycle Stages/Density**




Source: Dataquest (August 1997)

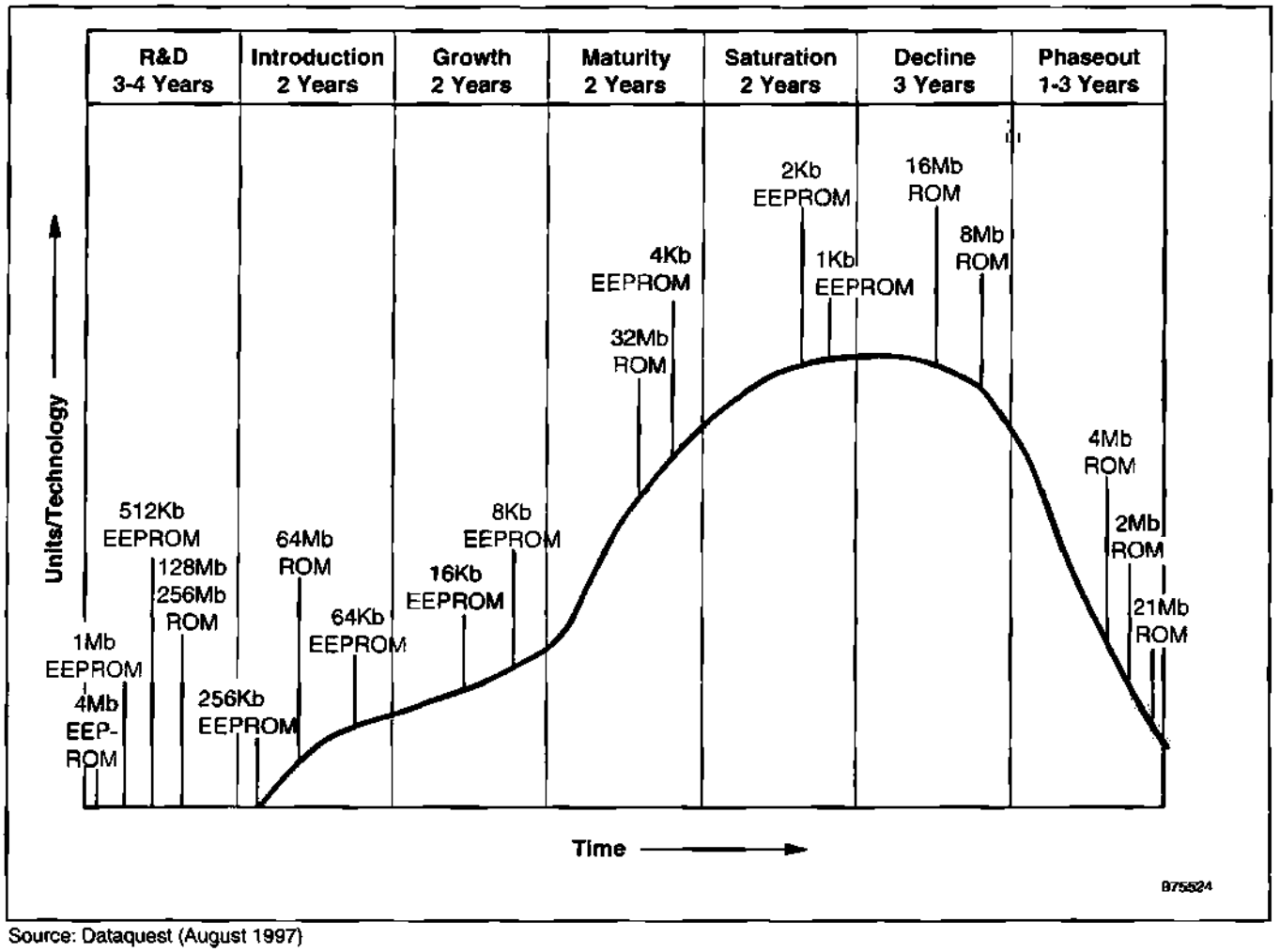
Figure 2 shows the life cycles for mask ROM and EEPROM at various densities. These two subsets of the nonvolatile family make for an interesting comparison. EEPROMs tend to be at very low densities, while ROMs include some of the largest densities in production. The 1Mb ROM is in the phaseout stage, while the 1Mb EEPROM is still in the R&D stage!

Asia/Pacific ROMs at 1Mb, 2Mb, and 4Mb are in the phaseout stage, with 8Mb and 16Mb mask ROMs in the decline phase. The 32Mb ROM still sits in the maturity stage of its life cycle curve, while the 64Mb part is in the introduction phase. The 128Mb and 256Mb parts are still in the R&D stage.

EEPROMs are "newer" in terms of life cycle positioning. The 1Kb and 2Kb both sit in the saturation stage of the life cycle curve, while the 4Kb is climbing up the maturity stage. The 8Kb and 16Kb parts are in the growth stage, with the 8Kb ahead. The 64Kb EEPROM remains in the introduction stage of its life cycle curve, relative to volumes sold, along with the 256Kb. EEPROMs from 512Kb to 4Mb remain in the R&D stage.


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**Figure 2**
**ROM and EEPROM Life Cycle Stages/Density**




Source: Dataquest (August 1997)

## Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar amounts. The rates used for 1995 and 1996 are outlined in Table 1.

**Table 1**
**Exchange Rates**

| | 1994 | 1995 |
|---|---|---|
| Japan (Yen/U.S.$) | 93.90 | 108.81 |
| France (French Franc/U.S.$) | 4.97 | 5.12 |
| Germany (Deutsche Mark/U.S.$) | 1.43 | 1.50 |
| United Kingdom (U.S.$/Pound Sterling) | 1.59 | 1.56 |

Source: Dataquest (August 1997)

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## The Nonvolatile Market

The nonvolatile market was worth over $6.45 billion in 1996, based on revenue shipments, a growth of some 3.5 percent from 1995. Table 2 shows the 1996 revenue for each nonvolatile device. This indicates the wide variation in the growth and contraction rates of each device family.

**Table 2**
**Worldwide Nonvolatile Revenue by Device Family**
**(Millions of Dollars)**

| Nonvolatile Device Family | 1995 | 1996 | 1996 Growth (%) |
|---|---|---|---|
| Flash | 1,942 | 2,866 | 47.6 |
| EPROM | 1,437 | 1,249 | -13.1 |
| EEPROM | 793 | 1,050 | 32.4 |
| Mask ROM | 2,067 | 1,290 | -37.6 |
| **Total** | **6,239** | **6,455** | **3.5** |

Source: Dataquest (August 1997)

Flash continues its stellar growth. Its revenue grew by nearly 48 percent from 1995 to 1996. Although this is considerably less than the almost 120 percent revenue growth from 1994 to 1995, 48 percent is no mean feat, considering the state of the semiconductor market in 1996. Most important, though, is that flash is now No. 1 in revenue of the nonvolatile devices.

The three other nonvolatile families, however, had varying fates in 1996. EEPROM grew by over 32 percent in revenue terms, but EPROM and mask ROM were not so fortunate—both posted contraction in 1996, coming in at about negative 13.1 percent and negative 37.6 percent, respectively. Mask ROM is no longer the highest revenue earner; flash took over in 1996.

## Market Share

Table 3 shows the 1996 nonvolatile market share by supplier, based on factory revenue. There has been considerable change in the 1996 overall rankings, compared to 1995, but the No. 1 spot remains unchanged. For the second straight year, a nonvolatile supplier that offers only one of these products was the overall nonvolatile revenue standings leader. Intel Corporation, by being the No. 1 flash supplier, took the overall nonvolatile market share leadership position.

Atmel Corporation rose up the ranks to the No. 2 position, trading places with Sharp Electronics Corporation. Despite Atmel's fall to No. 4 for flash market share, it rose to No. 2 for EPROM and maintained its No. 2 position in EEPROM.

Advanced Micro Devices Inc. came in at third position in the overall rankings, based on revenue. It was the second-largest flash revenue supplier and the third-largest EPROM supplier in 1996. In fourth position for the second year was SGS-Thomson Microelectronics B.V. It is still the worldwide

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No. 1 EPROM and EEPROM supplier, and it also grew its flash revenue in 1996, despite its fall to sixth in overall revenue.

Sharp plummeted from No. 2 position in 1995 to No. 5 in 1996, despite being the No. 1 mask ROM supplier and rising to fifth position in flash. In sixth position was Fujitsu Ltd., which rose two places in the 12-month period and is now the No. 3 flash supplier worldwide.

**Table 3**
**Top 10 Nonvolatile Suppliers by Revenue and Product Offering, 1996 (Millions of Dollars)**

| 1995 Rank | 1996 Rank | Company Name | 1996 Revenue | Flash Rank | EPROM Rank | EEPROM Rank | Mask ROM Rank |
|---|---|---|---|---|---|---|---|
| 1 | 1 | Intel | 950 | 1 | | | |
| 5 | 2 | Atmel | 793 | 4 | 2 | 2 | |
| 3 | 3 | AMD | 708 | 2 | 3 | | |
| 4 | 4 | SGS-Thomson | 689 | 6 | 1 | 1 | |
| 2 | 5 | Sharp | 526 | 5 | | | 1 |
| 8 | 6 | Fujitsu | 403 | 3 | | | |
| 10 | 7 | Macronix | 288 | | 5 | | 4 |
| 7 | 8 | NEC | 287 | | 10 | 9 | 3 |
| 9 | 9 | Texas Instruments | 243 | 9 | 4 | 6 | |
| 11 | 10 | Samsung | 224 | | | | 2 |
| | | All Others | 1,344 | | | | |
| | | **Total** | **6,455** | | | | |

Source: Dataquest (August 1997)

Macronix International Company Ltd. continued its rise up the market share ranks. It ranked No. 7 for 1996, a leap up from 10th position in 1995. NEC Corporation, however, dropped a place from 1995 to 1996 and is now ranked eighth.

The last two suppliers are Texas Instruments Inc., coming in at ninth position, and Samsung Electronics Company Ltd., coming in at 10th. TI remains in that position for the second straight year, but Samsung rose a place to enter the top 10. This mighty Korean company is now beginning to make its presence felt.

In revenue, the top five nonvolatile suppliers all posted earnings greater than $500 million. The suppliers in sixth to 10th position all had earnings between $250 million and just over $400 million.

Of the top five vendors, there are three clear groupings. In a league of its own is Intel, with revenue of $950 million for 1996. The question is by how much it will break the billion-dollar mark next year. Atmel, AMD, and SGS-Thomson all had respectable revenue, earning between $689 million and $793 million, but they still fall in the revenue shadow of Intel. Lagging the top five is Sharp, whose revenue fell from 1995 to 1996 and which now earns only $526 million from the nonvolatile arena.

# Market Share by Device Family

## Flash

Flash grew revenue by almost 48 percent in 1996, and it is now the highest revenue generator within the nonvolatile family. Table 4 shows the top five flash suppliers by revenue for 1996.

**Table 4**
**Market Share by Revenue for Flash, 1996 (Millions of Dollars)**

| 1995 Rank | 1996 Rank | Company Name | 1996 Revenue |
|---|---|---|---|
| 1 | 1 | Intel | 950 |
| 2 | 2 | AMD | 542 |
| 4 | 3 | Fujitsu | 369 |
| 3 | 4 | Atmel | 330 |
| 7 | 5 | Sharp | 149 |
| | | All Others | 526 |
| | | **Total** | **2,866** |

Source: Dataquest (August 1997)

All achieved high revenue growth, with Sharp's climb to fifth position in 1996 translating into an amazing 231.1 percent revenue growth. In another great year for Fujitsu, the company grew revenue by over 107 percent and jumped into third position overall, based on flash revenue. The NOR flash remains dominated by technology alliances, Intel-Sharp versus AMD-Fujitsu. Both alliances combined account for over 70 percent of the total worldwide flash market.

## EPROM

For the EPROM market, 1996 was another year of declining growth. The total worldwide market shrank by over 13 percent from 1995 to 1996. Table 5 shows the 1996 market share ranking by revenue for EPROMs.

**Table 5**
**Market Share by Revenue for EPROM, 1996 (Millions of Dollars)**

| 1995 Rank | 1996 Rank | Company Name | 1996 Revenue |
|---|---|---|---|
| 1 | 1 | SGS-Thomson | 337 |
| 4 | 2 | Atmel | 227 |
| 3 | 3 | AMD | 166 |
| 2 | 4 | Texas Instruments | 115 |
| 7 | 5 | Macronix | 84 |
| | | All Others | 320 |
| | | **Total** | **1,249** |

Source: Dataquest (August 1997)


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Although Atmel and Macronix both posted growth, the fate of the other top five players was different. Atmel grew by over 53 percent from 1995 to 1996 and Macronix by nearly 17 percent in the same period. SGS-Thomson's revenue remained largely flat from 1995 to 1996, while both AMD and TI experienced declines in their EPROM revenue (down 5.1 percent and 45.5 percent, respectively).

## EEPROM

The EEPROM market grew by a healthy 32.4 percent in 1996. Table 6 shows the top five EEPROM suppliers by revenue for 1996. There is no ranking change from 1995 among this group. All had revenue growth in 1996, but SGS-Thomson and Atmel were the only two to hurtle past $200 million, growing by over 50 percent each (51.5 percent and 55.3 percent, respectively).

**Table 6**
**Market Share by Revenue for EEPROM, 1996 (Millions of Dollars)**

| 1995 Rank | 1996 Rank | Company Name | 1996 Revenue |
|---|---|---|---|
| 1 | 1 | SGS-Thomson | 256 |
| 2 | 2 | Atmel | 236 |
| 3 | 3 | Xicor | 109 |
| 4 | 4 | Microchip Technology | 104 |
| 5 | 5 | National Semiconductor | 74 |
| | | All Others | 271 |
| | | **Total** | **1,050** |

Source: Dataquest (August 1997)

The other three top five suppliers had individual growth rates less than the overall EEPROM average. Xicor Inc. grew by less than 8 percent, Microchip Technology Inc. by about 27 percent, and National Semiconductor Corporation by less than 20 percent. National Semiconductor was the only one of these three suppliers with revenue less than $100 million.

## Mask ROM

Table 7 shows the top five mask ROM suppliers by revenue for 1996. Mask ROM revenue is shrinking seriously. Revenue was down 37.6 percent from 1995 to 1996. In 1996, flash has knocked it out of the No. 1 nonvolatile revenue spot for the first time.

All top five suppliers except Macronix saw their revenue tumble. Macronix managed 10 percent revenue growth in this shrinking market. However, Sharp (negative 44.7 percent), Samsung (negative 16.5 percent), NEC (negative 25.5 percent), and Toshiba Corporation (negative 64.3 percent) were not so lucky.

**Table 7**
**Market Share by Revenue for Mask ROM, 1996 (Millions of Dollars)**

| 1995 Rank | 1996 Rank | Company Name | 1996 Revenue |
|---|---|---|---|
| 1 | 1 | Sharp | 374 |
| 2 | 2 | Samsung | 193 |
| 3 | 3 | NEC | 184 |
| 4 | 4 | Macronix | 165 |
| 5 | 5 | Toshiba | 99 |
| | | All Others | 275 |
| | | **Total** | **1,290** |

Source: Dataquest (August 1997)

## Regional Nonvolatile Split by Device Type

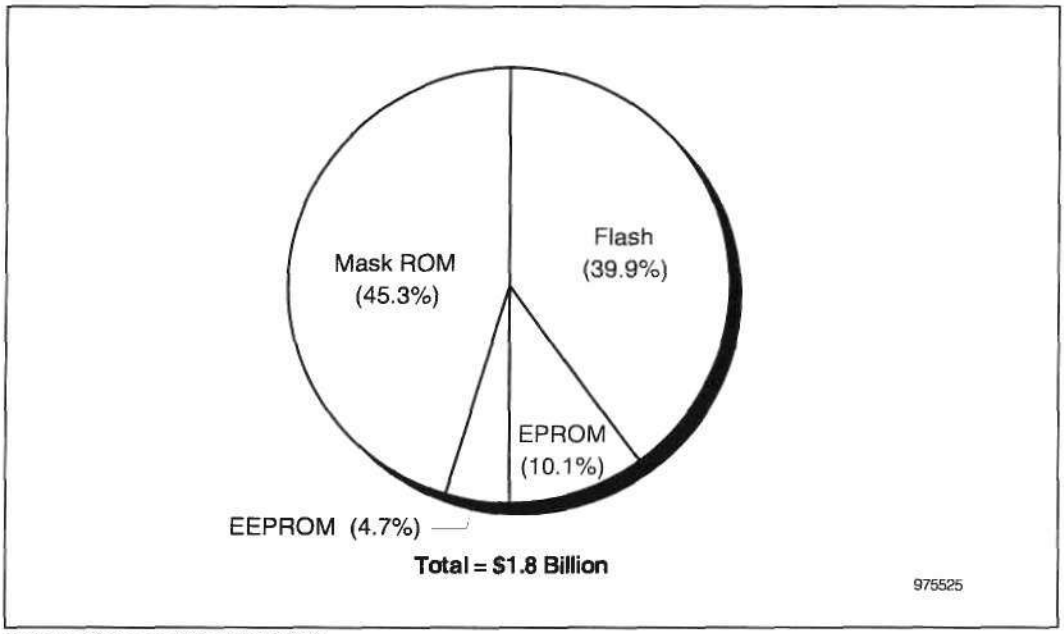
### Japanese Suppliers (Japanese Companies)

The Japanese companies had a tough year in 1996. They were the only regional block of suppliers to experience a revenue decline from 1995 to 1996, falling from $2.2 billion to $1.8 billion. This is a drop of nearly 20 percent in the 12-month period. Figure 3 shows the 1996 revenue by nonvolatile device families for Japanese companies. It can be seen that the misfortunes of the Japanese region companies are tied in to their dependence on mask ROM. This still represents 45 percent of the region's total revenue in 1996 despite mask ROM's general decline worldwide. The good news is that this region is increasing its flash revenue quite dramatically. Flash accounted for about 40 percent of total revenue in 1996, a revenue leap of over 127 percent from 1995 to 1996. EPROM and EEPROM are both declining in revenue in Japan and now make up 10 percent and 5 percent, respectively, of total nonvolatile market share for 1996.

### Japanese Buyers (Japanese Region Consumption)

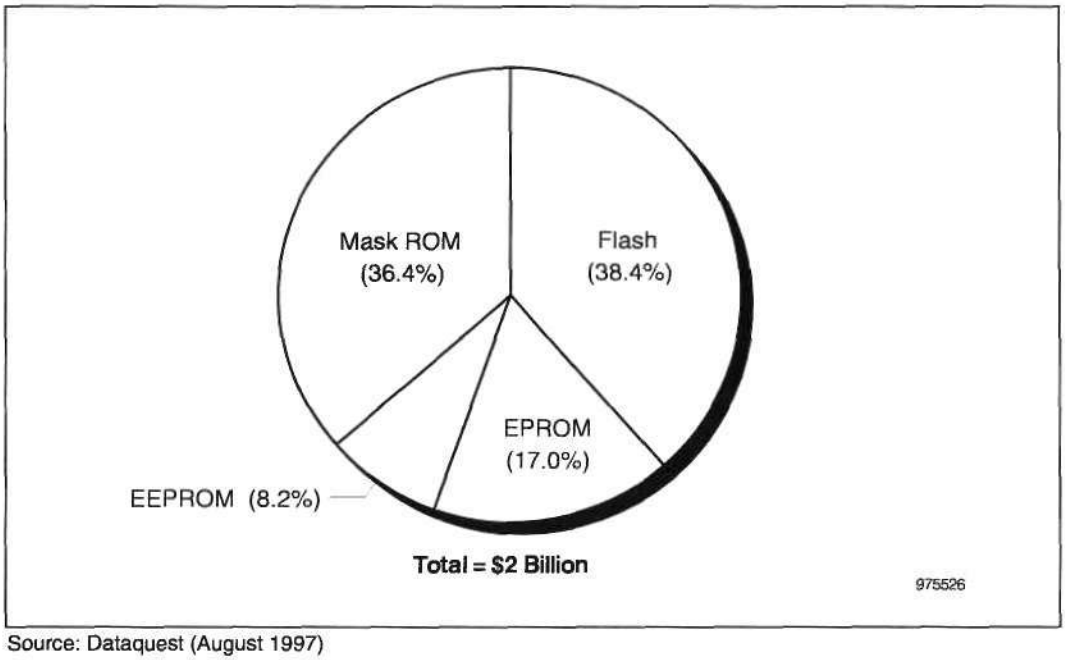
Figure 4 shows the nonvolatile revenue by device family for Japan in 1996. This is based on factory revenue from shipments to Japan, expressed in U.S. dollars. Although the Japanese suppliers had the second-highest nonvolatile revenue (behind the Americas suppliers) for 1996, Japanese buyers were the largest nonvolatile consumers (ahead of the Americas) for the same period. That said, this region experienced a revenue decline of $72 million from 1995 to 1996, coming in at $2.04 billion for 1996. The good news was that flash consumption increases were amazing. This region has gone from being the third-largest flash consumer in 1995 to being the second-largest in 1996, switching places with Europe in the process. Flash revenue increased 117.7 percent from 1995 to 1996. It now makes up 38 percent of the region's nonvolatile consumption. EEPROM also had a good growth year and accounted for 8 percent of the market. Now to the bad news. EPROM and mask ROM both had a bad year in 1996. Mask ROM revenue tumbled by 36.7 percent, and EPROM dropped by 20.7 percent.

**Figure 3**
**Japanese Suppliers' Nonvolatile Market Share, by Device Family, 1996**




Source: Dataquest (August 1997)

**Figure 4**
**Japanese Buyers' Nonvolatile Market Share (Consumption), by Device Family, 1996**




Source: Dataquest (August 1997)

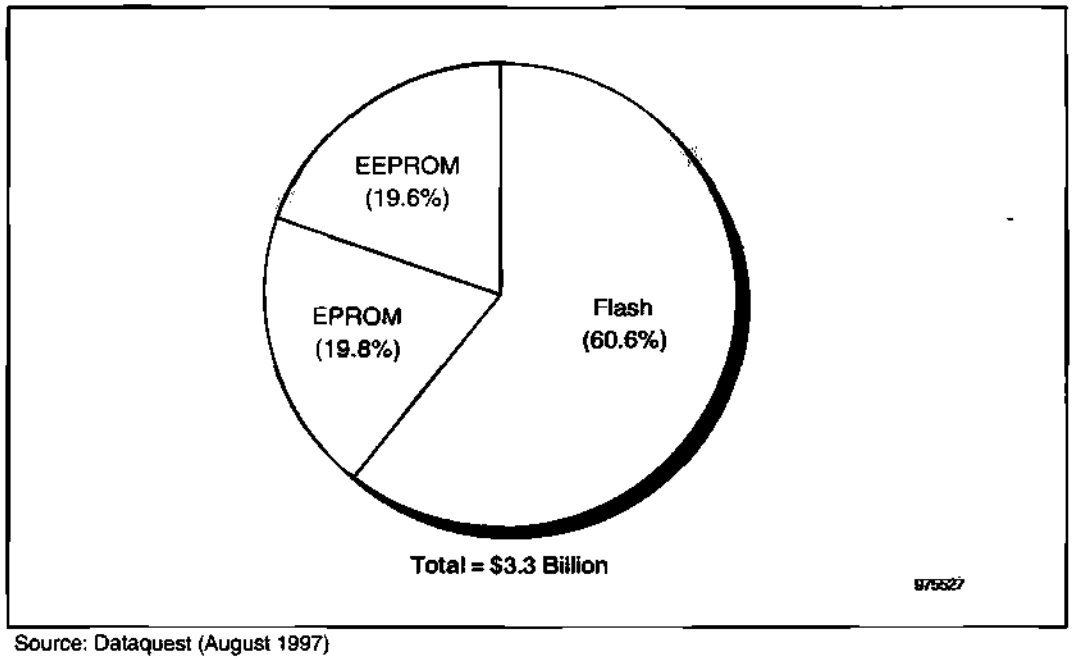

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# Americas

## Americas Suppliers

The year 1996 was another very good one for the suppliers in the Americas region, which represented 51 percent of the worldwide nonvolatile market in 1996 and experienced an 18.6 percent revenue increase from 1995 to 1996. Figure 5 shows the nonvolatile revenue by device family for 1996 for Americas suppliers. Flash accounted for 60 percent of the total Americas nonvolatile revenue at just shy of $2 billion (up 29.8 percent from 1995). EEPROM revenue rose by 40 percent and now makes up one-fifth of the region's total nonvolatile market. EPROM revenue, on the other hand, declined by 16 percent, coming in at $649 million for 1996 and accounting for 20 percent of the total nonvolatile market for the region.

**Figure 5**
**American Suppliers' Nonvolatile Market Share, by Device Family, 1996**



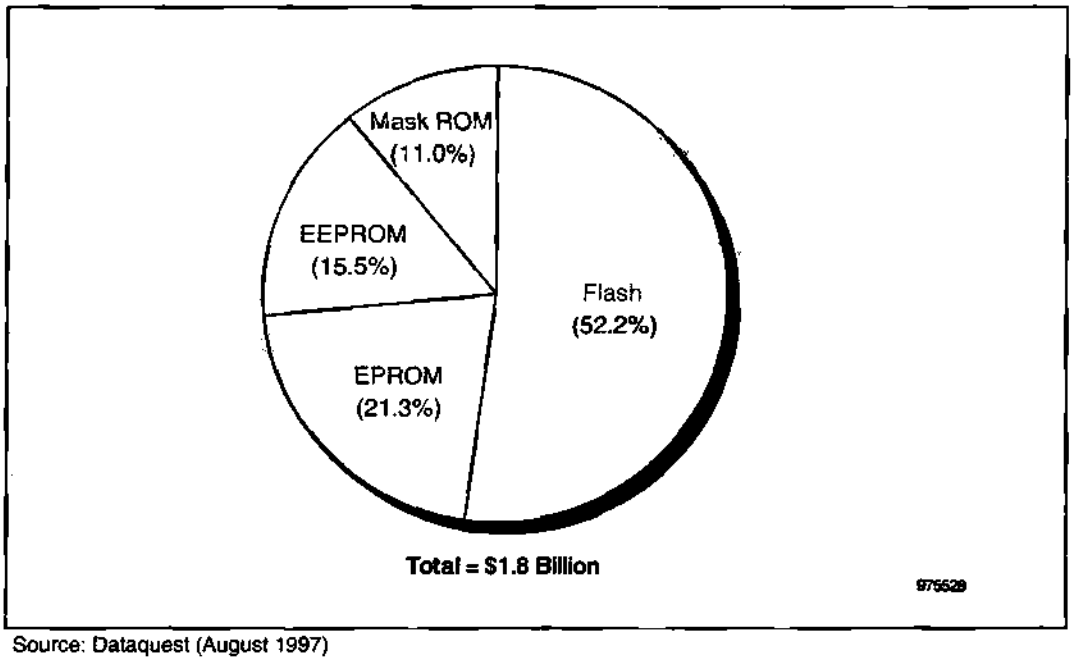

Source: Dataquest (August 1997)

## Americas Buyers

Figure 6 shows the nonvolatile revenue by device family for the Americas region in 1996. This is based on factory revenue from shipments to the Americas region, expressed in U.S. dollars. The American suppliers had the highest nonvolatile revenue for 1996, but American buyers were only the second-largest nonvolatile consumers (behind the Japanese) for the same period. Revenue dropped from $1.95 billion in 1995 to $1.82 billion in 1996. This is reflected in the declining consumption of EPROM, EEPROM, and mask ROM in the region. All three took a dollar decrease from 1995 to 1996 and now account for 22 percent, 15 percent, and 11 percent of the region's nonvolatile revenue. Flash, by contrast, had a brilliant year. The Americas region is the largest flash consumer in the world. Flash makes up 52 percent

of the region's nonvolatile revenue and came in at $950 million for 1996, just below the billion-dollar mark.

**Figure 6**
**American Buyers' Nonvolatile Market Share (Consumption), by Device Family, 1996**




Source: Dataquest (August 1997)

## Europe, Africa, and Middle East

### European Suppliers

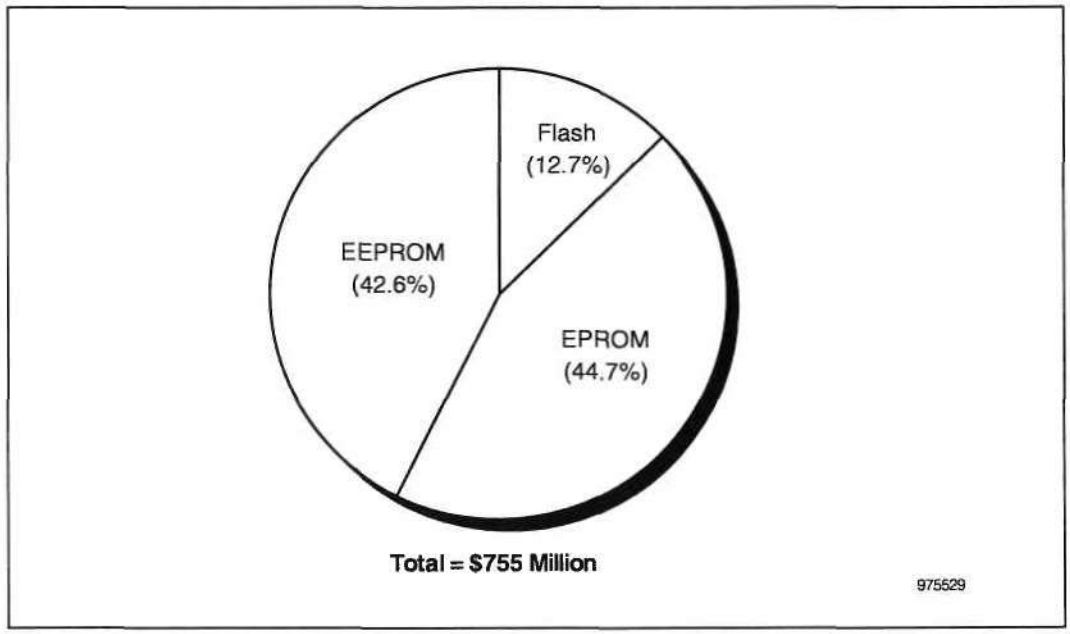
The European group of nonvolatile suppliers had a good year in 1996. They increased their revenue by 18 percent form 1995 to 1996, coming in at $755 million. Figure 7 shows the 1996 nonvolatile revenue by family type for European companies. EPROM and EEPROM were the largest in dollar terms, making up 45 percent and 43 percent of total revenue, respectively. For EPROM, revenue was largely flat from 1995 to 1996. However, EEPROM grew by $100 million (45 percent) in the same period. Flash was up in dollar terms as well, coming in at $96 million for the year, an increase of 17 percent over 1995.

### European Buyers

Figure 8 shows nonvolatile revenue by device family for the European region in 1996. This is based on factory revenue from shipments to the European region, expressed in U.S. dollars. With telecommunications so strong in Europe, it should be of little surprise that flash was ranked No. 1 in Europe, representing about 45 percent of total nonvolatile European revenue. Flash revenue increased by 32.7 percent and came in at $641 million. By contrast, EPROM and mask ROM revenue was down from 1995, by 15.3 percent and 33.3 percent, respectively. EPROM accounts for 20 percent and mask ROM for 5 percent of the region's total nonvolatile

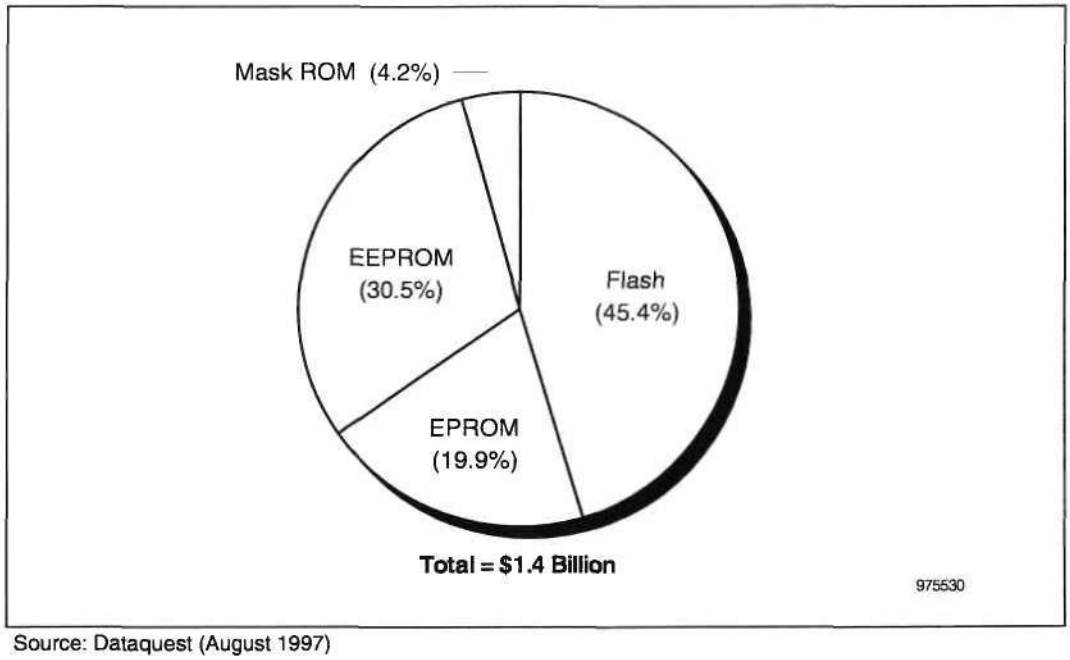
consumption for 1996. EEPROM, like flash, had a good year, posting a 57.3 percent revenue increase for the year, and now makes up 30 percent of Europe's nonvolatile consumption in dollar terms.

**Figure 7**
**European Suppliers' Nonvolatile Market Share, by Device Family, 1996**




Source: Dataquest (August 1997)

**Figure 8**
**European Buyers' Nonvolatile Market Share (Consumption), by Device Family, 1996**




Source: Dataquest (August 1997)

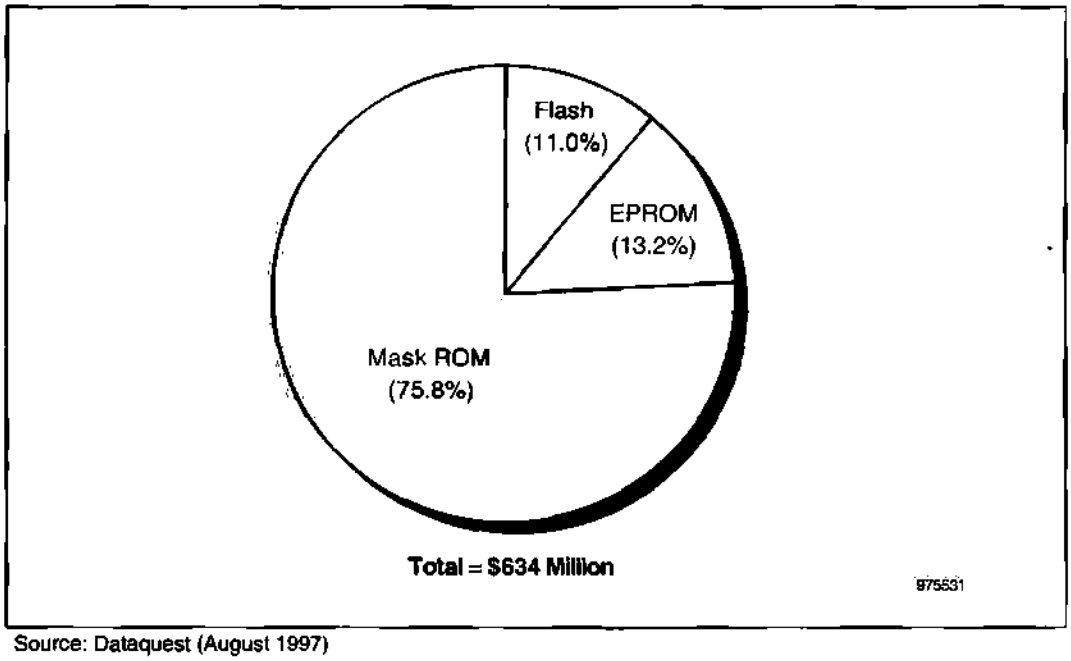

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# Asia/Pacific

## Asia/Pacific Suppliers

Asia/Pacific suppliers had an increase in revenue of just 3.4 percent from 1995 to 1996, coming in at $634 million and making the region the smallest in dollar terms. The 1996 nonvolatile revenue of Asia/Pacific suppliers is shown in Figure 9. Mask ROM accounts for the bulk of this revenue (over three-quarters in 1996), and this is a declining market. Mask ROM revenue was $480 million for this regional group of suppliers in 1996, down some 8.4 percent from 1995 in dollar terms. EPROM and flash both had positive revenue increases from 1995 to 1996, the former 16.7 percent (to $82 million) and the latter a staggering 400 percent (to $70 million).

**Figure 9**
**Asia/Pacific Suppliers' Nonvolatile Market Share, by Device Family, 1996**

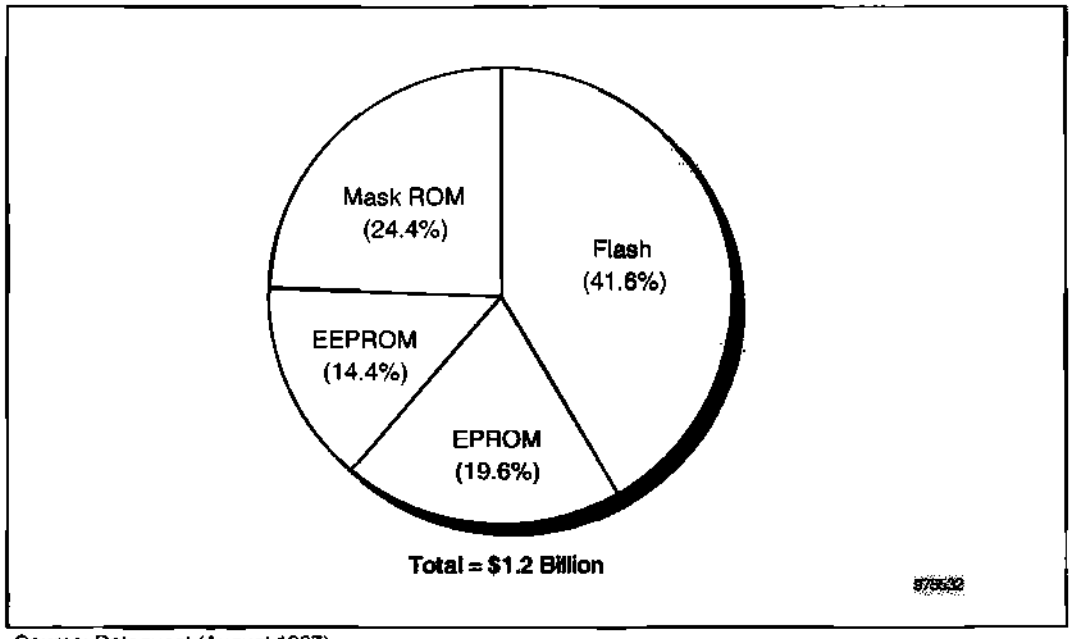



Source: Dataquest (August 1997)

## Asia/Pacific Buyers

Figure 10 shows the nonvolatile revenue by device family for the Asia/Pacific region in 1996. This is based on factory revenue from shipments to the Asia/Pacific region, expressed in U.S. dollars. This was both the smallest supplier region and the smallest buying region in 1996. Like the Japanese buyers, the Asia/Pacific buyers reported growth for flash and EEPROM and contraction for EPROM and mask ROM for 1996. Flash and EEPROM revenue virtually doubled from 1995 to 1996 and now account for 42 percent ($489 million) and 14 percent ($170 million) of the total nonvolatile market for 1996. EPROM and mask ROM were both down from 1995 to 1996, by 6 percent and 31 percent, respectively, and now account for 20 percent and 24 percent of the total nonvolatile market.

**Figure 10**
**Asia/Pacific Buyers' Nonvolatile Market Share (Consumption), by Device Family, 1996**




Source: Dataquest (August 1997)

# Technology Trends

## Flash

The technology trends in flash are:

- Domination by strong alliances—Intel and Sharp versus AMD and Fujitsu
- NOR technology revenue still strongest, but NOR suppliers investigating NAND technology and vice versa
- Trend toward higher densities and lower voltages
- Current main flash markets are PC BIOS, digital cellular phones, internetworking, rigid disk drives, and automotive
- Future applications include set-top boxes, Web TV, Net PC, digital cordless phones, digital photo and audio, and personal digital assistants
- Forecast good price reductions to continue, especially on higher-density devices

## EPROM

Trends in EPROM are:

- Mature market; revenue leveling off
- Fewer and fewer suppliers making the high-density parts

- EPROM average selling prices will slowly rise over time, but EPROM suppliers currently remain price competitive relative to flash at small to medium densities.

### EEPROM

Technology trends in EEPROM are:

- The most niche-like area of nonvolatile but will have very good growth patterns in the future
- Explosion of consumer electronics devices and increasing PC use helped fuel growth
- In Europe, smart/memory cards growing
- Will be second only to flash in revenue by 2001

### Mask ROM

Mask ROM technology trends are:

- Migration from cartridges to CD-ROMs hurting segment
- Lower DRAM prices in 1996 made mask ROM worse
- Forecast compound annual growth rate from 1997 to 2001 of 14 percent

## Dataquest Perspective

In the flash market, 1996 was enormously significant—it was the first year that flash overtook mask ROM to become the largest revenue family of the nonvolatile group. Dataquest forecasts that growth will remain healthy as more and more applications move from EPROM and mask ROM to flash. This growth will continue to the year 2000. From a procurement point of view, supply has really opened up. The NOR flash market remains dominated by alliances, with Intel/Sharp and AMD/Fujitsu controlling 70 percent of the total flash market, based on revenue. The two camps offer different products (Smart Voltage from Intel/Sharp and True Low Voltage from AMD/Fujitsu), and both have ramped up production and continue to migrate to lower voltages. Good price reductions are to be expected on mid- to high-density devices. Also, some suppliers offer price parity for all voltages at equivalent densities.

EPROM, on the other hand, has a less rosy future. The market is in gradual decline as users move to flash for volume applications. Dataquest forecasts continued growth at densities of 4Mb and above. Many EPROM suppliers remain committed to this family, and for many applications, it remains the most cost-effective solution. As with EPROM, mask ROM is in decline both in units and revenue. Aside from video game applications, there are no new volume-consuming applications. Most densities are nearing the final stages of their life cycle curve, and only densities at 32Mb and above are enjoying growth. Dataquest expects the market to continue the overall trend downward to the end of the decade. EEPROM continues to experience good growth in 1996, a trend Dataquest expects to continue. New applications such as handsets, pagers, smart cards, and other microcontroller-based

applications continue to fuel volume demand. Dataquest also sees that the density, while still in kilobits, is slowly starting to increase.

To summarize, many nonvolatile devices are in decline, so care should be taken on existing and future designs to ensure adequate supply. Buyers should consult the Dataquest life cycle curves and their individual suppliers' product road maps to ensure supply. In general, flash continues to be the nonvolatile device family that offers the greatest leeway for negotiating price and availability. However, on lower-density devices, care should be taken because supply is more limited in these end-of-life devices. The outlook for EEPROM remains positive, with more and more niche applications developing.


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**For More Information...**

Evelyn Cronin, Senior Industry Analyst ..... (408) 468-8075
Internet address ..... evelyn.cronin @dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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Perspective



Semiconductor Supply and Pricing Worldwide

# Market Analysis

# SRAM Demand in Fourth Gear While Supply Stays in Overdrive: SRAM Market Update

**Abstract:** *The SRAM market remains linked to the PC industry and has remained in oversupply since late 1995. Even those who do not use cache SRAM have been affected by the abundance of parts as suppliers shift production to more profitable noncache devices, thus improving overall availability. Although not as visible as the DRAM market, the SRAM market continues to mirror its volatile cousin in price, with some cache devices going down to or below cost because of oversupply. This update focuses on the life cycles and future of these important memory devices and on how the supply base is changing to meet market demand.*

*By Mark Giudici*

## Oversupply Remains despite Solid End-Use Demand

The continued need for cache memory in high-performance PCs continues to mold the direction of the overall static RAM (SRAM) market. The cache RAM requirements of the Pentium class of processors, the PowerPC, and other high-end microprocessors remain strong, and suppliers have been more than eager to meet this demand. Intel Corporation's chipset requirements have and will continue to heavily influence this market place. By announcing that it will have no more than five cache SRAM suppliers for its Pentium II class of chips, Intel will force all the other suppliers into the non-Intel market, potentially causing another glut in late 1997 to 1998.

The market remained in oversupply for fast cache devices (under 15ns) throughout 1996. The 32Kx32 part quickly became the commodity du jour, and pricing under cost was always a possibility. The follow-on 64Kx32 cache device appears to be filling in as a potential down-in-the-dirt-priced part as the next generation of cache products becomes more available. All of this

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competition has caused many SRAM suppliers to re-evaluate their product mix. The cache SRAM suppliers not chosen by Intel will definitely be reviewing long-term supply strategies in the latter half of 1997.

The 1996 cache SRAM market, defined as 256K, 1Mb, 4Mb, and 16Mb devices from under 4ns to 15ns is valued at $1.7 billion and is forecast to more than double to $3.8 billion in 1998. As mentioned previously, this market continues to be fueled by the increasing need for the high-speed, wide-word memory used by the 64-bit MPUs. Although the cache SRAM situation gets the most attention, the total SRAM market includes many other devices at different configurations and access speeds. This document covers the entire SRAM market, highlighting the technology trends, life cycle product curve, and leading suppliers. This document also provides a unit forecast and a SRAM user perspective.

## Density and Speed Trends

The SRAM market is made of many micromarkets delineated by total density, configuration, and speed. Specific applications, such as PCs, cellular phones, or consumer products, among others, drive demand for very specific devices. For example, the 256K SRAM continues to be most popular at speeds above 70ns and between 10 and 19ns, with minimal demand at speeds below 9ns or between 20 and 70ns.

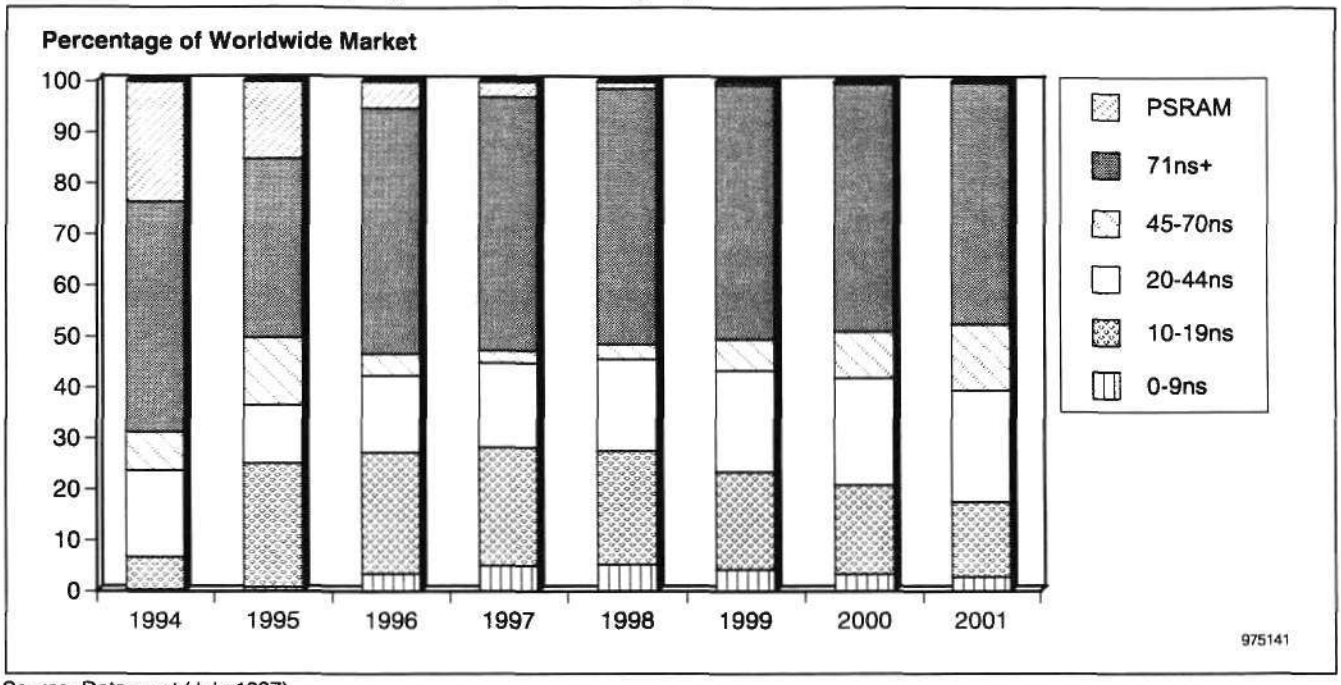
The 1996 total SRAM market, valued at $4.8 billion, shrank a dramatic 27 percent from 1995's high of $6.2 billion. However in comparison with 1994's $4.5 billion SRAM market, 1996 is relatively flat. The effects of oversupply show up directly when comparing annual SRAM average selling prices (ASP, equal to all revenue divided by all units). In 1994, the ASP was $5.11 billion, moving slowly up to $5.13 billion in 1995 because of continued strong demand and early 1995 supply allocations. The ASP in 1996 was $4.58 billion, a sharp 10.7 percent decline from two years of static pricing.

Figure 1 shows the trend in demand for the five main speed categories of SRAM. From 1994 to 1997, the two segments making up the faster-than-20ns devices (that is, cache applications) grew from 6 percent of the market in 1994 to a forecast 28 percent in 1997. Over the same period, the slow SRAM market will stabilize from 53 percent in 1994 to 52 percent forecast in 1997 because of the migration of these parts to other, non-PC related applications.

Figure 2 shows how the density of SRAM supply will change over time. In 1996, 69 percent of all SRAMs were at the 256K or smaller density. Dataquest estimates that, by the end of this year, more than half (52 percent) of the market will be over 1Mb in density. System designers and supply base managers need to keep this in mind when planning SRAM requirements, as lower-density SRAM will continue to be harder to source.

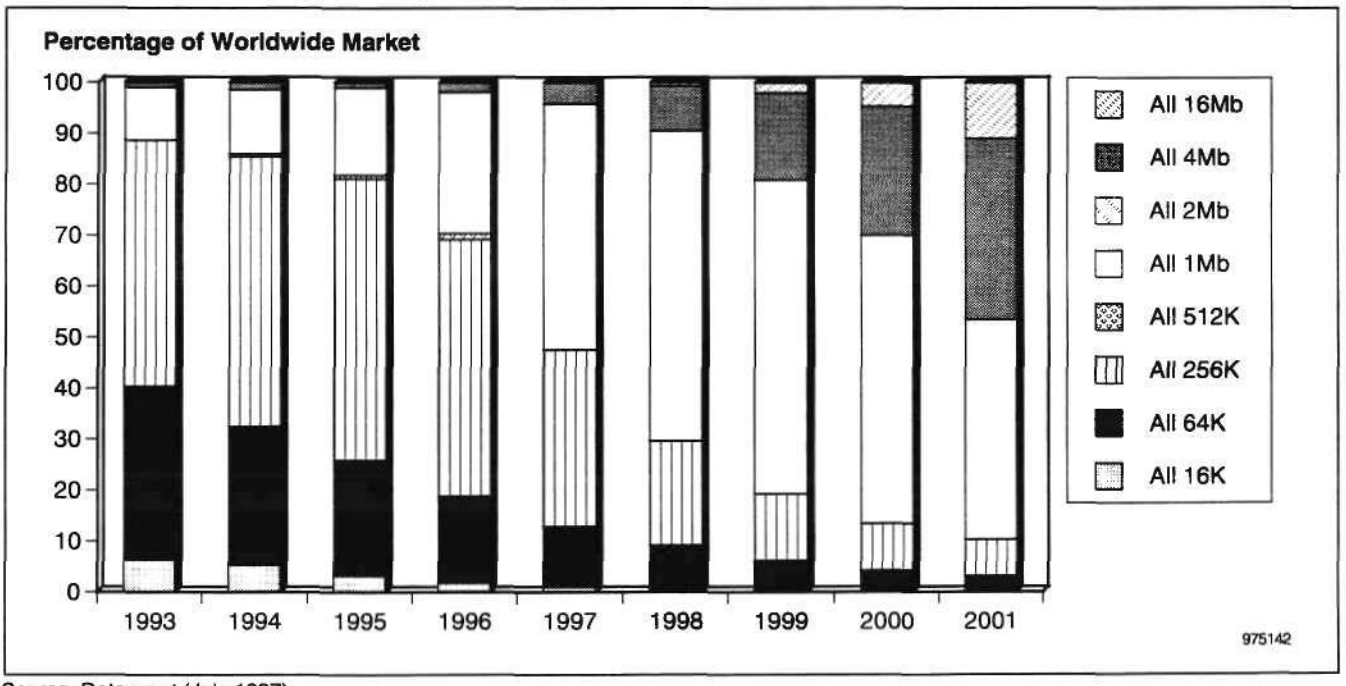
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## Figure 1
## Worldwide SRAM Megabyte Shipments by Speed




Source: Dataquest (July 1997)

## Figure 2
## Worldwide SRAM Unit Shipments by Density



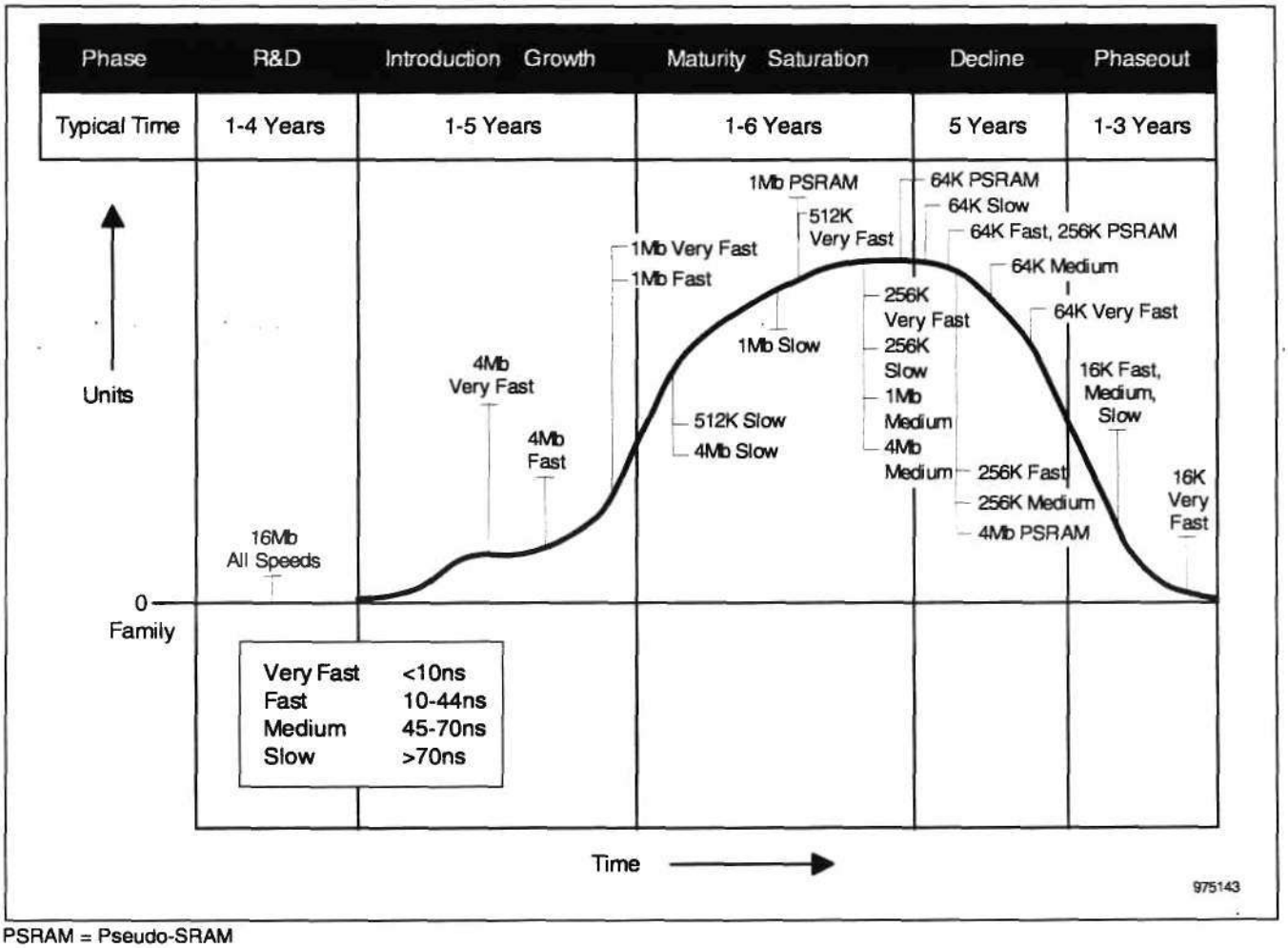

Source: Dataquest (July 1997)


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## SRAM Product Life Cycles

A pragmatic way to look at sourcing the components of a system is to place specific devices (in this case, SRAMs) on the IC life cycle curve. An IC generally has a five-stage life cycle: R&D, introduction/growth, maturity/saturation, decline, and phaseout. The life cycle curve shown in Figure 3 is based on actual 1996 SRAM shipment volume. Because of the varied applications that use SRAM, the overall SRAM life cycle is about twice that of DRAM. It is important to note that SRAM used in PCs (primarily pipelined burst x32 product) will have a much shorter-than-average SRAM life cycle because of the accelerated life cycle of the end-system application.

**Figure 3**
**SRAM Life Cycle Stages by Density**




PSRAM = Pseudo-SRAM
Source: Dataquest (July 1997)

Knowledge of where a particular device is in its life cycle is critical when deciding to design in or design out a device. Synchronizing system life cycles with semiconductor life cycles requires good coordination among system design engineering, component engineering, and procurement, ideally with each having equal weight in design/procurement decisions. The tails of the

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life cycle curve generally equal limited supplies and high prices, while the devices in the middle of the curve are available in high volume and at lower prices.

## Product/Supplier Matrix

The expanding combination of speed, density, and configurations of SRAM makes it very difficult to keep track of the worldwide SRAM supply base to ensure that all supply sources are explored. Compounding this situation is the tendency of many SRAM suppliers to focus on selected segments of the market. In an effort to reduce this confusion, Tables 1 through 7 show which SRAM densities and speeds companies actually shipped in 1996. An "x" indicates that a supplier shipped parts at the specified density and speed, and a dash means that no parts were shipped.

## Supply Base Profiles

The positions of 1995's top three SRAM suppliers remained unchanged in 1996, as shown in Table 8. As it did in DRAMs, Samsung Electronics Company Ltd. maintained its No. 1 position and grew revenue in a market in which most suppliers' revenue declined. Hitachi Ltd., which had been the SRAM market leader every year since Dataquest began studying the market until it was displaced by Samsung in 1995, maintained its No. 2 ranking by more than three percentage points of market share above next-ranked Motorola Incorporated. The top three suppliers all had or have broad product offerings that balanced the fretful 1996 cache pricing. Below Motorola there was considerable turbulence (with those more dependent on the 32Kx32 the more turbulent), yet all of the top 10 manufacturers from 1995 made the top 10 list for 1996.

**Table 1**
**16K Devices Shipped**

| | 0-9ns | 10-19ns | 20-44ns | 45-70ns | 71+ns | PSRAM |
|---|---|---|---|---|---|---|
| Cypress | - | x | x | x | - | - |
| Fujitsu | - | - | - | x | - | - |
| Hitachi | - | - | x | x | x | - |
| Integrated Device Technology | - | x | x | x | x | - |
| LG Semicon | - | - | - | - | x | - |
| Matra | - | - | x | x | x | - |
| Rohm | - | - | - | - | x | - |
| Sanyo | - | - | x | - | x | - |
| Seiko Epson | - | - | - | - | x | - |
| Sharp | - | - | - | - | x | - |
| UMC | - | - | x | - | x | - |
| Winbond | - | - | - | - | x | - |

Source: Dataquest (July 1997)


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**Table 2**
**64K Devices Shipped**

| | 0-9ns | 10-19ns | 20-44ns | 45-70ns | 71+ns | PSRAM |
|---|---|---|---|---|---|---|
| Alliance | - | x | - | - | - | - |
| Cypress | - | x | x | x | - | - |
| Fujitsu | - | x | x | x | x | - |
| G-Link | - | x | - | - | - | - |
| Hitachi | - | x | x | x | x | - |
| Hyundai | - | - | - | - | x | - |
| Integrated Device Technology | - | x | x | x | x | - |
| ISSI | - | x | - | - | - | - |
| LG Semicon | - | - | - | - | x | - |
| Matra | - | x | x | x | x | - |
| Matsushita | - | - | - | - | x | - |
| Mitsubishi | - | - | x | x | x | - |
| Mosel Vitelic | - | - | - | x | x | - |
| Motorola | - | x | x | - | - | - |
| NEC | - | - | - | x | x | - |
| Oki | - | - | - | - | x | - |
| Rohm | - | - | - | - | x | - |
| Samsung | - | - | x | - | x | - |
| Sanyo | - | - | - | - | x | - |
| Seiko Epson | - | - | - | - | x | - |
| Sharp | - | - | - | x | x | - |
| Sony | - | - | x | - | x | - |
| Texas Instruments | - | x | x | x | - | - |
| Toshiba | - | x | x | - | x | - |
| UMC | - | - | x | - | x | - |
| Winbond | - | - | - | x | - | - |

Source: Dataquest (July 1997)

Last year was not a positive one for memory suppliers in general or for SRAM suppliers in particular. Although Japanese suppliers still control over half (50.2 percent) of the worldwide SRAM market, they had the smallest revenue decline (14.5 percent) compared to suppliers in the other world regions. Because of the preponderance of cache suppliers in the Americas region, SRAM revenue there declined by 32.9 percent, leaving Americas with slightly over a quarter (26.9 percent) of the worldwide market. The third-ranked Asia/Pacific region also dropped nearly 25 percent from 1995 (24.5 percent). Asia/Pacific managed to retain its 22 percent of the worldwide SRAM market, while the small European SRAM supply base retained its less than 1 percent market foothold despite a 33 percent drop in 1996 revenue.


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**Table 3**
**256K Devices Shipped**

| | 0-9ns | 10-19ns | 20-44ns | 45-70ns | 71+ns | PSRAM |
|---|---|---|---|---|---|---|
| Alliance | - | x | x | - | - | - |
| Cypress | - | x | x | x | - | - |
| Electronic Designs Inc. | - | - | x | x | - | - |
| Fujitsu | x | x | x | - | x | - |
| G-Link | - | x | - | - | - | - |
| Hitachi | - | x | x | x | x | x |
| Hyundai | - | - | - | - | x | - |
| Integrated Device Technology | - | x | x | x | - | - |
| ISSI | - | x | - | x | - | - |
| LG Semicon | - | - | - | - | x | - |
| Matra | - | - | x | x | x | - |
| Matsushita | - | - | - | - | x | - |
| Micron | - | - | x | - | - | - |
| Mitsubishi | - | x | x | - | x | - |
| Mosel Vitelic | - | - | - | x | - | - |
| Motorola | x | x | x | x | - | - |
| NEC | - | - | x | x | x | - |
| Oki | - | - | - | - | x | - |
| Paradigm | - | x | x | - | - | - |
| Rohm | - | - | - | - | x | - |
| Samsung | - | x | - | - | x | - |
| Sanyo | - | - | - | - | x | - |
| Seiko Epson | - | - | - | - | x | - |
| SGS-Thomson | - | x | x | - | - | - |
| Sharp | - | - | x | x | x | x |
| Sony | - | - | x | x | x | - |
| Toshiba | - | x | x | - | x | x |
| UMC | - | x | x | - | x | - |
| Winbond | - | x | x | x | x | - |

Source: Dataquest (July 1997)

## Samsung

- Samsung maintained for the second year its position as the top SRAM supplier (tied with Hitachi).
- Its reluctant entry into the 32Kx32 cache market somewhat lessened the negative impact of 1996, and Samsung declined only 10 percent from 1995.
- Samsung introduced a 1.8V family of SRAMs targeted at telecom applications.


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## Table 4
## 512K Devices Shipped

| | 0-9ns | 10-19ns | 20-44ns | 45-70ns | 71+ns | PSRAM |
|---|---|---|---|---|---|---|
| Alliance | - | x | x | - | - | - |
| G-Link | - | x | - | - | - | - |
| Hitachi | - | - | - | x | x | - |
| ISSI | - | x | - | - | - | - |
| Motorola | x | x | - | - | - | - |
| Sanyo | - | - | - | - | x | - |
| Sony | - | - | x | - | - | - |

Source: Dataquest (July 1997)

## Table 5
## 1Mb Devices Shipped

| | 0-9ns | 10-19ns | 20-44ns | 45-70ns | 71+ns | PSRAM |
|---|---|---|---|---|---|---|
| Alliance | - | x | x | - | - | - |
| Cypress | - | - | x | x | - | - |
| Electronic Designs Inc. | - | x | x | x | x | - |
| Fujitsu | - | - | - | x | x | - |
| G-Link | - | x | - | - | - | - |
| Hitachi | x | x | x | x | x | x |
| IBM Microelectronics | x | - | - | - | - | - |
| Integrated Device Technology | x | x | x | - | - | - |
| ISSI | x | x | - | - | - | - |
| LG Semicon | - | - | - | - | x | - |
| Matra | - | - | x | x | - | - |
| Micron | - | x | - | - | - | - |
| Mitsubishi | - | - | - | x | x | - |
| Motorola | x | x | x | x | - | - |
| NEC | - | x | x | x | x | x |
| Oki | - | - | - | - | - | x |
| Paradigm | - | x | x | - | - | - |
| Rohm | - | - | - | - | x | - |
| Samsung | x | x | x | - | x | - |
| Sanyo | - | - | - | - | x | - |
| Seiko Epson | - | - | - | - | x | - |
| SGS-Thomson | - | x | - | - | - | - |
| Sharp | - | - | x | - | x | - |
| Sony | - | x | x | x | x | - |
| Toshiba | - | x | - | - | x | x |
| UMC | - | x | - | - | - | - |
| Winbond | - | x | - | - | - | - |

Source: Dataquest (July 1997)


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**Table 6**
**2Mb Devices Shipped**

| | 0-9ns | 10-19ns | 20-44ns | 45-70ns | 71+ns | PSRAM |
|---|---|---|---|---|---|---|
| Electronic Designs Inc. | - | - | x | x | - | - |
| Micron | x | x | - | - | - | - |
| Samsung | - | x | x | - | x | - |

Source: Dataquest (July 1997)

**Table 7**
**4Mb Devices Shipped**

| | 0-9ns | 10-19ns | 20-44ns | 45-70ns | 71+ns | PSRAM |
|---|---|---|---|---|---|---|
| Electronic Designs Inc. | - | - | x | x | x | - |
| Fujitsu | - | - | - | x | - | - |
| Hitachi | - | - | - | - | x | x |
| IBM Microelectronics | x | - | - | - | - | - |
| Mitsubishi | - | - | - | - | x | - |
| Motorola | - | x | x | x | - | - |
| NEC | - | x | x | - | - | - |
| Oki | - | - | - | - | - | x |
| Samsung | - | x | x | - | x | - |
| Sharp | - | - | - | - | x | - |
| Sony | - | - | - | - | x | - |
| Toshiba | - | - | - | - | x | x |

Source: Dataquest (July 1997)

## Hitachi

- Hitachi scratched back into the top SRAM slot, sharing it with Samsung, last year's usurper.
- Hitachi announced a 4Mb (512Kx8) 70ns, 3.3V device for portable applications and a low-voltage (3.3V), high-performance 1Mb (32Kx32) 5ns SRAM for advanced nonparity systems.

## Motorola

- Motorola's high-performance products provided a good buffer against cache SRAM price cuts—1996 revenue remained relatively unchanged over 1995 revenue.
- Motorola introduced a line of 2Mb and 4Mb known good die (KGD) SRAMs, called TrueDie, for use in mobile and high-performance computing applications.

## Toshiba Corporation

- Based on a Dataquest teardown analysis, Toshiba appears to be one of the chosen cache SRAM suppliers for the next-generation Intel processors.


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- Toshiba was one of the few gainers in 1996 SRAMs, rising from sixth position worldwide to fourth-ranked SRAM supplier, growing 13.9 percent in revenue.
- Toshiba and Fujitsu agreed on a BGA multichip package that mounts flash memory and SRAM in a single package.

### NEC Corporation

- Based on a Dataquest teardown analysis, NEC appears to be one of the chosen cache SRAM suppliers for the next-generation Intel processors.
- NEC announced at the International Solid-State Circuits Conference a 500-MHz, 4Mb double data rate (DDR) SRAM available for sampling as early as the first half of 1998.
- NEC has licensed Artesian Components Inc.'s embedded SRAM family to complement its growing embedded memory line.

### Sony Corporation

- As one of the companies experiencing the brunt of 1996, Sony saw revenue decline 26.5 percent last year, dropping it from fourth to sixth place in the SRAM ranking.
- Sony announced a family of six 4Mb SRAM devices manufactured on 0.35-micron BiCMOS and CMOS processes, running on 3.3V at speeds ranging from 4.5ns to 8ns.

**Table 8**
**Top 10 Worldwide Companies' Factory Revenue from Shipments of Static RAM Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | 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 (July 1997)


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### Mitsubishi Corporation

- Based on a Dataquest teardown analysis, Mitsubishi appears to be one of the chosen cache SRAM suppliers for the next-generation Intel processors.
- Mitsubishi unveiled a 113-sq. mm. 32-pin TSOP package for its 1Mb and 2Mb SRAM devices.
- Mitsubishi announced a 4Mb device family (1Mbx4, 4Mbx1, and 512Kx8) that runs on either 3.3V or 5V, featuring access times of 12ns, 15ns, and 20ns.

### Cypress Semiconductor Corporation

- Although experiencing a 15.7 percent decline in SRAM revenue, Cypress moved up one rung in the SRAM rankings, from ninth to eighth position.
- Cypress introduced an ultra-low-power family of 256K SRAMs that operate down to 1.5V.

### Integrated Device Technology Inc.

- Highlighting the nature of the 1996 SRAM market, IDT had a revenue decline of 35.1 percent and yet managed to rise to ninth place from 1995's 10th position.
- IDT announced a new SRAM family of synchronous dual port devices made up of four 512K and two 256K parts with output data rates as fast as 12ns, aimed at networking and telecom applications.

### Winbond Electronics Corporation

- One of the harder-hit SRAM suppliers, Winbond slipped back to 10th position in 1996 primarily because of the last year's cache SRAM price debacle, seeing revenue fall a breathtaking 52.4 percent after a phenomenal rise in 1995 of 119 percent.
- Winbond was one of two Taiwanese SRAM suppliers named in a semiconductor dumping suit by Micron Technology Inc.. Winbond denied the charges.

## Dataquest Perspective

Although the SRAM market remains very closely linked to the PC and DRAM markets, SRAMs differ in that a plethora of applications outside of computers use these parts. Because of the tie with PCs, supply and demand issues in that market indirectly affect the other, lower-volume users. The glut of cache SRAM last year resulted in a scramble to provide other, more profitable SRAM or products that could be made on SRAM production lines. The indirect result last year for non-PC companies was good availability of most SRAM devices at lower-than-average prices. Although not all users require wide bus synchronous SRAM, this segment of the market will continue to drive technology and density trends. The continuing game of ensuring adequate supplies of older SRAM devices while new system designs take advantage of higher-density SRAM parts was easier to play last

year. At current levels of demand and capacity available, the balancing game of older products and new products should remain easy through the first half of 1998. As noted in last year's update, the current buyer's market for SRAM should not lull users into thinking that long-term supplier relationships are no longer needed. Sharing future product and technology needs with suppliers will ensure users that they will have competitive sources of products while keeping overall costs down.

**For More Information...**

Mark Giudici, Director and Principal Analyst ..... (408) 468-8258
Internet address ..... mark.guidici@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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Perspective



Semiconductor Supply and Pricing Worldwide

# Market Analysis

# Third Quarter 1997 Procurement Pulse: Order Rates Are Mixed, Lead Times and Inventories Inch Upward, and Spot Prices Lead Contracts Down

**Abstract:** *The* **Procurement Pulse** *is a quarterly update (with interval updates, if events warrant) of critical issues and market trends based on surveys of semiconductor procurement managers in the North American region. Besides order rate, lead time, and inventory information, this survey also notes price status by semiconductor product family and package type, as well as key problems facing semiconductor users.*
*By Mark A. Giudici*

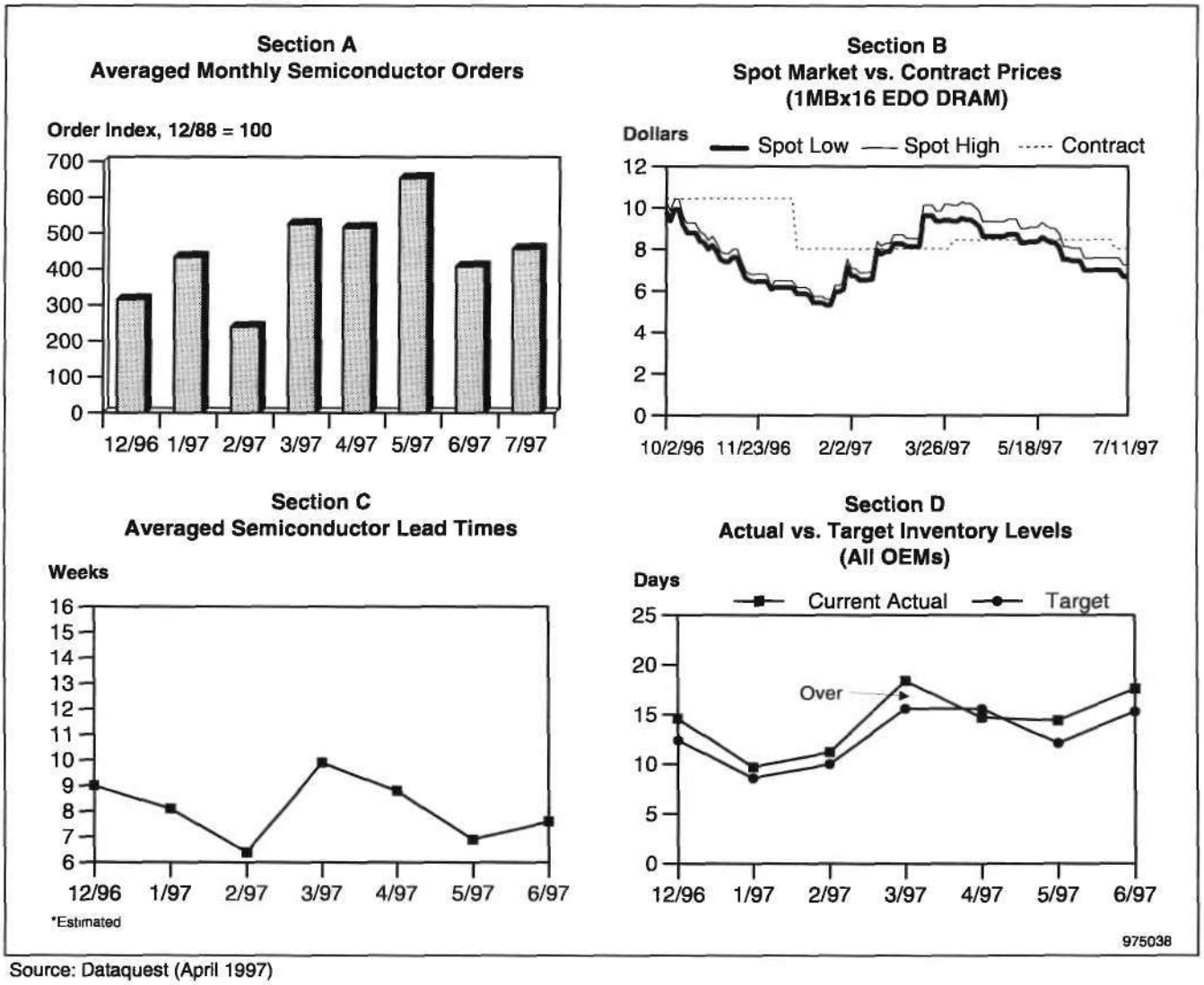
## Semiconductor Order Rate Expected to Bounce Back after Two Months of Cautious Forecasts

As seen in Section A of Figure 1, the outlook for semiconductor order activity has gone up and down and now up again since Dataquest's last report. Although slightly higher than June's forecast index, the outlook for July has historically been lower, a harbinger of the "summer slows." This year may prove different from other oversupplied years. The spike in DRAM spot pricing noted in Dataquest's last report has since corrected itself, and market dynamics, not supplier schemes, again continue to cause overall pricing to slowly decline. The overall sample continues to see price cuts for larger-volume contracts in all areas tracked in this survey—MPUs, DRAM, SRAM, and especially flash memory. Highlighting the resumption of actual supply versus demand, DRAM pricing for the overall sample declined on average by 2.9 percent after the relatively flat 0.6 percent decline noted last month. The computer subset of the respondents saw a sharper decline of 3.5 percent in DRAM prices after a 2.3 percent cut noted in June. While overall

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prices continue to decline, pricing for TSOPs and BGAs continues to earn (albeit smaller) premiums of 2 to 5 percent over more standard package offerings.

**Figure 1**
**Semiconductor Supply and Pricing**




Source: Dataquest (April 1997)

## Spot Market Pricing Again Leads Contract Pricing—Down

Since Dataquest's last report, the spot market has resumed its role as market bellwether, again leading contract DRAM pricing downward, as seen in Section B. The scheme to control prices that began in February and ended in May did so only in the volatile and low-volume spot market. This was an expensive way to increase margins, and it became evident to the suppliers involved that there are more efficient ways to increase profit than withholding product. The shift to the 64Mb DRAM device is now in full swing, and although Dataquest still foresees a market crossover from the 16Mb part in about the second or third quarter of 1998, some leading

suppliers may already be there. As noted over the past year, we expect continued volatility of spot market prices to vacillate around declining contract prices, causing uncertainty for some buyers. The overall trend, however, is for continued good availability, consistently declining contract prices, and low (8- to 10-week) lead times for the next six to nine months for contract buyers.

## Lead Times for Semiconductors Remain Manageable at under Eight Weeks

Section C highlights that the average lead time for respondents in June edged up slightly to 7.6 weeks, compared to a 6.9-week average noted in May. The current stability of lead times is in part because of the removal of uncertainty over DRAM supplies now that many of the larger Korean and Japanese suppliers have resumed shipments. The acknowledgment by both buyers and suppliers that 1996-style price cuts and availability are now history is causing some prudence in overzealous spot buyers, making contracted deliveries increasingly attractive. Good service levels combined with slowly declining prices are cementing many long-term supplier relations. Although there were no supply problems noted in this month's survey, good communications with suppliers often forestall possible problems. Last quarter, close to half of the respondents noted DRAM price/supply issues, but there now appear to be few supply problems to complain about.

## Semiconductor Inventories Back to Historical Levels

Section D shows that inventories continue to overshoot targeted levels and closely track target direction. As respondents forecast semiconductor order rates to modulate, Dataquest sees a corresponding slight increase in inventory levels more in line with historical levels. The overall targeted and actual semiconductor inventory levels for June were 15.3 days and 17.6 days, respectively, compared to May's 12.1-day and 14.4-day inventory levels. Although not shown, the computer subset again appears more aggressive than the average, with current target and actual inventory levels of 6.0 days and 10.0 days. Dataquest continues to expect to see stabilized inventory levels in the future in line with steady systems sales levels.

## Dataquest Perspective

Availability of semiconductors remains very good to excellent, and we expect it to remain this way for the rest of 1997. As mentioned last March, Dataquest continues to see contract prices decline despite the efforts of some memory suppliers to curtail output. Lead times have stabilized to meet customer demand, in line with the moderate price declines. Dataquest continues to forecast steady 1997 growth rates for PCs and other electronics relative to 1996, with the overall trend following an upward growth slope. User semiconductor inventory levels are now in line with user demand, and we expect to see continual balance in these indexes in the near future. Real allocations are not a problem, but the quick shift of some suppliers to the

64Mb DRAM density may well cause some supply dislocation if overall demand moves more quickly to 64Mb DRAM. With continued pricing competition at the 16Mb level, this scenario is possible but not highly probable. Dataquest expects to see excellent semiconductor availability through the end of 1997. DRAM and MPU price elasticity to date have not propped up contract prices. The good news for users is that overall declining contract prices will continue for the remainder of this year.

**For More Information...**

Mark Giudici, Director and Principal Analyst ..... (408) 468-8258
Internet address ..... mark.giudici@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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Perspective



Semiconductor Supply and Pricing Worldwide

# Market Analysis

# DRAM Product/Market Update 1997: A Market in Flux

**Abstract:** *This document provides insight to users of DRAM on how the current market oversupply is changing the traditional supply/demand equilibrium. The DRAM market rankings for 1996 by product density are examined, and the DRAM life cycle chart for these products is updated and analyzed.*
*By Evelyn Cronin*

## Overview

This Perspective looks at the DRAM market from a procurement standpoint. It is split into a number of sections. The first section examines the current states of the DRAM industry—both technology transitions and market issues. The second section contains the DRAM unit production forecast and life cycle curve analysis. The analysis of DRAM suppliers by 1996 market share is the third section, which is followed by a look at strategic DRAM alliances. The fifth section tracks the supply base by density, based on 1996 shipment data. The sixth section looks at nonstandard DRAM. The Perspective concludes with a summary and analysis of the DRAM market.

## The State of the DRAM Industry

Figure 1 shows some of the changes occurring in 1997 with which both buyers and suppliers are grappling—1997 is definitely the year of change.

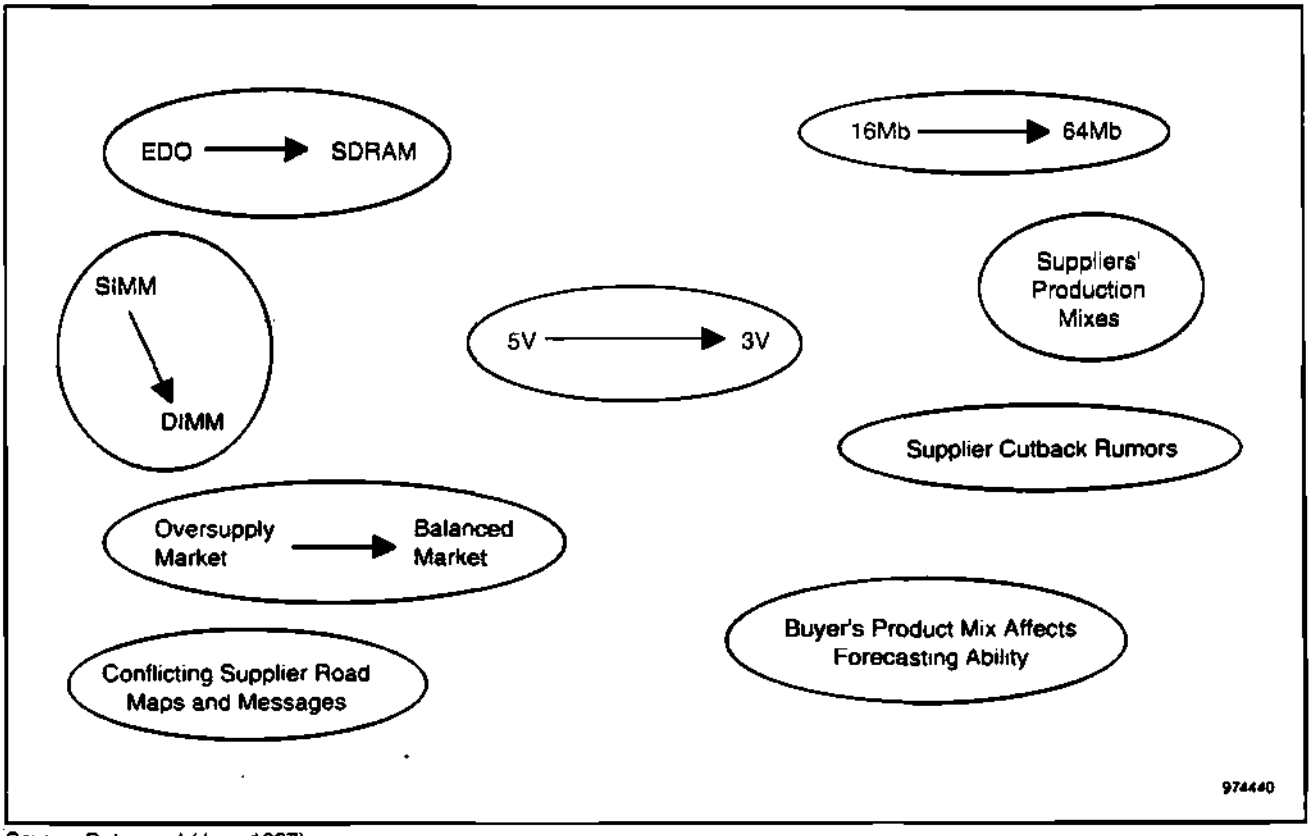
These changes or issues can be split into two categories:

- DRAM technology related
- DRAM market related

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**Figure 1**
**DRAM—Market in Flux**




Source: Dataquest (June 1997)

This Perspective looks at both sections, starting with DRAM technology-related transitions.

## DRAM Technology-Related Transitions

### The 16Mb-to-64Mb Transition

The 64Mb chip is becoming increasingly visible. Certain suppliers claim to be cutting back 16Mb production already to ramp up the 64Mb density. Many vendors have offered price parity to specific customers for 16Mb and 64Mb in an effort to migrate demand to the larger density. These vendors, the technology leaders, hope to gain market share at this newer density and to become the first-choice suppliers that blaze the trail and set the standards. But what should the buyer do?

### The 5V-to-3V Transition

The voltage level has also begun to move south. For the longest time, 5V was the standard for DRAM. Now, increasingly, 3V is becoming the voltage choice for customer applications. Thus, suppliers and buyers alike need to make forecast adjustments to ensure the correct mix.


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### The SIMM-to-DIMM Migration

This voltage move from 5V to 3V often ties in with the change in module type, from single inline memory modules (SIMMs) to dual inline memory modules (DIMMs). DIMMs are 3V products. For PC buyers, the use of a DIMM reduces the number of sockets required on the motherboard. It also means that the "two SIMMs per Pentium system" rule (meaning that the number of memory address lines must equal the number of Pentium 64 address lines, so that two 32-bit SIMMs are needed) becomes a thing of the past. The DIMM offers 64 address lines per module. However, SIMMs and DIMMs differ in length, socket type, and voltage level, among others.

### EDO to SDRAM

The technology transition from the asynchronous EDO to the synchronous SDRAM is beginning in earnest in 1997. Intel is backing this move for the PC arena and making it the base memory of choice for certain Pentium application systems. Also, chipset and motherboard support exist and will increase. Most large PC companies have come out with SDRAM-designed systems, and this number is forecast to increase in the second half of the year. Many believe that SDRAM will be *the* technology enabler for multimedia and consumer systems. Interest outside the PC sector is also great. Many other applications are designing in SDRAM chips (at 16Mb and 64Mb densities).

However, there is a large range in price and speed in the SDRAM offerings from different suppliers. Suppliers usually have their own take, depending on whether the company is a technology leader or laggard. That means that buyers hear many (often contradictory) messages from their supplier base. Which one to believe?

## DRAM Market-Related Issues

### Oversupply to Balanced Market

The DRAM market characteristics are changing. Although Dataquest forecasts that DRAM will remain in oversupply throughout 1997 on a megabyte basis, there will be some short-term capacity constraints on certain products. Also, although the market in 1997 is considered to be in oversupply, it will behave in a different manner than in 1996. It is important to remember that in 1997, the market is making a transition from oversupply to supply/demand equilibrium (a balanced market), while in 1996, it made the transition from supply constraint to oversupply.

### Supplier Production Cutback Rumors

Many suppliers, particularly those in Korea, were quick to announce DRAM production cutbacks in January 1997. This did cause DRAM pricing to increase slightly in the contract channel from the first quarter to the second quarter. However, the suppliers hoped to stabilize the market and to dry up the redistribution or spot market for DRAM sales. Spot market prices increased short term, but they quickly fell back down—trading never picked up, and product availability remained. This has led many to question whether production was cut back in any significant volume.


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### Suppliers' Production Mixes

All suppliers will be altering production mixes this year. Some suppliers are leading the charge by aggressively pushing the market to accept 64Mb chips, SDRAM technology, or DIMMs. These were the first to deal with internal production changes.

With the move from fast page mode (FPM) to EDO, there was typically a lag of about two months. Suppliers who are leading the migration to the newer technologies, however, are making changes to their production.

### Conflicting Supplier Road Maps and Messages

Wouldn't it make life a lot easier if all suppliers launched compatible production on the same day with identical pricing and availability messages? Unfortunately, reality is different. At the moment, contradictory and conflicting messages are coming from all DRAM suppliers on technology and market supply issues. Each has a different take on the market it offers to its customers. And the customer is left confused. Who should be trusted? Who should be called?

From a technology standpoint, the leading DRAM suppliers are split into three camps:

- Technology leaders
  - As the name would suggest, technology leaders are first to market on new technologies. They are aggressively moving the market forward.
- Technology followers
  - Followers typically launch products six to nine months after the technology leaders. They are usually forced to match the pricing of the technology leaders when they do.
- Technology laggards or also-rans
  - These companies are often a year of so behind the leaders. Their business is generic, standard multisourced devices. Often, their initial offering of a new technology comes from a sourcing agreement with a technology leader or follower. However, these companies usually stay with the market longer and will typically ride the product to the phaseout stage of the life cycle curve.

Looking at the road maps and listening to the messages of DRAM suppliers makes it easy to categorize them on SDRAM, 64Mb, and so on. Road maps and fab or yield capacity issues often explain the seemingly contradictory messages from the suppliers in times of flux.

### Buyers' Product Mixes Affect Forecasting Ability

In an ideal world, the Material/Manufacturing Requirement Plan (MRP) would be 100 percent accurate. When new products came out, they would ramp up on cue, as predicted, while the older products would tail off as per the forecast. Of course, suppliers would deliver product on the exact due date with no slippage. Tragically, real life has dealt the buyer a crueler hand.

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With so much happening on both the external supply side and the internal demand side, it is inevitable that wires will be crossed and the forecast will not be as "accurate" as usual. This puts the buyer in a crucial position, taking a lead role in communicating overall strategy to the suppliers externally and translating the supply-side road map into realistic volume production dates for internal planning purposes.

Because nearly all buyers are unsure of what their actual demand will be, suppliers have problems working out overall customer demand for their DRAM production staff during this turbulent time. This affects new and old product availability.

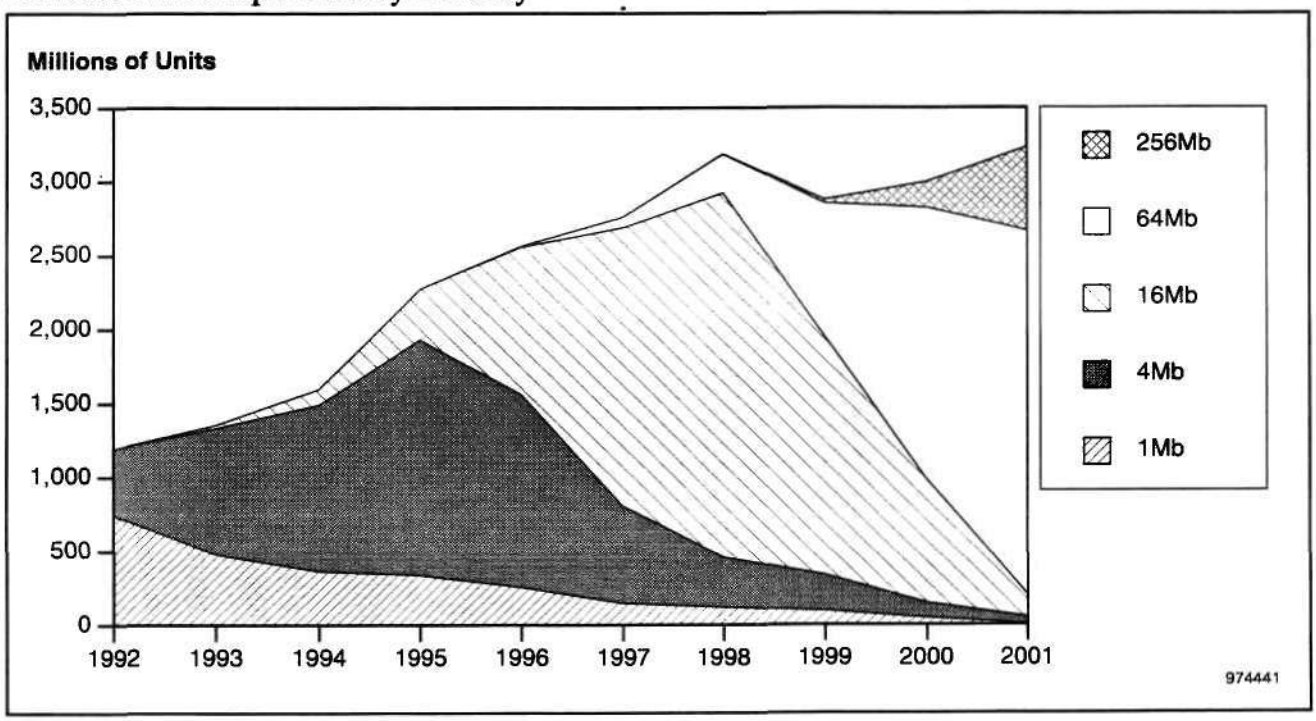
The bottom line is that those who thought they were out of deep water should think again! Buyer and supplier alike will be challenged in 1997 in ways significantly different from 1996.

## DRAM Unit Production and Life Cycle Curve

### Density

Figure 2 shows DRAM unit shipments by density. The historic unit shipment and forecast information reveals that 4Mb was the DRAM of choice for 1996, in terms of number of units shipped. However, more megabytes of DRAM were produced from 16Mb devices than from 4Mb devices in 1996.

**Figure 2**
**DRAM Unit Shipments by Density**




Source: Dataquest (June 1997)

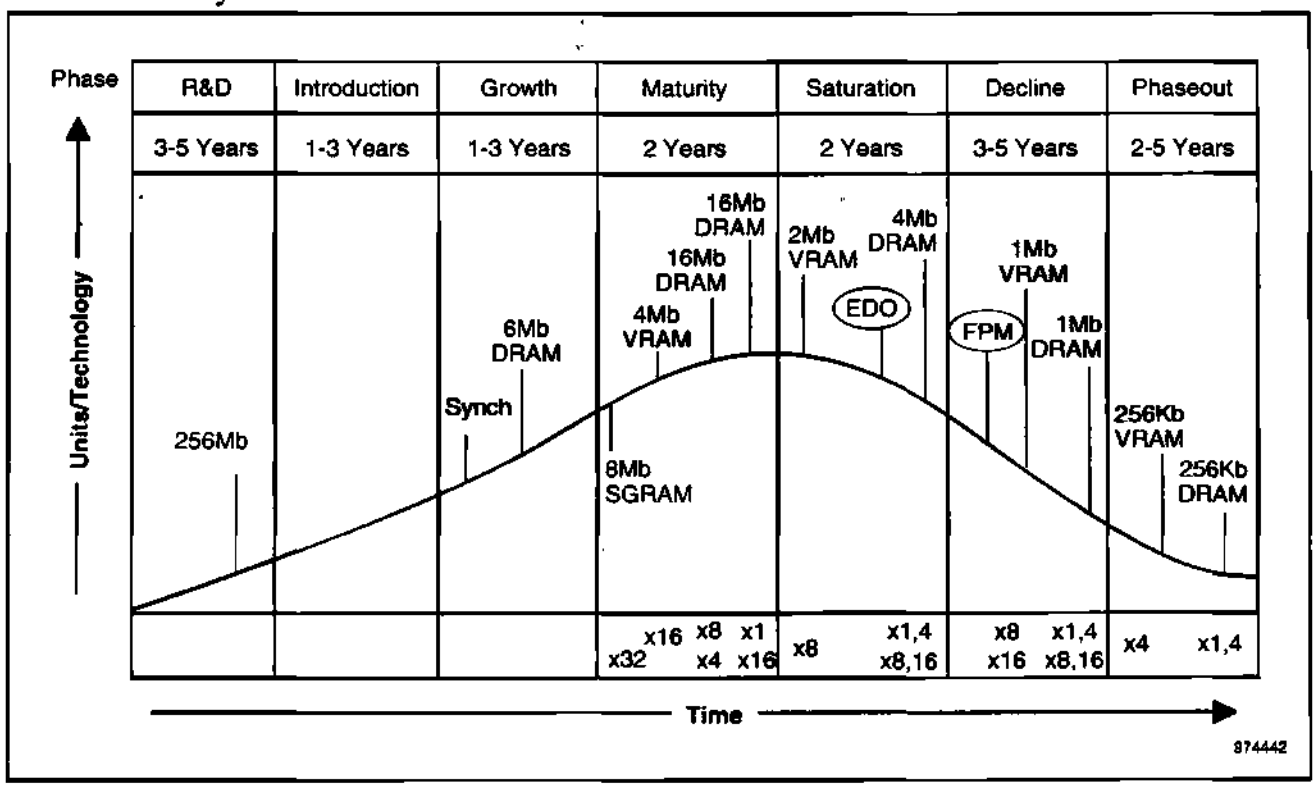

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In 1996, over 90 percent of DRAM units shipped were 4Mb and 16Mb chips, with the 1Mb and 64Mb chips accounting for the remaining 10 percent. This pattern remains essentially the same in 1997 but with 16Mb chips accounting for over 68 percent of the total units of chips shipped alone. This dominance of the 16Mb chip increases to over 77 percent in 1998 but falls back to about 56 percent in 1999. This falloff of 16Mb dominance in 1999 coincides with the rise in unit shipments of the 64Mb chip.

Despite all the talk about crossover, it is worth noting that 64Mb shipments rose from about 0.25 percent in 1996 to 2.6 percent in 1997 and 8.3 percent in 1998. In 1999, 64Mb begins to emerge from relative obscurity, with over 31 percent of all units shipped being at this density. In the year 2000, 61 percent of DRAM units shipped will be at 64Mb, and by forecast's end in 2001, this will have risen to over 76 percent.

Figure 3 offers a broader perspective by placing the various DRAM densities and configurations in a life cycle curve.

**Figure 3**
**DRAM Life Cycle Curve**




Source: Dataquest (June 1997)


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The position of the devices on the life cycle curve is based on the Dataquest forecast of unit shipments of the devices over time. Figure 3 uses 1996 DRAM unit shipments as the starting point and looks to the historical actual shipment and forecast shipment data to determine the position of individual devices.

Typically, for the 1Mb and above DRAM chip densities, the x1 and x4 configurations are produced first, with the x8 and the x16 configurations following later.

Both the video RAM (VRAM) and DRAM 256Kb chips remain in the phaseout stage of their life cycle curves. The 1Mb DRAM hovers at the back end of the decline phase, poised to move to the phaseout stage next year. The 1Mb VRAM chip remains in the middle of the decline phase of its life cycle curve.

The 4Mb DRAM chip reached its peak in 1995 and now remains at the back edge of the saturation stage of its life cycle curve. The 2Mb VRAM has moved to the saturation stage as well, based on the unit shipments of this device worldwide.

The 16Mb DRAM chips (x1 and x16 16Mb and x4 and x8 16Mb) are in the maturity phase of their life cycle curve. They should move to the saturation stage in 1997 in preparation for reaching their peak unit shipment level in 1998.

The 4Mb VRAM has rapidly moved up its life cycle curve and has entered its maturity phase. It should reach saturation stage in 1998 (the year of its forecast maximum unit shipments).

The 8Mb synchronous graphics RAM (SGRAM) is also progressing very quickly through the beginning phases of its life cycle curve and is at the entry stage of the maturity phase. Dataquest predicts that this device will reach its saturation stage in 1999 (the year of its maximum unit shipment level).

The 64Mb, at all configurations, has entered its growth phase. Dataquest forecasts that this device will move steadily through the growth and maturity phase as its unit shipments ramp up over time. Dataquest forecasts that the 64Mb should enter the maturity phase in 1999.

Dataquest would recommend not using the 256Kb and 1Mb devices for new product designs because these products will not be available in high volumes from most suppliers. These devices will be available for existing customers, however, to support older products where a design-out is impossible.

Although the 4Mb volumes are decreasing rapidly, this density will be available for nonmodule applications for specific vendors for some time. However, for PC customers, Dataquest would recommend migrating from this density except for video applications.

The 16Mb will be the chip most easily obtained for the next couple of years and, as such, is the ideal choice for cost-competitive solutions. The 64Mb

chip will not reach unit volume crossover with the 16Mb until 2000, but the 64Mb will reach price parity with the 16Mb on a megabyte basis in 1998. Therefore, this higher-density chip will be a cost-advantageous choice.

## Technology Type

Figure 3 also examines the relative position of the DRAM technology types on the life cycle curve.

In terms of technology type, the three main types featured on this life-cycle curve are FPM, EDO, and synchronous DRAM. Both FPM and EDO DRAM are asynchronous technologies. FPM DRAM has been the main driver for all applications for the past number of years. However, it was rapidly replaced by EDO DRAM in 1996, initially for PC applications.

To start with, EDO was launched at price parity with FPM. However, as the bulk of demand moved to the EDO technology, the FPM technology became the niche choice. In early 1997, some suppliers began to charge a premium for FPM chips and modules over the equivalent EDO versions. By second quarter 1997, this trend had gained momentum and is forecast to continue indefinitely. Although the price adder for FPM over EDO is only a matter of cents, it is still worth noting.

Currently, the FPM has moved to the decline phase of its life cycle curve. It will still be available for a number of years to come, but it will become more expensive relative to EDO over time. Dataquest would not advise using this technology if EDO or SDRAM can be substituted for newer designs with expected long lifetimes.

EDO is now at the saturation phase of its life cycle curve. Dataquest expects that the oversupply of 16Mb EDO product will continue in 1997. EDO product will remain cheaper than its FPM equivalent for the duration of the forecast.

SDRAM is being launched very aggressively by some key suppliers this year. Already, some major PC companies have announced products using this technology. Also, Intel has strongly backed SDRAM for multimedia PC applications.

Although, ultimately, 64Mb will be the density of choice for SDRAM, initially, suppliers will use 16Mb SDRAM for certain applications. SDRAM will take off and Dataquest expects it to be one of the "bells and whistles" for fourth quarter 1997 PCs.

Because of the limited supply base for SDRAM, Dataquest forecasts shortage possibilities of certain SDRAM speeds and configurations in fourth quarter 1997. Strong demand for SDRAM will affect the pricing of EDO. EDO will be the generic older technology that will be forced to compete on price only against the SDRAM. Thus, there is a strong potential for price destabilization on 16Mb EDO product by end 1997.

## Top DRAM Suppliers

Table 1 and Figure 4 show market share for the top DRAM suppliers.

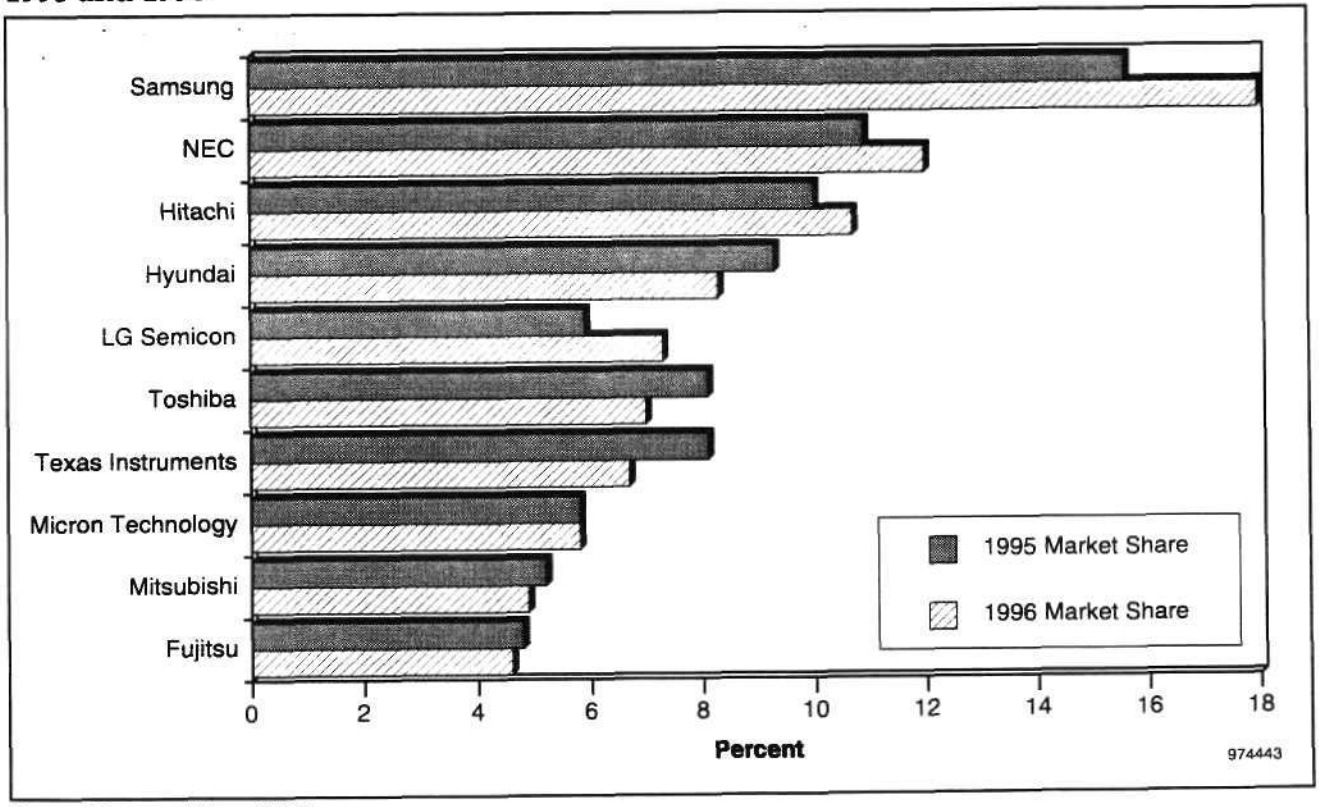
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**Table 1**
**DRAM Worldwide Market Share (Thousands of U.S. Dollars)**

| 1995 Rank | 1996 Rank | Company Name | 1995 Revenue | 1996 Revenue | 1996 Market Share (%) |
|---|---|---|---|---|---|
| 1 | 1 | Samsung | 6,592 | 4,672 | 18.0 |
| 2 | 2 | NEC | 4,592 | 3,108 | 12.0 |
| 3 | 3 | Hitachi | 4,239 | 2,767 | 10.7 |
| 4 | 4 | Hyundai | 3,950 | 2,147 | 8.3 |
| 7 | 5 | LG Semicon | 2,500 | 1,891 | 7.3 |
| 5 | 6 | Toshiba | 3,458 | 1,818 | 7.0 |
| 6 | 7 | Texas Instruments | 3,429 | 1,734 | 6.7 |
| 8 | 8 | Micron Technology | 2,434 | 1,511 | 5.8 |
| 9 | 9 | Mitsubishi | 2,201 | 1,283 | 4.9 |
| 10 | 10 | Fujitsu | 2,051 | 1,194 | 4.6 |
| | | Others | 6,803 | 3,802 | 14.7 |
| | | **Total Market** | **42,249** | **25,927** | **100.0** |

Source: Dataquest (June 1997)

**Figure 4**
**Market Share of Top 10 Worldwide DRAM Suppliers, Based on U.S. Dollar Revenue, 1995 and 1996**




Source: Dataquest (June 1997)


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All DRAM suppliers would like to forget 1996. No company in the top 10 had revenue growth; no company even managed flat revenue for this 12-month period.

Instead, the top 10 reads like a list of the walking wounded. We are forced to look at those who suffered the fewest casualties in the DRAM revenue war between the years!

LG Semicon Co. Ltd. lost the least and gained the most. It was the only company in the top 10 to rise in the ranking table, from seventh to fifth, and it also lost the least in revenue terms (just less than a quarter of its revenue).

Samsung Electronics Co. Ltd. was the only other top 10 company to experience less than a 30 percent revenue change from 1995 to 1996. NEC Corporation and Hitachi Ltd. retained their overall ranking positions, and each had negative revenue change of about a third in revenue.

These four (LG Semicon, Samsung, NEC, and Hitachi) must have been thankful—for such a brutal year, they did relatively well. They could have done better, but they could have done a lot worse, also.

However, although the revenue changes and overall ranking tell a significant portion of the story, the changes in market share from 1995 to 1996 add an important dimension to help complete the full picture.

Examining market share results of the top 10 suppliers from 1995 to 1996 gives a true reflection of which vendors were able to increase their market dominance and which were not, despite the revenue shortcomings experienced by all.

It is hardly surprising that Samsung, NEC, and Hitachi were able to use 1996 as an opportunity to gain market share, despite shrinking revenue! All three benefited from their strong OEM contract market in the first half, which then enjoyed higher prices than the spot market. All three had solid EDO production strategies and were able to rapidly and successfully make the transition to the newer technology in line with customer demand.

LG Semicon also gained market share in 1996, albeit by adopting a different strategy than the top three. It did not have solid OEM customer relations to fall back on, although it had made progress on that front in 1995, and it lacked a cutting-edge road map. However, LG Semicon was able to turn these two seemingly large handicaps into major advantages. LG Semicon listened to what the market and its customers were saying. It responded rapidly to the changing market dynamic by cutting prices on generic, multi-sourced products and by seeking new sales channels. Its aggressive approach meant it won business away from its more slowly moving "established" competitors (other Japanese and U.S. companies, along with Hyundai).

Micron Technology managed to remain flat—neither gaining nor losing market share from 1995 to 1996.

Those who lost both market share and revenue in the top 10 were Hyundai Electronics Co. Ltd., Toshiba Corporation, Texas Instruments Inc., Mitsubishi Corporation, and Fujitsu Ltd. The hope is that these six companies learned from their mistakes last year and will at least retain market share for 1997, with the aim of building.

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All DRAM suppliers are glad 1996 is over, but Dataquest forecasts that worse is to come in 1997. All suppliers must be hoping to have learned from last year's experiences and to translate these lessons into adequate disaster relief plans to help them through 1997.

## Strategic RAM Alliances

Table 2 shows worldwide DRAM technology alliances. Those made in 1996 are as follows:

- Hitachi announced an extension of its agreement with LG Semicon to include a joint venture and fab agreement on 16Mb and 64Mb DRAM. The venture will be 51 percent controlled by Hitachi, 49 percent by LG Semicon. Also, Hitachi and the Singapore government have a joint venture on 4Mb density DRAM.
- Hitachi and Nippon Steel Semiconductor joined forces with the Economic Development Board (EDB) in Singapore to form Tampines Singapore, a joint venture for 64Mb DRAM. Tampines Singapore will be split 35:35:30 among Hitachi, Nippon Steel, and EDB, respectively.
- Hyundai and Scotland Development unveiled funding for a plant in Halbeath Dunfermline, Scotland, for DRAM production. Also, a license agreement was taken by Hyundai for Rambus Inc. 16Mb and 64Mb technology.
- Inomicro has a sales agreement with Micron Technology Inc. for general DRAM. Tanisys has a sales agreement for Siemens memory module manufacture. Kanematsu Semicon has a joint-venture agreement with UMAX Computer Corporation for 16Mb DRAM.
- Intel Corporation came out with a very public announcement in December 1996 of an alliance with Rambus. Calling it a sales agreement, Intel stated then that Rambus was the architecture for future systems to facilitate greater bandwidth.
- NEC and Samsung have agreed to coordinate standards on 16Mb SDRAM. As both companies are the technology leaders for synchronous technology, this agreement allows customers to have a compatible second source of this new technology.
- Oki Electric Industries Co. Ltd. made an announcement on Multibank DRAM, signing a sales agreement with MoSys Inc. Also, Oki established a technology exchange and licensing agreement with Silicon Magic Inc. for embedded DRAM.
- Texas Instruments has had another busy alliances year. It signed a licensing agreement with Samsung covering DRAM in general. TI also increase its stake to 33 percent in the joint venture with China Development and Acer in Taiwan.
- TI also increased its ties with Kobe Steel Ltd./KTI. In addition to its existing 4Mb DRAM deal, TI has a joint venture for 16Mb and 64Mb with Kobe Steel/KTI.
- Finally, TI unveiled its stake in Alphatec Electronics plc, a joint venture with Alpha Microsystems (74 percent stake by Alpha, 26 percent stake by TI) in Thailand. This covers 16Mb and 64Mb DRAM.
- Toyota Group has decided to wet its feet in DRAM, announcing a joint venture with Texas Instruments for 256Mb DRAM. Tokyo Electron Ltd. has a sales agreement with LG Semicon for general DRAM.


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## Table 2
## Estimated Worldwide DRAM Technology Alliances as of May 1997

| Supplier | 1Mb DRAM | 4Mb DRAM | 16Mb DRAM | 64Mb DRAM | 256Mb DRAM | General DRAM | Others |
|---|---|---|---|---|---|---|---|
| Fujitsu | | | TSMC (FA) | TSMC (FA) | | | |
| Fujitsu | | | | Hyundai (JD) | | | |
| Fujitsu | | | | | | | TI cross license (LA) |
| Hitachi | LG Semicon (SS) | LG Semicon (FA) | LG Semicon (JV, FA)[1] | LG Semicon (JV, FA)[1] | | | |
| Hitachi | | Singapore government (JV) | | | | | |
| Hitachi | | | TI (JD) | TI (JD) | TI (JD) | | |
| Hitachi/Nippon Steel | | | | EDB/Tampines Singapore (JV)[2] | | | |
| Hyundai | | | | | | | Scotland Development for Halbeath Dunfermline fab (IV) |
| Hyundai | | | | | | | Rambus 16Mb and 64Mb (LA) |
| IBM | Enhanced Memory (LA) | | Enhanced Memory (LA) | | | | |
| IBM | | Micron (LA) | | | | | |
| IBM | | Kuroda Electric (FA) | | | | | |
| IBM | | | Siemens (JD) | | Siemens/Toshiba (JD) | | |
| Inomicro | | | | | | Micron (SA) | |
| Intel | | | | | | Rambus (SA) | |
| Kanematsu Semicon | | | UMAX (JV) | | | | |
| LG Semicon | Motorola (SS) | | | | | | |
| LG Semicon | Mosel Vitelic (FA) | | | | | | |
| LG Semicon | | Hitachi (FA) | | | | | |
| LG Semicon | | Siemens (FA) | | | | | |
| Micron | NEC (OEM) | NEC (OEM) | NEC (OEM) | | | | |
| Micron | Sanyo 64Kx16 (SS) | | | | | | |



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## Table 2 (Continued)
## Estimated Worldwide DRAM Technology Alliances as of May 1997

| Supplier | 1Mb DRAM | 4Mb DRAM | 16Mb DRAM | 64Mb DRAM | 256Mb DRAM | General DRAM | Others |
|---|---|---|---|---|---|---|---|
| Micron | | | Samsung SDRAM (JD) | | | | |
| Mitsubishi | | | Elitegroup/Powerchip (JV) | | | | |
| Motorola | LG Semicon (OEM) | LG Semicon (OEM) | | | | | |
| Motorola | Toshiba (FA) | Toshiba (FA) | Toshiba (JV) | | | | |
| NEC | Micron (OEM) | Micron (OEM) | Micron (OEM) | | | | |
| NEC | | Samsung in Europe (FA) | Samsung on SDRAM (CO) | | | | |
| NEC | | | | | AT&T (JD) | | |
| NMB | | Ramtron (JD) | Ramtron (JV) | | | | |
| NMB | | Hitachi (FA) | | | | | |
| Oki | | SGS-Thomson (JV) | | | | | |
| Oki | | Mosel Vitelic (FA) | Mosel Vitelic (JV) | | | | |
| Oki | | | | Nan Ya Plastics (LA, TE) | | | |
| Oki | | | | | | | MoSys on Multibank DRAM (SA) |
| Oki | | | | | | | Silicon Magic on Embedded DRAM (TE, LA) |
| Sanyo | | Mosaid (JV) | | | | | |
| Samsung | | Sony (FA) | Sony (JD) | | | | |
| Samsung | | | Oki SDRAM (JV) | | | | |
| Samsung | | | | | NEC (JD) | | |
| Samsung | | | NEC on SDRAM (CO) | | | | |
| Siemens | | | | ProMOS/Mosel Vitelic (JV) | ProMOS/Mosel Vitelic (JV) | | |
| Tanisys | | | | | | | Siemens on module manufacture (SA) |

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## Table 2 (Continued)
## Estimated Worldwide DRAM Technology Alliances as of May 1997

| Supplier | 1Mb DRAM | 4Mb DRAM | 16Mb DRAM | 64Mb DRAM | 256Mb DRAM | General DRAM | Others |
|---|---|---|---|---|---|---|---|
| TI | Mitsubishi (SS) | | | | | | |
| TI | | HP-Canon (JV) | HP-Canon (JV) | | | | |
| TI | | Samsung (JV, FA) | | | | | Samsung (LA) |
| TI | | Acer (JV, FA) | | | | | TI increase to 33% stake in JV with China Development and Acer in Taiwan |
| TI | | Kobe Steel (FA) | | | | | KTI/Kobe Steel for 16Mb and 64Mb fab (JV) |
| TI | | | | | Hitachi (JD) | | |
| TI | | | | | | | Fujitsu (LA) |
| TI | | | Alphatec Electronics (JV)[3] | Alphatec Electronics (JV)[3] | | | |
| Thorn-EMI | NMB (LA) | | | | | | |
| Tokyo Electron | | | | | | LG Semicon (SA) | |
| Toshiba | Motorola (SS) | Motorola (JV) | Motorola (JV) | | Motorola/ | | |
| Siemens | | | | | | | |
| Toshiba | Siemens (LA) | | | | | | |
| Toshiba | | | Winbond (LA, FA) | Winbond (LA, FA) | | | |
| Toshiba | | | | IBM (JV) | | | |
| Toyota Group | | | | | TI (JV) | | |

[1]51 percent Hitachi, 49 percent LG Semicon for 16Mb and 64Mb, in Korea
[2]Economic Development Board 30 percent, Nippon Steel 35 percent, Hitachi 35 percent, in Singapore
[3]74 percent Alpha, 26 percent TI for 16Mb and 64Mb, in Chachaersao, Thailand

Notes on agreement types:
CO—Coordination agreement. Two companies agree to coordinate standards (usually).
FA—Fab agreement. A company offers fab capacity for a partner's product technology.
IV—Investment. Companies agree on an investment for a plant or lab.
JD—Joint development. Two companies agree jointly to develop new products, which may or may not be marketed separately.
JV—Joint venture. Two companies form a new joint-venture company to develop, manufacture, and market new products.
LA—Licensing agreement. A company receives or issues a license to partner for an up-front fee or royalties.
OEM—OEM arrangement. A company sells products to an alliance partner, which are sold under the partner's name.
SA—Sales agreement. Two companies agree to allow one party to sell the product of the other.
SS—Second-source agreement. Two companies agree to develop consistent specifications to ensure a second source.
TE—Technology exchange. Two companies exchange technology, which may or may not include a transfer of money.
Source: Dataquest (June 1997)



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## Supply Base

For all DRAM suppliers, 1996 was a difficult and challenging year. The following supply base analysis for the top 10 suppliers makes this assumption as a starting point and then deals with the approach adopted by the vendors.

- Samsung
  - An excellent established OEM customer base gave Samsung a revenue head start for the first two quarters with contract orders.
  - It remained a consistent technology leader and driver for EDO in 1996, allowing it to minimize its exposure to FPM bloodbath pricing issues.
  - Samsung is leading the pack with NEC in the synchronous drive and is well-positioned for the future (enough capacity, good solid product road map).
- NEC
  - Like Samsung, NEC is a good, solid performer with a well-mixed customer base (from the applications side) that gave it good contract orders for the first half of 1996.
  - Its price fallout was compounded by yen/dollar depreciation issues in 1996.
  - Synchronous and 64Mb product strategies are being implemented aggressively, and the road map was well-received by customers.
- LG Semicon
  - LG Semicon was the only supplier to jump up the ranking positions in 1996. It was very price competitive on standard generic products for all of 1996.
  - Some mix issues on EDO/FPM modules hindered its revenue in the first half of 1996, but the company responded rapidly to changing market dynamics, which helped it in the second half of 1996.
  - It was less aggressive on synchronous and 64Mb devices (which will affect leading-edge design-wins and product approvals in PC and workstation environments), but it will still have plenty of orders for the generic product, albeit with less margin.

## Supply Base Analysis by Density

Market leaders by density are shown in Table 3. The five top suppliers hold about 60 percent of the 1Mb and 16Mb densities and over 80 percent of the newer 64Mb density. The 4Mb density (the No. 1 density in unit shipment terms for 1996) showed greater supplier polarization. At this density, the top five suppliers account for 46 percent of products shipped in 1996. Tables 4, 5, 6, and 7 give more details on unit production by density.


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**Table 3**
**1996 DRAM Market Leaders by Product Density (Based on Unit Shipments)**

| 1996 Rank | 1Mb | 4Mb | 16Mb | 64Mb |
|---|---|---|---|---|
| 1 | Sanyo | Micron | Samsung | Samsung |
| 2 | Toshiba | Hyundai | Hitachi | NEC |
| 3 | Mitsubishi | Hitachi | NEC | IBM Microelectronics |
| 4 | Fujitsu | Texas Instruments | Hyundai | Hyundai |
| 5 | Oki | Samsung | LG Semicon | LG Semicon |
| **Market Share of Top Five (%)** | **59.9** | **46.0** | **60.1** | **82.2** |

Source: Dataquest (June 1997)

## Supply Base for 1Mb DRAMs

The rankings of 1Mb suppliers, by unit shipments, are shown in Table 4. Total units for 1996 were 259 million, down from 340 million in 1995. The peak year for 1Mb was 1991, with 831 million units shipped. Note that none of the top five worldwide DRAM suppliers feature in the top five 1Mb supplier base.

**Table 4**
**1Mb DRAM Supplier Base, 1996 (Thousands of Units)**

| | Shipments | Rank |
|---|---|---|
| Sanyo | 41,000 | 1 |
| Toshiba | 37,205 | 2 |
| Mitsubishi | 33,000 | 3 |
| Fujitsu | 22,500 | 4 |
| Oki | 21,530 | 5 |
| Nippon Steel | 14,370 | 6 |
| Hyundai | 14,200 | 7 |
| Samsung | 14,070 | 8 |
| Mosel Vitelic | 12,200 | 9 |
| Texas Instruments | 8,245 | 10 |
| Siemens | 8,100 | 11 |
| Matsushita | 8,005 | 12 |
| LG Semicon | 7,950 | 13 |
| Sharp | 6,715 | 14 |
| NEC | 6,600 | 15 |
| Others | 3,411 | |
| **Market Total** | **259,101** | |

Source: Dataquest (June 1997)

In 1997, there will be a more dramatic decrease in output from the majority of 1Mb DRAM manufacturers. Dataquest forecasts that the total number of 1Mb units shipped in 1997 will be 151 million. Although this decrease is dramatic, most suppliers will remain in this market because the 1Mb density is still required for certain end-customer applications.


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## Supply Base for 4Mb DRAMs

Table 5 shows the 1996 4Mb DRAM supplier base, by unit shipments. Total production for 1996 was 1, 303 million units, down from 1, 591 million units for 1995.

Dataquest forecasts that, in 1997, the 4Mb DRAM production total will fall dramatically to 654 million units, a reduction of almost 50 percent for the year. This rapid fall is mainly because of the aggressive ramp-up of the 16Mb. Also, most modules used by PC applications are now populated with 16Mb chips, not 4Mb chips. This has helped reduce demand for the 4Mb density.

**Table 5**
**4Mb DRAM Supplier Base, 1996 (Thousands of Units)**

| | Shipments | Rank |
|---|---|---|
| Micron | 170,000 | 1 |
| Hyundai | 116,200 | 2 |
| Hitachi | 109,200 | 3 |
| Texas Instruments | 105,200 | 4 |
| Samsung | 99,000 | 5 |
| NEC | 91,450 | 6 |
| LG Semicon | 90,300 | 7 |
| Toshiba | 72,300 | 8 |
| Mitsubishi | 64,700 | 9 |
| IBM Microelectronics | 60,900 | 10 |
| Fujitsu | 60,000 | 11 |
| Siemens | 57,500 | 12 |
| Mosel Vitelic | 52,500 | 13 |
| Vanguard | 42,000 | 14 |
| Nippon Steel | 30,980 | 15 |
| Others | 80,930 | |
| **Market Total** | **1,303,160** | |

Source: Dataquest (June 1997)

Suppliers will continue to manufacture the 4Mb density even though unit shipment numbers are dwindling. This is to satisfy other, non-PC demands, for example, telecommunications or printers.

Hyundai, Hitachi, and Samsung (all in the top five of worldwide DRAM suppliers by revenue) are in the top five suppliers for worldwide 4Mb unit shipments.

## Supply Base for 16Mb DRAMs

The 16Mb ramp-up has been very dramatic. Volume of about 21 million units in 1993 increased to 344 million units in 1995 and then ramped up to 996 million units in 1996.


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Dataquest forecasts that 16Mb worldwide production output will almost double from 1996 to 1997, to reach 1, 883 million units this year. Dataquest believes that 1998 will be the saturation point for 16Mb, with estimated volumes at about 2, 461 million units worldwide. The 16Mb will fall off after this point, as 64Mb takes a more dominant position.

Table 6 shows the 16Mb DRAM supplier base, based on unit shipments, for 1996.

**Table 6**
**16Mb DRAM Supplier Base, 1996 (Thousands of Units)**

| | Shipments | Rank |
|---|---|---|
| Samsung | 170,800 | 1 |
| Hitachi | 121,500 | 2 |
| NEC | 118,660 | 3 |
| Hyundai | 101,625 | 4 |
| LG Semicon | 86,300 | 5 |
| Texas Instruments | 85,200 | 6 |
| Toshiba | 71,600 | 7 |
| Mitsubishi | 62,700 | 8 |
| Fujitsu | 45,900 | 9 |
| IBM Microelectronics | 34,770 | 10 |
| Micron | 34,650 | 11 |
| Siemens | 30,000 | 12 |
| Motorola | 10,900 | 13 |
| Oki | 7,440 | 14 |
| Matsushita | 7,400 | 15 |
| Others | 6,871 | |
| **Market Total** | **996,316** | |

Source: Dataquest (June 1997)

## Supply Base for 64Mb DRAMs

Shipments of 64Mb devices began in 1996 at a modest 6.7 million units. Dataquest forecasts that this should ramp up dramatically over the next few years. Unit shipments are forecast to increase from 72 million in 1997 to 265 million in 1998 to 901 million in 1999.

By 1999, there will be more megabytes of 64Mb shipped than of any other density, and unit shipments of the 64Mb device should be over 1, 841 million units. This should increase to 2, 464 million units by 2001.

Table 7 shows the 64Mb DRAM supplier base, based on unit shipments, for 1996.


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**Table 7**
**64Mb DRAM Supplier Base, 1996 (Thousands of Units)**

| | Shipments | Rank |
|---|---|---|
| Samsung | 2,444 | 1 |
| NEC | 1,883 | 2 |
| IBM Microelectronics | 401 | 3 |
| Hyundai | 400 | 4 |
| LG Semicon | 400 | 5 |
| Siemens | 360 | 6 |
| Hitachi | 300 | 7 |
| Texas Instruments | 266 | 8 |
| Toshiba | 130 | 9 |
| Fujitsu | 72 | 10 |
| Mitsubishi | 60 | 11 |
| Motorola | 10 | 12 |
| **Market Total** | **6,726** | |

Source: Dataquest (June 1997)

## Nonstandard RAM

At this point, standard DRAM covers FPM, EDO, and SDRAM. FPM and EDO are forms of asynchronous DRAM, while SDRAM is synchronous DRAM. The push for nonstandard RAM is coming mainly from multimedia and graphics applications that need memory capable of keeping up with fast 32-bit and 64-bit MPUs like the Pentium, PowerPC, and other RISC-based systems. Because both video RAMs (VRAMs) and SRAMs have decreased in price and availability has improved, these are often used for price-sensitive applications, even though they take up valuable board space. There are certain applications, however, that require quite specialized technology.

The following are some nonstandard RAMs, with descriptions.

- Rambus DRAM
  - This is licensed by 15 semiconductor companies and has been formally announced by Cirrus Logic, Hitachi, LG Semicon, LSI Logic Inc., NEC, Oki, Samsung, and Toshiba. Access memory is rated at 500 MB/sec. Nintendo has announced its use of Rambus in 64-bit machines.
- MoSys Multibank
  - This is a unique architecture, with several companies reviewing it. Access memory is rated at 660 MB/sec. The graphics version is of most interest.
- Enhanced Memory Systems Inc.'s (formerly Ramtron's) enhanced DRAM
  - Taiwan-based Digicom Systems Inc. is selling fast memory for high-performance 486 PCs. IBM announced that it is manufacturing enhanced DRAMs for Enhanced Memory Systems. Ocean Information Systems is the lone major customer; this technology has limited acceptance elsewhere. NMB Technologies Inc. also acts as a foundry for Enhanced Memory.

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- 3-D Memory
  - This is a Mitsubishi-proprietary design, of interest in graphics applications. Siemens and, possibly, Integrated Device Technology Inc. will act as foundries.
- Window RAM
  - This is similar to VRAM, with unused features removed. Window RAM is being developed by a small number of suppliers.
- Embedded DRAM
  - This concept (where DRAM is embedded into an ASIC design) is receiving a lot of interest, mainly at 16Mb. Both NeoMagic Corporation and Silicon Magic have designs and are working with foundries. It is definitely one of the hottest topic areas in system-level integration (SLI).

Dataquest defines SLI as an integrated circuit that contains a compute engine, memory, and logic on a single chip and that has more than 100, 000 utilized gates. There are two types of SLI—application-specific ICs (ASICs) and application-specific standard products (ASSPs, products sold to more than one user).

## Dataquest Perspective

As years go, 1996 was definitely memorable. Worldwide DRAM revenue dropped by nearly 39 percent from 1995 to 1996. All suppliers suffered battle scars, in spite of their DRAM technology armory, production capacity cannon fodder, and superpowerlike market dominance.

From a buyer's perspective, however, after three years of almost no price negotiations, suddenly all suppliers were willing to talk. Prices were first to fall, followed by lead times and a whole host of other factors, which helped lower the total cost of DRAM ownership.

As the market share changes from 1995 to 1996 show, some suppliers might have lost dollars, but they won the battle by gaining market share. These success stories were Samsung, NEC, and LG Semicon. Micron managed to come out neither losing nor gaining ground. All other top 10 players lost market share, based on Dataquest's revenue data.

For suppliers and buyers alike, 1997 is going to be another challenging year. As the second half of 1997 approaches, the DRAM market is becoming more complex. Newer technologies, voltages, chip densities, and module types are gaining momentum. However, suppliers remain polarized, with each adopting difference strategies and road maps. Tied in to these are the rumors from certain sources of possible production cutbacks. A challenging time is ahead for all buyers.

DRAM is forecast to remain in oversupply on a per-megabyte basis, but there is a real possibility that certain devices and modules will be difficult to obtain (for example x16 64Mb SDRAM and related modules) and certain speeds will be both expensive and constrained. Buyers are strongly urged to forecast and communicate requirements to suppliers.

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But not all messages are of doom and gloom. Price crossover will occur on 64Mb chips relative to 16Mb and on SDRAM technology relative to EDO rapidly and before unit shipment crossover. Also, even though certain DRAM products will be in short supply by the end of 1997, most buyers are locking in prices to ensure that the risk of price hikes is minimized.

Also, should the SDRAM technology take off rapidly, then the EDO 16Mb is reduced to being a generic, multisourced, older technology. It will be readily available and potentially oversupplied. This all leads to the conclusion that price reductions are possible as suppliers compete for a slice of the pie. The question remains as to whether the reductions will be calculated and controlled or fast, frenzied, and furious!


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**For More Information...**

Evelyn Cronin, Senior Industry Analyst ..... (408) 468-8075
Internet address ..... evelyn.cronin@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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Perspective



Semiconductor Supply and Pricing Worldwide

# Market Analysis

## Third Quarter 1997 Quarterly Price Survey Highlights

**Abstract:** *Dataquest has completed the third quarter 1997 North American contract pricing survey for the semiconductors tracked. This Perspective analyzes the main signals seen, both overall and by main family type, and their impact on contract buyers worldwide.*
*By Evelyn Cronin*

## General Market Characteristics

The main signals are: Price stability has kicked in on existing technologies, but good price reductions are still available on newer technologies and chip densities. Oversupply is set to continue, but as the market approaches supply/demand equilibrium, certain semiconductor families are beginning to tighten up.

Last quarter, many DRAM suppliers went public, announcing production cutbacks. Although prices for 4Mb and 16Mb asynchronous DRAM did increase in second quarter 1997 as a result, so far there has been no sign of any availability issues.

Also, at the time of this writing, the spot market once again has gone below the contract price points. This is a clear sign of excess product and insufficient customer orders in this channel.

As the second half of 1997 approaches, the DRAM market is becoming more complex. Newer technologies, voltages, chip densities, and module types are gaining momentum. However, suppliers remain polarized, with each adopting different strategies and road maps. A challenging time is ahead for all buyers.

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DRAM is forecast to remain in oversupply on a per-megabyte basis, but there is a real possibility that certain devices and modules will be difficult to obtain (for example, x16 64Mb SDRAM and related modules). Buyers are strongly urged to forecast and communicate requirements to suppliers.

For non-DRAM memory devices, the forecast is somewhat different. Flash and SRAM continue to exhibit good price reductions quarter on quarter (especially at higher densities). Availability also remains good. The outlook for EPROMs and ROMs is similar. Both should enjoy price reduction but at a more stable rate, and lead times remain unchanged. However, it should be remembered that the supply base for EPROMs is limited.

Standard logic pricing remains largely unchanged from last quarter. Likewise, for cell-based ICs (CBICs) and gate arrays, pricing has been flat. The buzzwords for application-specific ICs (ASICs) are system-level integration (SLI) and CBIC libraries.

All in all, 1997 will be a year in which buyers remain in the driving seat. However, there is a greater need for buyers to broadcast their companies' requirements and to take a stand on the competing technologies available. With DRAM especially, this is not the time to sit on the fence. Regardless of the buyer's company's end application, communicating current and future requirements is crucial.

Based on the trends seen in Dataquest's *North American Semiconductor Price Outlook—Third Quarter 1997* (SSPS-SS-MS-9703, June 1997), we have extracted key points.

## DRAM

Dataquest has split the DRAM highlights into two sections for this Perspective:

- DRAM devices
- DRAM modules

This has been done for ease of analysis, and both sections interrelate, coming from different data sources on the same survey inputs. Figures 1 and 2 show 16MB and 32MB DRAM module price crossover trends.

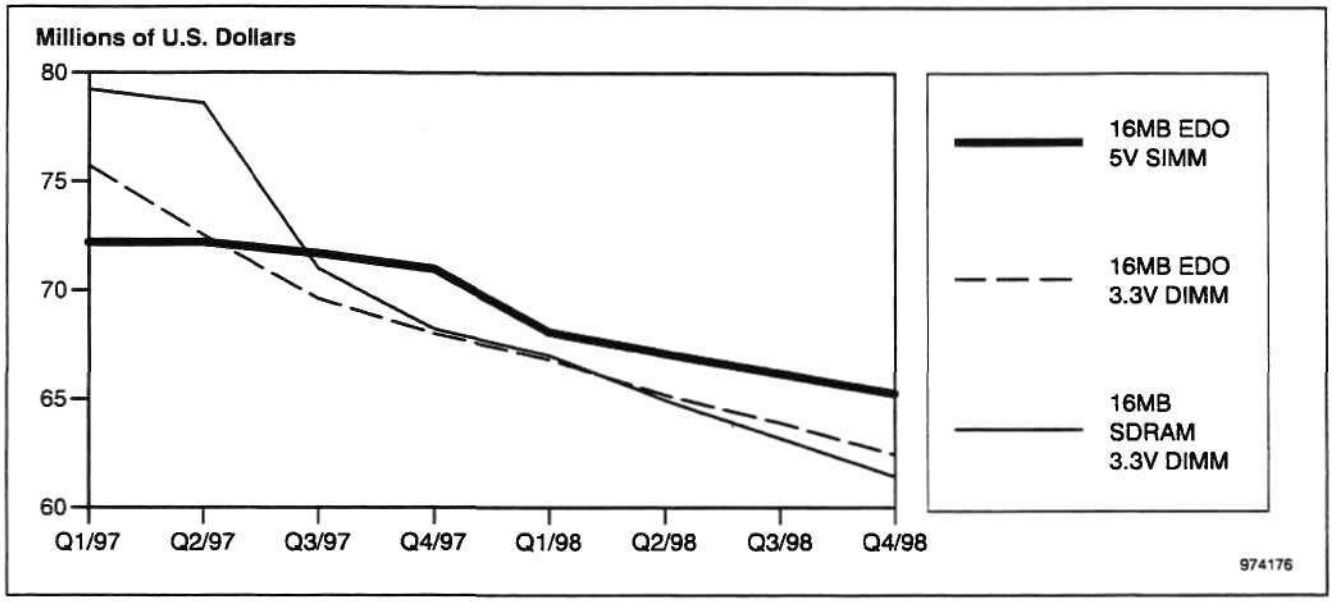
### DRAM Devices

The key points to remember about DRAM devices are:

- Suppliers' pricing strategies are encouraging the rapid migration to higher densities, especially in data processing applications.
- Also, suppliers are adopting aggressive strategies with the three different technologies, albeit with different suppliers employing quite different strategies.
- 4Mb remains fairly flat from last quarter's data points.

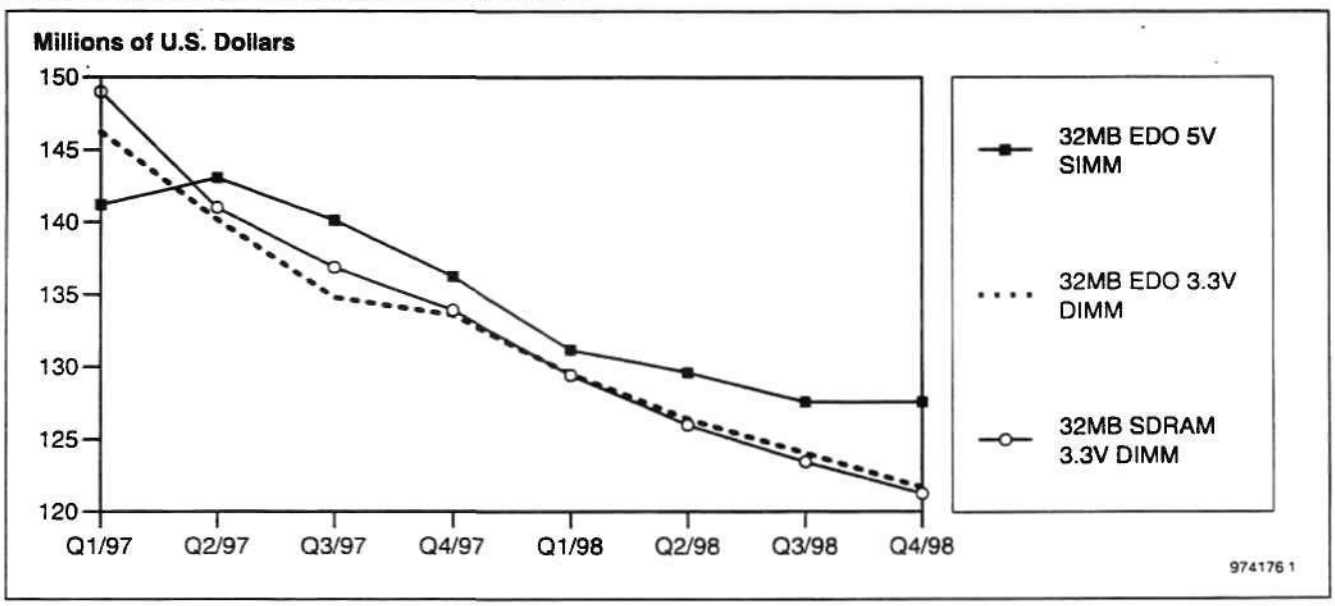

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**Figure 1**
**16MB DRAM Module Crossover Points**




Source: Dataquest (June 1997)

**Figure 2**
**32MB DRAM Module Crossover Points**




Source: Dataquest (June 1997)

- 4Mb fast page mode (FPM) will be more expensive than extended data out (EDO) by third quarter 1997. This ties in with the rapid migration seen to higher densities for data processing applications and the differing pricing strategies for the older technology types.
- 16Mb pricing is far less bullish on the asynchronous devices, with more long-term stability expected.


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- Based on the survey input, Dataquest saw a $3 range in 1Mbx16 EDO minimum/maximum pricing for second quarter 1997.
- 16Mb pricing increased from first quarter to second quarter from certain suppliers, affecting certain customers, on asynchronous devices
- Based on the survey results, 16Mb FPM will be more expensive than EDO by second quarter 1997. However, synchronous DRAM (SDRAM) will be more expensive than FPM at 1Mbx16 for the duration of the forecast, according to the survey participants.
- For 1997, 64Mb is experiencing far more aggressive price reduction in this forecast than in the previous forecast. This is mainly on EDO devices.
- However, Dataquest still sees a polarization in the 64Mb supply base.
  - Time-to-market lags of up to nine months are being seen in volume production of some devices, versus initial product introduction of others.
  - Seemingly contradictory pricing strategies from different suppliers are being seen. Ultimately, customers' adoption rates of the 64Mb will determine pricing points and shortage issues.
- For 64Mb devices, there is price parity on x4 and x8 for the individual technology types. However, premiums are charged for faster devices (higher megahertz) that vary from supplier to supplier.
- SDRAM will be cheaper than EDO of equivalent speed and pinout for x4 and x8 64Mb by second quarter 1997.
- For PC graphics applications, the 256Kbx16 4Mb versus 256Kbx32 synchronous graphics RAM (SGRAM) debate continues to rage. However, many players are entering this market, and customers clearly want to move to the newer technology. By first quarter 1998, 8Mb SGRAM will be cheaper per megabyte than 4Mb asynchronous chips.
- Year-end risks are SDRAM shortages and 16Mb EDO oversupply.

## DRAM Modules

The key points to remember about DRAM modules are:

- For asynchronous 5V DRAM single in-line memory modules (SIMMs), the FPM will be greater than the EDO on all densities, with and without parity. This ties into the chip pricing policy of most vendors.
- Also, because of the higher second quarter 1997 16Mb chip prices and the flatter long-term forecast, module prices are higher in second quarter 1997 than first quarter 1997, and prices are forecast to stay fairly stable over time.
- Quite a range of SIMM prices is seen at all densities from both users and suppliers. This would indicate the level of supply uncertainty in the market and the scaremongering tactics of some suppliers.

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- An interesting situation is forecast for EDO SIMM and dual in-line memory module (DIMM) pricing. Crossover on both (with EDO 3.3V DIMMs cheaper than EDO 5V SIMMs) will occur in 1997, with the average timing shown in Table 1.
- The forecast for the DIMM crossover from EDO to SDRAM (SDRAM DIMM becoming cheaper than EDO DIMM) is shown in Table 2.
- An interesting observation is that the density (16Mb-to-64Mb) crossover occurs faster on modules than on devices. The reason could be that suppliers wish to target OEM buyers (generally source modules) initially, not third-party module makers (generally source chips).

**Table 1**
**EDO SIMM/DIMM Crossover**

| Density | Price Crossover | EDO SIMM to EDO DIMM |
|---|---|---|
| 8MB | Q2/97 to Q3/97 | 2Mbx32 to 1Mbx64 |
| 16MB | Q2/97 | 4Mbx32 to 2Mbx64 |
| 32MB | Q2/97 | 8Mbx32 to 4Mbx64 |

Source: Dataquest (June 1997)

**Table 2**
**DIMM EDO/SDRAM Crossover**

| Density | Price Crossover | EDO DIMM to SDRAM DIMM |
|---|---|---|
| 8MB | Q1/98 | 1Mbx64 to 1Mbx64 |
| 16MB | Q2/98 | 2Mbx642 to Mbx64 |
| 32MB | Q1/98 | 4Mbx64 to 4Mbx64 |

Source: Dataquest (June 1997)

## SRAM

The key points about SRAM are:

- Overall pricing is down in this quarter's forecast, especially for the higher-density devices.
- The end-of-life trend that began last quarter is continuing for the lower-density devices tracked (x4 and x8 128Kb and x4 256Kb).
- For x8 256Kb cache SRAM, buyers are still bullish about price reductions, despite the public exit of some suppliers from this segment.
- For pipeline burst synchronous cache SRAM devices, the 2Mb-to-1Mb price crossover occurred in first quarter 1997 (on a per-megabyte basis).
- There is still speculation as to which suppliers Intel will use as the source of SRAMs for the new-generation processors (which come with a cache module).
  - Will this limit the total number of SRAM vendors?
  - What will those not chosen do?

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  - Will there be a price free-for-all on noncache SRAMs?
- On the x8 1Mb, the 15ns is still the cheapest device, while the 20ns and 25ns remain at price parity.
- The x8 4Mb remains cheaper than the x16 version at equivalent speeds.
- A premium still remains at 4Mb for 25ns devices over 70ns, and the survey participants forecast it to remain in place for the foreseeable future. However, as demand patterns shift, Dataquest expects this to change.
- Lead times remain unchanged from last quarter.

## Flash

The key points about flash are:

- Buyers are more bullish about price reductions this time around. This means that the flash market should offer relatively good availability for the next 18 months.
- Common messages on the trend to lower voltages are: The lower-voltage devices are forecast to be cheaper long term. Timing on this trend varies by flash density.
- On 4Mb (512Kbx8 SOP) devices, the 3V will be cheaper than the 5V, which will be cheaper than the 12V by second quarter 1997 for the same speed. This price forecast remains until 2001.
- By third quarter 1997, buyers are predicting that the 3V will cost less than the 5V, which will cost less than the 12V on the 8Mb (1Mbx8 TSOP) devices for the same speed. According to survey participants, this sequence will remain in place until the end of the forecast period.
- For 16Mb (2Mbx8 TSOP) devices, buyers forecast that the 3V will be cheaper than the 5V, which in turn will be cheaper than the 12V by the first quarter next year, at the same speed.
- Lead times remain unchanged from last quarter on all devices.

## Microprocessors

The key points to remember about MPUs are:

- Intel is decreasing prices on "high end" Pentiums very aggressively, effectively planning to make them entry-level PC processors by the fourth quarter of 1997.
- Intel's Pentium MMX family has a new member at 233 MHz. All are attractively priced, and Intel clearly is out for market share.
- Intel's new Pentium II family has made its debut with 512Kb of cache and frequency ranges of 233 MHz to 300 MHz. All can use the Pentium Pro chipsets (440FX and 440LX), which means that some very high-level

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machines are being launched this year. In price, volume acceptance will occur mainly in 1998.

- Not to be outdone, the PowerPC camp is coming out very strongly with the 604 processor family, which offers quite an attractive price/performance curve.

## ASICs

The key points to remember about ASICs are:

- One-micron technology is moving quickly to production-only status from many ASIC houses—that is, they have a policy of no new designs in this technology but will continue to manufacture existing designs.
- Generally, midrange gate count solutions are cheaper in gate arrays. However, for higher gate counts, cell-based ICs are usually a far more cost-effective solution.
- Under-10,000-gate designs are being served by a variety of field-programmable gate array/programmable logic device (FPGA/PLD) providers, each with its own standard.
- Pressure to gain business has pushed prototype lead times down from most suppliers. However, these lead times are usually less for gate array solutions.
- The 0.18-micron technology is being launched by many suppliers. However, it will most likely be the second half of 1998 before production designs appear.
- SLI designs are taking off in a big way—this trend is expected to continue.

## Dataquest Perspective

The year 1997 should continue to be challenging for buyers. Although the semiconductor market will remain in oversupply, certain device families will start to tighten as the market approaches supply/demand equilibrium. The bottom line: Demand remains strong for all devices.

The real concern this year is the state of flux of the DRAM market. Each supplier has its own angle on which variable will take off when. Buyers are left interpreting the data and tying it in with their chipset road maps, motherboard plans, and other factors. It is vital for buyers to communicate internal requirements effectively with key suppliers and to lock in future demand early.

Intel remains a marketing Goliath, influencing not just its direct customers but also its semiconductor competitors. Intel influences DRAM vendors and will potentially control which SRAM vendors remain volume cache suppliers.


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Although Intel's road map is often more aggressive than most companies can realistically achieve in the stated time frame, it should be watched by all buyers, whether working for a PC company or not. Niche DRAM players will remain, but there is a bigger chance of multisourced supply by choosing standard (read PC) product. Likewise, SRAM suppliers not chosen by Intel as an SRAM source for its new processor will have to tackle the noncache market aggressively. This could translate into further price movement for telecom, routers, and so on.

On all devices, reduction of total cost of ownership is the goal of buyers. The cheapest buying price does not always translate into the most cost-effective solution!

**For More Information...**

Evelyn Cronin, Senior Industry Analyst ..... (408) 468-8075
Internet address ..... evelyn.cronin@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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Perspective



Semiconductor Supply and Pricing Worldwide

# Market Analysis

# 1996 ASIC Product and Market Update: Reality Bites

**Abstract:** *In a year in which overall semiconductor market revenue declined by 6.3 percent, the ASIC market grew by 27 percent—an outstanding performance. This article highlights the status of the ASIC industry and notes important developments in this critical semiconductor market from a user's perspective. We provide analysis using the latest market data, product life cycle, supplier base, and market outlook information. Strategic recommendations are made to users.*

*By Evelyn Cronin*

## ASIC Market 1996: Reality Bites

Application-specific ICs (ASICs) are an arena that has matured over the past five years. Last year's performance has convinced even the most skeptical that it is a force to be reckoned with, a market segment that can buck the tide of the rest of the semiconductor market. Although 1996's growth rate failed to match the record-breaking heights set in 1995, it was extremely healthy, given the dynamics of the semiconductor industry in 1996.

An interesting development is the rapid rise of cell-based IC solutions and the decline of the gate array segment. In 1996, revenue for the cell-based IC business surpassed that of gate arrays for the first time. This trend will continue as ASIC suppliers fuel the cell-based IC market to accelerate their growth and improve their market rankings. The winning vendors will be those that can offer cost-effective solutions from well-stocked cell libraries to their targeted customer niches.

Overall ASIC revenue growth was 27 percent from 1995 to 1996. Gate array revenue plummeted by 6.2 percent, with cell-based ICs rising by 27.3 percent. Programmable logic devices (PLDs) had a positive growth of 11.9

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percent. There were some shining stars within the top 10 of each category. Overall and within the PLD area, Philips launched itself into the top 10, growing at a mind-boggling 520 percent from 1995 to 1996. Within gate arrays, it was Texas Instruments that challenged the tide of negative growth. TI grew by 19.1 percent in this shrinking market. And among cell-based ICs, it is the worldwide No. 1-ranked supplier (NEC) that stepped into the growth spotlight, achieving 114.8 percent revenue growth from 1995 to 1996.

This document provides ASIC users with practical and strategic information for choosing devices, technologies, and suppliers. Dataquest's analysis comprises four sections. The first serves as a guide to cost-effective, long-term procurement by analyzing the ASIC process technology life cycle curve and key milestones. The second section reviews the product strategies of the top 10 worldwide ASIC suppliers. The third section looks at the supply base for the three different ASIC components (cell based ICs, gate arrays, and PLDs). The fourth section looks briefly at system-level integration (SLI) and its impact on the ASIC market.

This arrangement provides a concise way of assessing the market dynamics of the ASIC industry and the best way to obtain these devices for the remainder of this decade. The goal of this article is to enable ASIC users to meet their needs for these critical devices with a sound strategy that will provide a cost-effective, stable, and long-term supply despite shifts in the market.

## Definitions

An ASIC is a logic product customized for a single user. Dataquest defines an ASIC to include gate arrays, cell based ICs, and PLDs. Dataquest defines gate arrays as semicustom digital or linear/digital ICs containing a configuration of uncommitted logic elements, which are customized by interconnecting the logic elements with one or more routing layers. Cell-based ICs are customized digital or mixed-linear/digital ICs that use a full set of masks; the device consists of precharacterized cells or macros including standard cells, megacells, and compilable cells customized by using automatic place and route. PLDs are ASIC devices that are programmed after assembly.

Rankings are based on dollar shipments, which include the following four sources of revenue:

- Device revenue—both merchant and intracompany
- Nonrecurring engineering (NRE) revenue
- ASIC software revenue
- PLD development kit revenue

As mentioned earlier, ASIC revenue includes cell-based ICs, gate arrays, and PLDs only. Full-custom IC revenue is excluded from the ASIC market share. Also, ASIC revenue is from MOS/BiCMOS products only—it excludes bipolar products.

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An important point to keep in mind when looking at the ASIC dollar revenue is the impact of the yen/dollar exchange rate. In 1996, the yen depreciated 13.7 percent against the dollar. Dataquest calculates the exchange rates as ¥93.9 per U.S.$1 in 1995 and ¥108.8 per U.S.$1 in 1996. This had a negative impact on the growth rate of all Japanese ASIC companies.

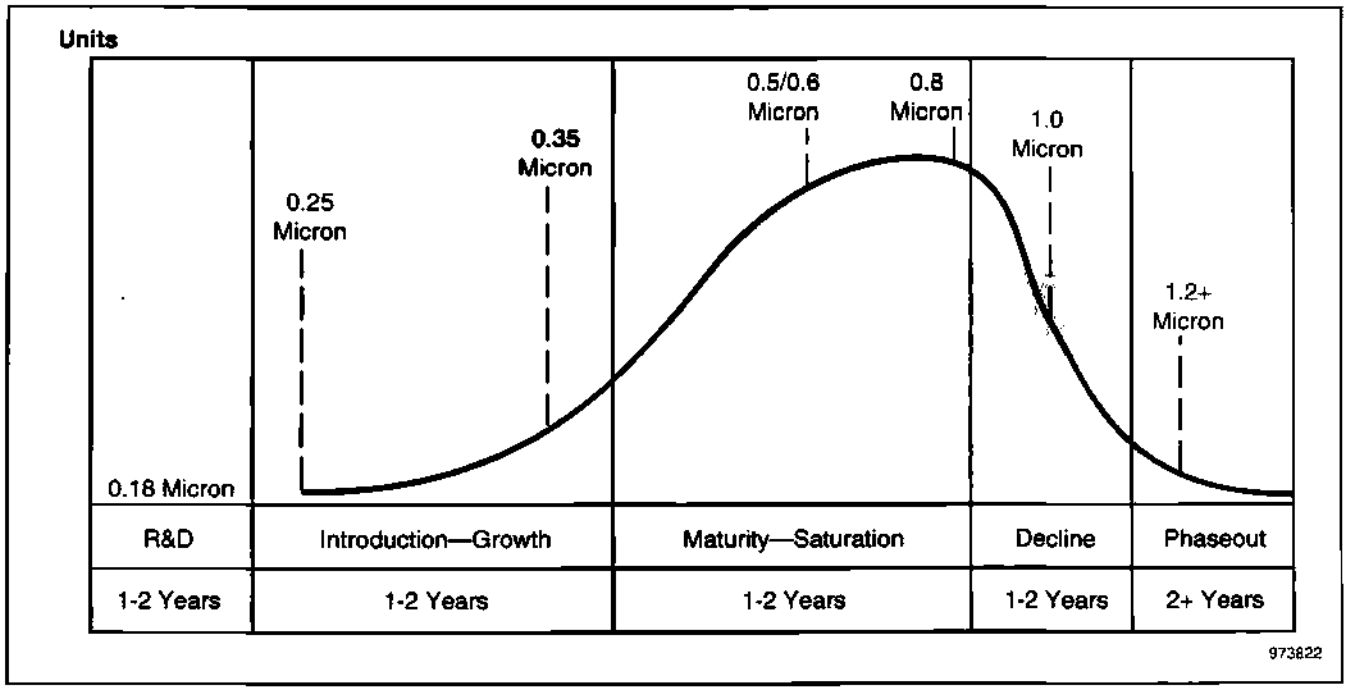
## ASIC Technology Life Cycles

For this Perspective, the process technology life cycles are analyzed, which covers the main generational changes to ASICs. This section is designed to assist users in adjusting to forces affecting the marketplace over the short to long term. Because an ASIC is as much a technology as a specific product, this market does not lend itself to traditional life cycle analysis. Thus, there are two separate figures in this section—one looking at the life cycle of the ASIC technologies (generations), the other looking at the most notable ASIC milestones over a six-year period.

## ASIC Process Life Cycle

Figure 1 shows the ASIC technology life cycle curve for the different process generations. Each process can manufacture cell-based ICs, gate arrays, and PLDs. Historically, depending on the supplier, there is typically a lag of one or two quarters for cell-based ICs over gate arrays, caused by the time needed to update cell libraries. Nowadays, certain manufacturers are introducing cell-based designs at the same time as gate arrays.

**Figure 1**
**ASIC Technology Life Cycle Curve**




Source: Dataquest (May 1997)


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The production workhorse designs of the ASIC world are now the 0.5/0.6-micron and 0.8-micron generation designs. (Please note that all sizes refer to drawn gate length.) Based on 1996 shipments, these products had the highest volumes. Both are established products, in the maturity-saturation phase of their life cycles. Although the 0.5/0.6-micron technology probably has about one more year left in this stage, on average, the 0.8-micron is at the right edge of the curve, poised to decline in volume in 1997.

The 1.0-micron technology is still being used for many applications but has moved to production-only status with many ASIC suppliers (that is to say, no new designs are made in this process, but existing designs are still manufactured).

The 1.2-micron technology is in the phaseout stage of its life cycle and will remain in this stage for the foreseeable future. Some existing production designs will require support for many years, and suppliers will have to honor contractual agreements.

All process generations greater than 1.2 micron are in the phaseout stage, as well. However, many larger ASIC suppliers have made 2-micron offerings obsolete, and a custom manufacturer may be the only choice in some cases if additional orders are required.

On all purchases of decline- and phaseout-stage ASIC processes, it is extremely important to forecast requirements to ensure that suppliers are fully aware of a purchaser's anticipated needs over time. Also, the fine print on contracts should be checked to see what obligations exist on both sides.

Just because the process generation is slipping toward the phaseout stage doesn't mean that the supplier will switch off production immediately. In many cases, a product is in the phaseout stage for up to seven years (or longer, depending on what was agreed). It may not be the sleekest, sexiest design, but it may well be the best fit (read lowest remaining lifetime cost) for the chosen application, and a rework is nonsense.

On the other end of the spectrum, the 0.25- and 0.35-micron ASIC generations are beginning to make their presence known and are in the introduction-growth phase. The 0.25 micron is barely on the curve, occupying a position at the far left side of the introduction stage—it is the real new kid on the block. The 0.35 micron has been around for slightly longer and is beginning to grow in volume.

The latest and greatest process generation is the 0.18 micron. Suppliers seem to be trying to outdo themselves in the race to launch working designs at this size. Although some think this could be the year for some designs to come out in this generation, realistically, next year is more likely.

## ASIC Milestones

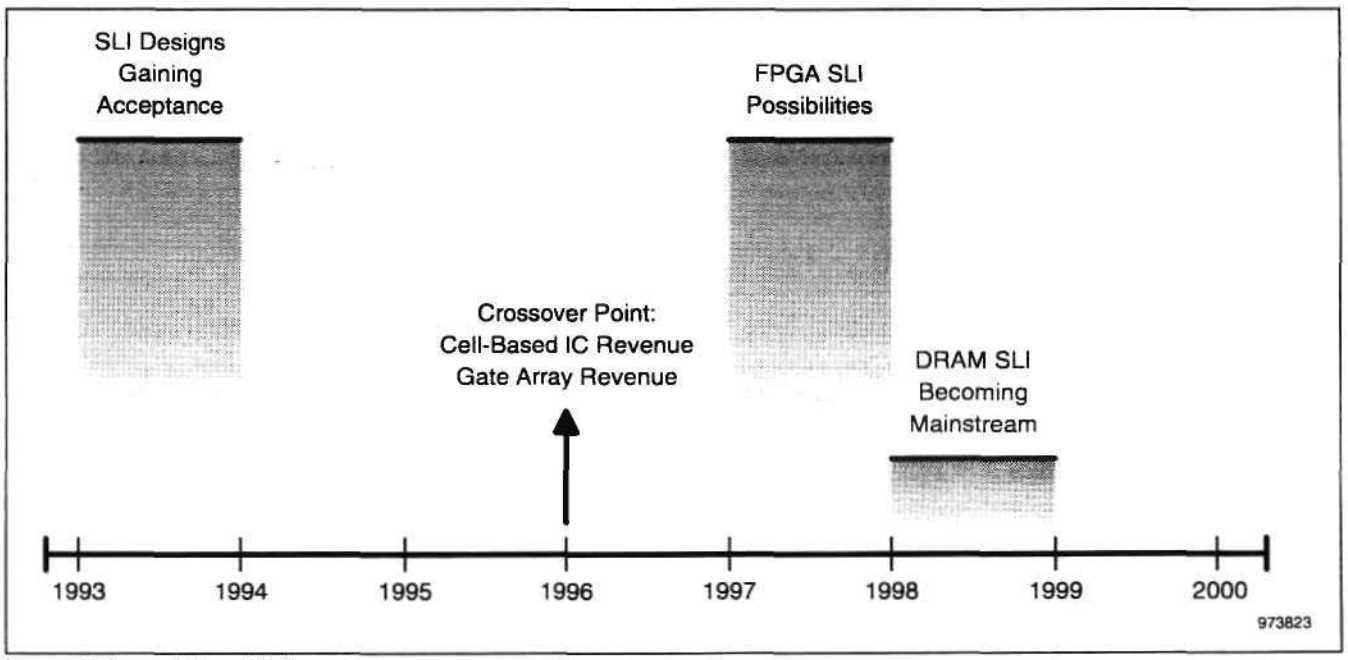
Figure 2 shows some of the notable milestones in the ASIC world. Looking back, two things hit the ASIC watcher. The first is the awakening of interest

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in system-level integration and the production emergence of SLI ASIC designs around 1993 and 1994. SLI ASIC design started in about 1990, but it took some time to translate into production. In 1996, a major psychological barrier was broken—cell-based IC revenue surpassed that of gate arrays. Cell-based ICs had come of age! The next notable milestone involved both PLDs and SLI—over the next 18 months, SLI field-programmable gate array (FPGA) combined products will become possible. And finally, as the decade and millennium come to a close, DRAM SLI will begin to become mainstream.

A backdrop to those four events is the continued process generation change occurring behind the scenes, facilitating achievement of many of the milestones. Newer and newer gate array and cell-based IC designs will use the smaller-size geometries, and buyers and designers alike will be faced with the challenge of coming up with the most cost-effective and compact solution for their given application. Exciting times are ahead as a world of possibilities emerge.

**Figure 2**
**Notable ASIC Milestones**




Source: Dataquest (May 1997)

## Supplier Analysis

This section analyzes the product and market strategies of the leading suppliers of ASIC products. This analysis covers product positioning, market rankings, geographic focus, and related issues. Table 1 highlights Dataquest's final 1996 worldwide overall ASIC market share ranking of the top 10 suppliers in terms of revenue. This table serves as the background for the analysis of the top 10 suppliers and also for the product life cycle/supplier base discussion. Table 2 shows ASIC revenue, both overall

and for each segment. For information regarding product definitions, exchange rates used, and so on, please refer to the Definitions section earlier in this Perspective.

**Table 1**
**1996 Worldwide Market Share Rankings for Total MOS/BiCMOS ASIC Supplier Ranking (Revenue in Millions of Dollars)**

| 1995 Overall Ranking | 1996 Overall Ranking | Company | 1996 Market Share (%) | 1996 Revenue |
|---|---|---|---|---|
| 1 | 1 | NEC | 11.4 | 1,689 |
| 2 | 2 | LSI Logic | 7.7 | 1,136 |
| 3 | 3 | Fujitsu | 7.6 | 1,120 |
| 6 | 4 | Lucent Technologies | 7.1 | 1,060 |
| 7 | 5 | IBM | 6.8 | 1,003 |
| 5 | 6 | Texas Instruments | 5.7 | 841 |
| 4 | 7 | Toshiba | 5.6 | 836 |
| 9 | 8 | VLSI Technology | 4.1 | 615 |
| 10 | 9 | Hitachi | 3.9 | 577 |
| 8 | 10 | Xilinx | 3.8 | 566 |
| | | Top 10 Subtotal | 63.7 | 9,443 |
| | | Total Market | 100.0 | 14,829 |

Source: Dataquest (April 1997)

**Table 2**
**1996 ASIC Rankings—Overall and by the Three Composite Areas**

| Overall 1996 Ranking | Company | Cell-Based IC Ranking | Gate Array Ranking | PLD Ranking |
|---|---|---|---|---|
| 1 | NEC | 2 | 1 | - |
| 2 | LSI Logic | 4 | 3 | - |
| 3 | Fujitsu | 8 | 2 | - |
| 4 | Lucent Technologies | 1 | - | 6 |
| 5 | IBM | 3 | 7 | - |
| 6 | Texas Instruments | 6 | 5 | - |
| 7 | Toshiba | 11 | 4 | - |
| 8 | VLSI Technology | 5 | 18 | - |
| 9 | Hitachi | 12 | 6 | - |
| 10 | Xilinx | - | - | 1 |

Source: Dataquest (April 1997)

In a year in which the overall semiconductor market fell by 6.3 percent, the ASIC market grew by 27 percent—a truly exceptional achievement in such a bad year.

## NEC Corporation

NEC retained the No. 1 position for worldwide ASIC sales for the third successive year, increasing market share to 11.4 percent and growing

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revenue by over 29 percent. NEC is the largest gate array supplier, capturing nearly 17 percent of the market despite experiencing a 1.6 percent revenue decline. Most important, NEC showed that its cell-based IC focus has really started to pay off. The company rose from being No. 6 (in 1995) to being the second-largest cell-based IC supplier worldwide, growing its revenue by a whopping 114.8 percent in the process. In CBICs, NEC emphasizes the 0.25-micron generation. Despite all these achievements, NEC still derives the bulk of its revenue from intracompany or captive business. NEC is improving its external focus with dedicated sales teams targeting certain segments. It continues to build its cell design libraries and has a strong presence in the SLI segment.

### LSI Logic Inc.

Although NEC retains the No. 1 position for overall ASIC sales, LSI Logic remains the No. 1 merchant market and stayed in the No. 2 position for worldwide sales. However, LSI Logic dropped in revenue terms by just over 2 percent, so it failed to continue its successes of 1995. LSI Logic retained its No. 3 rank for gate array sales but is the No. 1 merchant market supplier in this category despite decreasing revenue by 14.3 percent. One disappointment for LSI Logic was its No. 4 position in cell-based ICs—it slipped from the second slot of 1995 and grew revenue in this segment by a meager 14.6 percent (compared to 114.8 percent by NEC, 48.5 percent by Lucent Technologies, and 75.8 percent by IBM). LSI Logic continue to offer leading-edge technology to system designers offering standard cells, gate arrays, embedded arrays, cell-based ICs, and SLIs. However, the 0.35- and 0.25-micron products are cell-based only.

### Fujitsu Ltd.

Fujitsu stayed in No. 3 position for 1996 for overall ASIC sales but saw its revenue fall by 3.2 percent from 1995 to 1996 and its market share stay at about 7.6 percent. For MOS/BiCMOS gate arrays, Fujitsu retains its No. 2 position with just under a 14 percent market share despite losing 14.3 percent in revenue terms. Most of Fujitsu's revenue comes from intracompany sales, largely driven by the Fujitsu group's monstrous growth in PCs within the Japanese market. On cell-based ICs, Fujitsu remained in eighth position, growing at a modest 8.8 percent.

### Lucent Technologies

Lucent Technologies (part of AT&T before 1996) continues to move up the overall ASIC chart, coming in at fourth position in sales revenue for 1996. It grew revenue by over 37 percent, the second-highest growth level of a top 10 player, and passed the billion-dollar milestone. Lucent really does not feature as a gate array player but is king of the castle in cell-based ICs—retaining the No. 1 position and growing revenue by well over 48 percent. It continues its assault on the merchant cell-based IC market, focusing on designs with high intellectual property content in large unit volumes. Its market share is now 13.2 percent, but NEC is nipping at its heels. Lucent Technologies PLD performance remains solid, and the company retained sixth position and grew revenue by 4.2 percent, to reach $75 million.

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### IBM Corporation

IBM continues to gain momentum, rising from seventh in 1995 to fifth position in 1996 and growing revenue by nearly 40 percent (the highest of all top 10 overall ASIC worldwide suppliers). Its revenue also passed the psychologically important billion-dollar mark. Despite decreasing gate array revenue by 10.6 percent (although remaining at seventh position), it was in cell-based ICs that IBM really shone. Its cell-based IC revenue increased by 75.8 percent (the second highest in the worldwide cell-based IC revenue rankings), coming in at about $733 million. Like NEC and Fujitsu, IBM traditionally is a captive suppler. It has been present in the merchant market only since 1993, so its rapid rise is a testament to its core strength. Its aim is to supply high-density, cost-effective gate array and cell-based ICs, and it is building up a large design cell library. From its captive experience, IBM has focused mainly on data processing but is also looking at consumer and communications, as well.

### Texas Instruments Inc.

Texas Instruments was knocked from its No. 5 position to No. 6 by IBM in 1996 but did manage a nearly 7 percent overall worldwide ASIC revenue increase. TI was among the few companies that managed positive growth in gate arrays in 1996, at 19.1 percent, but it did not move from fifth position. For cell-based ICs, however, TI was in the unique position of being the only top 10 supplier to shrink its revenue (by 1 percent) in this fast-growing category. It also fell to sixth position.

### Toshiba Corporation

The year 1996 was not a good one for Toshiba, which fell from fourth position in 1995 to seventh position in 1997 and saw its revenue shrink by 9.4 percent in that time as well, based on overall worldwide ASIC revenue. In gate arrays, Toshiba maintained the No. 4 position but reduced revenue by nearly 16 percent. Also, in the fast-growing cell-based IC segment, Toshiba dropped out of the top 10 (coming in at No. 11) and grew by a meager 8.1 percent in this exploding segment. There is no denying that Toshiba did suffer badly from the yen/dollar depreciation. It still does offer a three-day turnaround for prototype gate arrays, which it must exploit to heighten its visibility as both a high-volume and quick high-technology ASIC supplier. Toshiba also still has its design planning methodologies agreement with Synopsys for deep-submicron geometries.

### VLSI Technology Inc.

VLSI Technology had a much better time in 1995 than in 1996. It rose from tenth to eighth position in the overall worldwide revenue rankings, growing by 28.4 percent in the process. VLSI had another weak year in MOS/BiCMOS gate arrays, dropping from 13th to 18th position, shrinking revenue by nearly 30 percent. Its primary focus remains on cell-based ICs, and this year was another strong year for the company. Positioned No. 5 again in cell-based IC worldwide revenue, VLSI grew by 42.6 percent (the fourth highest in the top 10 of this segment).


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### Hitachi Ltd.

Hitachi managed to rise to ninth position for overall worldwide ASIC revenue, growing revenue by nearly 30 percent and achieving a 3.9 percent market share. In gate arrays, it grew by just over 12 percent (with just under 7 percent market share) and maintained its sixth position. It also had a great year in cell-based ICs, moving from 15th to 12th position and achieving a near 91 percent revenue jump in the process. However, with cell-based IC sales of $266 million, it still is well behind the big boys of the cell-based IC world. Although Hitachi have been trying to grow its merchant gate array and cell-based IC sales, the majority of its revenue still comes from intracompany sales. Given the decline of the yen against the dollar, it may be that the company's growth would have been larger if circumstances had been different. For cell-based ICs, Hitachi's focus with its high-density solutions is home-use information electronics and multimedia-compatible equipment applications. To this end, it continues to work on cell design libraries.

### Xilinx Inc.

Xilinx dropped by two positions from 1995 to 1995, filling the 10th slot in worldwide overall ASIC revenue. Its revenue is now $566 million, commanding 3.8 percent of the total market. Xilinx is unique in that it is the only top 10 player that derives its entire revenue from the PLD business. This does limit Xilinx's ability to grow and to tap into the lucrative cell-based IC market. In PLDs, Xilinx used to be in a league of its own. However, in 1996, Altera narrowed the gap considerably and is now No. 11 in overall ASIC worldwide sales revenue from its PLD business alone. PLDs traditionally tend to be low-gate-density solutions, but Xilinx is pushing the boundaries, offering 40,000-gate FPGA devices.

## Supply Base Analysis

This section uses information on ASIC product/technology life cycles and suppliers in presenting a product family evaluation of the supply base over the long term for MOS/BiCMOS gate arrays, cell-based ICs, and PLDs. The goals of this section are to provide users with a practical means of gauging the long-term supply and direction for these ASICs and to provide help in selecting suppliers for these devices.

Each segment contains a table showing the size of the market in terms of factory revenue in 1996 and a ranking, including suppliers' shares in each product segment. The product/technology life cycle analysis serves as the basis for a summary assessment from a user's perspective on the availability expected for MOS/BiCMOS gate arrays, MOS/BiCMOS cell-based ICs, and MOS/BiCMOS PLDs. The summary includes a statement on whether the user faces a favorable or critical supply base for each product technology. Building on the prior sections, factors affecting the supply base, such as supplier strategies, are discussed.

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## Supply Base for MOS/BiCMOS Gate Arrays

Although there was no change in the ranking of the top 10 gate array suppliers from 1995 to 1996, the market size itself decreased. The market shrank by 6.2 percent, from $5.977 billion in 1995 to $5.609 billion in 1996. Revenue shrank for seven of the top 10 gate array suppliers shown in Table 3. The three exceptions were Texas Instruments (growing at 19.1 percent), Hitachi (growing at 12.1 percent), and Motorola (which grew at 1.0 percent).

The gate array market had a double whammy in 1996 that accelerated the market decline. The first was the yen/dollar depreciation (13.7 percent decrease), which affected all vendors with Japanese customers. The second was the rapid migration to cell-based IC solutions. Nine of the top 10 gate array suppliers are also in the top 20 cell-based IC worldwide rankings—Mitsubishi is the exception. Thus, a lot of the top 10 gate array suppliers sacrificed this segment for the cell-based IC applications, which usually offer the added benefit of higher margins.

Table 3 shows the 1996 top 10 gate array suppliers, based on worldwide revenue, and the percentage market share for each.

**Table 3**
**1996 Supply Base for MOS/BiCMOS Gate Arrays (Percentage Share of Factory Revenue)**

| Company | Market Share (%) |
|---|---|
| NEC | 16.9 |
| Fujitsu | 13.8 |
| LSI Logic | 10.3 |
| Toshiba | 10.1 |
| Texas Instruments | 7.7 |
| Hitachi | 6.9 |
| IBM | 4.8 |
| Mitsubishi | 4.0 |
| Motorola | 3.7 |
| GEC-Plessey | 1.9 |
| Others | 19.9 |
| Total Market ($B) | 5.609 |

Source: Dataquest (April 1997)

## Supply Base for MOS/BiCMOS Cell-Based ICs

Cell-based ICs were cooking with gas in 1996. It was the hottest of the ASIC segments and for the first time was the largest of the three in revenue terms. The market craved cell-based ICs, with customers hungry for designs, and the suppliers were only too willing to oblige. The worldwide cell-based IC market grew by 27.3 percent, from $5.747 billion in 1995 to $7.317 billion in 1996. This was in spite of yen/dollar exchange fluctuations and increasing price pressure. This market had the highest number of shakeouts in supplier pecking order of the three ASIC areas.

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Revenue growth rates for the top five were staggering, with NEC achieving 114.8 percent and rocketing into second position.

Table 4 shows the 1996 top 10 cell-based IC suppliers, based on worldwide revenue. It also illustrates the percentage market share of each.

**Table 4**
**Supply Base for MOS/BiCMOS Cell-Based ICs (Percentage Share of Factory Revenue)**

| Company | Market Share (%) |
|---|---|
| Lucent Technologies | 13.2 |
| NEC | 10.1 |
| IBM | 10.0 |
| LSI Logic | 7.6 |
| VLSI Technology | 7.5 |
| Texas Instruments | 5.5 |
| Hewlett-Packard | 5.2 |
| Fujitsu | 4.7 |
| Symbios | 4.7 |
| SGS-Thomson | 4.2 |
| Others | 27.3 |
| Total Market ($B) | 7,317 |

Source: Dataquest (April 1997)

### Supply Base for MOS/BiCMOS PLDs

As a segment, PLDs grew by just under 12 percent in 1996, from $1.701 billion in 1995 to $1.903 billion in 1996. The ranking of the top 10 suppliers was relatively unchanged from 1995, the exception being Philips, which moved into ninth position from its No. 12 1995 ranking, knocking out International CMOS Technology.

The major development was the positive inroads made by Altera on closing the gap between itself and Xilinx. If Altera keeps it up, first place is reachable in 1997. Advanced Micro Devices was the only top 10 PLD supplier that showed a contraction in 1996. There is no denying that 1996 was a tough year for AMD, but it is poised for better fortune in 1997 with Vantis and a dedicated salesforce.

Table 5 shows the 1996 top 10 PLD suppliers, based on worldwide revenue, and their percentage market shares.

## System-Level Integration

System-level integration is placing ever-higher levels of total system functionality on a single chip. It is a term introduced into the market by Dataquest in 1995, chosen to illustrate that system design in the future will include hardware/software co-design.

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Dataquest defines SLI as an integrated circuit that contains a compute engine, memory, and logic on a single chip and that has more than 100,000 utilized gates. There are two types of SLI—ASICs and application-specific standard products (ASSPs, products sold to more than one user).

**Table 5**
**Supply Base for MOS/BiCMOS PLDs (Percentage Share of Factory Revenue)**

| Company | Market Share (%) |
|---|---|
| Xilinx | 29.7 |
| Altera | 26.1 |
| Advanced Micro Devices | 12.8 |
| Lattice | 10.5 |
| Actel | 7.8 |
| Lucent Technologies | 3.9 |
| Cypress Semiconductor | 3.2 |
| Atmel | 1.8 |
| Philips | 1.6 |
| QuickLogic | 1.3 |
| Others | 1.3 |
| Total Market ($B) | 1,903 |

Source: Dataquest (April 1997)

The first steps toward SLI brought microprocessors and SRAM on-chip. Now, with advances in silicon process techniques, it is possible to have true one-transistor (1T) DRAM memory join the other components on the ASIC.

The basic difference between a silicon process optimized for logic and one optimized for DRAM is the emphasis on interconnect technology versus capacitor construction. Embedded DRAM can be defined as a product that includes large amounts (more than 100,000 gates) of random logic and single-transistor DRAM on a single chip. Embedded SRAM usually has a smaller amount of on-chip memory (relative to DRAM). SRAM on an ASIC can be constructed using two different approaches:

- Built out of logic gates, typically used on a gate array
- Built out of dedicated six-transistor (6T) SRAM bit cells, typically used for cell-based or embedded array designs

The main SLI ASIC applications at present are: set-top boxes, multimedia, personal electronics, video games, portable computing, and portable communications. It is a segment that Dataquest predicts will skyrocket, accounting for over 50 percent of all ASICs sold by the year 2000.

A Perspective on embedded controllers, to be published by the Semiconductor Supply and Pricing Worldwide program in June 1997, will examine the area of DRAM SLI in more detail.


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## Dataquest Perspective

The year 1996 gave the ASIC market a bite of reality, slowing its seemingly breakneck growth. However, for the ASIC market to grow by 27 percent in a year in which semiconductors experienced 6.3 percent contraction and the net worth of the yen against the dollar decreased by 13.7 percent is remarkable.

The fruits of success were reaped by those suppliers with strategies that were both focused and fluid. These strategies focused on well-defined customer applications, building on past accomplishments. The winning strategies were also sufficiently fluid to facilitate support for the next "killer application."

The success of cell-based ICs in 1996 in surpassing the worldwide revenue of gate arrays for the first time is significant. More and more suppliers are focusing on this lucrative market to capture business. However, for a supplier to be successful, it must have a well-stocked and -rounded design cell library focused on SLI and must be able to migrate designs quickly to smaller geometries.

This, of course, opens a Pandora's box of intellectual property (IP) issues. At present, an increasingly large number of suppliers is trying to home in on the cell-based ICs, often going at the same application area/segment. Likewise, ASIC designers are a scarce and valuable commodity, and many are changing companies, attracted by better offers. IP is arguably the single most valuable asset of an ASIC vendor, and a vendor will surely fight if it feels its IP is being attacked or threatened by a competitor. It is almost inevitable that lawsuits will follow as rival suppliers fight to protect their intellectual turf.

For buyers, there are two types of IP nightmares:

- The buyer suspects that the supplier is using the buyer's ASIC design to support a rival customer's solution.
- The buyer accepts a design from a suppliers only to discover that the supplier is being sued by a customer or rival vendor over IP infringements.

Unfortunately, the whole IP area is gray, with little legislation safeguarding the parties involved. It seems that people on all sides are aware of the issues, but no firm solutions have yet been developed. It is something that buyers need to become more aware of, because they will be the ones caught in the crossfire. Knowledge is a weapon—buyers should arm themselves.

Other issues facing buyers are process related. A vital task is managing the migration to smaller geometries and ensuring that the optimal solution is achieved. Sexy new designs may be fun, but the workhorse volume designs in older geometries are still key.

One trend that will become more mainstream is embedded SLI design. DRAM SLI and FPGA SLI will both become more and more established over

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the next few years. However, these products are like Flash Gordon's "Ming the Merciless" for ASIC vendors. Vendors must have an excellent handle on design issues and state-of-the-art manufacturing processes. If not, they will perish. Vendors must look at their suppliers' fab and process investment road map. Is it sufficient to ensure rapid technology adoption and to expand for future business? What has its track record been on new designs and newer geometries, and have there been many teething problems with yields? Is the supplier a leader or a follower?

With ASICs, the buyer and supplier need a relationship of trust, understanding, respect, flexibility, and longevity. Product cycle times are shrinking, while more and more front-edge design work is being moved to the suppliers. Suppliers must understand the buyers' systems and application markets, which means that buyers must feel able to trust their suppliers. The suppliers' cell libraries must be the right fit for the end markets, and suppliers must offer the best all-around total cost of ownership. The suppliers that succeed will be those that best meet the needs of buyers.

**For More Information...**

Evelyn Cronin, Senior Industry Analyst ..... (408) 468-8075
Internet address ..... evelyn.cronin@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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Perspective



Semiconductor Supply and Pricing Worldwide

# Market Analysis

## Embedded IC Update

**Abstract:** *This document analyzes the events in the embedded IC market from a user's perspective, focusing on key products, suppliers, and the near-term direction of this critical market. We examine both major microcontroller and ASIC sides of this market based on 1996 shipment data.*
*By Mark Giudici, Tom Starnes, and Jordan Selburn*

## Variety of Supply plus On-Board Memory Makes for a User Opportunity and Challenge

This document analyzes the developments of the embedded IC market (embedded microcomponents and embedded application-specific ICs, or ASICs) from a market and supply base perspective. The following are some definitions that will be helpful in understanding this document better.

- Microcontroller (MCU): An MCU is a MOS digital integrated circuit designed for standalone operation that includes a programmable processing unit, program memory, read/write data memory, and some input/output capability. The processing unit contains an instruction decoder, arithmetic logic unit (ALU), registers, and additional logic. The MCU functions by fetching and executing instructions and manipulating data held in on-chip program and data memory (not including cache memories). MCU devices must be available with on-chip program or data store. As an option, some MCU devices do not have on-chip memory for use during the debug and development phase of the system. On-chip peripherals often assist in sophisticated input, output, and control functions. The MCU category includes MCUs incorporating, or originating from, an ASIC design. Dataquest defines MCUs as not including digital signal processors. Dataquest divides MCUs into 4-bit, 8-

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bit, or 16-bit and greater word width. All MCUs are designed into embedded applications. A similar term is microcomputer.

- Word width: This is the width, in bits, of the on-chip integer unit. This measurement is independent of the data bus width or any other bus associated with the device. The processor may operate on wider and narrower data types resulting with multiple passes through the arithmetic logic unit (ALU) or special hardware. Most microcontrollers are 4 bits, 8 bits, or 16 bits wide. A similar term is bit size.
- System-level integration (SLI): This is often referred to as "system on a chip." Dataquest defines SLI as: an integrated circuit that contains a compute engine, memory, and logic on a single chip and that has more than 100,000 utilized gates. There are two types of SLI: ASICs and application-specific standard products (ASSPs, which are sold to more than one user). This article will examine the latest inclusion in this process: embedding DRAM onto customized logic chips.
- Embedded applications: All microcontrollers are in embedded applications. The designs of embedded applications with microcomponents always perform a fixed set of functions once the system ships from the manufacturer. Those functions typically define the end product. The system may be reconfigurable by the end user but not programmable by a high-level language such as BASIC or FORTRAN. Usually the end user would not even know what type of processor was in the equipment. These products consist primarily of families such as the 68HCxx and 80xx and NEC's and Toshiba's families, as well as, recently, an increasing number of ASIC offerings with embedded memory. Based on clients' interest level, this Perspective will focus on microcontrollers and the emerging SLI market.

This document is divided into two sections plus a summary. The first section serves as an overview of the microcontroller market, noting market size, top suppliers, and trends. The second section reviews the nascent SLI arena and the trends developing that will affect users of this promising but potentially confusing market. A summary section then will review this product segment and note what users of these parts need in order to make the most of these cost-effective product solutions.

## Microcontroller Market Trends

### Overview

MCUs are the second of four primary categories of microcomponent semiconductors. We analyze trends in the marketplace, along with the conditions that will influence their outcome.

Microcontrollers had a banner year in 1995, growing over 35 percent. For MCUs, 1996 has been a mixed bag. Each vendor has its own particular challenges and timing, depending on its product mix and its markets and customers. The year should close out with a 3.4 percent revenue growth for microcontrollers, with some lagging continuing into 1997. Overall, Dataquest expects microcontrollers to remain a strong, growing part of the

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microcomponent product mix with a growth rate returning to well over 20 percent. In total revenue, 16-bit and larger MCUs will grow the most and show the greatest change, but 8-bit MCUs will continue to dominate the market well into the new millennium. If the players can tolerate the 1996 flatness, real prosperity will return in short order. Watch for a $20 billion business going out of the 20th century, with over 20 percent growth.

**The Future: What Does It Look Like?**

To see forward, it helps to know from whence one came. The year 1995 was such a boom year that in early 1996, everyone was simply looking up. Perhaps an occasional glance down might have revealed some unexpected hazards. The phenomenal growth in the personal computer and communications industries outstripped suppliers' abilities to serve their customers' needs. Protecting their flanks and ignoring some basic business tenets, customers overordered and developed backup procedures to cover any shortages. Excess inventory was easy to burn off, and pricing did not matter as much as supply. Vendors worked feverishly to build and reconfigure fab, assembly, and test facilities to improve capacity to supply a seemingly insatiable market. When the well-documented flood of unused DRAM hit the market after PC sales slowed before Christmas, compound effects in the semiconductor supply and demand system turned the entire industry upside down. OEMs found too many PCs in the channel and on their docks. They stopped ordering chips to build PCs they did not need to build. They pushed their subsystem suppliers to quit shipping the disk drives, monitors, and sound cards they did not need. OEMs pushed their subsystem suppliers to slow down but to remain ready to ship more units on a moment's notice. Subsystem manufacturers did not want to hold too much inventory, so they pushed back on their chip suppliers to ship fewer chips but to be ready to restart supply at any time.

How did this affect microcontrollers? Other segments, spooked by the well-publicized events in the data processing industry, took a reality check. First affected were the applications in the data processing industry, some severely. As the semiconductor industry went through its shrinking pains, Wall Street and other industries took note. As supply freed up, other application segments became flush with incoming chips. Management awakened to the dominoes falling in the data processing industry and revamped its own purchasing policies. Management scrutinized channel inventories, then made chip inventories leaner. Management then followed up by matching purchase orders more closely with declining lead times, then listening carefully for vendors offering price decreases. Eventually, the downturn affected all the segments because of fear, because of the balance of supply and demand, and because this really is a cyclical business.

However, the most perplexing aspect of the business cycle of 1996 is that the global economy is still in very good health and electronic equipment in general is still in pretty good demand. To date, there is no global recession, no mass of unemployed workers, no inadequate supply of money to borrow. The demand for the end equipment still seems to be there. As a result of the continual steady demand, there has been an ever-increasing number of

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vendors coming into the microprocessor and microcontroller business. Its high growth and reported profits have attracted the attention of the stock market, captive and specialty semiconductor manufacturers, DRAM manufacturers, reduced-instruction-set computing (RISC) vendors, and total newcomers. Existing MCU vendors add architectures between former product lines to fill any cracks. Every one of these vendors targets a given piece of the pie. Although the pie grows from year to year, the targeted shares still add up to greater than 100 percent. As with any potentially oversupplied market, a thinning of the MCU supplier ranks (also known as a shakeout) is very possible as users decide about the long-term compatibility and viability of their supply bases.

### Embedded Microprocessors Buck Trend of 1996

Microcontrollers (a subset of embedded microprocessors) had their best year ever in 1995, growing 36.4 percent in revenue and 18.7 percent in unit shipments. That was a hard year to beat, and 1996 did not do it. (Note that at the time of this writing, the finalized microcontroller rankings were not yet completed.) In the larger 1996 programmable embedded microprocessor market, Motorola Inc. held its position as the No. 1 embedded programmable microprocessor vendor, coming out at just an 18 percent market share (see Table 1). NEC lost a little more ground in its second-place slot with a 13 percent share. Texas Instruments Inc., with its strong digital signal processor (DSP) presence, was a strong third-place runner in this category, and Hitachi Ltd. was a close fourth place, thanks to big gains in its microcontroller-classed 32-bit RISC, the SH-1. Intel Corporation is in the top five MCU vendors, mostly on the strength of its 16-bit i960 product line. Further down in overall MCUs, the 8051 contingent made some significant gains in market share, outpacing the total average. Oddly, the top five vendors grew much less than the average for all MCUs, and the lower segment of the supply base had much higher gains.

**Table 1**
**Leading Embedded Programmable Microprocessor Vendors (Millions of Dollars)**

| 1996 Rank | | 1996 Revenue | 1996 Market Share (%) |
|---|---|---|---|
| 1 | Motorola | 2,637 | 18 |
| 2 | NEC | 1,846 | 13 |
| 3 | Texas Instruments | 1,358 | 9 |
| 4 | Hitachi | 1,338 | 9 |
| 5 | Intel | 967 | 7 |
| | Others | 6,565 | 44 |
| | Total | 14,711 | 100 |

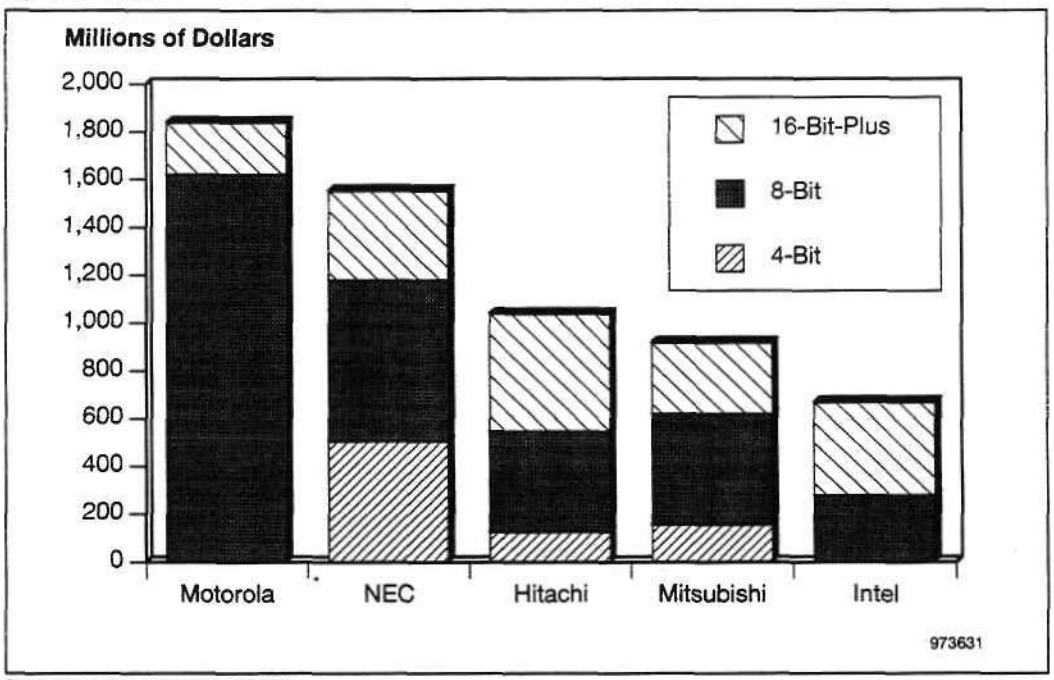
Source: Dataquest (May 1997)

There is no single formula for becoming a successful microcontroller vendor. At the time of this writing, the final shipment data by bit width for 1996 was not yet complete. Figure 1 illustrates the makeup of the top five 1995 vendors' microcontrollers, looking at word width. Motorola clearly has a dominant role in 8-bit MCUs, and neither Motorola nor Intel has 4-bit MCUs

on the market. The Japanese companies, with almost a lock on 4-bit MCUs, have products in all three categories, and NEC looks to be the most balanced.

Please note that data in this document is also in Dataquest's *1996 Microcontroller Forecast* (MCRO-WW-MT-9603, October 14, 1996).

**Figure 1**
**Word Width of Leading Microcontroller Vendors' Product Portfolio by Revenue**




Source: Dataquest (May 1997)

## Microcontrollers with Embedded DRAM—The MCU Model toward SLI

Core processors and peripherals based on the 68000 will soon be available together with dynamic random-access memory (DRAM) on the same piece of silicon, ushering in a new era for integrated processors. The most popular embedded architecture will be freed from the constraints placed on the primary component of the memory system that typically feeds it. This will allow the embedded application designers to further distinguish themselves from the PC engineers. There are many interesting aspects of this combination of technologies, companies, and products that could change the way embedded application designers think about their system configuration.

### Typical Embedded System Design and Memory Selection

The design of the traditional embedded electronic system involves choosing a microprocessor from the selection available in the architecture that best accommodates the particular type of product being built, be it a laser printer, a set-top box, or a palm-size communicator. Interfaces, inputs, and outputs determine the best combination of peripheral circuits that the new product

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uses. Some chosen might be: serial communications, parallel input/output (I/O), timers, or direct memory access (DMA) peripherals.

The configured memory system must feed instructions into the processor and supply data to the programs at run time. The memory might consist of semiconductor products such as read-only memory (ROM) or might involve a disk drive in larger systems. Static random-access memory (SRAM) is used for the fastest parts of the memory system, especially in caches, but in most systems, the largest portion of semiconductor memory will be DRAM.

DRAM has the best combination of low cost per bit with very good (but not the best) performance. This allows a cost-effective product to be built without a serious compromise in performance. Traditionally the large DRAM memory has been a set of chips separate from the processor. This gives flexibility both to the system designer to select the appropriate quantity of memory for the application and to the vendors to optimize the manufacture of the processor independent of the manufacture of the memory chips. DRAMs consistently drive to put the greatest number of bits possible on the chip at a particular price (that number now sits at 16Mb), and this is not always the best for embedded applications. (Note that Mb indicates megabits and MB indicates megabytes of memory.)

## Use of SRAM

Static RAM has the advantage of being significantly faster than DRAM (15ns versus 60ns), but it achieves this at a very high cost. On a standalone SRAM chip, four transistors make up the typical SRAM memory cell; six transistors make up an SRAM cell processed on the same chip as logic circuits such as microprocessors. But just a single transistor makes up the DRAM cell in a DRAM chip—a fourfold or sixfold improvement. The higher packing density of DRAM drives its price advantage over SRAM.

When memory is being added to processor chips, fast SRAM is attractive for caches, primarily because it uses the same basic IC process lines as the processor logic. DRAM, on the other hand, strives so hard for ever-lower cost with its high density that it uses very different techniques through the production line than logic circuits. The large caches used by the highest-performance RISC processors dedicate the majority of their die size to caches that range from 64KB to 128KB (512Kb to 1Mb). This may be large for SRAM, but it is small compared to available DRAM chips. If DRAM cells were used, the density of this memory could quadruple.

These issues and topics of bandwidth, throughput, power consumption, transmission line effects, pin count, reliability, and board space have burdened the microprocessor designer as well as the embedded system designer for years. The two main issues boil down to memory chip organization and the width of the processor-memory interface. If the processor and the DRAM could reside on the same piece of silicon, it would open up many new possibilities in system design, improving both cost and performance of the final system. Enter Mitsubishi.

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## Mitsubishi's DRAM and the First MPU with DRAM On-Chip

Mitsubishi has been a significant player in the DRAM memory market for some years now. In 1995, it was the No. 9 supplier of DRAM to the world with over 5 percent market share. Mitsubishi now makes limited 64Mb extended data out (EDO) DRAM and looks for success in this next generation of DRAMs, due out in production by late 1997 or early 1998. Mitsubishi has also been developing some exotic application-specific memories, such as its CD-RAM, (a blending of cache SRAM and DRAM), and 3D-RAM, which adds special acceleration hardware to the cache and DRAM to speed up video graphics operations.

Mitsubishi announced a product in March 1996 with a new RISC processor deeply embedded in a DRAM chip. The M32R/D contains a proprietary 32-bit RISC core with a 2KB cache memory and 2MB (16Mb) of DRAM on-chip. Data and instructions are transferred between the caches and the on-chip DRAM over a 128-bit-wide data bus at a rate up to 1 GB/sec. This eliminates over 60 percent of the time it would take to make these accesses over a 32-bit-wide external bus. Transfers of 128 bits over an external 128-bit bus would be ludicrous in most systems today because of the high pin count, current spikes, and minimum memory configuration that would be necessary to accommodate them. However, when the M32R/D goes to external memory, it does so over a more economical 16-bit bus at moderate rates while allowing very fast transfers between the on-chip memories to keep the processor well fed. This effectively gives the M32R/D a two-level (L2) cache, with the second level containing a whopping 2MB of data or instructions.

However, the M32R/D is a brand-new microprocessor architecture. New processor architectures take a long time to establish themselves, and history shows them to have a high failure rate. There are numerous issues of support, documentation, knowledgeable programmers, interested customers, legacy, and many other issues that can suffocate a new architecture in the highly competitive microprocessor world. Would an embedded system designer use the M32R/D even if it comes with the 2MB of DRAM on chip and is perfect for the specific application? The best technical solution does not always win the day (in fact, this happens rarely). All those other issues come into play and often supersede the technical merits. The M32R/D appears to be gaining some special design-wins and has demonstrated execution of the Java programming language but is a relatively unknown architecture. The well-thought-out design of the M32R/D takes advantage of its sizable on-chip DRAM, perhaps the beginning of what system and chip designers should be considering in their system layout.

Mitsubishi made a second, very important achievement in developing the M32R/D. It made a DRAM cell that can be processed on the same wafer, with much the same steps, as a typical logic (ASIC or microprocessor, or MPU) production line. It is also as small as those that run in the fabs usually dedicated to processing DRAM (for the same process geometries). This is a very valuable technology. DRAM, as a library element available to

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microprocessor, microcontroller, or customer-designed ASIC developers, opens a whole new world of opportunities. Maybe Motorola would be interested in this.

## Motorola's Established 68000 Family

Motorola's 68000 architecture is the leading microprocessor architecture for applications outside DOS-based PCs. Last year, as in many years before, the 68000 family was the No. 1 microprocessor architecture in embedded applications. In the embedded microprocessor world, among the most critical decision factors are the support products that help an OEM design the microprocessor into its end products. The history and market share of a microprocessor determines just how much support may be available, whether it is development tools and languages or simply the ability of the OEM to hire qualified programmers with an intimate knowledge of the architecture. Motorola's 68000 has a huge advantage here.

Integrating microprocessors with a selection of peripheral circuits is another crucial factor for success in the embedded marketplace. Motorola has a variety of 68000 family-integrated processors to address a number of markets. Motorola has refined the 68000 architecture for embedded applications and customization, culminating in its ColdFire family of products. ColdFire processors will run most of the original 68000 family code, but are streamlined to run it much faster. Also, the ColdFire chips integrate peripherals along with the core processor. The fitting of the right match of processor performance and peripherals to a particular application is one of the key differentiators in today's processor market, and Motorola's earlier 68300 products have a strong position there.

One element missing from Motorola's and everyone else's bag of tricks for integrated processors has been a good DRAM module. The problem has been the mismatch in the silicon fabrication processes used for normal DRAMs and the process used for microprocessors. Maybe Motorola should talk to Mitsubishi.

## Two Companies Engage to Get Things Really Rolling

Mitsubishi and Motorola got together in early 1996 to compare notes. In October, they announced their intention to work together to put microprocessor cores together with DRAM on a single chip. Motorola will give its 68EC000 and the ColdFire core processors to Mitsubishi for use in customer-specific ASICs. In return, Mitsubishi will give Motorola its logic-processed DRAM technology for use in integrated microprocessors and ASIC-type products, as well as giving Motorola access to its new M32R processor core. Both companies will market products with the 68EC000, ColdFire, and M32R core processor integrated with a set of peripheral circuits and an appropriate quantity of DRAM on a single piece of silicon. As a result of the exchange, Mitsubishi may produce customer-specific devices, while Motorola may also produce standard products. This is an exciting engagement for both Mitsubishi and Motorola, as well as the industry. It will change the way engineers design their electronic products. Engineers not only can get their hands on a processor and some peripherals, but they can

also bolt large (or small) quantities of DRAM onto their own unique chip—just the right size of DRAM. There are many advantages: fewer chips, fewer solder joints, smaller packages, lower power consumption, and less excess. They can also use their favorite processor architecture with all the familiar support and tools. With on-chip memory, there is much greater flexibility for adding or organizing the memory in the best way for the application, without doubling the cost as might happen with external DRAM. Despite these good ideas, as of this writing, the two companies have yet to announce any specific product families to emanate from this agreement.

## The Power of Pins on the Package

DRAM MPUs have an advantage in power consumption as well as board space. An embedded processor dedicates a noticeable number of pins to I/O. Many of these pins control the on-chip peripheral circuits on integrated processors and microcontrollers. As with a microcontroller, if external access to memory is eliminated or minimized, then the number of pins on the package comes down. Even if the pins are there, they can share their time with other functions (such as peripherals) or at least save power by not being exercised. A bus used for accessing external peripherals would generally do just fine with eight data pins and eight or 12 address lines—far fewer than the 32 plus 32 that usually get used by memory buses.

Any time that electrical signals move from one chip to another, lots of current is used. It multiplies linearly as the number of signals increases and is worst when the signals must drive an array of chips, as is typical with memories. A processor with enough on-chip DRAM does not need all the extra pins and power (and the resulting battery drain) required for external memory accesses.

Nothing is free, of course. Having fewer pins can affect the testing of these chips. As it is, all the tests typically done on DRAM would need to be done on the embedded DRAM. Having fewer pins to access the DRAM could slow the test procedure dramatically, and test time is extremely valuable (longer test time equals greater cost). Verification of all the functionality of the microprocessor and peripheral circuits also takes its share of test time. Overall, test time could be expected to be about the same as or slightly longer than the sum of the time needed to test the standalone equivalent MPU and to test a similar-size DRAM.

## Embedded ASIC Trends toward the SLI Goal

### Single-Chip Systems in the Homestretch

There is a strong and accelerating trend in the ASIC industry toward system-level integration, 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-

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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 about 12 percent 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.

## Leading SLI Suppliers

Most semiconductor suppliers, regardless of whether they are standard product suppliers or ASIC suppliers, realize that there is a sizable market emerging for systems on a single piece of silicon. The reality is that if a company does not participate in this market in the near future in some form, the company will find it hard to compete in the semiconductor market in the year 2000. Therefore, nearly all ASIC suppliers and standard product suppliers have targeted this market for growth. Leading ASIC suppliers in the 1996 market included the following:

- LSI Logic
- IBM
- Lucent Technologies (AT&T)
- VLSI Technology
- NEC
- Toshiba
- Hewlett-Packard
- Texas Instruments
- Motorola

Other companies actively pursuing the SLI ASIC market with increasing revenue include Fujitsu, Hitachi, Mitsubishi, Matsushita, AMS, GEC-Plessey, SGS-Thomson, Symbios, Samsung, and LG Semicon.

Most ASIC suppliers (including LSI Logic) also sell some SLI standard products built from past ASICs that have been proven winners. It is more difficult for standard product suppliers that do not offer ASICs to compete in the SLI market because they do not have as much experience in design methodology and library reuse. Standard product suppliers, in many cases, use different foundries for each product and fine-tune the products to reduce die size, which is counterproductive in design reuse and causes increased time to market for next-generation products.

## 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:

- Fewer 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 less somewhat lower memory density. Conversely, most vendors start with a memory process to embed DRAM into an ASIC. 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.

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. (All references to gate geometry refer to the drawn gate length of the transistor.)

The current state of the art for embedded DRAM within ASICs is that these products will begin prototype production in the latter half of 1997, with full production beginning to ramp in mid-1998. Products using the enabling embedded memory technology through the 0.18-micron generation will be introduced in 1998, with full production beginning in 1999. Dataquest forecasts the that 0.18-micron generation will become the mainstream ASIC technology starting in 2000 and 2001.


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### Alternatives to Embedded DRAM

In addition to the embedded DRAM solution discussed earlier, there are other memory alternatives for integration with logic. The primary ones are:

- Static RAM
- Three-transistor DRAM
- Standalone DRAM
- Packaging solutions, such as multichip modules

### 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)

**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 Technology | | | | X |
| Texas Instruments | X | | | X |
| IBM | | | | X |
| VLSI Technology | | | X | X |
| Samsung | X | | | X |

Source: Dataquest (April 1997)


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# Embedded DRAM Forecast

## Forecast for 1997 to 2001

Table 4 shows the five-year forecast for embedded DRAM by application. The expected year 2000 revenue of over $4 billion shows 40-times growth from 1997. Although 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.

**Table 4**
**Worldwide Embedded DRAM ASIC/ASSP 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)

Three applications dominate the growth of the embedded DRAM market: graphics controllers, disk drive controllers, and networking (LAN/WAN hubs and switches). These three markets will account for almost 75 percent of the total in 2000.

# Dataquest Perspective

The embedded IC arena offers many attributes to a large segment of the semiconductor user community. These products, while often used by computer companies, have one of the broadest application bases in the total IC market. Telecommunications, industrial, consumer, automotive, medical, and even PCs increasingly use embedded ICs as a cost-effective, often custom, product solution. The economies of scale and reliability of known MPU cores, combined with ever-increasing options of I/O, memory and bit width, allow for greater flexibility in solving system performance issues.

From the more customized ASIC perspective, embedded memory cores within logic cells or gates offer both promise and perplexity—the benefits of combining the two are well-known, but the road to those benefits is still a bit bumpy. Sourcing an MCU is much like sourcing an ASIC. The potential user has the most flexibility and leverage before making the sourcing decision because the outcome often results in a sole-sourced part. Maintaining flexibility in using multiple chip designs and opting for system migration path plans that use modifications or integration of existing chip designs often help in lowering the total cost of the system.


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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, clearly 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 fulfill 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. ASICs used SRAM in the early 1990s. 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 that of SRAM as the demand for memory bits continues to skyrocket. Although 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 at which a majority of SLI ASICs and ASSPs will contain some amount of embedded 1T memory. Even programmable logic is likely to embrace this technology beyond 2001 in the form of large fixed memory blocks. MCU and embedded DRAM arrangements—breakthroughs like the Motorola-Mitsubishi deal—will increase the expansion of DRAM into the standardized controller market, opening up a design/performance/cost bottleneck. For users, cooperation between the design and procurement groups before the part is designed in will ensure that both the best technical and sourcing solutions are made.

**For More Information...**

Mark Giudici, Director and Principal Analyst ..... (408) 468-8258
Internet address ..... mark.giudici@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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Semiconductor Supply and Pricing Worldwide

# Market Analysis

# Second Quarter 1997 Procurement Pulse: Order Rates Flatten, Lead Times and Inventories Rise, and Spot Prices Exceed Contract Prices

**Abstract:** *The* **Procurement Pulse** *is a quarterly update (with interval updates, if events warrant) of critical issues and market trends based on surveys of semiconductor procurement managers in the North American region. Besides order rate, lead time, and inventory information, this survey also notes price status by semiconductor product family and package type, as well as key problems facing semiconductor users.*
*By Mark Giudici*

## Semiconductor Order Rate Expected to Bounce Back after Two Months of Cautious Forecasts

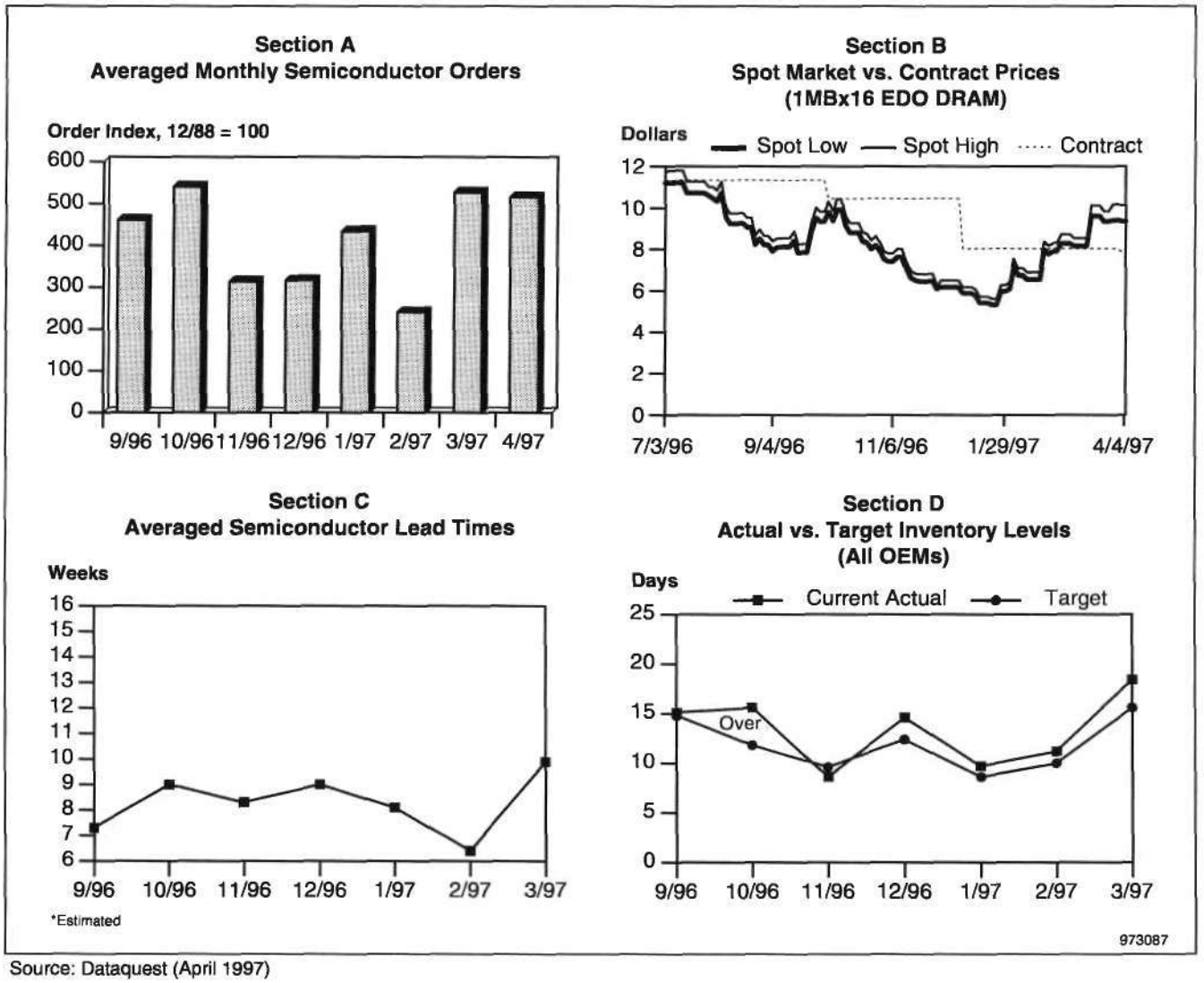
As seen in Section A of Figure 1, the outlook for semiconductor order activity has picked up since our last report and is expected to level off in the near term. While flat with March's forecast index, the outlook for April has historically shown where the market heads for the rest of the year, as order rates and inventory levels generally stabilize. This flattening of the order rate may in part be because of some short-term upturns in DRAM pricing noted for the first time in over 16 months. The overall sample continues to see price cuts for larger-volume contracts in all areas tracked in this survey—microprocessors (MPUs), logic, flash memory, and SRAM (except for some DRAMs). DRAM pricing for the overall sample actually rose an average of 4.4 percent in March after an unchanged price picture in February. The computer subset of the respondents saw a smaller rise of 2.8 percent in DRAM prices after unchanged prices noted in February. While overall prices continue to decline, except for DRAM, in the near term, thin small-outline

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packages (TSOPs) and ball grid arrays (BGAs) continue to earn premiums of 5 to 10 percent over more standard package offerings.

**Figure 1**
**Semiconductor Supply**




Source: Dataquest (April 1997)

## Spot Market and Contract Prices Cross Paths

In response to client requests, we have added a new graph to the *Procurement Pulse*. In addition to the spot market prices provided every week in Dataquest's *Semiconductor DQ Monday Report*, we provide Section B to highlight how contract 1Mbx16 DRAM prices compare with spot prices. Although overall demand for semiconductors remains strong, it appears that selected DRAM suppliers have curtailed production or shipments (or both) to stay the tide of DRAM price decline. In the near term, the spot market has reacted with higher prices, while contractual buyers have not noticed this managed market tactic. As noted over the past year, we expect continued volatility, with spot market prices vacillating around declining contract

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prices, causing uncertainty for some buyers. The overall trend, however, is for continued good availability, consistently declining contract prices, and low (eight- to 10-week) lead times for the next six to nine months for contract buyers.

## Lead Times for Semiconductors Near the 10-Week Mark

Section C highlights that the average lead time for respondents in March jumped to 9.9 weeks, compared with a 6.4 week average noted in February. The relative instability of lead times is in part because of the perceived uncertainty of DRAM supplies despite overall good availability of every other semiconductor product segment. The acknowledgment by both buyers and suppliers that 1996-style price cuts and availability are now history is encouraging some prudence among overzealous spot buyers, making contracted deliveries increasingly attractive. Good service levels combined with slowly declining prices are cementing many long-term supplier relationships. Of the entire sample, over 40 percent noted some problem with DRAM, but that was the only product area. The other semiconductor products enjoy good availability and reasonable pricing. Last quarter, over half of the respondents noted price fluctuations/inventory adjustments and end-of-life ordering as the key issues. This month, close to half of the respondents noted only DRAM availability as the main issue.

## Semiconductor Inventories Back to Historical Levels

Section D highlights how inventories continue to overshoot targeted levels and closely track target direction. As respondents forecast semiconductor order rates to flatten, as noted earlier, we see a corresponding slight increase in inventory levels—primarily in DRAMs to offset any near-term real or perceived price increases. The overall targeted and actual semiconductor inventory levels for March were 15.6 days and 18.4 days, respectively, compared with February's 10.0-day and 11.2-day inventory levels. While not shown, the computer subset again appears more aggressive than the average, with current target and actual inventory levels of 12.0 days and 16.3 days. We continue to expect to see stabilized inventory levels in the future in line with system sales levels.

## Dataquest Perspective

Availability of semiconductors remains very good to excellent (despite DRAM market manipulations) and we expect it to remain this way for the rest of 1997. Contract prices continue to decline, despite the efforts of some memory suppliers to curtail output, and lead times have stabilized to meet customer demand. Even with the current increases in the DRAM spot market, the volume of business through this channel remains surprisingly low. This reflects the continued user focus on total cost, not price alone, when determining a component buy. Dataquest continues to forecast steady 1997 growth rates for PCs and other electronics relative to 1996, with the overall trend following an upward growth slope. User semiconductor

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inventory levels are now in line with user demand, and we expect to see continual balance in these indexes in the near future. Real allocations are not a problem, but the near-term DRAM issue may well play itself out, forcing a quicker shift to 64Mb DRAMs if enough suppliers can come up with parts. At this time, this scenario is possible but not highly probable. Dataquest expects to see excellent semiconductor availability through the end of 1997. DRAM and MPU price elasticity to date have not propped up contract prices. While DRAM spot market prices have crossed contract prices on the upward path, the overall DRAM capacity situation will force suppliers sooner or later to release inventory or wafer starts because of economic necessity. The good news for users is that overall declining contract prices will continue to be with us for the rest of this year.

**For More Information...**

Mark Giudici, Director and Principal Analyst ..... (408) 468-8258
Internet address ..... mark.giudici@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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# Market Analysis

## Second Quarter 1997 Quarterly Price Survey Highlights

**Abstract:** *Dataquest has completed the second quarter 1997 North American contract pricing survey for the semiconductors tracked. This Perspective analyzes the main signals seen, both overall and by main family type, and their impact on contract buyers worldwide.*
*By Evelyn Cronin*

## General Market Characteristics

The main signals: Oversupply is set to continue, but the dawning of a period of relative price stability for DRAM has begun.

This period of price stability is greatly aided by the public announcements from certain vendors of DRAM production cutbacks. This new age of DRAM price stability is significant for all buyers, even those who do not purchase this commodity. As DRAM is an extremely large chunk of overall semiconductor revenue, price stability has a positive impact on the revenue of the whole segment. This should translate into a less turbulent year for both unit DRAM devices and Wall Street share prices in the technology segment.

For buyers, this might not be viewed as being too rosy a scenario—price stability lessens their ability to negotiate lower price. Suppliers will argue the necessity to ensure that research and development is maintained longer term. Thus, total cost of ownership reduction becomes even more key for DRAM, and buyers can build on the work done last year.

Also, although long-term relationships remain critical with DRAM vendors, these partnerships should be split into two groups: technology DRAM partners and standard DRAM partners. The technology leaders will

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guarantee the buyer access to leading-edge product in a timely fashion. The buyer's company can use this to differentiate its products and to stay at the cutting edge. However, not all DRAM bought will be leading-edge stuff—the bulk will be standard, current product. It is here that the standard partners shine. These suppliers can be used to obtain the most attractive (lowest) price possible on high-volume standard devices. This supplier management model is equally valid for other multisourced product.

For non-DRAM devices, however, opportunities for good price reductions continue to exist. On all (save MPUs), there is a fair selection of product sources all competing for a slice of the same demand pie. This means that 1997 is set to be another "Year of the Buyer."

Based on the trends seen in Dataquest's *North American Second Quarter 1997 Price Outlook*, we have extracted key points.

## DRAM

The key points to remember about DRAM are:

- Fast page mode (FPM) will become more expensive than extended data out (EDO) by the second half of 1997 as production decreases because of the market transition.
- The price flattening trend will continue on all asynchronous devices—price reductions will be minimal for 1997 and 1998.
- Long term, prices on 4Mb and 16Mb are set to increase as these devices move to the decline stage of the life cycle and suppliers scale back production.
- Reference pricing for Korean and Japanese suppliers is set to be reintroduced by the European Union, which will further impact selling and buying strategies there.
- Synchronous product is being targeted at a certain segment very aggressively.
- However, for synchronous DRAM, 64Mb will be the density of choice—this is going to be far more price competitive per megabyte than the 16Mb SDRAM. Also, 64Mb SDRAM will ramp down in price faster than 64Mb EDO.
- Currently, there is no real adder for dual in-line memory modules (DIMMs) over single in-line memory modules (SIMMs). Any price difference is because of pricing strategies on chips.

## SRAM

The key points about SRAM are:

- Starting early in 1998, x4 and x8 64Kb and x4 256Kb will be in the end-of-life stage from many suppliers.

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- For x8 256Kb and x32 1Mb cache devices, lead time polarization from suppliers will occur. Some clearly want out of this cutthroat segment and have adjusted lead times up to nearly five months to dissuade customers.
- Overall, prices are still in decline for higher-density devices as costs per megabyte for the chips decrease.

## Flash

The key points about flash are:

- Lead times are pretty much unchanged this quarter, with one notable exception!
- 5V and 3V crossover starts to occur with 8Mb in the third quarter; others will follow.
- By the beginning of 1998, price parity will exist for 4Mb and above flash densities, irrespective of voltage.
- Moderate price reductions are forecast below 4Mb, with the most aggressive price reductions forecast for the 4Mb, 8Mb, and 16Mb densities.
- Long-term pricing shows more stabilization.

## Microprocessors

The key points to remember about MPUs are:

- Intel is decreasing prices on selected Pentiums fairly aggressively in a deliberate bid to influence fourth quarter 1997 PC buying trends.
- Intel's Pentium MMX has launched, and the pricing is very attractive in the second half of 1997, especially at 166 MHz.
- Not to be outdone, the PowerPC camp is coming out very strongly with the 604 processor family, which offers quite an attractive price/performance curve.

## ASICs

The key points to remember about ASICs are:

- One-micron technology is moving quickly to production-only status from many ASIC houses—that is to say, they have a policy of no new designs in this technology but will continue to manufacture existing designs.
- Generally, midrange gate count solutions are cheaper in gate arrays. However, for higher gate counts, cell-based ICs (CBICs) are usually a far more cost-effective solution.


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- Under-10,000-gate designs are being served by the variety of FPGA/PLD providers, each with its own standard.
- Pressure to gain business has pushed prototype lead times down from most suppliers. However, these lead times are usually less for gate array solutions.

## Dataquest Perspective

All in all, 1997 looks like it will continue to be a challenging year. All devices will continue to be in oversupply, albeit to a lesser degree than in 1996. The level of oversupply is related to device family. However, with numerous technology transitions due this year, there may well be short-term supply constraints from some vendors. But these will right themselves quickly.

There are many opportunities for reducing total cost of ownership that the savvy buyer can make happen. However, particularly with DRAM and SRAM, some suppliers suffered badly in 1996, forced to sell below cost, in some cases. Thus, these vendors cannot continue to deliver the same stellar price reductions in 1997—this year will be more controlled.

Also, many DRAM vendors are starting to remove their focus from noncontract selling channels. Although this definitely does not put DRAM back on allocation, it does mean that spot markets, among others, may not offer any price advantage this year. As of this writing, spot market prices are back up to contract levels and may exceed contract prices in the future because of the previously mentioned supply shift. Of all DRAM sales channels, contract buyers will be the least affected. DRAM manufacturers will continue to emphasize the contract channel and may well return to long-term partnership-type purchasing with key customers.

**For More Information...**
Evelyn Cronin, Senior Industry Analyst ..... (408) 468-8075
Internet address ..... evelyn.cronin@dataquest.com
Via fax ..... (408) 954-1780

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Semiconductor Supply and Pricing Worldwide

# Market Analysis

## 1997 Semiconductor Cost Model Update

**Abstract:** *This Perspective updates the Dataquest semiconductor cost model and IC package cost table. Detailed examples of the 16Mb and next-generation 64Mb DRAM cost models that use the latest cost variables follow a brief review of the model's description. By Mark Giudici*

### DRAM Cost Update 97: Cost-Based Pricing Returns Big Time!

Procurement departments often use cost model analysis in two ways: near-term cost/price optimization and in aiding long-range system cost analysis. Also, using semiconductor cost models during years of technology transition (for example, DRAM density crossover) often is useful in positioning procurement strategies in line with a company's system offering. The current buyer's market resulted from last year's shift in availability from an undersupply to an oversupply (relative to steady demand) for many semiconductor products.

### Dataquest Cost Model Synopsis

The Dataquest semiconductor cost model uses 16 variables of semiconductor manufacture (once past the processed wafer stage). These variables cover the main areas where costs accrue and processes improve. The variables that have the most influence over cost are the following: semiconductor process, wafer size, die size, sort yield, package type, and final test yield. Improvements have been made to the model this year that take into account process maturity and its effect on yield.

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## Cost Model Applications

Semiconductor cost models are predominantly used to compile costs for use in near-term contract negotiations. By identifying cost reduction areas, price negotiation results often benefit the parts buyer. Applying experience-curve theory to cost model applications can give both short- and long-term cost/price scenarios that can be a basis for strategic planning.

Strategic use of cost models in long-range planning has been underutilized because of the indirect influence of cost over price as the time horizon expands. Some users apply different learning curves to individual variables in the model in combination with price forecast analysis. In this way one can better understand future trends and have alternate strategies at hand if any variable actually differs from its expected trend line. We suggest this use of cost modeling as a part of a proactive strategic procurement plan.

### Cost versus Price

In a competitive market, semiconductor manufacturers pass cost reductions on to their customers. Therefore, a knowledge of semiconductor costs and cost trends is useful for projecting long-term procurement costs and selecting the most cost-effective semiconductor device for a particular application.

The cost/price relationship for semiconductor products varies from: product to product, company to company, and with time, as a function of business conditions. One way to perform cost/price to analysis is to monitor prices and costs over a period of several years for selected product types and identify the average gross margin for these types. By using this procedure, semiconductor users can develop a good feel for the cost/price relationship for the semiconductor products they buy.

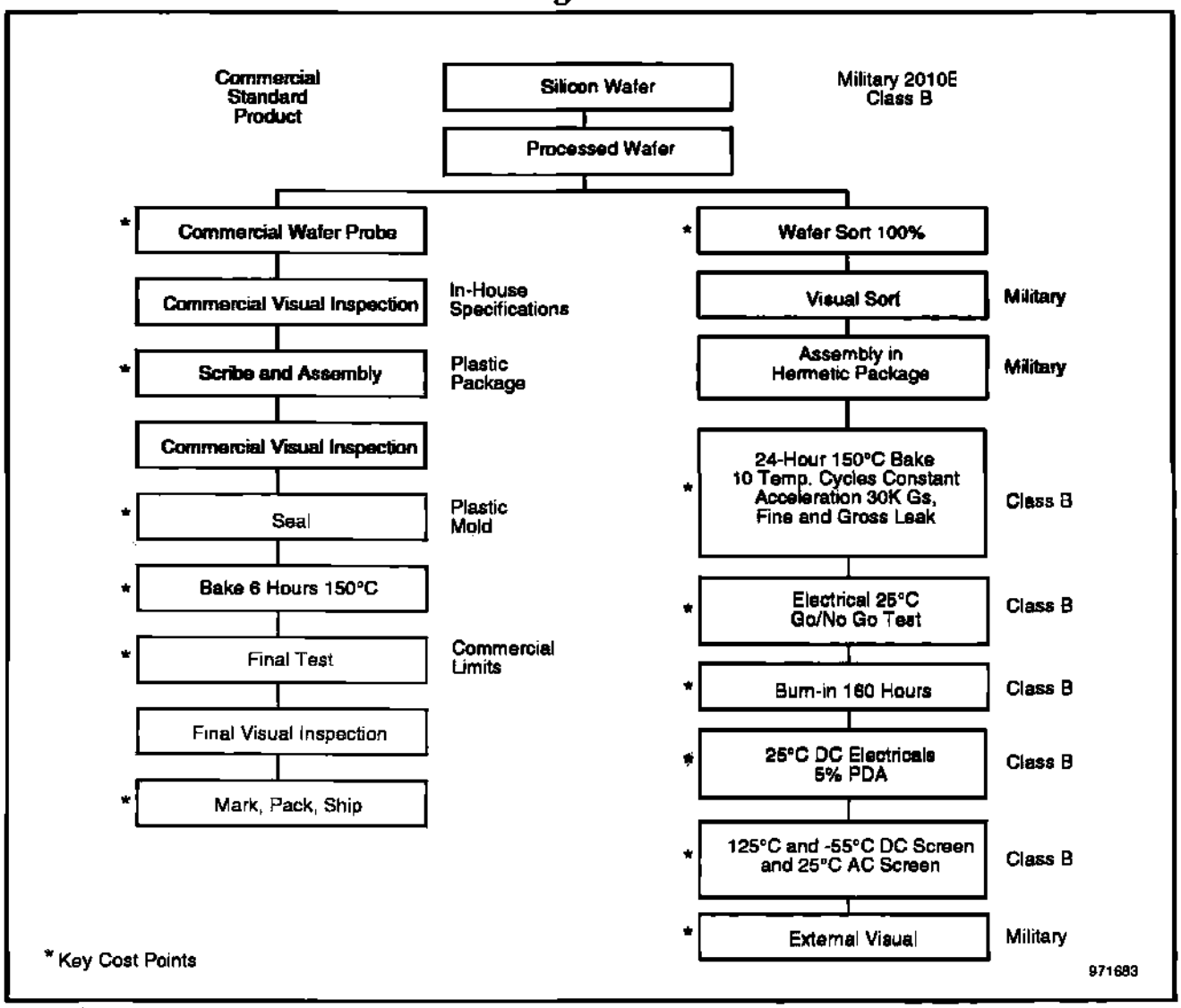
## Cost Factors

As mentioned above, the key factors affecting the cost of a finished semiconductor device are the semiconductor process, wafer size, die size, sort yield, package type, and final test yield. The cost of a semiconductor incrementally increases by adding the cost of each step in the manufacturing process to the finished product. Figure 1 illustrates the typical manufacturing process flow for semiconductor devices. Our cost model categorizes costs into the following four areas:

- Wafer processing and die sort
- Assembly
- Final test
- Screening, qualification, mark, pack, and ship


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## Figure 1
## Commercial and MIL-STD Manufacturing Flow




Source: Dataquest (March 1997)

The manufacturing process begins with a raw, unprocessed silicon wafer that costs from under $15 (100 mm wafer) to approximately $120 (200mm wafer). After completing more than 100 processing steps, the cost of a processed wafer is 10 to 30 times the initial cost of the unprocessed wafer. The wafer cost is a function of the following:

- The relative complexity and maturity of the IC process/lithography
- The number of masks
- The photolithographic requirements of the process used
- The clean room environment required by the process

A complex relationship exists for each of these elements with the end cost of the product. Some of these interacting relationships involve the depreciation schedule of a fabrication plant (that is, $500 million to $1 billion fab cost

over a five-year period) in relation to wafer output, process learning curves within a fab, back-end test cost amortization, and royalty payments (if required) by process or device type.

The cost of a wafer increases with each layer required. Additional mask layers could introduce more defects and decrease yields. In general, more complex processes produce more expensive die. Table 1 lists the typical number of mask layers for most common integrated circuit processes.

Wafer costs increase as device features become smaller. However, smaller features result in more die per wafer. Although the wafer cost will be higher, the cost per function per chip because of the increased density often will be lower.

The class of fab or clean room environment has a very large impact on the final cost of a semiconductor device. As device features become smaller, circuits become more susceptible to yield loss because of the particles in the fab environment (that is, a 0.5-micron particle would not be a major problem in a 1.0-micron fab line, while the same particle would be catastrophic in a 0.6-micron line).

**Table 1**
**Number of IC Process Mask Layer**

| Process | Single Layer Metal | Multilayer Metal |
|---|---|---|
| Schottky TTL | 7 | 9 |
| Bipolar Linear | 7 to 9 | 9 to 11 |
| ECL | 8 | 10 |
| NMOS | 8 | 10 |
| HMOS | 9 | 11 |
| CMOS | 10 | 12 to 15 |
| HCMOS | 11 | 13 to 16 |
| BiCMOS | 14 | 16 to 20 |

Source: Dataquest (March 1997)

## Package Costs

The type of packaging a semiconductor device uses often makes up a large portion of the overall semiconductor cost. For example, going from a ceramic to a plastic package using the same die often will reduce the manufacturing cost and related price by a factor of 2. Table 2 shows the latest cost estimates for semiconductor packaging in 1997. This table highlights how different packaging options can alter finished semiconductor pricing.

## Cost Model Formula

Dataquest's semiconductor cost model uses the variables and algorithms shown in Table 3 to estimate semiconductor costs. Because of the flexibility of the model, a variety of semiconductor devices can be costed out depending on many of the key variables noted earlier (that is, die size, wafer size, process, package, among others).

## Table 2
## Total (Die-Free) Assembled Package Cost, 1997 (Dollars per Package) Volume Production, More than 100,000 Units

| No. of Pins | Plastic DIP | CER DIP | Side-Braze | Ceramic PGA | Plastic PGA | Plastic Chip Carrier PLCC | Ceramic Chip Carrier (Leadless) LCCC | Ceramic Chip Carrier (Leaded) LCC | SOJ | SOIC | TSOP Type I | TSOP Type II | SSOP | Plastic QUAD | TQFP 1.4mm Body | TQFP 1mm Body | Ceramic QUAD | Metal QUAD | TAB Tape/ Site | Ceramic BGA | Plastic BGA Single Layer | Plastic BGA Multi-layer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 0.06 | 0.21 | 1.25 | | | | | | | 0.06 | | | | | | | | | | | | |
| 14 | 0.09 | 0.22 | 1.65 | | | | | 1.15 | | 0.10 | 0.18 | | | | | | | | | | | |
| 16 | 0.11 | 0.26 | 1.65 | | | | 0.90 | 1.20 | | 0.12 | 0.18 | | | | | | | | | | | |
| 18 | 0.12 | 0.30 | 1.80 | | | 0.19 | 1.00 | 1.30 | | 0.14 | | | | | | | | | | | | |
| 20 | 0.15 | 0.30 | 2.10 | | | 0.19 | 1.10 | 1.45 | 0.26 | 0.16 | 0.27 | 0.54 | 0.21 | | | | | | | | | |
| 22 | 0.17 | 0.32 | 2.55 | | | | 1.20 | | 0.28 | 0.21 | 0.36 | | | | | | | | | | | |
| 24 | 0.20 | 0.41 | 2.85 | | | | 1.30 | 1.75 | 0.32 | 0.22 | 0.42 | 0.54 | | | | | | | | | | |
| 28 | 0.23 | 0.45 | 3.40 | | | 0.23 | 1.50 | 2.05 | 0.34 | 0.23 | 0.48 | 0.54 | 0.37 | | | | | | | | | |
| 32 | 0.31 | 0.68 | 3.95 | | | 0.29 | 1.70 | 2.40 | 0.36 | 0.35 | 0.49 | 0.63 | 0.43 | 0.44 | 0.40 | | | | | | | |
| 40 | 0.35 | 0.96 | 4.95 | | | | 2.30 | 2.90 | 0.38 | 0.42 | 0.55 | 0.68 | | 0.45 | | | | | | | | |
| 44 | 0.36 | | | | | 0.33 | 2.45 | 4.50 | | | 0.65 | | | 0.48 | 0.44 | 0.55 | | | | | | |
| 48 | 0.42 | | 6.20 | | | | 2.70 | | | | | | 0.75 | 0.53 | 0.58 | | | | | | | |
| 52 | | | | | | 0.42 | 3.10 | | | | | | | 0.60 | | | | | | | | |
| 56 | | | | | | | | | | | | | 1.08 | | | | | | | | | |
| 64 | 0.54 | | | 4.90 | 1.20 | | 3.75 | 5.10 | | | | | | 0.61 | 0.61 | 0.72 | | | 0.92 | 1.12 | | |
| 68 | | 3.30 | | 5.10 | 2.45 | 0.55 | 3.90 | 5.50 | | | | | | 0.68 | | | 5.22 | | 0.97 | 2.11 | | |
| 84 | | 4.00 | | 6.20 | 3.50 | 0.66 | 4.80 | | | | | | | 0.78 | 0.70 | | 6.12 | | 1.20 | 4.54 | | |
| 100 | | | | 7.90 | 3.70 | | 5.30 | | | | | | | 0.75 | 0.88 | 1.10 | 9.40 | 3.50 | 1.40 | | | |
| 128 | | | | 9.50 | 4.20 | | | | | | | | | 1.18 | 1.40 | | 11.50 | 3.60 | 1.80 | 8.06 | | |
| 132 | | | | 11.10 | 4.55 | | | | | | | | | 1.26 | 1.60 | | 13.80 | | 1.80 | | | |
| 144 | | | | 11.00 | 5.90 | | | 22.10 | | | | | | 1.32 | 1.70 | | 15.50 | 4.12 | 1.80 | 11.09 | 2.95 | 4.52 |
| 160 | | | | 12.00 | 7.10 | | | 51.60 | | | | | | 1.56 | 1.80 | | 17.40 | 4.26 | 4.40 | 12.80 | | |
| 164 | | | | | | | | | | | | | | | | | | | 4.40 | | | |
| 169 | | | | 12.50 | 7.80 | | | | | | | | | | | | | | | | 2.75 | 5.91 |
| 184 | | | | | 9.50 | | | | | | | | | 1.90 | | | | | 4.40 | 16.56 | | |
| 196 | | | | 11.50 | | | | | | | | | | | 2.30 | | | | 4.40 | | | |
| 208 | | | | 17.85 | 9.60 | | | 51.25 | | | | | | 1.96 | 2.60 | | 21.10 | 4.77 | 4.40 | 20.38 | 3.40 | |
| 225 | | | | 18.70 | | | | 52.75 | | | | | | | | | | | | | 3.55 | 7.89 |
| 232 | | | | | 11.65 | | | | | | | | | 2.95 | | | | 6.23 | 4.40 | | | |
| 240 | | | | | | | | | | | | | | | | | | 7.17 | 4.40 | 24.00 | | |
| 244 | | | | 21.30 | 11.30 | | | | | | | | | 3.25 | | | 27.70 | | 4.40 | 25.38 | | |
| 256 | | | | | 11.90 | | | 39.50 | | | | | | 3.85 | 3.20 | | 31.20 | 8.19 | 9.20 | 27.14 | 3.57 | 9.50 |
| 296 | | | | 36.20 | 13.10 | | | | | | | | | | | | | | 9.20 | | | |
| 299 | | | | | 25.90 | | | | | | | | | | | | | | | | | |
| 304 | | | | | | | | | | | | | | 4.60 | | | | 9.48 | 9.20 | 33.44 | 4.91 | 10.64 |
| 308 | | | | | | | | | | | | | | | | | | | 9.20 | | | |
| 313 | | | | | | | | | | | | | | | | | | | | | 5.20 | |


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## Table 2 (Continued)
## Total (Die-Free) Assembled Package Cost, 1997 (Dollars per Package) Volume Production, More than 100,000 Units

| No. of Pins | Plastic DIP | CER DIP | Side-Braze | Ceramic PGA | Plastic PGA | Plastic Chip Carrier PLCC | Ceramic Chip Carrier (Leadless) LLCC | Ceramic Chip Carrier (Leaded) LCC | SOJ | SOIC | TSOP Type I | TSOP Type II | SSOP | Plastic QUAD | TQFP 1.4mm Body | TQFP 1mm Body | Ceramic QUAD | Metal QUAD | TAB Tape/ Sits | Ceramic BGA | Plastic BGA Single Layer | Plastic BGA Multi-layer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 324 | | | | 50.10 | | | | | | | | | | | | | | | | 36.12 | 5.40 | 11.95 |
| 340 | | | | | | | | 132.00 | | | | | | | | | | | | | 5.50 | |
| 352 | | | | | | | | | | | | | | | | | | | | | 5.60 | 12.50 |
| 361 | | | | | | | | | | | | | | | | | | | 16.40 | 40.61 | | |
| 368 | | | | 49.50 | | | | | | | | | | | | | | | | | | |
| 376 | | | | 51.30 | | | | | | | | | | | | | | | 16.40 | | | |
| 387 | | | | 52.10 | 44.40 | | | | | | | | | | | | | | | 50.51 | 5.58 | |
| 442 | | | | | | | | | | | | | | | | | | | | | | |
| 448 | | | | 59.00 | | | | | | | | | | | | | | | | | | |
| 475 | | | | | | | | | | | | | | | | | | | 18.80 | 56.82 | | |
| 480 | | | | | | | | | | | | | | | | | | | | | 12.80 | 16.80 |
| 504 | | | | 79.50 | 29.50 | | | | | | | | | | | | | 44.45 | 22.50 | 59.88 | 14.80 | 19.60 |
| 625 | | | | | | | | | | | | | | | | | | | 28.80 | 76.25 | | |
| 672 | | | | | | | | | | | | | | | | | | | 29.50 | | | |
| Package Materials | | | | | | | | | | | | | | | | | | | | | | |
| Lead Frame | C194 | A42 | A42 | A42 | Cu | C151 | A42/ LDCC | | C194 | C194 | A42/ Cu | A42/ Cu | Cu | Cu | Cu | Cu | A42 | Cu | Cu with Sn plate | Cu vias | PCB | PCB |
| Lead Form | TH | TH | TH | TH | J | J | Gull/ None | | Gull/J | Gull/J | Gull | Gull | Gull | Gull | Gull | Gull | Gull | Gull | Gull | Solder | Solder | Solder |
| Wire | Au | Al | Al | Au | Au | Au | Al | | Au | Au | Au | Au | Au | Au | Al | Al | Al | Au | NA | Au | Au | Au |
| Lid | Epoxy | Cera-mic | Au/ Kovar | Au/ Kovar | Au/ Epoxy | Epoxy | Au/ Kovar | | Epoxy | Epoxy | Epoxy | Epoxy | Epoxy | Epoxy | Epoxy | Epoxy | Au/ Kovar | Al cap | NA | Au/ Pb-Sn | Epoxy | Epoxy |
| Preform | NA | Glass | Au/ Sn | Au/Sn | NA | NA | Au/Sn | | NA | NA | NA | NA | NA | NA | NA | NA | Au/Sn | NA | NA | NA | NA | NA |

NA = Not applicable
Source: Dataquest (March 1997)



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## Table 3
## Semiconductor Cost Model Algorithms or Variables

| Section | Algorithm or Variable |
|---|---|
| Wafer Sort | |
| Wafer Size (Diameter in inches) | =A |
| Capacity Utilization (%) | =B |
| Geometry (Microns) | =C |
| Processed Wafer Cost ($) | =D |
| Die area (Square Mils) | =E |
| Active Area Factor | =F |
| Number of Masks (Type of Process) | =G |
| Defect Density per Square Inch/per Mask | =H |
| Gross Die per Wafer | =I =(0.75*pi*(A/2)^2*10^6)/E |
| Processed Wafer Cost per Gross Die ($) | =J =(D/I) |
| Test Cost per Hour ($) | =K |
| Wafers Tested per Hour | =L =1/((#*I)/3600) |
| Wafer Sort Cost per Gross Die ($) | =M =(K/L)/I |
| Cost per Gross Die at Wafer Sort ($) | =N =(J+M) |
| Wafer Sort Yield (%) | =O =2.718^((-H*G)*E) |
| Cost per Sorted Die ($) | =P =N*100/O |
| Assembly | |
| Material Cost/Sorted Die + Package Cost ($) | =Q |
| Number of Package Pins | =R |
| Assembly Yield (%) | =S |
| Cost per Assembled Die ($) | =T =(P+Q)/S*100 |
| Final Test | |
| Test Time per Die (Sec.) | =U |
| Cost per Hour of Testing | =V |
| Test Cost per Die ($) | =W =U*V/3600 |
| Final Test Yield (%) | =X |
| Cost per Final Tested Unit ($) | =Y =(T+W)/X*100 |
| Mark, Pack, and Ship | |
| Cost at 99 Percent Yield (%) | =Z =(Y*0.01) |
| Total Fabrication Cost per Unit ($) | =AA =Y+Z |
| Foreign Market Value (FMV) Formula Adders | |
| R&D Expense (15 Percent) | =AB =0.15*AA |
| S,G&A Expense (10 Percent) | =AC =(AA+AB)*0.10 |
| Profit (8 Percent) | =AD =(AA+AB+AC)*0.08 |
| Constructed FMV | =AE =(AA+AB+AC+AD) |

# = Test seconds per die
Source: Dataquest (March 1997)


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## Understanding Yields

Only a portion of die on a given wafer will meet the electrical test specifications to which the die was designed. The percentage of good die per wafer is known as yield. As a silicon wafer is processed, each step decreases the final yield of good parts that meet specification and are shippable.

### Calculating Yield

There are several methods to calculate electrical test yields of semiconductor wafers. Dataquest uses a variant of the exponential equation called Murphy's formula to approximate yield:

$$\text{Yield} = e^{(-DA)};$$

where $e$ is the constant 2.72, D is the defect density in defects per square inch, and A is the area of the chip in square inches. This mathematical formula is useful for analyzing the key factors that affect semiconductor yields: the number of defects on the wafer and the number of chips on the wafer. The number of die per wafer is determined by the area of each chip. Defects on a wafer are caused by particles in the air falling on the wafer or process irregularities made during semiconductor manufacture. An increase in mask levels requires more time in the fab area, thus increasing the chance of defects occurring either from the air or processing error.

### Yield Trade-Offs

By taking a typical 16Mb DRAM with two different die sizes (approximately 112,000 square mils and 142,000 square mils) in two different manufacturing areas, one with five defects per square inch and the other with one defect per square inch, one can easily see in Table 4 the advantages of using a clean room with fewer particulates. This points out why it is more economical to ship larger die if the fabrication area is cleaner, because more die per wafer are shippable.

### Yield and Related Costs

Semiconductor chips are electrically tested several times to separate die that meet specifications from those that do not. Wafer sort, assembly, and final test are the three areas in semiconductor manufacturing where related testing occurs.

**Table 4**
**16Mb DRAM Yield Loss to Defects (Percentage Good Die/Number of Good Chips per 8-Inch Wafer)**

| Chip Size (Mils$^2$) | Yield with 5 Defects/In.$^2$ (%) | Good Die | Yield with 1 Defect/In.$^2$ (%) | Fab Area Good Die |
|---|---|---|---|---|
| 127,000 | 52.9 | 163 | 87.8 | 272 |
| 110,000 | 56.9 | 203 | 89.4 | 320 |

Note: A cleaner fabrication area allows for more shippable product even if the die size is larger than in a "dirtier" area.
Source: Dataquest (March 1997)


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### Electrical Wafer Sort

The first test, electrical wafer sort, is done on processed wafers by a computer-based tester at a test station specifically designed for that IC. The tester automatically tests each die on the wafer by contacting each pad on each chip and marking with an ink dot those dice that do not pass the test. Test costs consist of equipment operating costs, direct operator costs, and the amount of time required to test each die. Equipment operating costs are dominated by the depreciation of the test equipment. Semiconductor test equipment is generally depreciated over three to five years and can range in price from $350,000 to over $1 million, depending on test/product requirements. Dataquest uses estimates of test costs per hour ranging from $25 to $125 per hour. The most complex integrated circuit test costs range from $65 to $125 per hour.

Dataquest assumes that a test operator supports each piece of test equipment and estimates the labor cost per hour to be $20. The total test cost then, including labor, ranges from $45 to $145 per hour.The time to test a wafer is determined by the circuit complexity, the number of chips per wafer, and the yield. Good dice take about five times as long to test as bad dice. Test programs are formulated and used to minimize test time by testing functions of the device statistically proven to most likely fail first. Test times for good dice are kept to a minimum by performing only those tests that assure 85 to 90 percent test yield when packaged. Wafer sort times for full-production VLSI chips take no longer than nine seconds for each chip.

### Assembly and Packaging

Semiconductor chips in the form of processed and tested wafers are electrically functional and could be used as they are. Functional die in wafer form, although theoretically functional, are too fragile unpackaged for practical use. In order to have a protective container for a device, various packages are available to provide different devices with different degrees of ruggedness. Ranging from ceramic packages with gold contacts to blobs of epoxy covering chips on PC boards, the encapsulation method for electrically good die is determined by the end use of the system that the part goes into. Packaging technology has continuously improved, but the basic assembly steps have not changed significantly during the past 25 years. The three main areas of assembly are the following:

- Die separation
- Die attach and lead/ball bond
- Encapsulation

### Die Separation

This step refers to the method of separating the individual die on a wafer. One technique is very similar to the method of cutting glass. A plastic film is attached to the back of the wafer after which a diamond stylus automatically scratches the wafer between each die, both horizontal and vertical. Once the total wafer is scribed on these "scribe lines," the wafer is placed on a machine that fractures it along these lines. Some manufacturers use laser scribe machines to etch a line along the scribe line. Thick wafers require diamond sawing (and commensurate wider scribe lines) in order to prevent die loss because of uncontrolled fractures.


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After the wafer is completely broken into individual die, each chip is visually inspected under a microscope to ensure removal of any that were physically damaged during the "slice and dice" procedure. Chips are also eliminated at this point if they do not conform to dimensional design rules. Good dice are separated and moved to the next step of manufacture, die attach, and lead bond.

### Die Attach and Lead Bond

Assuming the use of a standard plastic Small Outline (SOJ)-lead package, good dice are attached to metal lead frames with a small amount of molten gold or low-cost epoxy. It is imperative that a die be securely attached to the lead frame in order for it to withstand later testing requirements made of the finished device. The next step is bonding the pads of the chip to individual leads of the package with either gold (becoming more rare) or aluminum wire that is less than 1 thousandth of an inch in diameter. Thermocompression bonding involves heating the lead frame and attached die to about 340° C. The bonding wire is automatically pressed against the bonding pad on the heated die, fusing the wire to the die. The wire is then drawn to its respective bonding pad on the lead frame, which is also then fused. Automated bonding machines are capable of bonding more than 1,500 packages per hour. Once the die is attached with bonded leads, another visual inspection is performed to eliminate devices that were damaged or bonded incorrectly.

### Encapsulation

Assembled lead frames for plastic SOJs are placed in molds into which molten epoxy plastic is injected, thus forming the body of the semiconductor device. Between 20 and 50 packages are encapsulated at once, resulting in low production costs. The molded packages are then cured in a 200° C oven for 40 hours. Excess metal is then removed from the devices and the leads are formed to the finished product configuration. The parts are tested for open or shorted circuits that might have resulted during encapsulation. The surviving packaged parts are now ready for final test.

### Final Test

After the dice have been packaged, they undergo one final test. Packaged parts are transferred from assembly to the final test area in static-free plastic tubes or trays that are inserted into automated package handlers. The handler releases one packaged part at a time into a test socket or head that is wired to an automated test system. Most manufacturers use multiple-head test systems to increase the throughput of a test system.

Each unit is stringently tested at this step, across "worst case" conditions. The circuits are tested for maximum and minimum speeds, for power dissipation, and for many combinations of inputs and outputs in order to meet all guaranteed device specifications. The automated test system performs thousands of separate tests in seconds. A typical final test by the manufacturer runs from less than one second for a TTL logic device to up to 10 seconds for some 16Mb DRAMs.

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The final test must be stringent enough to ensure that the device performs over its guaranteed temperature range. The environmental conditions are usually ensured in one of the following two ways:

- All devices are tested at the high temperature end of the specifications.
- The devices are tested at room temperature over sufficiently wide tolerances (guard bands) so that operation at the temperature extremes is ensured.

The first approach is obviously the safer (more conservative) method, but it is also much more expensive. As a result, most semiconductor suppliers will correlate the room temperature characteristics with the characteristics at temperature extremes, add a safety guard band to the room temperature test parameters, and then test at room temperature. Samples are regularly taken from the production lots and tested across the full range of environmental conditions to ensure that the correlation parameters are accurate.

The functions of wafer sort and the final test correlate very closely. Often both tests are performed in the same room and/or on the same test machine; the chief difference is the test program. One of the main functions of the wafer sort program is to minimize the amount of additional labor and materials that would be assigned in producing bad ICs.

Wafer sort cannot eliminate all potentially defective dice, however, because:

- Most sophisticated circuits cannot completely be tested in wafer form because of parasitic effects resulting from probes and wiring, incident room light, and other factors involved with physically sorting the dice.
- Some of the dice may be damaged during the assembly process.
- The dice cannot be tested across the temperature range in wafer form because the wafer and probes cannot be easily maintained at temperatures below ambient.

The objective of wafer sort is to ensure that enough of the potentially rejectable chips are discarded so that final test yields will be high enough to support a desired level of profitability. Excessively high final test yields are not necessarily acceptable. This may mean that potentially good devices are being thrown away at wafer sort. As a result, many manufacturers will adjust the tightness of their internal wafer sort test to allow the final test yields to fall in the range of 80 to 90 percent good units.

## Cost Model Examples

Tables 5 and 6 illustrate how cost models can highlight cost differentials of different DRAM densities. These models use best-case variables from information gathered in press and trade articles and forecasts yield/cost improvements based on historical trends from previous products.

The cost models illustrate how world-class manufacturers can experience manufacturing economies of scale as units ramp up in production volume. Comparing these models with actual market prices for the same time period is useful in learning where a given supplier stands concerning technology and production efficiency.

## Table 5
## 16Mb DRAM Cost Model

| | 1996 | 1997 | 1998 | 2000 |
|---|---|---|---|---|
| Wafer Sort | | | | |
| Wafer Size (Diameter in inches) | 8 | 8 | 8 | 8 |
| Capacity Utilization (%) | 100.00 | 100.00 | 100.00 | 100.00 |
| Geometry (Microns) | 0.60 | 0.50 | 0.40 | 0.35 |
| Processed Wafer Cost ($) | 1550 | 1550 | 1650 | 1650 |
| Die Area (Square Mils) | 112000 | 89600 | 80640 | 72576 |
| Active Area Factor | 1.00 | 1.00 | 1.00 | 1.00 |
| Number of Masks | 16 | 16 | 18 | 18 |
| Defect Density per Square Inch | 0.125 | 0.063 | 0.056 | 0.056 |
| Gross Die per Wafer | 359 | 449 | 499 | 554 |
| Processed Wafer Cost per Gross Die ($) | 4.32 | 3.45 | 3.31 | 2.98 |
| Test Cost per Hour ($) | 110.00 | 110.00 | 110.00 | 110.00 |
| Wafers Tested per Hour | 0.11 | 0.10 | 0.10 | 0.11 |
| Wafer Sort Cost per Gross Die ($) | 2.75 | 2.44 | 2.14 | 1.83 |
| Cost per Gross Die at Wafer Sort ($) | 7.07 | 5.90 | 5.45 | 4.81 |
| Wafer Sort Yield (%) | 80 | 91 | 92 | 93 |
| Cost per Sorted Die ($) | 8.84 | 6.45 | 5.91 | 5.17 |
| Assembly | | | | |
| Material Cost/Sorted Die—SOJ pkg.($) | 0.34 | 0.34 | 0.34 | 0.34 |
| Number of Pins | 28 | 28 | 28 | 28 |
| Assembly Yield (%) | 99 | 99 | 99 | 99 |
| Cost per Assembled Die ($) | 9.27 | 6.86 | 6.31 | 5.57 |
| Final Test | | | | |
| Test Time per Die (sec.) | 15.00 | 15.00 | 15.00 | 10.00 |
| Cost per Hour of Testing ($) | 90.00 | 90.00 | 90.00 | 90.00 |
| Test Cost per Die ($) | 0.38 | 0.38 | 0.38 | 0.25 |
| Final Test Yield (%) | 95 | 95 | 98 | 98 |
| Cost per Final Tested Unit ($) | 10.16 | 7.62 | 6.82 | 5.94 |
| "Mark, Pack, and Ship" | | | | |
| Cost at 99% Yield (%) | 0.10 | 0.08 | 0.07 | 0.06 |
| Total Fabricated Cost per Net Unit ($) | 10.26 | 7.69 | 6.89 | 6.00 |
| FMV Formula Adders | | | | |
| R&D Expense (15%) | 1.54 | 1.15 | 1.03 | 0.90 |
| SG&A Expense (10%) | 1.18 | 0.88 | 0.79 | 0.69 |
| Profit (8%) | 1.04 | 0.78 | 0.70 | 0.61 |
| Constructed Foreign Market Value (FMV) | 14.02 | 10.51 | 9.41 | 8.19 |

Source: Dataquest (March 1997)


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## Table 6
## 64Mb Cost Model

| | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|
| Wafer Sort | | | | |
| Wafer Size (Diameter in Inches) | 8 | 8 | 8 | 8 |
| Capacity Utilization (%) | 100.00 | 100.00 | 100.00 | 100.00 |
| Geometry (Microns) | 0.40 | 0.35 | 0.35 | 0.35 |
| Processed Wafer Cost ($) | 1550 | 1650 | 1650 | 1650 |
| Die Area (Square Mils) | 303700 | 242960 | 194368 | 155494 |
| Active Area Factor | 1.00 | 1.00 | 1.00 | 1.00 |
| Number of Masks | 16 | 18 | 18 | 18 |
| Defect Density per Square Inch | 0.125 | 0.111 | 0.111 | 0.111 |
| Gross Die per Wafer | 124 | 155 | 194 | 242 |
| Processed Wafer Cost per Gross Die ($) | 12.49 | 10.63 | 8.51 | 6.81 |
| Test Cost per Hour ($) | 160.00 | 140.00 | 120.00 | 120.00 |
| Wafers Tested per Hour | 0.16 | 0.13 | 0.10 | 0.08 |
| Wafer Sort Cost per Gross Die ($) | 8.00 | 7.00 | 6.00 | 6.00 |
| Cost per Gross Die at Wafer Sort ($) | 20.49 | 17.63 | 14.51 | 12.81 |
| Wafer Sort Yield (%) | 54 | 62 | 68 | 73 |
| Cost per Sorted Die ($) | 37.61 | 28.67 | 21.40 | 17.48 |
| Assembly | | | | |
| Material Cost/Sorted Die—PQFP pkg.($) | 0.48 | 0.48 | 0.48 | 0.48 |
| Number of Pins | 44 | 44 | 44 | 44 |
| Assembly Yield (%) | 99 | 90 | 90 | 90 |
| Cost per Assembled Die ($) | 38.47 | 32.39 | 24.31 | 19.95 |
| Final Test | | | | |
| Test Time per Die (sec.) | 90.00 | 80.00 | 60.00 | 60.00 |
| Cost per Hour of Testing ($) | 160.00 | 140.00 | 120.00 | 120.00 |
| Test Cost per Die ($) | 4.00 | 3.11 | 2.00 | 2.00 |
| Final Test Yield (%) | 90 | 90 | 90 | 90 |
| Cost per Final Tested Unit ($) | 47.19 | 39.44 | 29.23 | 24.39 |
| "Mark, Pack, and Ship" | | | | |
| Cost at 99% Yield (%) | 0.47 | 0.39 | 0.29 | 0.24 |
| Total Fabricated Cost per Net Unit ($) | 47.66 | 39.83 | 29.53 | 24.63 |
| FMV Formula Adders | | | | |
| R&D Expense (15%) | 7.15 | 5.98 | 4.43 | 3.70 |
| SG&A Expense (10%) | 5.48 | 4.58 | 3.40 | 2.83 |
| Profit (8%) | 4.82 | 4.03 | 2.99 | 2.49 |
| Constructed Foreign Market Value (FMV) | 65.12 | 54.42 | 40.34 | 33.66 |

Source: Dataquest (March 1997)

## Dataquest Perspective

The individual unit cost of a semiconductor forms the most tangible variable in the total cost of a semiconductor device. Understanding cost models and the variables that go into a model allows for more efficient and educated allocations of resources both in planning and in the execution of those plans. By applying different assumptions to different variables in the model, one may uncover areas of cost not initially considered important. Many different "what if" scenarios are often required to best utilize cost modeling in long-range system analysis As different suppliers improve yields and lower costs, individual company price points can often hint at efficiency gains or losses for differing technologies (ASICs) or the next-generation products.

Models are inherently flexible. If historical data differs from calculated model results, updates quickly correct inconsistencies. Checking and updating a model against known data ensures that the model is correct and current. Revisions to the existing algorithms to better match reality should only be made when basic changes occur, not for perturbations that deviate from the norm. As improvements are made to this model in the upcoming months, clients will be notified.

Those in procurement use cost modeling and experience curve analysis for both short- and long-term contract negotiations. The current transition in market dynamics from a seller's to a more balanced market again allows use of cost base pricing. Good communications with suppliers regarding yield improvements or other cost savings in combination with cost model use potentially can allow for price reductions for astute procurement groups. Periodic "reality checks" of the model assures planners that they used the best information available at the time. Using cost modeling in this way provides a tangible benchmark for procurement to use with their suppliers in terms of cost and price reduction for critical semiconductor parts.

**For More Information...**

Mark Giudici, Director and Principal Analyst ..... (408) 468-8258
Internet address ..... mark.giudici@dataquest.com
Via fax ..... (408) 954-1780

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Perspective



Semiconductor Supply and Pricing Worldwide

# Market Analysis

# First Quarter 1997 Procurement Pulse: Order Rates Rebound while Lead Times and Inventories Stabilize

**Abstract:** *The Procurement Pulse is a quarterly update (with interval updates, if events warrant) of critical issues and market trends based on surveys of semiconductor procurement managers in the North American region. Besides order rate, lead time, and inventory information, this survey also notes price status by semiconductor product family and package type, as well as key problems facing semiconductor users.*
*By Mark Giudici*

## Semiconductor Order Rate Expected to Bounce Back after Two Months of Cautious Forecasts

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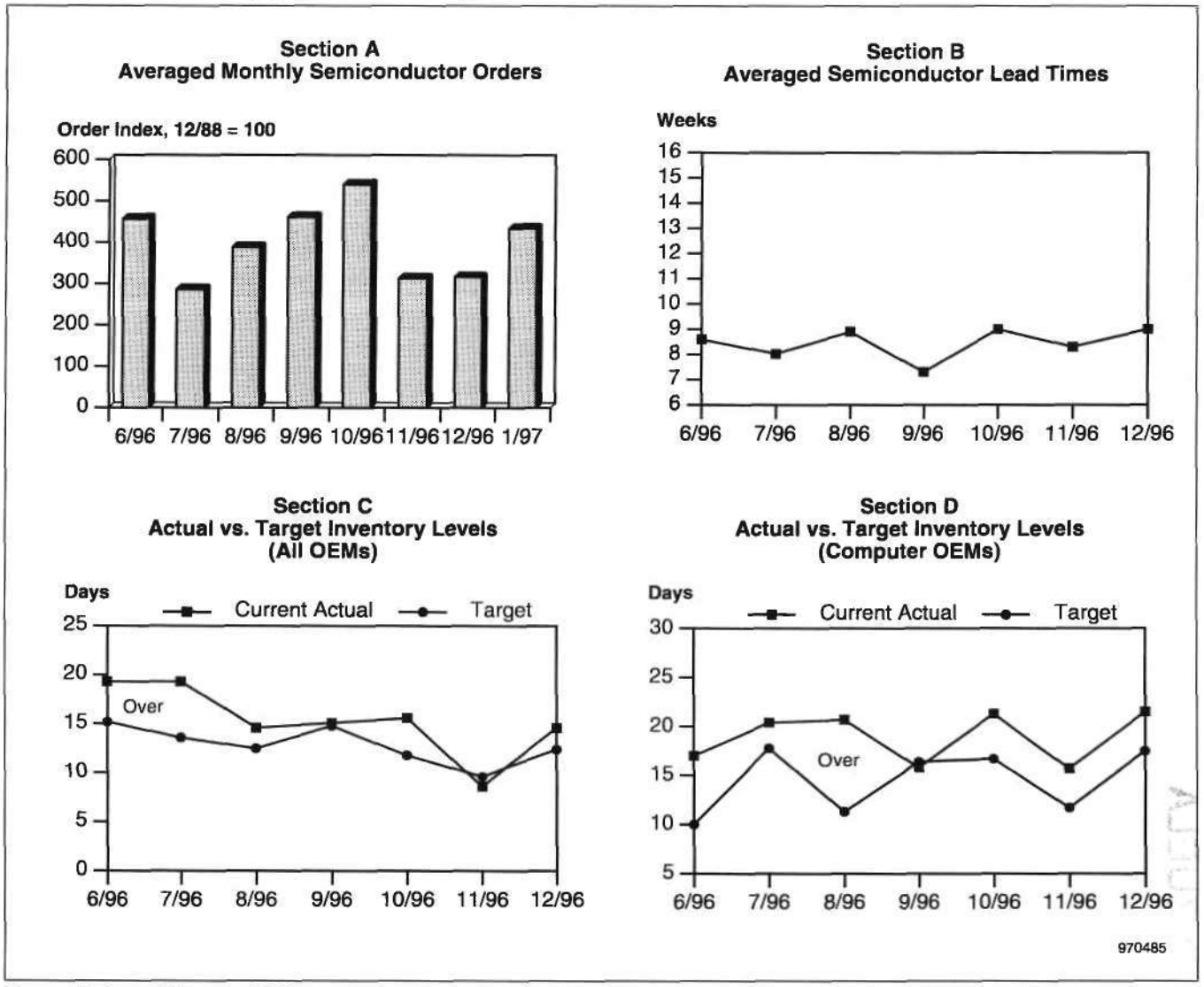
As seen in Section A of Figure 1, the outlook for semiconductor order activity is expected to pick up after the slowdown of forecast expectations over the past two months. Although 37 percent higher than last December's forecast index, the outlook for January has historically increased over the inventory rundown-influenced year-end low order outlook. This increase in order activity is expected despite lower overall prices of semiconductors. The continued buoyancy of the electronics market continues to benefit from these price declines where steady unit volumes are being ordered at lower dollar outlays. The overall sample continues to see price cuts for larger-volume contracts in all areas tracked in this survey—DRAM, MPUs, logic, flash memory, and SRAM (especially in DRAM and MPUs). DRAM pricing for the overall sample fell, on average, 1.6 percent in December after a 1.1 percent average drop noted in November. The computer subset of the respondents saw a more aggressive DRAM price cut of 4 percent in December after a 4 percent average drop noted in November. Although

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overall prices continue to decline, pricing for different semiconductor packaging (except for two respondents using TSOP) has reached parity.

**Figure 1**

**Semiconductor Supply and Pricing**




Source: Dataquest (January 1996)

## Lead Times for Semiconductors Hover around Nine Weeks

Section B of Figure 1 shows that the average lead time for respondents in December inched up to 9.0 weeks, compared with an 8.6-week average noted in November. The relative stability of lead times around nine weeks over the past three quarters reflects the excellent availability and pricing of parts that has kept customer-required delivery schedules the norm. Now, well over a year into a buyer's market, many procurement managers continue to balance price cuts with supply base relations. Good service levels combined with ever-lower prices are cementing many long-term supplier relations. Out of the entire sample, only two respondents noted problems with products,

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those being ASICs and some older standard logic parts. For the vast majority of the respondents and the overall market, however, there are no problems regarding product availability or pricing. Like last quarter, over half of this month's respondents noted price fluctuations or inventory adjustments and end-of-life ordering as the key issues now taking precedence. As noted over the past year, we expect the volatility of the spot market to continue to vacillate around declining contract prices, causing uncertainty for some buyers. The overall trend, however, is for continued good availability, consistently declining prices, and low lead times (eight to 10 weeks) for the next six to nine months.

## Semiconductor Inventories Back to Historical Levels

Sections C and D of Figure 1 highlight how inventories have stabilized over the past three quarters and are in synchrony with system unit demand. Even with semiconductor order rates forecast to rise as noted above, we do not expect semiconductor inventories to rise, as availability is good and prices are expected to continue their decline. The overall targeted and actual semiconductor inventory levels for December were 12.4 days and 14.6 days, respectively, compared with November's 9.6-day and 8.6-day inventory levels. The computer subset now appears less aggressive than the average, possibly realigning increases in inventory with anticipated higher first quarter 1997 sales. The current target and actual inventory levels of 17.5 days and 21.5 days compare with November levels of 11.7 and 15.3 days on hand for the computer subset. We continue to expect to see stabilized inventory levels in line with system sales levels.

## Dataquest Perspective

Availability of semiconductors remains very good to excellent, and we expect it to remain this way for the rest of 1997. Prices continue to decline, despite the efforts of some memory suppliers to curtail output, and lead times have stabilized to meet customer demand. Even with relentlessly low prices on the DRAM spot market, the volume of business through this channel is surprisingly low. This reflects the focus of users on total cost, not price alone, when determining a component buy. Although Dataquest forecasts steady 1997 growth rates for PCs and other electronics relative to 1996, the overall trend follows an upward growth slope. User semiconductor inventory levels are now in line with user demand, and we expect to see continual balance in these indexes in the near future. Allocations are not a problem, as obsolescence now has users' attention. Dataquest expects to see excellent semiconductor availability through the end of 1997. DRAM and MPU price elasticity to date have not propped up prices. Although the spot market continues to lead contract pricing lower, cost barriers will continue to moderate steep price cuts in this area. The good news for users is that declining prices will continue to be with us for the remainder of this year.


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**For More Information...**

Mark Giudici, Director/Principal Analyst ..... (408) 468-8258
Internet address ..... mgiudici@dataquest.com
Via fax ..... (408) 954-1780

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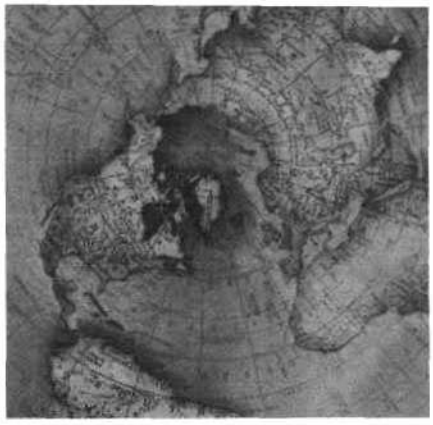
251 River Oaks Parkway, San Jose, CA 95134-1913
(408) 468-8000 Fax (408) 954-1780

January 5, 1998

# Errata

The tables in Dataquest's *North American Semiconductor Price Outlook, First Quarter 1998* (SSPS-WW-MS-9705, December 29, 1997) contained an incorrect source month. 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 Director and Principal Analyst Mark Giudici at (408) 468-8258 or at mark.guidici@dataquest.com.



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MARIA VALENZUELA

# North American Semiconductor Price Outlook—First Quarter 1998

Market Statistics

**Program:** Semiconductor Supply and Pricing Worldwide
**Product Code:** SSPS-WW-MS-9705
**Publication Date:** December 29, 1997
**Filing:** Market Statistics

# North American Semiconductor Price Outlook—First Quarter 1998



Market Statistics

**Program:** Semiconductor Supply and Pricing Worldwide
**Product Code:** SSPS-WW-MS-9705
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# Table of Contents

Page

1. North American Semiconductor Price Outlook—First Quarter 1998... 1
   Methodology and Sources ..... 1
   Price Variations..... 1
2. Market Statistics Tables..... 3

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# List of Tables


| Table | | Page |
|---|---|---|
| 2-1 | Estimated Standard Logic Price Trends—North American Bookings | 3 |
| 2-2 | Estimated Long-Range Standard Logic Price Trends—North American Bookings | 5 |
| 2-3 | Estimated Microprocessor Price Trends—North American Bookings | 6 |
| 2-4 | Estimated Long-Range Microprocessor Price Trends—North American Bookings | 8 |
| 2-5 | Estimated DRAM Price Trends—North American Bookings | 9 |
| 2-6 | Estimated Long-Range DRAM Price Trends—North American Bookings | 11 |
| 2-7 | Estimated Static RAM Price Trends—North American Bookings | 12 |
| 2-8 | Estimated Long-Range Static RAM Price Trends—North American Bookings | 13 |
| 2-9 | Estimated ROM Price Trends—North American Bookings | 14 |
| 2-10 | Estimated Long-Range ROM Price Trends—North American Bookings | 15 |
| 2-11 | Estimated EPROM Price Trends—North American Bookings | 16 |
| 2-12 | Estimated Long-Range EPROM Price Trends—North American Bookings | 17 |
| 2-13 | Estimated Flash Memory Price Trends—North American Bookings | 18 |
| 2-14 | Estimated Long-Range Flash Memory Price Trends—North American Bookings | 19 |
| 2-15 | Estimated Gate Array Pricing—North American Production Bookings | 20 |
| 2-16 | Estimated CBIC Pricing—North American Production Bookings | 21 |


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# Chapter 1
# North American Semiconductor Price Outlook—First Quarter 1998

## Methodology and Sources

This document provides information on and forecasts for the North American bookings prices of more than 200 semiconductor devices. Dataquest collects price information on a quarterly basis from North American suppliers and major buyers of these products. North American bookings price information is analyzed by Semiconductor Supply and Pricing Worldwide (SSPS) analysts for consistency and reconciliation. The information finally is rationalized with worldwide billings price data in association with product analysts, resulting in the current forecast. This document includes associated long-range forecasts.

For SSPS clients that use the SSPS online service through CompuServe, the prices presented here correlate with the quarterly and long-range price tables dated December 1997 in the SSPS online service. Clients who want to access the information on the World Wide Web can pay extra for a Dataquest Interactive subscription, which allows users to access all their deliverables at their desktops. For additional product coverage and more detailed product specifications, please refer to those sources.

### Price Variations

Actual negotiated market prices may vary from these prices 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 value of a company's product. These prices are intended for use as price guidelines.


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# Chapter 2
# Market Statistics Tables

Tables 2-1 through 2-16 show statistics on North American semiconductor prices.

**Table 2-1**
**Estimated Standard Logic Price Trends—North American Bookings**
**(Volume: 100,000 per Year; Package: PLCC; Dollars)**

| | Q4/97 | Q1/98 | Q2/98 | Q3/98 | Q4/98 | 1998 Year | Q1/99 | Q2/99 | Q3/99 | Q4/99 | 1999 Year | Lead Times (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **74LS TTL** | | | | | | | | | | | | |
| 74LS00 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 3-8 |
| 74LS74 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 3-8 |
| 74LS138 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 3-8 |
| 74LS244 | 0.24 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 3-8 |
| **74AC TTL** | | | | | | | | | | | | |
| 74AC00 | 0.17 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 3-8 |
| 74AC74 | 0.20 | 0.18 | 0.18 | 0.17 | 0.17 | 0.17 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 3-8 |
| 74AC138 | 0.29 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 3-8 |
| 74AC244 | 0.39 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 3-8 |
| **74F TTL** | | | | | | | | | | | | |
| 74F00 | 0.14 | 0.12 | 0.12 | 0.11 | 0.11 | 0.12 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 3-8 |
| 74F74 | 0.15 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 3-8 |
| 74F138 | 0.18 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 3-8 |
| 74F244 | 0.22 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.22 | 0.22 | 0.21 | 3-8 |
| **74HC CMOS** | | | | | | | | | | | | |
| 74HC00 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 3-8 |
| 74HC74 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 3-8 |
| 74HC138 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 3-8 |
| 74HC244 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.22 | 0.22 | 0.21 | 3-8 |
| **74ALS TTL** | | | | | | | | | | | | |
| 74ALS00 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 3-8 |
| 74ALS74 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.16 | 0.15 | 3-8 |
| 74ALS138 | 0.21 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 3-8 |
| 74ALS244 | 0.30 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.26 | 0.28 | 0.26 | 0.26 | 0.26 | 3-8 |
| **74AS TTL** | | | | | | | | | | | | |
| 74AS00 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 3-8 |
| 74AS74 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 3-8 |
| 74AS138 | 0.40 | 0.40 | 0.39 | 0.39 | 0.39 | 0.39 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 3-8 |
| 74AS244 | 0.63 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.60 | 0.60 | 0.59 | 0.59 | 0.60 | 3-8 |


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**Table 2-1 (Continued)**
**Estimated Standard Logic Price Trends—North American Bookings**
**(Volume: 100,000 per Year; Package: PLCC; Dollars)**

| | Q4/97 | Q1/98 | Q2/98 | Q3/98 | Q4/98 | 1998 Year | Q1/99 | Q2/99 | Q3/99 | Q4/99 | 1999 Year | Lead Times (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **74BC*** | | | | | | | | | | | | |
| 74BC00 | 0.20 | 0.19 | 0.19 | 0.18 | 0.18 | 0.19 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 3-8 |
| 74BC244 | 0.53 | 0.48 | 0.48 | 0.46 | 0.46 | 0.47 | 0.44 | 0.44 | 0.40 | 0.40 | 0.42 | 3-8 |
| 74BC373 | 0.55 | 0.50 | 0.50 | 0.46 | 0.46 | 0.48 | 0.44 | 0.44 | 0.42 | 0.42 | 0.43 | 3-8 |
| 74ACT244 | 0.41 | 0.38 | 0.38 | 0.36 | 0.36 | 0.37 | 0.35 | 0.35 | 0.33 | 0.33 | 0.34 | 3-8 |
| 74ACT245 | 0.44 | 0.40 | 0.40 | 0.37 | 0.37 | 0.39 | 0.36 | 0.36 | 0.34 | 0.34 | 0.35 | 3-8 |
| 74ABT244 | 0.57 | 0.49 | 0.49 | 0.48 | 0.48 | 0.49 | 0.46 | 0.46 | 0.44 | 0.44 | 0.45 | 3-8 |
| 74ABT245 | 0.61 | 0.52 | 0.52 | 0.51 | 0.51 | 0.52 | 0.49 | 0.49 | 0.46 | 0.46 | 0.48 | 3-8 |

*Pricing for 74BC excludes 74ABT and 74BCT.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1997)


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## Table 2-2
## Estimated Long-Range Standard Logic Price Trends—North American Bookings (Volume: 100,000 per Year; Package: PLCC; Dollars)

| | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|
| **74LS TTL** | | | | | |
| 74LS00 | 0.13 | 0.13 | 0.13 | 0.14 | 0.15 |
| 74LS74 | 0.16 | 0.16 | 0.16 | 0.16 | 0.17 |
| 74LS138 | 0.17 | 0.17 | 0.17 | 0.17 | 0.18 |
| 74LS244 | 0.22 | 0.21 | 0.20 | 0.20 | 0.20 |
| **74AC TTL** | | | | | |
| 74AC00 | 0.15 | 0.14 | 0.13 | 0.13 | 0.13 |
| 74AC74 | 0.17 | 0.16 | 0.15 | 0.15 | 0.15 |
| 74AC138 | 0.28 | 0.26 | 0.23 | 0.22 | 0.22 |
| 74AC244 | 0.36 | 0.33 | 0.31 | 0.30 | 0.30 |
| **74F TTL** | | | | | |
| 74F00 | 0.12 | 0.11 | 0.10 | 0.10 | 0.10 |
| 74F74 | 0.14 | 0.14 | 0.14 | 0.14 | 0.15 |
| 74F138 | 0.17 | 0.17 | 0.17 | 0.17 | 0.18 |
| 74F244 | 0.21 | 0.21 | 0.22 | 0.22 | 0.22 |
| **74HC CMOS** | | | | | |
| 74HC00 | 0.11 | 0.11 | 0.11 | 0.11 | 0.12 |
| 74HC74 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 |
| 74HC138 | 0.17 | 0.17 | 0.17 | 0.18 | 0.18 |
| 74HC244 | 0.21 | 0.21 | 0.22 | 0.22 | 0.23 |
| **74ALS TTL** | | | | | |
| 74ALS00 | 0.14 | 0.14 | 0.11 | 0.11 | 0.12 |
| 74ALS74 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 |
| 74ALS138 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| 74ALS244 | 0.27 | 0.26 | 0.26 | 0.26 | 0.26 |
| **74AS TTL** | | | | | |
| 74AS00 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| 74AS74 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| 74AS138 | 0.39 | 0.37 | 0.35 | 0.34 | 0.34 |
| 74AS244 | 0.61 | 0.60 | 0.58 | 0.57 | 0.57 |
| **74BC*** | | | | | |
| 74BC00 | 0.19 | 0.17 | 0.16 | 0.16 | 0.16 |
| 74BC244 | 0.47 | 0.42 | 0.40 | 0.39 | 0.39 |
| 74BC373 | 0.48 | 0.43 | 0.31 | 0.40 | 0.40 |
| 74ACT244 | 0.37 | 0.34 | 0.30 | 0.29 | 0.29 |
| 74ACT245 | 0.39 | 0.35 | 0.34 | 0.33 | 0.32 |
| 74ABT244 | 0.49 | 0.45 | 0.40 | 0.37 | 0.37 |
| 74ABT245 | 0.52 | 0.48 | 0.42 | 0.40 | 0.40 |

*Pricing for 74BC excludes 74ABT and 74BCT.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1997)


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**Table 2-3**
**Estimated Microprocessor Price Trends—North American Bookings (Volume: 25,000 per Year; Dollars)**
**(Package: 32/64-Bit Devices—Ceramic PGA; Exceptions Noted)**

| | Q4/97 | Q1/98 | Q2/98 | Q3/98 | Q4/98 | 1998 | Q1/99 | Q2/99 | Q3/99 | Q4/99 | 1999 | Lead Times |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 68EC020-25 PQFP | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 2-7 |
| 68EC030-25 PQFP | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 | 2-7 |
| 68040-25 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 2-7 |
| 68LC040-25 CQFP 184 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 2-7 |
| Pentium-100 3.3V | 70.00 | 70.00 | 70.00 | EOL | EOL | 70.00 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Pentium-100 2.9V | 85.00 | 85.00 | 85.00 | EOL | EOL | 85.00 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Pentium-120 3.3V | 85.00 | 85.00 | 85.00 | EOL | EOL | 85.00 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Pentium-120 2.9V | 85.00 | 85.00 | 85.00 | EOL | EOL | 85.00 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Pentium-133 3.3V | 100.00 | 100.00 | 100.00 | EOL | EOL | 100.00 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Pentium-133 2.9V | 85.00 | 85.00 | 85.00 | EOL | EOL | 85.00 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Pentium-150 3.3V | 100.00 | 85.00 | 85.00 | EOL | EOL | 85.00 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Pentium-150 2.9V | 100.00 | 100.00 | 100.00 | EOL | EOL | 100.00 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Pentium-166 3.3V | 90.00 | 90.00 | 90.00 | EOL | EOL | 90.00 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Pentium-200 3.3V | 100.00 | 100.00 | 100.00 | EOL | EOL | 100.00 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Pentium MMX 166 MHz 2.8V PGA | 105.00 | 95.00 | 85.00 | 82.50 | 80.00 | 85.63 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Pentium MMX 200 MHz 2.8V PGA | 205.00 | 115.00 | 90.00 | 85.00 | 85.00 | 93.75 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Pentium MMX 233 MHz 2.8V PGA | 280.00 | 175.00 | 125.00 | 105.00 | 95.00 | 125.00 | 90.00 | 85.00 | 80.00 | 80.00 | 83.75 | 2-7 |
| Pentium Pro-180 256K Cache | 380.00 | 380.00 | 380.00 | 380.00 | 380.00 | 380.00 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Pentium Pro-200 256K Cache | 450.00 | 450.00 | 450.00 | 450.00 | 450.00 | 450.00 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Pentium Pro-200 512K Cache | 985.00 | 985.00 | 985.00 | 985.00 | 985.00 | 985.00 | 985.00 | 985.00 | 985.00 | 985.00 | 985.00 | 2-7 |
| PentiumPro-2001MCache | 2,600.00 | 2,600.00 | 2,600.00 | 2,600.00 | 2,600.00 | 2,600.00 | 2,600.00 | 2,600.00 | 2,600.00 | 2,600.00 | 2,600.00 | 2-7 |
| Pentium II 233 MHz 512K Cache | 380.00 | 248.00 | 188.00 | 160.00 | 150.00 | 186.50 | 125.00 | 125.00 | 125.00 | 125.00 | 125.00 | 2-7 |
| Pentium II 266 MHz 512K Cache | 500.00 | 350.00 | 300.00 | 250.00 | 225.00 | 281.25 | 210.00 | 210.00 | 210.00 | 210.00 | 210.00 | 2-7 |
| Pentium II 300 MHz 512K Cache | 750.00 | 505.00 | 400.00 | 350.00 | 310.00 | 391.25 | 240.00 | 190.00 | 160.00 | 140.00 | 182.50 | 2-7 |



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**Table 2-3 (Continued)**
**Estimated Microprocessor Price Trends—North American Bookings (Volume: 25,000 per Year; Dollars)**
**(Package: 32/64-Bit Devices—Ceramic PGA; Exceptions Noted)**

| | Q4/97 | Q1/98 | Q2/98 | Q3/98 | Q4/98 | 1998 | Q1/99 | Q2/99 | Q3/99 | Q4/99 | 1999 | Lead Times |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PowerPC 603-80 | 60.00 | 60.00 | 60.00 | 60.00 | 60.00 | 60.00 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Powe PC 603-133 | 100.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| PowerPC 604-166 | 160.00 | 130.00 | 130.00 | 130.00 | 130.00 | 130.00 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| PowerPC 604-225 | 310.00 | 280.00 | 265.00 | 240.00 | 230.00 | 253.75 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| PowerPC 604-240 | 325.00 | 300.00 | 275.00 | 250.00 | 240.00 | 266.25 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Power PC 604-300 | 350.00 | 325.00 | 300.00 | 275.00 | 250.00 | 287.50 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| Power PC 604-350 | 550.00 | 500.00 | 475.00 | 450.00 | 420.00 | 461.25 | EOL | EOL | EOL | EOL | EOL | 2-7 |
| PowerPC 603e-80 | 60.00 | 60.00 | 60.00 | 60.00 | 60.00 | 60.00 | 60.00 | 60.00 | 60.00 | 60.00 | 60.00 | 2-7 |
| Powe PC 603e-133 | 42.31 | 33.85 | 33.85 | 33.85 | 33.85 | 33.85 | 33.85 | 33.85 | 33.85 | 33.85 | 33.85 | 2-7 |
| PowerPC 604e-166 | 142.00 | 135.00 | 135.00 | 135.00 | 135.00 | 135.00 | 135.00 | 135.00 | 135.00 | 135.00 | 135.00 | 2-7 |
| PowerPC 604e-225 | 173.00 | 164.00 | 164.00 | 156.00 | 156.00 | 160.00 | 156.00 | 156.00 | 156.00 | 156.00 | 156.00 | 2-7 |
| PowerPC 604e-240 | 227.00 | 204.00 | 204.00 | 166.00 | 166.00 | 185.00 | 166.00 | 166.00 | 166.00 | 166.00 | 166.00 | 2-7 |
| Power PC 604e-300 | 362.00 | 326.00 | 300.00 | 275.00 | 200.00 | 275.25 | 185.00 | 185.00 | 185.00 | 185.00 | 185.00 | 2-7 |
| Power PC 604e-350 | 496.00 | 424.00 | 390.00 | 350.00 | 275.00 | 359.75 | 235.00 | 200.00 | 200.00 | 200.00 | 208.75 | 2-7 |

EOL = End of life
NA = Not available
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (December 1997)


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## Table 2-4
## Estimated Long-Range Microprocessor Price Trends—North American Bookings (Volume: 25,000 per Year; Dollars) (Package: 32/64 Bit Devices—Ceramic PGA; Exceptions Noted)

| | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|
| 68EC020-25 PQFP | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 |
| 68EC030-25 PQFP | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 |
| 68040-25 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 |
| 68LC040-25 CQFP 184 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 |
| Pentium-100 3.3V | 70.00 | EOL | EOL | EOL | EOL |
| Pentium-100 2.9V | 85.00 | EOL | EOL | EOL | EOL |
| Pentium-120 3.3V | 85.00 | EOL | EOL | EOL | EOL |
| Pentium-120 2.9V | 85.00 | EOL | EOL | EOL | EOL |
| Pentium-133 3.3V | 100.00 | EOL | EOL | EOL | EOL |
| Pentium-133 2.9V | 85.00 | EOL | EOL | EOL | EOL |
| Pentium-150 3.3V | 85.00 | EOL | EOL | EOL | EOL |
| Pentium-150 2.9V | 100.00 | EOL | EOL | EOL | EOL |
| Pentium-166 3.3V | 90.00 | EOL | EOL | EOL | EOL |
| Pentium-200 3.3V | 100.00 | EOL | EOL | EOL | EOL |
| Pentium MMX 166 MHz 2.8V PGA | 85.63 | EOL | EOL | EOL | EOL |
| Pentium MMX 200 MHz 2.8V PGA | 93.75 | EOL | EOL | EOL | EOL |
| Pentium MMX 233 MHz 2.8V PGA | 125.00 | 83.75 | EOL | EOL | EOL |
| Pentium Pro-180 256K Cache | 380.00 | EOL | E[illegible] | EOL | EOL |
| Pentium Pro-200 256K Cache | 450.00 | EOL | EOL | EOL | EOL |
| [illegible]um Pro-200 [illegible]K Cache | 985.00 | 985.00 | EOL | EOL | EOL |
| [illegible]um Pro-200 1M Cache | 2,600.00 | 2,600.00 | EOL | EOL | EOL |
| Pentium II 233 MHz 512K Cache | 186.50 | 125.00 | EOL | EOL | EOL |
| Pentium II 266 MHz 512K Cache | 281.25 | 210.00 | EOL | EOL | EOL |
| Pentium II 300 MHz 512K Cache | 391.25 | 182.50 | EOL | EOL | EOL |
| PowerPC 603-80 | 60.00 | EOL | EOL | EOL | EOL |
| Powe PC 603-133 | 90.00 | EOL | EOL | EOL | EOL |
| PowerPC 604-166 | 130.00 | EOL | EOL | EOL | EOL |
| PowerPC 604-225 | 253.75 | EOL | EOL | EOL | EOL |
| PowerPC 604-240 | 266.25 | EOL | EOL | EOL | EOL |
| Power PC 604-300 | 287.50 | EOL | EOL | EOL | EOL |
| Power PC 604-350 | 461.25 | EOL | EOL | EOL | EOL |
| PowerPC 603e-80 | 60.00 | 60.00 | EOL | EOL | EOL |
| Powe PC 603e-133 | 33.85 | 33.85 | EOL | EOL | EOL |
| PowerPC 604e-166 | 135.00 | 135.00 | EOL | EOL | EOL |
| PowerPC 604e-225 | 160.00 | 156.00 | 156.00 | EOL | EOL |
| PowerPC 604e-240 | 185.00 | 166.00 | 166.00 | EOL | EOL |
| Power PC 604e-300 | 275.25 | 185.00 | 185.00 | EOL | EOL |
| Power PC 604e-350 | 359.75 | 208.75 | 200.00 | EOL | EOL |

EOL = End of life
NA = Not available
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (December 1997)

## Table 2-5
## Estimated DRAM Price Trends—North American Bookings (Contract Volume; U.S. Dollars)*

| | Q4/97 | Q1/98 | Q2/98 | Q3/98 | Q4/98 | 1998 | Q1/99 | Q2/99 | Q3/99 | Q4/99 | 1999 | Lead Times |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4Mbx1 DRAM 70ns SOJ 5V | 2.37 | 2.25 | 2.21 | 2.16 | 2.12 | 2.19 | 2.01 | 1.91 | 1.82 | 1.73 | 1.87 | 3-8 |
| 1Mbx4 DRAM 60ns SOJ 5V FPM | 1.90 | 1.81 | 1.77 | 1.73 | 1.70 | 1.75 | 1.61 | 1.53 | 1.46 | 1.38 | 1.50 | 3-8 |
| 1Mbx4 DRAM 60ns SOJ 5V EDO | 1.90 | 1.81 | 1.77 | 1.73 | 1.70 | 1.75 | 1.61 | 1.53 | 1.46 | 1.38 | 1.50 | 3-8 |
| 512Kx8 DRAM 70ns 5V | 2.15 | 2.04 | 2.00 | 1.96 | 1.92 | 1.98 | 1.83 | 1.73 | 1.65 | 1.57 | 1.69 | 3-8 |
| 256Kx16 DRAM 70ns SOJ 5V | 2.69 | 2.64 | 2.50 | 2.45 | 2.41 | 2.50 | 2.28 | 2.17 | 2.06 | 1.96 | 2.12 | 3-8 |
| 4Mbx4 DRAM 60ns SOJ 5V FPM | 5.45 | 4.91 | 4.66 | 4.43 | 4.21 | 4.55 | 4.00 | 3.80 | 3.61 | 3.43 | 3.71 | 3-8 |
| 4Mbx4 DRAM 60ns SOJ 5V EDO | 5.41 | 4.87 | 4.63 | 4.39 | 4.17 | 4.52 | 3.97 | 3.77 | 3.58 | 3.40 | 3.68 | 3-8 |
| 1Mbx16 DRAM 60ns TSOP 5V FPM | 5.43 | 4.89 | 4.64 | 4.41 | 4.19 | 4.53 | 3.98 | 3.78 | 3.59 | 3.41 | 3.69 | 3-8 |
| 1Mbx16 DRAM 60ns TSOP 5V EDO | 5.40 | 4.86 | 4.62 | 4.39 | 4.17 | 4.51 | 3.96 | 3.76 | 3.57 | 3.39 | 3.67 | 3-8 |
| 1Mbx16 3.3V SDRAM | 6.66 | 5.99 | 5.69 | 5.41 | 5.14 | 5.56 | 4.88 | 4.64 | 4.41 | 4.19 | 4.53 | 3-8 |
| 2Mbx8 DRAM 60ns TSOP 5V FPM | 5.45 | 4.91 | 4.66 | 4.43 | 4.21 | 4.55 | 4.00 | 3.80 | 3.61 | 3.43 | 3.71 | 3-8 |
| 2Mbx8 DRAM SDRAM 3.3V | 6.66 | 5.99 | 5.69 | 5.41 | 5.14 | 5.56 | 4.88 | 4.64 | 4.41 | 4.19 | 4.53 | 3-8 |
| 16Mbx4 DRAM SOJ 60ns 3.3V EDO | 30.37 | 27.33 | 24.60 | 22.14 | 21.03 | 23.78 | 19.98 | 18.98 | 18.03 | 17.13 | 18.53 | 3-8 |
| 16Mbx4 DRAM SOJ 3.3V SDRAM | 31.01 | 27.91 | 25.12 | 22.61 | 21.48 | 24.28 | 20.40 | 19.38 | 18.41 | 17.49 | 18.92 | 3-8 |
| 8Mbx8 DRAM SOJ 60ns 3.3V EDO | 30.37 | 27.33 | 24.60 | 22.14 | 21.03 | 23.78 | 19.98 | 18.98 | 18.03 | 17.13 | 18.53 | 3-8 |
| 8Mbx8 DRAM SOJ 3.3V SDRAM | 31.01 | 27.91 | 25.12 | 22.61 | 21.48 | 24.28 | 20.40 | 19.38 | 18.41 | 17.49 | 18.92 | 3-8 |
| 4Mbx16 DRAM SOJ 60ns 3.3V EDO | 30.37 | 27.33 | 24.60 | 22.14 | 21.03 | 23.78 | 19.98 | 18.98 | 18.03 | 17.13 | 18.53 | 3-8 |
| 4Mbx16 DRAM SOJ 3.3V SDRAM | 31.01 | 27.91 | 25.12 | 22.61 | 21.48 | 24.28 | 20.40 | 19.38 | 18.41 | 17.49 | 18.92 | 3-8 |
| 1Mbx32 SIMM 60ns 5V FPM | 11.40 | 10.26 | 9.75 | 9.26 | 8.80 | 9.52 | 8.36 | 7.94 | 7.54 | 7.17 | 7.75 | 3-8 |
| 1Mbx36 SIMM 60ns 5V FPM | 13.40 | 12.16 | 11.61 | 11.08 | 10.58 | 11.36 | 10.05 | 9.55 | 9.07 | 8.62 | 9.32 | 3-8 |
| 2Mbx32 SIMM 60ns 5V FPM | 22.81 | 20.53 | 19.50 | 18.52 | 17.60 | 19.04 | 16.72 | 15.88 | 15.09 | 14.33 | 15.51 | 3-8 |
| 2Mbx36 SIMM 60ns 5V FPM | 28.46 | 25.42 | 24.61 | 23.82 | 23.07 | 24.23 | 21.92 | 20.82 | 19.78 | 18.79 | 20.33 | 3-8 |
| 4Mbx32 SIMM 60ns 5V FPM | 45.61 | 41.05 | 39.00 | 37.05 | 35.20 | 38.07 | 33.44 | 31.76 | 30.18 | 28.67 | 31.01 | 3-8 |
| 4Mbx36 SIMM 60ns 5V FPM | 56.91 | 52.12 | 49.52 | 47.36 | 45.30 | 48.57 | 43.03 | 40.88 | 38.84 | 36.90 | 39.91 | 3-8 |
| 8Mbx32 SIMM 60ns 5V FPM | 91.22 | 82.10 | 78.00 | 74.10 | 70.39 | 76.15 | 66.87 | 63.53 | 60.35 | 57.33 | 62.02 | 3-8 |
| 8Mbx36 SIMM 60ns 5V FPM | 107.18 | 97.26 | 92.86 | 88.66 | 84.66 | 90.86 | 80.43 | 76.41 | 72.59 | 68.96 | 74.60 | 3-8 |
| 1Mbx32 SIMM 60ns 5V EDO | 11.34 | 10.21 | 9.70 | 9.21 | 8.75 | 9.47 | 8.31 | 7.90 | 7.50 | 7.13 | 7.71 | 3-8 |
| 1Mbx36 SIMM 60ns 5V EDO | 13.34 | 12.10 | 11.55 | 11.03 | 10.53 | 11.30 | 10.01 | 9.51 | 9.03 | 8.58 | 9.28 | 3-8 |
| 2Mbx32 SIMM 60ns 5V EDO | 22.68 | 20.41 | 19.39 | 18.42 | 17.50 | 18.93 | 16.63 | 15.79 | 15.00 | 14.25 | 15.42 | 3-8 |
| 2Mbx36 SIMM 60ns 5V EDO | 28.33 | 25.95 | 24.65 | 23.58 | 22.55 | 24.18 | 21.42 | 20.35 | 19.34 | 18.37 | 19.87 | 3-8 |


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**Table 2-5 (Continued)**
**Estimated DRAM Price Trends—North American Bookings (Contract Volume; U.S. Dollars)***

| | Q4/97 | Q1/98 | Q2/98 | Q3/98 | Q4/98 | 1998 | Q1/99 | Q2/99 | Q3/99 | Q4/99 | 1999 | Lead Times |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4Mbx32 SIMM 60ns 5V EDO | 45.36 | 40.82 | 38.78 | 36.84 | 35.00 | 37.86 | 33.25 | 31.59 | 30.01 | 28.51 | 30.84 | 3-8 |
| 4Mbx36 SIMM 60ns 5V EDO | 54.39 | 49.40 | 47.19 | 45.08 | 43.08 | 46.19 | 40.92 | 38.88 | 36.93 | 35.09 | 37.95 | 3-8 |
| 8Mbx32 SIMM 60ns 5V EDO | 90.72 | 81.65 | 77.57 | 73.69 | 70.00 | 75.73 | 66.50 | 63.18 | 60.02 | 57.02 | 61.68 | 3-8 |
| 8Mbx36 SIMM 60ns 5V EDO | 106.68 | 96.81 | 92.42 | 88.25 | 84.27 | 90.44 | 80.06 | 76.06 | 72.25 | 68.64 | 74.25 | 3-8 |
| 1Mbx64 60ns 3.3V EDO | 25.92 | 23.33 | 22.16 | 21.05 | 20.00 | 21.64 | 19.00 | 18.05 | 17.15 | 16.29 | 17.62 | 3-8 |
| 2Mbx64 60ns 3.3V EDO | 45.36 | 41.20 | 39.14 | 37.18 | 35.33 | 38.21 | 33.56 | 31.88 | 30.29 | 28.77 | 31.13 | 3-8 |
| 4Mbx64 60ns 3.3V EDO | 127.55 | 114.80 | 103.32 | 92.99 | 88.34 | 99.86 | 83.92 | 79.72 | 75.74 | 71.95 | 77.83 | 3-8 |
| 1Mbx64 3.3V SDRAM | 27.97 | 25.17 | 23.92 | 22.72 | 21.58 | 23.35 | 20.51 | 19.48 | 18.51 | 17.58 | 19.02 | 3-8 |
| 2Mbx64 3.3V SDRAM | 55.94 | 50.35 | 47.83 | 45.44 | 43.17 | 46.70 | 41.01 | 38.96 | 37.01 | 35.16 | 38.04 | 3-8 |
| 4Mbx64 3.3V SDRAM | 130.24 | 117.22 | 105.50 | 94.95 | 90.20 | 101.96 | 85.69 | 81.40 | 77.33 | 73.47 | 79.47 | 3-8 |
| 256Kx16 VRAM 70ns SOP | 9.15 | 9.10 | 9.05 | 9.00 | 8.90 | 9.01 | 8.88 | 8.85 | 8.84 | 8.84 | 8.85 | 3-8 |
| 256Kx32 66 MHz 3.3V SGRAM | 5.60 | 5.30 | 5.24 | 5.05 | 4.92 | 5.13 | 4.87 | 4.85 | 4.82 | 4.81 | 4.84 | 3-8 |

*Contract volume is at least 100,000 per order, except for VRAMs.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1997)



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## Table 2-6
## Estimated Long-Range DRAM Price Trends—North American Bookings (Contract Volume; U.S. Dollars)*

| | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|
| 4Mbx1 DRAM 70ns SOJ 5V | 2.19 | 1.87 | 1.89 | 1.91 | 1.92 |
| 1Mbx4 DRAM 60ns SOJ 5V FPM | 1.75 | 1.50 | 1.51 | 1.53 | 1.54 |
| 1Mbx4 DRAM 60ns SOJ 5V EDO | 1.75 | 1.50 | 1.51 | 1.53 | 1.54 |
| 512Kx8 DRAM 70ns 5V | 1.98 | 1.69 | 1.71 | 1.73 | 1.75 |
| 256Kx16 DRAM 70ns SOJ 5V | 2.50 | 2.12 | 2.14 | 2.16 | 2.18 |
| 4Mbx4 DRAM 60ns SOJ 5V FPM | 4.55 | 3.71 | 3.63 | 3.56 | 3.59 |
| 4Mbx4 DRAM 60ns SOJ 5V EDO | 4.52 | 3.68 | 3.60 | 3.53 | 3.57 |
| 1Mbx16 DRAM 60ns TSOP 5V FPM | 4.53 | 3.69 | 3.62 | 3.55 | 3.58 |
| 1Mbx16 DRAM 60ns TSOP 5V EDO | 4.51 | 3.67 | 3.60 | 3.53 | 3.56 |
| 1Mbx16 3.3V SDRAM | 5.56 | 4.53 | 4.44 | 4.35 | 4.39 |
| 2Mbx8 DRAM 60ns TSOP 5V FPM | 4.55 | 3.71 | 3.63 | 3.56 | 3.59 |
| 2Mbx8 DRAM SDRAM 3.3V | 5.56 | 4.53 | 4.44 | 4.35 | 4.39 |
| 16Mbx4 DRAM SOJ 60ns 3.3V EDO | 23.78 | 18.53 | 16.68 | 15.14 | 13.75 |
| 16Mbx4 DRAM SOJ 3.3V SDRAM | 24.28 | 18.92 | 17.03 | 15.46 | 14.04 |
| 8Mbx8 DRAM SOJ 60ns 3.3V EDO | 23.78 | 18.53 | 16.68 | 15.14 | 13.75 |
| 8Mbx8 DRAM SOJ 3.3V SDRAM | 24.28 | 18.92 | 17.03 | 15.46 | 14.04 |
| 4Mbx16 DRAM SOJ 60ns 3.3V EDO | 23.78 | 18.53 | 16.68 | 15.14 | 13.75 |
| 4Mbx16 DRAM SOJ 3.3V SDRAM | 24.28 | 18.92 | 17.03 | 15.46 | 14.04 |
| 1Mbx32 SIMM 60ns 5V FPM | 9.52 | 7.75 | 7.60 | 7.45 | 7.52 |
| 1Mbx36 SIMM 60ns 5V FPM | 11.36 | 9.32 | 9.14 | 8.96 | 9.04 |
| 2Mbx32 SIMM 60ns 5V FPM | 19.04 | 15.51 | 15.20 | 14.89 | 15.04 |
| 2Mbx36 SIMM 60ns 5V FPM | 24.23 | 20.33 | 19.92 | 19.52 | 19.72 |
| 4Mbx32 SIMM 60ns 5V FPM | 38.07 | 31.01 | 30.39 | 29.78 | 30.08 |
| 4Mbx36 SIMM 60ns 5V FPM | 48.57 | 39.91 | 39.11 | 38.33 | 38.71 |
| 8Mbx32 SIMM 60ns 5V FPM | 76.15 | 62.02 | 60.78 | 59.57 | 60.16 |
| 8Mbx36 SIMM 60ns 5V FPM | 90.86 | 74.60 | 73.10 | 71.64 | 72.36 |
| 1Mbx32 SIMM 60ns 5V EDO | 9.47 | 7.71 | 7.56 | 7.40 | 7.48 |
| 1Mbx36 SIMM 60ns 5V EDO | 11.30 | 9.28 | 9.10 | 8.91 | 9.00 |
| 2Mbx32 SIMM 60ns 5V EDO | 18.93 | 15.42 | 15.11 | 14.81 | 14.96 |
| 2Mbx36 SIMM 60ns 5V EDO | 24.18 | 19.87 | 19.47 | 19.08 | 19.27 |
| 4Mbx32 SIMM 60ns 5V EDO | 37.86 | 30.84 | 30.22 | 29.62 | 29.91 |
| 4Mbx36 SIMM 60ns 5V EDO | 46.19 | 37.95 | 37.19 | 36.45 | 36.82 |
| 8Mbx32 SIMM 60ns 5V EDO | 75.73 | 61.68 | 60.45 | 59.24 | 59.83 |
| 8Mbx36 SIMM 60ns 5V EDO | 90.44 | 74.25 | 72.77 | 71.31 | 72.03 |
| 1Mbx64 60ns 3.3V EDO | 21.64 | 17.62 | 15.86 | 14.40 | 13.08 |
| 2Mbx64 60ns 3.3V EDO | 38.21 | 31.13 | 28.01 | 25.44 | 23.10 |
| 4Mbx64 60ns 3.3V EDO | 99.86 | 77.83 | 70.05 | 63.61 | 57.75 |
| 1Mbx64 3.3V SDRAM | 23.35 | 19.02 | 17.12 | 15.54 | 14.11 |
| 2Mbx64 3.3V SDRAM | 46.70 | 38.04 | 34.23 | 31.08 | 28.22 |
| 4Mbx64 3.3V SDRAM | 101.96 | 79.47 | 71.53 | 64.95 | 58.97 |
| 256Kx16 VRAM 70ns SOP | 9.01 | 8.85 | 8.83 | 8.83 | 8.90 |
| 256Kx32 66 MHz 3.3V SGRAM | 5.13 | 4.84 | 4.78 | 4.75 | 4.72 |

*Contract volume is at least 100,000 per order, except for VRAMs.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1997)


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## Table 2-7
## Estimated Static RAM Price Trends—North American Bookings (Volume: Slow SRAM—50,000 per Year; Fast SRAM—20,000 per Year; Package: PDIP; Dollars)

| | Q4/97 | Q1/98 | Q2/98 | Q3/98 | Q4/98 | 1998 | Q1/99 | Q2/99 | Q3/99 | Q4/99 | 1999 | Lead Times |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16Kx4 35ns | 2.14 | 2.09 | 2.09 | 2.09 | 2.11 | 2.10 | 2.11 | 2.11 | 2.13 | 2.13 | 2.12 | 2-4 |
| 8Kx8 25ns | 1.04 | 1.00 | 1.00 | 0.96 | 0.96 | 0.98 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 2-4 |
| 8Kx8 100-120ns | 1.20 | 1.16 | 1.16 | 1.14 | 1.14 | 1.15 | 1.11 | 1.11 | 1.10 | 1.10 | 1.10 | 2-4 |
| 64Kx4 10ns | 5.40 | 5.01 | 4.85 | 4.78 | 4.77 | 4.85 | 4.75 | 4.68 | 4.65 | 4.60 | 4.67 | 2-4 |
| 64Kx4 25ns | 1.80 | 1.60 | 1.60 | 1.55 | 1.55 | 1.58 | 1.53 | 1.53 | 1.51 | 1.51 | 1.52 | 2-4 |
| 32Kx8 12ns | 1.26 | 1.25 | 1.25 | 1.27 | 1.27 | 1.26 | 1.27 | 1.27 | 1.27 | 1.27 | 1.27 | 2-4 |
| 32Kx9 12ns Burst | 3.31 | 3.27 | 3.25 | 3.23 | 3.21 | 3.24 | 3.19 | 3.19 | 3.17 | 3.17 | 3.18 | 2-4 |
| 32Kx8, 15ns, 5V | 1.12 | 1.10 | 1.10 | 1.10 | 1.10 | 1.10 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 | 2-4 |
| 32Kx8, 15ns, 3.3V | 1.12 | 1.12 | 1.12 | 1.14 | 1.14 | 1.13 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 2-4 |
| 32Kx8 25ns | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 2-4 |
| 32Kx8 70-100ns SOJ | 1.30 | 1.26 | 1.24 | 1.23 | 1.22 | 1.24 | 1.21 | 1.21 | 1.21 | 1.21 | 1.21 | 2-4 |
| 64Kx8 12ns Burst | 13.50 | 13.35 | 12.20 | 11.80 | 11.35 | 12.18 | 11.25 | 11.17 | 11.03 | 10.95 | 11.10 | 2-4 |
| 256Kx4 20ns | 4.15 | 3.65 | 3.60 | 3.45 | 3.42 | 3.53 | 3.33 | 3.30 | 3.26 | 3.22 | 3.28 | 2-4 |
| 128Kx8, 15ns | 3.68 | 3.37 | 3.26 | 3.16 | 3.12 | 3.23 | 2.97 | 2.96 | 2.94 | 2.91 | 2.94 | 2-4 |
| 128Kx8, 20ns | 3.82 | 3.35 | 3.24 | 3.14 | 3.10 | 3.21 | 2.97 | 2.96 | 2.94 | 2.92 | 2.95 | 2-4 |
| 128Kx8 25ns | 3.82 | 3.35 | 3.24 | 3.14 | 3.10 | 3.21 | 2.97 | 2.96 | 2.94 | 2.92 | 2.95 | 2-4 |
| 128Kx8 70-100ns SOJ | 3.05 | 2.96 | 2.95 | 2.86 | 2.83 | 2.90 | 2.76 | 2.73 | 2.72 | 2.71 | 2.73 | 2-4 |
| 32Kx32 15ns, 3.3V PQFP | 3.27 | 3.20 | 3.15 | 3.10 | 3.04 | 3.12 | 3.00 | 2.97 | 2.95 | 2.94 | 2.97 | 3-6 |
| 32Kx32 8ns 3.3V PBSynch | 2.77 | 2.75 | 2.72 | 2.69 | 2.67 | 2.71 | 2.67 | 2.65 | 2.63 | 2.63 | 2.65 | 3-6 |
| 64Kx32 8ns 3.3V PBSynch | 5.30 | 5.00 | 4.95 | 4.68 | 4.60 | 4.81 | 4.55 | 4.50 | 4.40 | 4.35 | 4.45 | 3-6 |
| 256Kx16 70-100ns | 14.60 | 13.50 | 13.00 | 12.50 | 12.28 | 12.82 | 12.15 | 12.05 | 12.00 | 11.92 | 12.03 | 3-8 |
| 256Kx16 25ns | 17.48 | 16.68 | 16.17 | 15.33 | 15.04 | 15.81 | 14.61 | 14.32 | 13.84 | 13.75 | 14.13 | 3-8 |
| 512Kx8 70ns | 13.31 | 13.09 | 12.60 | 12.26 | 11.85 | 12.45 | 11.70 | 11.60 | 11.29 | 11.11 | 11.43 | 3-8 |
| 512Kx8 25ns | 17.44 | 16.91 | 16.06 | 14.77 | 14.04 | 15.45 | 13.79 | 13.32 | 13.00 | 12.85 | 13.24 | 3-8 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1997)



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**Table 2-8**
**Estimated Long-Range Static RAM Price Trends—North American Bookings (Volume: Slow SRAM—50,000 per Year; Fast SRAM—20,000 per Year; Package: PDIP; Dollars)**

| | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|
| 16Kx4 35ns | 2.10 | 2.12 | 2.14 | 2.16 | 2.17 |
| 8Kx8 25ns | 0.98 | 0.96 | 0.96 | 0.97 | 1.00 |
| 8Kx8 100-120ns | 1.15 | 1.10 | 1.08 | 1.08 | 1.12 |
| 64Kx4 10ns | 4.85 | 4.67 | 4.57 | 4.55 | 4.55 |
| 64Kx4 25ns | 1.58 | 1.52 | 1.51 | 1.51 | 1.51 |
| 32Kx8 12ns | 1.26 | 1.27 | 1.30 | 1.35 | 1.50 |
| 32Kx9 12ns Burst | 3.24 | 3.18 | 3.16 | 3.15 | 3.15 |
| 32Kx8, 15ns, 5V | 1.10 | 1.13 | 1.18 | 1.25 | 1.50 |
| 32Kx8, 15ns, 3.3V | 1.13 | 1.15 | 1.17 | 1.25 | 1.50 |
| 32Kx8 25ns | 1.12 | 1.14 | 1.18 | 1.25 | 1.50 |
| 32Kx8 70-100ns SOJ | 1.24 | 1.21 | 1.20 | 1.20 | 1.20 |
| 64Kx8 12ns Burst | 12.18 | 11.10 | 10.60 | 10.45 | 10.20 |
| 256Kx4 20ns | 3.53 | 3.28 | 3.20 | 3.18 | 3.17 |
| 128Kx8, 15ns | 3.23 | 2.94 | 2.89 | 2.82 | 2.79 |
| 128Kx8, 20ns | 3.21 | 2.95 | 2.89 | 2.82 | 2.79 |
| 128Kx8 25ns | 3.21 | 2.95 | 2.89 | 2.82 | 2.79 |
| 128Kx8 70-100ns SOJ | 2.90 | 2.73 | 2.69 | 2.66 | 2.62 |
| 32Kx32 15ns, 3.3V PQFP | 3.12 | 2.97 | 2.93 | 3.00 | 3.20 |
| 32Kx32 8ns 3.3V PBSynch | 2.71 | 2.65 | 2.70 | 3.10 | 3.35 |
| 64Kx32 8ns 3.3V PBSynch | 4.81 | 4.45 | 4.33 | 5.00 | 5.55 |
| 256Kx16 70-100ns | 12.82 | 12.03 | 11.75 | 11.10 | 10.79 |
| 256Kx16 25ns | 15.81 | 14.13 | 13.50 | 12.75 | 11.95 |
| 512Kx8 70ns | 12.45 | 11.43 | 11.02 | 10.95 | 10.75 |
| 512Kx8 25ns | 15.45 | 13.24 | 12.42 | 11.89 | 11.12 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1997)

**Table 2-9**
**Estimated ROM Price Trends—North American Bookings (Speed/Package: ( ≤1Mb Density—150ns and Above; 28-Pin PDIP; ≥2Mb Density—200ns and Above; 32-Pin PDIP) (Volume: 50,000 per Year; Dollars)**

| | Q4/97 | Q1/98 | Q2/98 | Q3/98 | Q4/98 | 1998 | Q1/99 | Q2/99 | Q3/99 | Q4/99 | 1999 | Lead Times |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 128Kx8 ROM | 1.64 | 1.58 | 1.55 | 1.51 | 1.51 | 1.54 | 1.50 | 1.48 | 1.46 | 1.45 | 1.47 | 4-8 |
| 64Kx16 ROM | 1.80 | 1.73 | 1.70 | 1.66 | 1.66 | 1.69 | 1.64 | 1.61 | 1.59 | 1.59 | 1.61 | 4-8 |
| 256Kx8 ROM | 2.14 | 2.10 | 2.08 | 2.05 | 2.05 | 2.07 | 2.02 | 2.00 | 1.98 | 1.97 | 1.99 | 4-8 |
| 512Kx8 ROM | 2.80 | 2.70 | 2.68 | 2.55 | 2.62 | 2.64 | 2.60 | 2.57 | 2.53 | 2.50 | 2.55 | 4-8 |
| 256Kx16 ROM[1] | 2.80 | 2.70 | 2.68 | 2.55 | 2.62 | 2.64 | 2.60 | 2.57 | 2.53 | 2.50 | 2.55 | 4-8 |
| 1Mbx8 ROM[2] | 3.70 | 3.62 | 3.58 | 3.53 | 3.49 | 3.56 | 3.45 | 3.40 | 3.38 | 3.35 | 3.40 | 4-8 |
| 1Mbx16 ROM | 5.65 | 5.55 | 5.50 | 5.46 | 5.46 | 5.49 | 5.40 | 5.35 | 5.30 | 5.30 | 5.34 | 4-8 |
| 2Mbx8 ROM | 5.65 | 5.55 | 5.50 | 5.46 | 5.46 | 5.49 | 5.40 | 5.35 | 5.30 | 5.30 | 5.34 | 4-8 |
| 2Mbx16 ROM | 11.30 | 11.00 | 11.00 | 10.70 | 10.45 | 10.79 | 10.35 | 10.35 | 10.20 | 10.20 | 10.28 | 4-8 |
| 4Mbx8 ROM | 11.30 | 11.00 | 11.00 | 10.70 | 10.45 | 10.79 | 10.35 | 10.35 | 10.20 | 10.20 | 10.28 | 4-8 |
| 4Mbx16 ROM | 15.00 | 14.50 | 14.50 | 14.00 | 14.00 | 14.25 | 13.85 | 13.85 | 13.60 | 13.55 | 13.71 | 4-9 |
| 8Mbx8 ROM | 14.90 | 14.40 | 14.40 | 13.90 | 13.90 | 14.15 | 13.75 | 13.75 | 13.50 | 13.35 | 13.59 | 4-9 |

[1]256Kx16 ROM: 150ns and above; 40-pin PDIP
[2]1Mbx8 ROM: 150ns and above; 32-pin SOP
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1997)



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**Table 2-10**
**Estimated Long-Range ROM Price Trends—North American Bookings (Speed/Package: (≤1Mb Density—150ns and Above; 28-Pin PDIP; ≥2Mb Density—200ns and Above; 32-Pin PDIP) (Volume: 50,000 per Year; Dollars)**

| | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|
| 128Kx8 ROM | 1.54 | 1.47 | 1.45 | 1.43 | 1.42 |
| 64Kx16 ROM | 1.69 | 1.61 | 1.57 | 1.55 | 1.54 |
| 256Kx8 ROM | 2.07 | 1.99 | 1.96 | 1.94 | 1.92 |
| 512Kx8 ROM | 2.64 | 2.55 | 2.47 | 2.42 | 2.4 |
| 256Kx16 ROM[1] | 2.64 | 2.55 | 2.47 | 2.42 | 2.4 |
| 1Mbx8 ROM[2] | 3.56 | 3.40 | 3.30 | 3.28 | 2.27 |
| 1Mbx16 ROM | 5.49 | 5.34 | 5.26 | 5.22 | 5.18 |
| 2Mbx8 ROM | 5.49 | 5.34 | 5.26 | 5.22 | 5.18 |
| 2Mbx16 ROM | 10.79 | 10.28 | 10.11 | 9.89 | 9.49 |
| 4Mbx8 ROM | 10.79 | 10.28 | 10.11 | 9.89 | 9.49 |
| 4Mbx16 ROM | 14.25 | 13.71 | 13.44 | 13.13 | 12.86 |
| 8Mbx8 ROM | 14.15 | 13.59 | 13.21 | 12.97 | 12.56 |

[1]256Kx16 ROM: 150ns and above; 40-pin PDIP
[2]1Mbx8 ROM: 150ns and above; 32-pin SOP
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1997)

**Table 2-11**
**Estimated EPROM Price Trends—North American Bookings (Volume: 50,000 per Year; Package: Windowed CERDIP; Speed: 150ns and Above; Dollars)**

| | Q4/97 | Q1/98 | Q2/98 | Q3/98 | Q4/98 | 1998 | Q1/99 | Q2/99 | Q3/99 | Q4/99 | 1999 | Lead Times |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32Kx8 EPROM | 1.32 | 1.26 | 1.23 | 1.22 | 1.21 | 1.23 | 1.21 | 1.19 | 1.18 | 1.13 | 1.18 | 2-3 |
| 64Kx8 EPROM | 1.39 | 1.31 | 1.29 | 1.27 | 1.26 | 1.28 | 1.25 | 1.23 | 1.22 | 1.16 | 1.21 | 2-3 |
| 128Kx8 EPROM | 1.80 | 1.65 | 1.65 | 1.60 | 1.59 | 1.62 | 1.56 | 1.55 | 1.52 | 1.52 | 1.54 | 2-3 |
| 256Kx8 EPROM | 2.73 | 2.68 | 2.66 | 2.52 | 2.50 | 2.59 | 2.45 | 2.45 | 2.42 | 2.42 | 2.44 | 2-3 |
| 128Kx16 EPROM | 3.13 | 3.08 | 3.03 | 2.82 | 2.80 | 2.93 | 2.75 | 2.75 | 2.71 | 2.71 | 2.73 | 2-3 |
| 512Kx8 EPROM | 4.51 | 4.06 | 4.03 | 3.95 | 3.91 | 3.99 | 3.86 | 3.86 | 3.79 | 3.77 | 3.82 | 2-3 |
| 256Kx16 EPROM | 6.15 | 5.33 | 5.14 | 4.94 | 4.74 | 5.03 | 4.65 | 4.60 | 4.48 | 4.43 | 4.54 | 2-3 |
| 1Mbx8 EPROM | 8.20 | 7.38 | 7.33 | 7.18 | 6.65 | 7.13 | 6.63 | 6.68 | 6.35 | 6.25 | 6.48 | 2-3 |
| 512Kx16 EPROM | 9.30 | 8.25 | 8.13 | 8.00 | 7.88 | 8.06 | 7.55 | 7.55 | 7.20 | 7.05 | 7.34 | 2-3 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1997)



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## Table 2-12
## Estimated Long-Range EPROM Price Trends—North American Bookings (Volume: 50,000 per Year; Package: Windowed CERDIP; Speed: 150ns and Above; Dollars)

| | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|
| 32Kx8 EPROM | 1.23 | 1.18 | 1.12 | 1.11 | 1.10 |
| 64Kx8 EPROM | 1.28 | 1.21 | 1.15 | 1.13 | 1.11 |
| 128Kx8 EPROM | 1.62 | 1.54 | 1.49 | 1.48 | 1.47 |
| 256Kx8 EPROM | 2.59 | 2.44 | 2.40 | 2.37 | 2.36 |
| 128Kx16 EPROM | 2.93 | 2.73 | 2.67 | 2.65 | 2.62 |
| 512Kx8 EPROM | 3.99 | 3.82 | 3.72 | 3.64 | 3.60 |
| 256Kx16 EPROM | 5.03 | 4.54 | 4.37 | 4.32 | 4.29 |
| 1Mbx8 EPROM | 7.13 | 6.48 | 6.16 | 6.07 | 5.98 |
| 512Kx16 EPROM | 8.06 | 7.34 | 6.96 | 6.82 | 6.77 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1997)

**Table 2-13**
**Estimated Flash Memory Price Trends—North American Bookings (12V; Volume: 10,000 per Year; Speed: 150ns; Dollars)**

| | Q4/97 | Q1/98 | Q2/98 | Q3/98 | Q4/98 | 1998 | Q1/99 | Q2/99 | Q3/99 | Q4/99 | 1999 | Lead Times |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 64Kx8 PDIP/PLCC | 2.33 | 2.19 | 2.15 | 2.15 | 2.15 | 2.16 | 2.15 | 2.15 | 2.15 | 2.15 | 2.15 | 5 |
| 64Kx8 TSOP | 2.59 | 2.43 | 2.38 | 2.29 | 2.19 | 2.32 | 2.17 | 2.17 | 2.17 | 2.17 | 2.17 | 5 |
| 128Kx8 PDIP/PLCC | 2.35 | 2.25 | 2.19 | 2.17 | 2.14 | 2.19 | 2.14 | 2.14 | 2.13 | 2.13 | 2.14 | 3 |
| 128Kx8 TSOP 12V | 2.43 | 2.24 | 2.21 | 2.18 | 2.18 | 2.20 | 2.16 | 2.16 | 2.15 | 2.15 | 2.16 | 4 |
| 128Kx8 TSOP 5V | 2.86 | 2.64 | 2.55 | 2.46 | 2.44 | 2.52 | 2.40 | 2.37 | 2.36 | 2.33 | 2.37 | 4 |
| 256Kx8 TSOP 12V | 4.81 | 4.41 | 4.26 | 4.16 | 4.09 | 4.23 | 4.05 | 4.03 | 3.98 | 3.96 | 4.00 | 4 |
| 256Kx8 TSOP/5V | 4.31 | 3.88 | 3.80 | 3.65 | 3.49 | 3.71 | 3.47 | 3.44 | 3.41 | 3.37 | 3.42 | 4 |
| 512Kx8 PDIP/PLCC | 4.68 | 4.18 | 4.08 | 3.92 | 3.82 | 4.00 | 3.77 | 3.73 | 3.68 | 3.62 | 3.70 | 4 |
| 512Kx8 TSOP 12V | 5.53 | 4.65 | 4.31 | 4.28 | 4.20 | 4.36 | 4.15 | 4.10 | 4.05 | 4.00 | 4.08 | 4 |
| 512Kx8 TSOP/5V | 5.23 | 4.47 | 4.18 | 4.12 | 3.98 | 4.19 | 3.94 | 3.90 | 3.84 | 3.80 | 3.87 | 4 |
| 512Kx8 SSOP/3V | 4.61 | 4.14 | 3.89 | 3.84 | 3.80 | 3.92 | 3.74 | 3.70 | 3.66 | 3.60 | 3.67 | 4 |
| 1Mbx8 TSOP/12V | 7.85 | 7.39 | 7.10 | 6.90 | 6.55 | 6.99 | 6.38 | 6.30 | 6.25 | 6.10 | 6.26 | 4 |
| 1Mbx8 TSOP/5V | 7.77 | 7.25 | 6.89 | 6.60 | 6.20 | 6.74 | 6.12 | 6.00 | 5.90 | 5.75 | 5.94 | 4 |
| 1Mbx8 TSOP/3V | 7.70 | 6.95 | 6.60 | 6.23 | 5.95 | 6.43 | 5.77 | 5.68 | 5.52 | 5.45 | 5.60 | 4 |
| 2Mbx8 TSOP/12V | 15.22 | 13.78 | 13.38 | 12.79 | 12.11 | 13.02 | 11.98 | 11.70 | 11.65 | 11.55 | 11.72 | 4 |
| 2Mbx8 TSOP/5V | 15.04 | 13.43 | 12.89 | 12.37 | 12.01 | 12.68 | 11.80 | 11.41 | 11.30 | 11.22 | 11.43 | 4 |
| 2Mbx8 TSOP/3V | 15.50 | 13.43 | 12.82 | 12.30 | 11.80 | 12.59 | 11.21 | 10.78 | 10.50 | 10.35 | 10.71 | 4 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1997)



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## Table 2-14
## Estimated Long-Range Flash Memory Price Trends—North American Bookings (12V; Volume: 10,000 per Year; Speed: 150ns; Dollars)

| | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|
| 64Kx8 PDIP/PLCC | 2.16 | 2.15 | 2.15 | 2.15 | 2.19 |
| 64Kx8 TSOP | 2.32 | 2.17 | 2.16 | 2.16 | 2.18 |
| 128Kx8 PDIP/PLCC | 2.19 | 2.14 | 2.12 | 2.11 | 2.11 |
| 128Kx8 TSOP 12V | 2.20 | 2.16 | 2.14 | 2.12 | 2.11 |
| 128Kx8 TSOP 5V | 2.52 | 2.37 | 2.30 | 2.28 | 2.27 |
| 256Kx8 TSOP 12V | 4.23 | 4.00 | 3.92 | 3.87 | 3.85 |
| 256Kx8 TSOP/5V | 3.71 | 3.42 | 3.31 | 3.28 | 3.25 |
| 512Kx8 PDIP/PLCC | 4.00 | 3.70 | 3.57 | 3.51 | 3.48 |
| 512Kx8 TSOP 12V | 4.36 | 4.08 | 3.95 | 3.91 | 3.88 |
| 512Kx8 TSOP/5V | 4.19 | 3.87 | 3.74 | 3.69 | 3.67 |
| 512Kx8 SSOP/3V | 3.92 | 3.67 | 3.56 | 3.51 | 3.49 |
| 1Mbx8 TSOP/12V | 6.99 | 6.26 | 6.01 | 5.95 | 5.91 |
| 1Mbx8 TSOP/5V | 6.74 | 5.94 | 5.67 | 5.62 | 5.59 |
| 1Mbx8 TSOP/3V | 6.43 | 5.60 | 5.35 | 5.30 | 5.28 |
| 2Mbx8 TSOP/12V | 13.02 | 11.72 | 11.48 | 11.37 | 11.33 |
| 2Mbx8 TSOP/5V | 12.68 | 11.43 | 11.05 | 10.97 | 10.92 |
| 2Mbx8 TSOP/3V | 12.59 | 10.71 | 10.10 | 10.01 | 9.97 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1997)

## Table 2-15
## Estimated Gate Array Pricing—North American Production Bookings (Volume: 20,000 Units; Based on Utilized Gates Only; NRE = Netlist to Prototype; Millicents per Gate)

| | 10-29.99K Gates | | | 30-59.99K Gates | | | 60-99.99K Gates | | | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|
| Gate Count Technology | 1998 | 1999 | 2000 | 1998 | 1999 | 2000 | 1998 | 1999 | 2000 | (Weeks) |
| CMOS | | | | | | | | | | Production: |
| 0.8 Micron | 20.00 | 19.00 | 19.00 | 16.00 | 15.00 | 14.00 | 14.00 | 13.00 | 12.00 | 4-10 |
| 0.6 Micron | 22.00 | 21.00 | 20.00 | 15.00 | 14.00 | 13.00 | 16.00 | 15.00 | 13.00 | 4-10 |
| 0.5 Micron | 25.00 | 24.00 | 23.00 | 21.00 | 20.00 | 20.00 | 18.00 | 17.00 | 15.00 | 4-10 |
| 0.35 Micron | 34.00 | 34.00 | 34.00 | 28.00 | 26.00 | 26.00 | 20.00 | 19.00 | 17.00 | 4-10 |
| | | | | | | | | | | Prototype: |
| NRE CMOS Average Charge ($K) | 43.00 | 43.00 | 43.00 | 53.00 | 51.00 | 51.00 | 73.00 | 72.00 | 72.00 | 1-4 |

| | 10-29.99K Gates | | | >300K Gates | | | Lead Time |
|---|---|---|---|---|---|---|---|
| Gate Count Technology | 1998 | 1999 | 2000 | 1998 | 1999 | 2000 | (Weeks) |
| CMOS | | | | | | | Production: |
| 0.8 Micron | 22.00 | 21.00 | 19.00 | NR | NR | NR | 4-10 |
| 0.6 Micron | 22.00 | 21.00 | 19.00 | 30.00 | 29.00 | 29.00 | 4-10 |
| 0.5 Micron | 24.00 | 22.00 | 20.00 | 32.00 | 32.00 | 32.00 | 4-10 |
| 0.35 Micron | 31.00 | 30.00 | 29.00 | 38.00 | 38.00 | 38.00 | 4-10 |
| | | | | | | | Prototype: |
| NRE CMOS Average Charge ($K) | 105.00 | 103.00 | 103.00 | 125.00 | 120.00 | 120.00 | 1-4 |

NR = Not relevant
NRE = Nonrecurring engineering charge
Notes: The actual NRE may vary from these because of device amortization, testing, intellectual property rights, and other factors. Actual negotiated market prices may vary substantially from these because of manufacturer-specific factors such as intellectual property rights, alliances, service, package types, pad or core constraints, and volume discount. For volumes of *1 million or greater, discount the above prices by a further 50 to 60 percent. For core-limited solutions with volumes greater than 10,000 units, CBICs may be more cost-effective than* gate arrays.
Source: Dataquest (December 1997)



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## Table 2-16
## Estimated CBIC Pricing—North American Production Bookings (Volume: 20,000 Units; Based on Utilized Gates Only; NRE = Netlist to Prototype; Millicents per Gate)

| | 10-29.99K Gates | | | 30-59.99K Gates | | | 60-99.99K Gates | | | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1998 | 1999 | 2000 | 1998 | 1999 | 2000 | 1998 | 1999 | 2000 | (Weeks) |
| CMOS | | | | | | | | | | Production: |
| 0.8 Micron | 24.00 | 22.00 | 21.00 | 16.00 | 14.00 | 13.00 | 11.00 | 10.00 | 9.00 | 6-14 |
| 0.6 Micron | 25.00 | 24.00 | 23.00 | 16.00 | 15.00 | 14.00 | 12.00 | 10.00 | 9.00 | 6-14 |
| 0.5 Micron | 27.00 | 26.00 | 26.00 | 24.00 | 22.00 | 20.00 | 19.00 | 17.00 | 14.00 | 6-14 |
| 0.35 Micron | 39.00 | 37.00 | 37.00 | 35.00 | 34.00 | 32.00 | 24.00 | 22.00 | 19.00 | 6-14 |
| | | | | | | | | | | Prototype: |
| **NRE CMOS Average Charge ($K)** | 66.00 | 65.00 | 65.00 | 72.00 | 71.00 | 71.00 | 82.00 | 82.00 | 82.00 | 3-6 |

| | 10-29.99K Gates | | | >300K Gates | | | Lead Time |
|---|---|---|---|---|---|---|---|
| | 1998 | 1999 | 2000 | 1998 | 1999 | 2000 | (Weeks) |
| CMOS | | | | | | | Production: |
| 0.8 Micron | 15.00 | 14.00 | 12.00 | NR | NR | NR | 6-14 |
| 0.6 Micron | 14.00 | 13.00 | 10.00 | 18.00 | 17.00 | 15.00 | 6-14 |
| 0.5 Micron | 12.00 | 10.00 | 9.00 | 15.00 | 14.00 | 12.00 | 6-14 |
| 0.35 Micron | 11.00 | 10.00 | 9.00 | 9.00 | 8.00 | 7.00 | 6-14 |
| | | | | | | | Prototype: |
| **NRE CMOS Average Charge ($K)** | 133.00 | 131.00 | 131.00 | 161.00 | 160.00 | 158.00 | 3-6 |

NR = Not relevant

NRE = Nonrecurring engineering charge

Notes: The actual NRE may vary from these because of device amortization, testing, intellectual property rights, and other factors. Actual negotiated market prices may vary substantially from these because of manufacturer-specific factors such as intellectual property rights, alliances, service, package types, pad or core constraints, and volume discount. For volumes of 1 million or greater, discount the above prices by a further 50 to 60 percent. For core-limited solutions with volumes greater than 10,000 units, CBICs may be more cost-effective than gate arrays.

Source: Dataquest (December 1997)


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**For More Information...**

Evelyn Cronin, Senior Industry Analyst ..... (408) 468-8075
Internet address ..... evelyn.cronin@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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## DATAQUEST WORLDWIDE OFFICES


**NORTH AMERICA**

**Worldwide Headquarters**
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: 1-408-468-8000
Facsimile: 1-408-954-1780

**East Coast Research Center**
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6262

**Dataquest Global Events**
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

**EUROPE**

**European Headquarters**
Tamesis, The Glanty
Egham, Surrey TW20 9AW
United Kingdom
Phone: +44 1784 431 611
Facsimile: +44 1784 488 980

**Dataquest France**
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: +33 1 41 35 13 00
Facsimile: +33 1 41 35 13 13

**Dataquest Germany**
Martin-Kollar-Strasse 15
D-81829 München
Germany
Phone: +49 89 42 70 4-0
Facsimile: +49 89 42 70 4-270

**JAPAN**

**Japan Headquarters**
Aobadai Hills 4-7-7
Aobadai
Meguro-ku, Tokyo 153
Japan
Phone: 81-3-3481-3670
Facsimile: 81-3-3481-3644

**ASIA/PACIFIC**

**Asia/Pacific Headquarters**
Suite 5904-7, Central Plaza
18 Harbour Road, Wanchai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

**Dataquest Korea**
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

**Dataquest Taiwan**
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

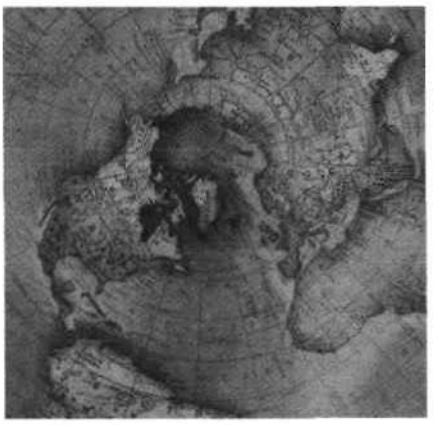
**Dataquest Singapore**
6 Temasek Boulevard, #26-02/03
Suntec City Tower 4
Singapore 038986
Phone: 65-333-6773
Facsimile: 65-333-6768

**Dataquest Thailand**
12/F, Vanissa Building
29 Soi Chidlom
Ploenchit Road
Patumwan, Bangkok 10330
Thailand
Phone: 662-655-0577
Facsimile: 662-655-0576

**Dataquest Australia**
80 Alfred Street
Milsons Point NSW 2061
Australia
Phone: 61-2-9941-4860
Facsimile: 61-2-9941-4868


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# North American Semiconductor Price Outlook—Fourth Quarter 1997

Market Statistics

**Program:** Semiconductor Supply and Pricing Worldwide
**Product Code:** SSPS-WW-MS-9704
**Publication Date:** September 29, 1997
**Filing:** Market Statistics

# North American Semiconductor Price Outlook—Fourth Quarter 1997



Market Statistics

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# Table of Contents

Page

1. North American Semiconductor Price Outlook—Fourth Quarter 1997 ..... 1
   Methodology and Sources ..... 1
   Price Variations ..... 1
2. Market Statistics Tables ..... 3

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# List of Tables


| Table | | Page |
|---|---|---|
| 2-1 | Estimated Standard Logic Price Trends—North American Bookings | 4 |
| 2-2 | Estimated Long-Range Standard Logic Price Trends—North American Bookings | 5 |
| 2-3 | Estimated Microprocessor Price Trends—North American Bookings | 6 |
| 2-4 | Estimated Long-Range Microprocessor Price Trends—North American Bookings | 8 |
| 2-5 | Estimated DRAM Price Trends—North American Bookings | 9 |
| 2-6 | Estimated Long-Range DRAM Price Trends—North American Bookings | 11 |
| 2-7 | Estimated Static RAM Price Trends—North American Bookings | 12 |
| 2-8 | Estimated Long-Range Static RAM Price Trends—North American Bookings | 13 |
| 2-9 | Estimated ROM Price Trends—North American Bookings | 14 |
| 2-10 | Estimated Long-Range ROM Price Trends—North American Bookings | 14 |
| 2-11 | Estimated EPROM Price Trends—North American Bookings | 15 |
| 2-12 | Estimated Long-Range EPROM Price Trends—North American Bookings | 15 |
| 2-13 | Estimated Flash Memory Price Trends—North American Bookings | 16 |
| 2-14 | Estimated Long-Range Flash Memory Price Trends—North American Bookings | 17 |
| 2-15 | Estimated Gate Array Pricing—North American Production Bookings | 18 |
| 2-16 | Estimated CBIC Pricing—North American Production Bookings | 19 |


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# Chapter 1
# North American Semiconductor Price Outlook—Fourth Quarter 1997

## Methodology and Sources

This document provides information on and forecasts for the North American bookings prices of more than 200 semiconductor devices. Dataquest collects price information on a quarterly basis from North American suppliers and major buyers of these products. North American bookings price information is analyzed by Semiconductor Supply and Pricing Worldwide (SSPS) analysts for consistency and reconciliation. The information finally is rationalized with worldwide billings price data in association with product analysts, resulting in the current forecast. This document includes associated long-range forecasts.

For SSPS clients that use the SSPS online service through CompuServe, the prices presented here correlate with the quarterly and long-range price tables dated September 1997 in the SSPS online service. Clients who want to access the information via the World Wide Web can pay extra for a Dataquest Interactive subscription, which allows users to access all their deliverables at their desktops. For additional product coverage and more detailed product specifications, please refer to those sources.

### Price Variations

Actual negotiated market prices may vary from these prices 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 value of a company's product. These prices are intended for use as price guidelines.


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## Chapter 2
# Market Statistics Tables

Tables 2-1 through 2-16 show statistics on North American semiconductor prices.


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## Table 2-1
## Estimated Standard Logic Price Trends—North American Bookings (Volume: 100,000 per Year; Package: PLCC; Dollars)

| | 1997 | | | | 1997 | 1998 | | | | 1998 | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Q1 | Q2 | Q3 | Q4 | Year | Q1 | Q2 | Q3 | Q4 | Year | (Weeks) |
| **74LS TTL** | | | | | | | | | | | |
| 74LS00 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 3-6 |
| 74LS74 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 3-6 |
| 74LS138 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.18 | 0.18 | 0.17 | 0.17 | 0.17 | 3-6 |
| 74LS244 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 3-6 |
| **74AC TTL** | | | | | | | | | | | |
| 74AC00 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.15 | 0.15 | 0.15 | 0.14 | 0.15 | 3-6 |
| 74AC74 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.19 | 0.19 | 0.18 | 0.17 | 0.19 | 3-6 |
| 74AC138 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.28 | 0.28 | 0.27 | 0.27 | 0.28 | 3-6 |
| 74AC244 | 0.40 | 0.40 | 0.39 | 0.39 | 0.39 | 0.36 | 0.35 | 0.35 | 0.35 | 0.35 | 3-6 |
| **74F TTL** | | | | | | | | | | | |
| 74F00 | 0.13 | 0.13 | 0.14 | 0.14 | 0.14 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 3-6 |
| 74F74 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 3-6 |
| 74F138 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 3-6 |
| 74F244 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.23 | 0.23 | 0.23 | 0.23 | 0.22 | 3-6 |
| **74HC CMOS** | | | | | | | | | | | |
| 74HC00 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 | 0.11 | 0.11 | 0.11 | 3-6 |
| 74HC74 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 3-6 |
| 74HC138 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 3-6 |
| 74HC244 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.22 | 0.22 | 0.22 | 0.22 | 0.21 | 3-6 |
| **74ALS TTL** | | | | | | | | | | | |
| 74ALS00 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 3-6 |
| 74ALS74 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 3-6 |
| 74ALS138 | 0.22 | 0.21 | 0.21 | 0.21 | 0.21 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 3-6 |
| 74ALS244 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 3-6 |
| **74AS TTL** | | | | | | | | | | | |
| 74AS00 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 3-6 |
| 74AS74 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 3-6 |
| 74AS138 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 3-6 |
| 74AS244 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 3-6 |
| **74BC*** | | | | | | | | | | | |
| 74BC00 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.19 | 0.19 | 0.18 | 0.17 | 0.19 | 3-6 |
| 74BC244 | 0.53 | 0.53 | 0.53 | 0.53 | 0.53 | 0.48 | 0.47 | 0.46 | 0.44 | 0.47 | 3-6 |
| 74BC373 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.50 | 0.49 | 0.46 | 0.46 | 0.48 | 3-6 |
| 74ACT244 | 0.42 | 0.42 | 0.41 | 0.41 | 0.41 | 0.39 | 0.37 | 0.37 | 0.36 | 0.37 | 3-6 |
| 74ACT245 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.40 | 0.39 | 0.39 | 0.37 | 0.39 | 3-6 |
| 74ABT244 | 0.58 | 0.58 | 0.58 | 0.57 | 0.58 | 0.53 | 0.53 | 0.51 | 0.48 | 0.51 | 3-6 |
| 74ABT245 | 0.62 | 0.62 | 0.62 | 0.61 | 0.62 | 0.57 | 0.56 | 0.55 | 0.52 | 0.55 | 3-6 |

*Pricing for 74BC excludes 74ABT and 74BCT.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (August 1997)

## Table 2-2
## Estimated Long-Range Standard Logic Price Trends—North American Bookings (Volume: 100,000 per Year; Package: PLCC; Dollars)

| Product | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| **74LS TTL** | | | | | |
| 74LS00 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| 74LS74 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |
| 74LS138 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| 74LS244 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 |
| **74AC TTL** | | | | | |
| 74AC00 | 0.17 | 0.15 | 0.14 | 0.14 | 0.13 |
| 74AC74 | 0.20 | 0.19 | 0.18 | 0.17 | 0.17 |
| 74AC138 | 0.29 | 0.28 | 0.26 | 0.25 | 0.24 |
| 74AC244 | 0.39 | 0.35 | 0.34 | 0.32 | 0.32 |
| **74F TTL** | | | | | |
| 74F00 | 0.14 | 0.13 | 0.13 | 0.13 | 0.13 |
| 74F74 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| 74F138 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |
| 74F244 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 |
| **74HC CMOS** | | | | | |
| 74HC00 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| 74HC74 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 |
| 74HC138 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| 74HC244 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| **74ALS TTL** | | | | | |
| 74ALS00 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| 74ALS74 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |
| 74ALS138 | 0.21 | 0.20 | 0.19 | 0.19 | 0.19 |
| 74ALS244 | 0.30 | 0.27 | 0.25 | 0.24 | 0.24 |
| **74AS TTL** | | | | | |
| 74AS00 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| 74AS74 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| 74AS138 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| 74AS244 | 0.63 | 0.62 | 0.61 | 0.6 | 0.6 |
| **74BC*** | | | | | |
| 74BC00 | 0.20 | 0.19 | 0.18 | 0.17 | 0.17 |
| 74BC244 | 0.53 | 0.47 | 0.45 | 0.44 | 0.43 |
| 74BC373 | 0.55 | 0.48 | 0.44 | 0.42 | 0.41 |
| 74ACT244 | 0.41 | 0.37 | 0.35 | 0.33 | 0.32 |
| 74ACT245 | 0.44 | 0.39 | 0.36 | 0.35 | 0.35 |
| 74ABT244 | 0.58 | 0.51 | 0.47 | 0.45 | 0.44 |
| 74ABT245 | 0.62 | 0.55 | 0.51 | 0.49 | 0.48 |

*Pricing for 74BC excludes 74ABT and 74BCT.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (August 1997)

## Table 2-3
## Estimated Microprocessor Price Trends—North American Bookings (Volume: 25,000 per Year; Dollars) (Package: 32/64-Bit Devices—Ceramic PGA; Exceptions Noted)

| | 1997 | | | | 1997 | 1998 | | | | 1998 | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Q1 | Q2 | Q3 | Q4 | Year | Q1 | Q2 | Q3 | Q4 | Year | (Weeks) |
| 68EC020-25 PQFP | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 3-8 |
| 68EC030-25 PQFP | 19.00 | 18.75 | 18.75 | 18.75 | 18.81 | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 | 3-8 |
| 68040-25 | 25.00 | 24.00 | 24.00 | 22.00 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 3-8 |
| 68LC040-25 CQFP 184 | 25.00 | 24.00 | 24.00 | 22.00 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 3-8 |
| Pentium-75 | 70.00 | 70.00 | 70.00 | 70.00 | 70.00 | EOL | EOL | EOL | EOL | EOL | 3-8 |
| Pentium-90 | 70.00 | 70.00 | 70.00 | 70.00 | 70.00 | EOL | EOL | EOL | EOL | EOL | 3-8 |
| Pentium-100 3.3V | 75.00 | 75.00 | 70.00 | 70.00 | 72.50 | 70.00 | 70.00 | EOL | EOL | EOL | 3-8 |
| Pentium-100 2.9V | 90.00 | 90.00 | 85.00 | 85.00 | 87.50 | 85.00 | 85.00 | EOL | EOL | EOL | 3-8 |
| Pentium-120 3.3V | 90.00 | 85.00 | 85.00 | 85.00 | 86.25 | 85.00 | 85.00 | EOL | EOL | EOL | 3-8 |
| Pentium-120 2.9V | 90.00 | 85.00 | 85.00 | 85.00 | 86.25 | 85.00 | 85.00 | EOL | EOL | EOL | 3-8 |
| Pentium-133 3.3V | 110.00 | 100.00 | 100.00 | 100.00 | 102.50 | 100.00 | 100.00 | EOL | EOL | EOL | 3-8 |
| Pentium-133 2.9V | 150.00 | 140.00 | 100.00 | 85.00 | 118.75 | 85.00 | 85.00 | EOL | EOL | EOL | 3-8 |
| Pentium-150 3.3V | 140.00 | 140.00 | 100.00 | 100.00 | 120.00 | 85.00 | 85.00 | EOL | EOL | EOL | 3-8 |
| Pentium-150 2.9V | 250.00 | 225.00 | 130.00 | 100.00 | 176.25 | 100.00 | 100.00 | EOL | EOL | EOL | 3-8 |
| Pentium-166 3.3V | 295.00 | 200.00 | 120.00 | 90.00 | 176.25 | 90.00 | 90.00 | EOL | EOL | EOL | 3-8 |
| Pentium-200 3.3V | 450.00 | 250.00 | 145.00 | 100.00 | 236.25 | 100.00 | 100.00 | EOL | EOL | EOL | 3-8 |
| Pentium MMX 166 MHz 2.8V PGA | 350.00 | 260.00 | 200.00 | 100.00 | 227.50 | 100.00 | 90.00 | 90.00 | 90.00 | 92.50 | 3-8 |
| Pentium MMX 200 MHz 2.8V PGA | 500.00 | 400.00 | 330.00 | 210.00 | 360.00 | 120.00 | 120.00 | 120.00 | 120.00 | 120.00 | 3-8 |
| Pentium MMX 233 MHz 2.8V PGA | NA | 600.00 | 380.00 | 300.00 | 426.67 | 190.00 | 190.00 | 190.00 | 190.00 | 190.00 | 3-8 |
| Pentium Pro-166C | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 | EOL | EOL | EOL | EOL | EOL | 3-8 |
| Pentium Pro-180 256K Cache | 410.00 | 380.00 | 380.00 | 380.00 | 387.50 | 380.00 | 380.00 | 380.00 | 380.00 | 380.00 | 3-8 |
| Pentium Pro-200 256K Cache | 475.00 | 475.00 | 450.00 | 450.00 | 462.50 | 450.00 | 450.00 | 450.00 | 450.00 | 450.00 | 3-8 |
| Pentium Pro-200 512K Cache | 993.00 | 993.00 | 985.00 | 985.00 | 989.00 | 985.00 | 985.00 | 985.00 | 985.00 | 985.00 | 3-8 |
| Pentium Pro-200 1M Cache | NA | NA | 2,600.00 | 2,600.00 | 2,600.00 | 2,600.00 | 2,600.00 | 2,600.00 | 2,600.00 | 2,600.00 | 3-9 |
| Pentium II 233 MHz 512K Cache | NA | 600.00 | 500.00 | 450.00 | 516.67 | 400.00 | 350.00 | 300.00 | 220.00 | 317.50 | 3-8 |
| Pentium II 266 MHz 512K Cache | NA | 750.00 | 650.00 | 500.00 | 633.33 | 420.00 | 370.00 | 310.00 | 250.00 | 337.50 | 3-8 |
| Pentium II 300 MHz 512K Cache | NA | 1,900.00 | 830.00 | 730.00 | 1,153.33 | 580.00 | 450.00 | 400.00 | 320.00 | 437.50 | 3-8 |



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## Table 2-3 (Continued)
## Estimated Microprocessor Price Trends—North American Bookings (Volume: 25,000 per Year; Dollars) (Package: 32/64-Bit Devices—Ceramic PGA; Exceptions Noted)

| | 1997 | | | | 1997 | 1998 | | | | 1998 | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Q1 | Q2 | Q3 | Q4 | Year | Q1 | Q2 | Q3 | Q4 | Year | (Weeks) |
| PowerPC 601-80 | 70.00 | 68.00 | 68.00 | 68.00 | 68.50 | EOL | EOL | EOL | EOL | EOL | 3-8 |
| PowerPC 601-100 | 80.00 | 75.00 | 75.00 | 75.00 | 76.25 | EOL | EOL | EOL | EOL | EOL | 3-8 |
| PowerPC 603-80 | 63.00 | 61.00 | 61.00 | 60.00 | 61.25 | 60.00 | 60.00 | 60.00 | 60.00 | 60.00 | 3-8 |
| Powe PC 603-133 | 125.00 | 113.00 | 110.00 | 100.00 | 112.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 3-8 |
| PowerPC 604-166 | 200.00 | 167.00 | 167.00 | 160.00 | 173.50 | 130.00 | 130.00 | 130.00 | 130.00 | 130.00 | 3-8 |
| PowerPC 604-225 | 400.00 | 400.00 | 325.00 | 310.00 | 358.75 | 280.00 | 265.00 | 240.00 | 230.00 | 253.75 | 3-8 |
| PowerPC 604-240 | 500.00 | 450.00 | 375.00 | 325.00 | 412.50 | 300.00 | 275.00 | 250.00 | 240.00 | 266.25 | 3-8 |
| Power PC 604-300 | NA | NA | 400.00 | 350.00 | 375.00 | 325.00 | 300.00 | 275.00 | 250.00 | 287.50 | 3-9 |
| Power PC 604-350 | NA | NA | 600.00 | 550.00 | 575.00 | 500.00 | 475.00 | 450.00 | 420.00 | 461.25 | 3-8 |

EOL = End of life
NA = Not available
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (August 1997)

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**Table 2-4**
**Estimated Long-Range Microprocessor Price Trends—North American Bookings (Volume: 25,000 per Year; Dollars) (Package: 32/64 Bit Devices—Ceramic PGA; Exceptions Noted)**

| Product | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| 68EC020-25 PQFP | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 |
| 68EC030-25 PQFP | 18.81 | 18.75 | 18.75 | 18.75 | 18.75 |
| 68040-25 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 |
| 68LC040-25 CQFP 184 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 |
| Pentium-75 | 70.00 | EOL | EOL | EOL | EOL |
| Pentium-90 | 70.00 | EOL | EOL | EOL | EOL |
| Pentium-100 3.3V | 72.50 | EOL | EOL | EOL | EOL |
| Pentium-100 2.9V | 87.50 | EOL | EOL | EOL | EOL |
| Pentium-120 3.3V | 86.25 | EOL | EOL | EOL | EOL |
| Pentium-120 2.9V | 86.25 | EOL | EOL | EOL | EOL |
| Pentium-133 3.3V | 102.50 | EOL | EOL | EOL | EOL |
| Pentium-133 2.9V | 118.75 | EOL | EOL | EOL | EOL |
| Pentium-150 3.3V | 120.00 | EOL | EOL | EOL | EOL |
| Pentium-150 2.9V | 176.25 | EOL | EOL | EOL | EOL |
| Pentium-166 3.3V | 176.25 | EOL | EOL | EOL | EOL |
| Pentium-200 3.3V | 236.25 | EOL | EOL | EOL | EOL |
| Pentium MMX 166 MHz 2.8V PGA | 227.50 | 92.50 | 90.00 | EOL | EOL |
| Pentium MMX 200 MHz 2.8V PGA | 360.00 | 120.00 | 120.00 | EOL | EOL |
| Pentium MMX 233 MHz 2.8V PGA | 426.67 | 190.00 | 190.00 | EOL | EOL |
| Pentium Pro-166C | 600.00 | EOL | EOL | EOL | EOL |
| Pentium Pro-180 256K Cache | 387.50 | 380.00 | 225.00 | EOL | EOL |
| Pentium Pro-200 256K Cache | 462.50 | 450.00 | 375.00 | EOL | EOL |
| Pentium Pro-200 512K Cache | 989.00 | 985.00 | 635.00 | EOL | EOL |
| Pentium Pro-200 1M Cache | 2,600.00 | 2,600.00 | 2,600.00 | 2,600.00 | EOL |
| Pentium II 233 MHz 512K Cache | 516.67 | 317.50 | 220.00 | 220.00 | EOL |
| Pentium II 266 MHz 512K Cache | 633.33 | 337.50 | 250.00 | 250.00 | EOL |
| Pentium II 300 MHz 512K Cache | 1,153.33 | 437.50 | 320.00 | 320.00 | EOL |
| PowerPC 601-80 | 68.50 | EOL | EOL | EOL | EOL |
| PowerPC 601-100 | 76.25 | EOL | EOL | EOL | EOL |
| PowerPC 603-80 | 61.25 | 60.00 | EOL | EOL | EOL |
| Powe PC 603-133 | 112.00 | 90.00 | EOL | EOL | EOL |
| PowerPC 604-166 | 173.50 | 130.00 | EOL | EOL | EOL |
| PowerPC 604-225 | 358.75 | 253.75 | EOL | EOL | EOL |
| PowerPC 604-240 | 412.50 | 266.25 | EOL | EOL | EOL |
| Power PC 604-300 | 375.00 | 287.50 | 250.00 | EOL | EOL |
| Power PC 604-350 | 575.00 | 461.25 | 425.00 | EOL | EOL |

EOL = End of life
NA = Not available
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (August 1997)

## Table 2-5
## Estimated DRAM Price Trends—North American Bookings (Contract Volume; U.S. Dollars)*

| Product | 1997 Q1 | 1997 Q2 | 1997 Q3 | 1997 Q4 | 1997 Year | 1998 Q1 | 1998 Q2 | 1998 Q3 | 1998 Q4 | 1998 Year | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4Mbx1 DRAM 70ns SOJ 5V | 2.60 | 2.55 | 2.45 | 2.44 | 2.51 | 2.43 | 2.43 | 2.43 | 2.43 | 2.43 | 3-8 |
| 1Mbx4 DRAM 60ns SOJ 5V FPM | 2.40 | 2.35 | 2.22 | 2.21 | 2.30 | 2.31 | 2.36 | 2.38 | 2.39 | 2.36 | 3-8 |
| 1Mbx4 DRAM 60ns SOJ 5V EDO | 2.40 | 2.35 | 2.18 | 2.15 | 2.27 | 2.26 | 2.31 | 2.33 | 2.34 | 2.31 | 3-8 |
| 512Kx8 DRAM 70ns 5V | 2.82 | 2.66 | 2.56 | 2.52 | 2.64 | 2.45 | 2.44 | 2.39 | 2.39 | 2.42 | 3-8 |
| 256Kx16 DRAM 70ns SOJ 5V | 3.36 | 3.30 | 2.85 | 2.83 | 3.09 | 2.87 | 2.87 | 2.91 | 2.91 | 2.89 | 3-8 |
| 4Mbx4 DRAM 60 ns SOJ 5V FPM | 8.66 | 8.73 | 7.10 | 7.10 | 7.90 | 7.05 | 7.05 | 7.10 | 7.15 | 7.09 | 3-8 |
| 4Mbx4 DRAM 60ns SOJ 5V EDO | 8.66 | 8.52 | 6.95 | 6.80 | 7.73 | 6.75 | 6.74 | 6.70 | 6.70 | 6.72 | 3-8 |
| 1Mbx16 DRAM 60ns TSOP 5V FPM | 8.03 | 8.48 | 7.00 | 7.00 | 7.63 | 7.00 | 7.00 | 7.15 | 7.15 | 7.08 | 3-8 |
| 1Mbx16 DRAM 60ns TSOP 5V EDO | 8.03 | 8.46 | 6.70 | 6.50 | 7.42 | 6.45 | 6.42 | 6.40 | 6.40 | 6.42 | 3-8 |
| 1Mbx16 3.3V SDRAM | 10.25 | 9.73 | 8.00 | 8.00 | 9.00 | 7.84 | 7.66 | 7.46 | 7.36 | 7.58 | 3-8 |
| 2Mbx8 DRAM 60ns TSOP 5V FPM | 9.00 | 8.86 | 7.10 | 7.10 | 8.02 | 7.05 | 7.05 | 7.15 | 7.15 | 7.10 | 3-8 |
| 2Mbx8 DRAM SDRAM 3.3V | 10.25 | 9.73 | 8.00 | 8.00 | 9.00 | 7.70 | 7.50 | 7.31 | 7.17 | 7.42 | 3-8 |
| 16Mbx4 DRAM SOJ 60ns 3.3V EDO | 75.00 | 57.00 | 40.14 | 36.40 | 52.14 | 33.83 | 32.45 | 28.84 | 27.97 | 30.77 | 3-8 |
| 16Mbx4 DRAM SOJ 3.3V SDRAM | 75.00 | 56.75 | 42.64 | 38.35 | 53.19 | 33.36 | 32.46 | 28.81 | 27.30 | 30.49 | 3-8 |
| 8Mbx8 DRAM SOJ 60ns 3.3V EDO | 75.00 | 57.00 | 40.14 | 36.40 | 52.14 | 33.83 | 32.45 | 28.84 | 27.97 | 30.77 | 3-8 |
| 8Mbx8 DRAM SOJ 3.3V SDRAM | 75.00 | 56.75 | 42.64 | 38.35 | 53.19 | 33.36 | 32.46 | 28.81 | 27.30 | 30.49 | 3-8 |
| 4Mbx16 DRAM SOJ 60ns 3.3V EDO | 75.00 | 57.00 | 40.14 | 36.40 | 52.14 | 33.83 | 32.45 | 28.84 | 27.97 | 30.77 | 3-8 |
| 4Mbx16 DRAM SOJ 3.3V SDRAM | 75.00 | 56.75 | 42.64 | 38.35 | 53.19 | 33.36 | 32.46 | 28.81 | 27.30 | 30.49 | 3-8 |
| 1Mbx32 SIMM 60ns 5V FPM | 19.00 | 19.88 | 17.50 | 17.40 | 18.45 | 17.35 | 17.30 | 17.50 | 18.00 | 17.54 | 3-8 |
| 1Mbx36 SIMM 60ns 5V FPM | 21.00 | 21.80 | 20.45 | 20.07 | 20.83 | 19.97 | 19.78 | 20.09 | 21.44 | 20.32 | 3-8 |
| 2Mbx32 SIMM 60ns 5V FPM | 36.12 | 39.16 | 31.50 | 31.50 | 34.57 | 31.30 | 31.25 | 31.02 | 32.00 | 31.39 | 3-8 |
| 2Mbx36 SIMM 60ns 5V FPM | 41.50 | 43.18 | 39.45 | 39.02 | 40.79 | 38.50 | 37.65 | 37.44 | 38.00 | 37.90 | 3-8 |
| 4Mbx32 SIMM 60ns 5V FPM | 72.20 | 73.22 | 60.87 | 60.61 | 66.73 | 60.13 | 59.57 | 58.44 | 60.00 | 59.54 | 3-8 |
| 4Mbx36 SIMM 60ns 5V FPM | 82.75 | 83.21 | 78.03 | 76.95 | 80.24 | 74.61 | 73.35 | 72.31 | 74.00 | 73.57 | 3-8 |
| 8Mbx32 SIMM 60ns 5V FPM | 141.20 | 145.28 | 121.20 | 120.12 | 131.95 | 119.64 | 118.98 | 118.81 | 121.15 | 119.65 | 3-8 |
| 8Mbx36 SIMM 60ns 5V FPM | 164.25 | 166.52 | 147.86 | 145.87 | 156.13 | 143.48 | 139.59 | 138.74 | 142.06 | 140.97 | 3-8 |
| 1Mbx32 SIMM 60ns 5V EDO | 19.00 | 19.81 | 17.10 | 17.00 | 18.23 | 17.00 | 16.67 | 16.49 | 16.25 | 16.60 | 3-8 |
| 1Mbx36 SIMM 60ns 5V EDO | 21.00 | 21.76 | 20.10 | 20.01 | 20.72 | 19.70 | 19.40 | 19.30 | 19.20 | 19.40 | 3-8 |
| 2Mbx32 SIMM 60ns 5V EDO | 36.12 | 38.16 | 31.00 | 30.75 | 34.01 | 31.61 | 30.99 | 29.87 | 29.50 | 30.49 | 3-8 |

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## Table 2-5
## Estimated DRAM Price Trends—North American Bookings (Contract Volume; U.S. Dollars)*

| | 1997 | | | | 1997 | 1998 | | | | 1998 | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Q1 | Q2 | Q3 | Q4 | Year | Q1 | Q2 | Q3 | Q4 | Year | (Weeks) |
| 2Mbx36 SIMM 60ns 5V EDO | 41.50 | 43.18 | 38.95 | 38.35 | 40.50 | 37.88 | 37.12 | 36.56 | 36.05 | 36.90 | 3-8 |
| 4Mbx32 SIMM 60ns 5V EDO | 72.20 | 72.20 | 60.32 | 60.12 | 66.21 | 59.42 | 58.74 | 57.99 | 57.42 | 58.39 | 3-8 |
| 4Mbx36 SIMM 60ns 5V EDO | 82.75 | 83.21 | 78.03 | 76.95 | 80.24 | 73.09 | 72.83 | 71.64 | 70.25 | 71.95 | 3-8 |
| 8Mbx32 SIMM 60ns 5V EDO | 141.20 | 143.07 | 120.88 | 119.76 | 131.23 | 118.06 | 115.98 | 114.59 | 114.13 | 115.69 | 3-8 |
| 8Mbx36 SIMM 60ns 5V EDO | 164.25 | 165.12 | 146.77 | 145.11 | 155.31 | 142.26 | 139.20 | 138.11 | 137.55 | 139.28 | 3-8 |
| 1Mbx64 60ns 3.3V EDO | 42.13 | 40.58 | 31.05 | 30.84 | 36.15 | 31.50 | 30.84 | 29.88 | 29.53 | 30.44 | 3-8 |
| 2Mbx64 60ns 3.3V EDO | 79.25 | 78.60 | 60.98 | 60.58 | 69.85 | 61.22 | 59.32 | 58.58 | 57.64 | 59.19 | 3-8 |
| 4Mbx64 60ns 3.3V EDO | 149.00 | 141.00 | 125.00 | 123.75 | 134.69 | 120.81 | 118.08 | 116.53 | 113.75 | 117.29 | 3-8 |
| 1Mbx64 3.3V SDRAM | 42.13 | 40.58 | 35.02 | 34.58 | 38.08 | 33.50 | 32.27 | 31.63 | 31.01 | 32.10 | 3-8 |
| 2Mbx64 3.3V SDRAM | 79.25 | 78.60 | 68.80 | 66.11 | 73.19 | 64.15 | 62.58 | 61.20 | 59.62 | 61.89 | 3-8 |
| 4Mbx64 3.3V SDRAM | 149.00 | 141.00 | 132.47 | 129.98 | 138.11 | 124.45 | 121.80 | 119.08 | 116.76 | 120.52 | 3-8 |
| 256Kx16 VRAM 70ns SOP | 11.60 | 10.05 | 9.75 | 9.15 | 10.14 | 9.10 | 9.05 | 9.00 | 8.90 | 9.01 | 3-8 |
| 256Kx32 66 MHz 3.3V SGRAM | 10.00 | 8.04 | 5.94 | 5.69 | 7.42 | 5.50 | 5.38 | 5.13 | 5.00 | 5.25 | 3-8 |

*Contract volume is at least 100,000 per order, except for VRAMs.Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as
Source: Dataquest (August 1997)



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## Table 2-6
## Estimated Long-Range DRAM Price Trends—North American Bookings (Contract Volume; U.S. Dollars)*

| Product | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| 4Mbx1 DRAM 70ns SOJ 5V | 2.51 | 2.43 | 2.50 | 2.55 | 2.65 |
| 1Mbx4 DRAM 60ns SOJ 5V FPM | 2.30 | 2.36 | 2.45 | 2.55 | 2.65 |
| 1Mbx4 DRAM 60ns SOJ 5V EDO | 2.27 | 2.31 | 2.40 | 2.50 | 2.65 |
| 512Kx8 DRAM 70ns 5V | 2.64 | 2.42 | 2.37 | 2.50 | 2.66 |
| 256Kx16 DRAM 70ns SOJ 5V | 3.09 | 2.89 | 3.00 | 3.60 | 3.91 |
| 4Mbx4 DRAM 60 ns SOJ 5V FPM | 7.90 | 7.09 | 6.70 | 7.70 | 8.50 |
| 4Mbx4 DRAM 60ns SOJ 5V EDO | 7.73 | 6.72 | 6.61 | 7.60 | 8.50 |
| 1Mbx16 DRAM 60ns TSOP 5V FPM | 7.63 | 7.08 | 6.70 | 7.70 | 8.50 |
| 1Mbx16 DRAM 60ns TSOP 5V EDO | 7.42 | 6.42 | 6.63 | 7.60 | 8.50 |
| 1Mbx16 3.3V SDRAM | 9.00 | 7.58 | 6.90 | 6.85 | 6.80 |
| 2Mbx8 DRAM 60ns TSOP 5V FPM | 8.02 | 7.10 | 6.70 | 7.70 | 8.50 |
| 2Mbx8 DRAM SDRAM 3.3V | 9.00 | 7.42 | 6.75 | 6.67 | 6.60 |
| 16Mbx4 DRAM SOJ 60ns 3.3V EDO | 52.14 | 30.77 | 26.88 | 31.00 | 32.00 |
| 16Mbx4 DRAM SOJ 3.3V SDRAM | 53.19 | 30.49 | 26.74 | 25.68 | 24.97 |
| 8Mbx8 DRAM SOJ 60ns 3.3V EDO | 52.14 | 30.77 | 26.88 | 25.93 | 25.11 |
| 8Mbx8 DRAM SOJ 3.3V SDRAM | 53.19 | 30.49 | 26.74 | 25.68 | 24.97 |
| 4Mbx16 DRAM SOJ 60ns 3.3V EDO | 52.14 | 30.77 | 26.88 | 25.93 | 25.11 |
| 4Mbx16 DRAM SOJ 3.3V SDRAM | 53.19 | 30.49 | 26.74 | 25.68 | 24.97 |
| 1Mbx32 SIMM 60ns 5V FPM | 18.45 | 17.54 | 18.00 | 18.50 | 19.00 |
| 1Mbx36 SIMM 60ns 5V FPM | 20.83 | 20.32 | 21.50 | 22.00 | 22.00 |
| 2Mbx32 SIMM 60ns 5V FPM | 34.57 | 31.39 | 32.00 | 33.00 | 33.00 |
| 2Mbx36 SIMM 60ns 5V FPM | 40.79 | 37.90 | 39.00 | 41.00 | 43.00 |
| 4Mbx32 SIMM 60ns 5V FPM | 66.73 | 59.54 | 60.00 | 62.00 | 70.00 |
| 4Mbx36 SIMM 60ns 5V FPM | 80.24 | 73.57 | 76.00 | 79.00 | 85.00 |
| 8Mbx32 SIMM 60ns 5V FPM | 131.95 | 119.65 | 124.00 | 126.00 | 130.00 |
| 8Mbx36 SIMM 60ns 5V FPM | 156.13 | 140.97 | 148.00 | 156.00 | 168.00 |
| 1Mbx32 SIMM 60ns 5V EDO | 18.23 | 16.60 | 15.75 | 16.95 | 19.00 |
| 1Mbx36 SIMM 60ns 5V EDO | 20.72 | 19.40 | 18.57 | 19.75 | 21.80 |
| 2Mbx32 SIMM 60ns 5V EDO | 34.01 | 30.49 | 28.75 | 30.63 | 37.50 |
| 2Mbx36 SIMM 60ns 5V EDO | 40.50 | 36.90 | 35.55 | 38.11 | 41.45 |
| 4Mbx32 SIMM 60ns 5V EDO | 66.21 | 58.39 | 56.75 | 59.98 | 72.12 |
| 4Mbx36 SIMM 60ns 5V EDO | 80.24 | 71.95 | 68.65 | 72.85 | 83.00 |
| 8Mbx32 SIMM 60ns 5V EDO | 131.23 | 115.69 | 111.89 | 122.00 | 141.50 |
| 8Mbx36 SIMM 60ns 5V EDO | 155.31 | 139.28 | 135.99 | 144.00 | 165.00 |
| 1Mbx64 60ns 3.3V EDO | 36.15 | 30.44 | 28.62 | 27.95 | 27.40 |
| 2Mbx64 60ns 3.3V EDO | 69.85 | 59.19 | 56.25 | 54.95 | 54.25 |
| 4Mbx64 60ns 3.3V EDO | 134.69 | 117.29 | 111.94 | 109.85 | 107.50 |
| 1Mbx64 3.3V SDRAM | 38.08 | 32.10 | 28.50 | 27.85 | 27.22 |
| 2Mbx64 3.3V SDRAM | 73.19 | 61.89 | 56.12 | 54.56 | 54.12 |
| 4Mbx64 3.3V SDRAM | 138.11 | 120.52 | 111.55 | 109.67 | 107.35 |
| 256Kx16 VRAM 70ns SOP | 10.14 | 9.01 | 8.60 | 9.25 | 10.00 |
| 256Kx32 66 MHz 3.3V SGRAM | 7.42 | 5.25 | 4.75 | 4.50 | 4.22 |

*Contract volume is at least 100,000 per order, except for VRAMs.Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as
Source: Dataquest (August 1997)


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## Table 2-7
## Estimated Static RAM Price Trends—North American Bookings (Volume: Slow SRAM—50,000 per Year; Fast SRAM—20,000 per Year; Package: PDIP; Dollars)

| | 1997 | | | | 1997 | 1998 | | | | 1998 | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Q1 | Q2 | Q3 | Q4 | Year | Q1 | Q2 | Q3 | Q4 | Year | (Weeks) |
| 16Kx4 35ns | 2.19 | 2.17 | 2.16 | 2.14 | 2.17 | 2.09 | 2.09 | 2.09 | 2.11 | 2.10 | 2-4 |
| 8Kx8 25ns | 1.18 | 1.16 | 1.07 | 1.04 | 1.11 | 1.04 | 1.03 | 1.03 | 1.03 | 1.03 | 2-4 |
| 8Kx8 100-120ns | 1.39 | 1.31 | 1.20 | 1.20 | 1.28 | 1.20 | 1.20 | 1.17 | 1.17 | 1.18 | 2-4 |
| 64Kx4 10ns | 7.00 | 6.28 | 5.74 | 5.40 | 6.11 | 5.04 | 4.89 | 4.83 | 4.83 | 4.90 | 2-4 |
| 64Kx4 25ns | 2.06 | 1.90 | 1.84 | 1.80 | 1.90 | 1.70 | 1.70 | 1.60 | 1.60 | 1.65 | 2-4 |
| 32Kx8 12ns | 1.50 | 1.42 | 1.33 | 1.26 | 1.38 | 1.27 | 1.27 | 1.26 | 1.26 | 1.27 | 2-4 |
| 32Kx9 12ns Burst | 3.67 | 3.42 | 3.32 | 3.31 | 3.43 | 3.27 | 3.25 | 3.23 | 3.21 | 3.24 | 2-4 |
| 32Kx8, 15ns, 5V | 1.21 | 1.17 | 1.12 | 1.12 | 1.15 | 1.10 | 1.10 | 1.09 | 1.09 | 1.10 | 2-4 |
| 32Kx8, 15ns, 3.3V | 1.26 | 1.18 | 1.12 | 1.12 | 1.17 | 1.10 | 1.10 | 1.10 | 1.10 | 1.10 | 2-4 |
| 32Kx8 25ns | 1.20 | 1.16 | 1.12 | 1.12 | 1.15 | 1.09 | 1.09 | 1.08 | 1.08 | 1.09 | 2-4 |
| 32Kx8 70-100ns SOJ | 1.53 | 1.40 | 1.34 | 1.30 | 1.39 | 1.25 | 1.24 | 1.22 | 1.21 | 1.23 | 2-4 |
| 64Kx8 12ns Burst | 15.15 | 14.10 | 14.03 | 13.50 | 14.20 | 13.35 | 12.20 | 11.80 | 11.35 | 12.18 | 2-4 |
| 256Kx4 20ns | 5.22 | 4.74 | 4.32 | 4.15 | 4.61 | 3.85 | 3.79 | 3.60 | 3.56 | 3.70 | 2-4 |
| 128Kx8, 15 ns | 4.67 | 4.30 | 3.93 | 3.68 | 4.14 | 3.49 | 3.36 | 3.21 | 3.15 | 3.30 | 3-8 |
| 128Kx8, 20 ns | 4.82 | 4.50 | 4.02 | 3.82 | 4.29 | 3.54 | 3.41 | 3.25 | 3.18 | 3.34 | 3-8 |
| 128Kx8 25ns | 4.82 | 4.50 | 4.02 | 3.82 | 4.29 | 3.54 | 3.41 | 3.25 | 3.18 | 3.34 | 3-8 |
| 128Kx8 70-100ns SOJ | 4.65 | 3.78 | 3.15 | 3.05 | 3.66 | 3.02 | 3.01 | 2.97 | 2.95 | 2.99 | 3-8 |
| 32Kx32 15ns, 3.3V PQFP | 3.59 | 3.46 | 3.40 | 3.27 | 3.43 | 3.14 | 3.09 | 2.95 | 2.90 | 3.02 | 3-6 |
| 32Kx32 8ns 3.3V PBSynch | 3.29 | 3.17 | 2.83 | 2.77 | 3.02 | 2.72 | 2.68 | 2.63 | 2.59 | 2.65 | 3-6 |
| 64Kx32 8ns 3.3V PBSynch | 6.29 | 5.80 | 5.48 | 5.30 | 5.72 | 5.03 | 4.94 | 4.70 | 4.54 | 4.80 | 3-6 |
| 256Kx16 70-100ns | 19.15 | 17.90 | 15.19 | 14.60 | 16.71 | 13.57 | 13.00 | 12.57 | 12.33 | 12.87 | 3-8 |
| 256Kx16 25ns | 20.41 | 18.70 | 18.11 | 17.48 | 18.67 | 16.79 | 16.11 | 15.13 | 14.50 | 15.63 | 3-8 |
| 512Kx8 70ns | 17.96 | 16.52 | 13.97 | 13.31 | 15.44 | 13.11 | 12.65 | 12.26 | 11.81 | 12.48 | 3-8 |
| 512Kx8 25ns | 22.00 | 20.72 | 18.37 | 17.44 | 19.63 | 16.68 | 15.88 | 14.75 | 13.70 | 15.25 | 3-8 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (August 1997)


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**Table 2-8**
**Estimated Long-Range Static RAM Price Trends—North American Bookings (Volume: Slow SRAM—50,000 per Year; Fast SRAM—20,000 per Year; Package: PDIP; Dollars)**

| Product | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| 16Kx4 35ns | 2.17 | 2.10 | 2.12 | 2.12 | 2.16 |
| 8Kx8 25ns | 1.11 | 1.03 | 1.00 | 1.00 | 1.30 |
| 8Kx8 100-120ns | 1.28 | 1.18 | 1.16 | 1.16 | 1.40 |
| 64Kx4 10ns | 6.11 | 4.90 | 5.80 | 6.40 | 6.59 |
| 64Kx4 25ns | 1.90 | 1.65 | 1.70 | 1.80 | 1.95 |
| 32Kx8 12ns | 1.38 | 1.27 | 1.26 | 1.45 | 1.70 |
| 32Kx9 12ns Burst | 3.43 | 3.24 | 3.20 | 3.35 | 3.55 |
| 32Kx8, 15ns, 5V | 1.15 | 1.10 | 1.15 | 1.30 | 1.45 |
| 32Kx8, 15ns, 3.3V | 1.17 | 1.10 | 1.10 | 1.35 | 1.45 |
| 32Kx8 25ns | 1.15 | 1.09 | 1.15 | 1.30 | 1.45 |
| 32Kx8 70-100ns SOJ | 1.39 | 1.23 | 1.35 | 1.40 | 1.65 |
| 64Kx8 12ns Burst | 14.20 | 12.18 | 11.01 | 12.15 | 13.00 |
| 256Kx4 20ns | 4.61 | 3.70 | 3.45 | 4.60 | 5.10 |
| 128Kx8, 15ns | 4.14 | 3.30 | 3.14 | 3.12 | 3.60 |
| 128Kx8, 20ns | 4.29 | 3.34 | 3.16 | 3.14 | 3.60 |
| 128Kx8 25ns | 4.29 | 3.34 | 3.16 | 3.14 | 3.60 |
| 128Kx8 70-100ns SOJ | 3.66 | 2.99 | 2.94 | 2.94 | 3.60 |
| 32Kx32 15ns, 3.3V PQFP | 3.43 | 3.02 | 2.90 | 3.50 | 4.00 |
| 32Kx32 8ns 3.3V PBSynch | 3.02 | 2.65 | 3.20 | 4.00 | 4.70 |
| 64Kx32 8ns 3.3V PBSynch | 5.72 | 4.80 | 4.43 | 4.17 | 4.50 |
| 256Kx16 70-100ns | 16.71 | 12.87 | 11.00 | 10.42 | 10.20 |
| 256Kx16 25ns | 18.67 | 15.63 | 12.55 | 11.37 | 10.40 |
| 512Kx8 70ns | 15.44 | 12.48 | 11.00 | 10.51 | 10.24 |
| 512Kx8 25ns | 19.63 | 15.25 | 12.55 | 11.37 | 10.40 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (August 1997)

**Table 2-9**
**Estimated ROM Price Trends—North American Bookings (Speed/Package: ≤1Mb Density—150ns and Above; 28-pin PDIP; ≥2Mb Density—200ns and Above; 32-pin PDIP) (Volume: 50,000 per Year; Dollars)**

| | 1997 | | | | 1997 | 1998 | | | | 1998 | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Q1 | Q2 | Q3 | Q4 | Year | Q1 | Q2 | Q3 | Q4 | Year | (Weeks) |
| 128Kx8 ROM | 1.74 | 1.69 | 1.69 | 1.64 | 1.69 | 1.58 | 1.58 | 1.51 | 1.51 | 1.55 | 4-8 |
| 64Kx16 ROM | 2.00 | 1.92 | 1.88 | 1.80 | 1.90 | 1.73 | 1.73 | 1.66 | 1.66 | 1.70 | 4-8 |
| 256Kx8 ROM | 2.20 | 2.18 | 2.14 | 2.14 | 2.17 | 2.10 | 2.10 | 2.05 | 2.05 | 2.08 | 4-8 |
| 512Kx8 ROM | 3.10 | 3.00 | 2.90 | 2.80 | 2.95 | 2.70 | 2.70 | 2.66 | 2.66 | 2.68 | 4-8 |
| 256Kx16 ROM[1] | 3.10 | 3.00 | 2.90 | 2.80 | 2.95 | 2.70 | 2.70 | 2.66 | 2.66 | 2.68 | 4-8 |
| 1MbX8 ROM[2] | 4.00 | 3.90 | 3.80 | 3.70 | 3.85 | 3.62 | 3.62 | 3.53 | 3.53 | 3.58 | 4-8 |
| 1Mbx16 ROM | 6.00 | 5.80 | 5.70 | 5.65 | 5.79 | 5.55 | 5.55 | 5.46 | 5.46 | 5.51 | 4-8 |
| 2Mbx8 ROM | 5.87 | 5.72 | 5.70 | 5.65 | 5.74 | 5.55 | 5.55 | 5.46 | 5.46 | 5.51 | 4-8 |
| 2Mbx16 ROM | 12.00 | 11.75 | 11.50 | 11.30 | 11.64 | 11.00 | 11.00 | 10.74 | 10.74 | 10.87 | 4-8 |
| 4Mbx8 ROM | 12.00 | 11.60 | 11.40 | 11.30 | 11.58 | 11.00 | 11.00 | 10.74 | 10.74 | 10.87 | 4-8 |
| 4Mbx16 ROM | 16.00 | 15.80 | 15.40 | 15.00 | 15.55 | 14.50 | 14.50 | 14.00 | 14.00 | 14.25 | 4-9 |
| 8Mbx8 ROM | 15.50 | 15.30 | 15.20 | 14.90 | 15.23 | 14.40 | 14.40 | 13.90 | 13.90 | 14.15 | 4-9 |

[1]256Kx16 ROM: 150ns and above; 40-pin PDIP
[2]1Mbx8 ROM: 150ns and above; 32-pin SOP
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (August 1997)

**Table 2-10**
**Estimated Long-Range ROM Price Trends—North American Bookings (Speed/Package: ≤1Mb Density—150ns and Above; 28-pin PDIP; ≥2Mb Density—200ns and Above; 32-pin PDIP) (Volume: 50,000 per Year; Dollars)**

| Product | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| 128Kx8 ROM | 1.69 | 1.55 | 1.50 | 1.47 | 1.44 |
| 64Kx16 ROM | 1.90 | 1.70 | 1.63 | 1.61 | 1.59 |
| 256Kx8 ROM | 2.17 | 2.08 | 2.01 | 1.98 | 1.96 |
| 512Kx8 ROM | 2.95 | 2.68 | 2.60 | 2.56 | 2.52 |
| 256Kx16 ROM[1] | 2.95 | 2.68 | 2.60 | 2.56 | 2.52 |
| 1Mbx8 ROM[2] | 3.85 | 3.58 | 3.48 | 3.42 | 3.39 |
| 1Mbx16 ROM | 5.79 | 5.51 | 5.38 | 5.30 | 5.22 |
| 2Mbx8 ROM | 5.74 | 5.51 | 5.40 | 5.30 | 5.22 |
| 2Mbx16 ROM | 11.64 | 10.87 | 10.60 | 10.50 | 10.35 |
| 4Mbx8 ROM | 11.58 | 10.87 | 10.60 | 10.50 | 10.35 |
| 4Mbx16 ROM | 15.55 | 14.25 | 13.80 | 13.50 | 13.50 |
| 8Mbx8 ROM | 15.23 | 14.15 | 13.65 | 13.40 | 13.27 |

[1]256Kx16 ROM: 150ns and above; 40-pin PDIP
[2]1Mbx8 ROM: 150ns and above; 32-pin SOP
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (August 1997)

## Table 2-11
## Estimated EPROM Price Trends—North American Bookings (Volume: 50,000 per Year; Package: Windowed CERDIP; Speed: 150ns and Above; Dollars)

| | 1997 | | | | 1997 | 1998 | | | | 1998 | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Q1 | Q2 | Q3 | Q4 | Year | Q1 | Q2 | Q3 | Q4 | Year | (Weeks) |
| 32Kx8 EPROM | 1.37 | 1.36 | 1.33 | 1.32 | 1.35 | 1.32 | 1.29 | 1.28 | 1.27 | 1.29 | 2-3 |
| 64Kx8 EPROM | 1.43 | 1.43 | 1.39 | 1.39 | 1.41 | 1.38 | 1.36 | 1.33 | 1.31 | 1.34 | 2-3 |
| 128Kx8 EPROM | 1.93 | 1.90 | 1.83 | 1.80 | 1.87 | 1.73 | 1.73 | 1.70 | 1.70 | 1.72 | 2-3 |
| 256Kx8 EPROM | 2.77 | 2.77 | 2.75 | 2.73 | 2.76 | 2.68 | 2.66 | 2.52 | 2.50 | 2.59 | 2-3 |
| 128Kx16 EPROM | 3.65 | 3.31 | 3.20 | 3.13 | 3.32 | 3.08 | 3.03 | 2.82 | 2.80 | 2.93 | 2-3 |
| 512Kx8 EPROM | 4.97 | 4.68 | 4.58 | 4.51 | 4.69 | 4.38 | 4.32 | 4.20 | 4.17 | 4.26 | 2-3 |
| 256Kx16 EPROM | 7.58 | 6.38 | 6.24 | 6.15 | 6.59 | 6.10 | 5.78 | 5.43 | 5.08 | 5.59 | 2-3 |
| 1Mbx8 EPROM | 8.50 | 8.40 | 8.30 | 8.20 | 8.35 | 8.15 | 8.10 | 8.05 | 8.00 | 8.08 | 2-3 |
| 512Kx16 EPROM | 9.50 | 9.45 | 9.40 | 9.30 | 9.41 | 9.20 | 9.15 | 9.10 | 9.05 | 9.13 | 2-3 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (August 1997)

## Table 2-12
## Estimated Long-Range EPROM Price Trends—North American Bookings (Volume: 50,000 per Year; Package: Windowed CERDIP; Speed: 150ns and Above; Dollars)

| Product | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| 32Kx8 EPROM | 1.35 | 1.29 | 1.22 | 1.20 | 1.20 |
| 64Kx8 EPROM | 1.41 | 1.34 | 1.29 | 1.26 | 1.25 |
| 128Kx8 EPROM | 1.87 | 1.72 | 1.68 | 1.63 | 1.60 |
| 256Kx8 EPROM | 2.76 | 2.59 | 2.45 | 2.39 | 2.37 |
| 128Kx16 EPROM | 3.32 | 2.93 | 2.79 | 2.72 | 2.65 |
| 512Kx8 EPROM | 4.69 | 4.26 | 4.14 | 4.08 | 4.01 |
| 256Kx16 EPROM | 6.59 | 5.59 | 5.01 | 4.93 | 4.88 |
| 1Mbx8 EPROM | 8.35 | 8.08 | 7.98 | 7.89 | 7.81 |
| 512Kx16 EPROM | 9.41 | 9.13 | 8.94 | 8.87 | 8.79 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (August 1997)


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**Table 2-13**
**Estimated Flash Memory Price Trends—North American Bookings (12V; Volume: 10,000 per Year; Speed: 150ns; Dollars)**

| | 1997 | | | | 1997 | 1998 | | | | 1998 | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Q1 | Q2 | Q3 | Q4 | Year | Q1 | Q2 | Q3 | Q4 | Year | (Weeks) |
| 64Kx8 PDIP/PLCC | 2.75 | 2.61 | 2.44 | 2.33 | 2.53 | 2.19 | 2.15 | 2.15 | 2.15 | 2.16 | 5 |
| 64Kx8 TSOP | 2.83 | 2.68 | 2.63 | 2.59 | 2.68 | 2.43 | 2.38 | 2.29 | 2.19 | 2.32 | 5 |
| 128Kx8 PDIP/PLCC | 2.58 | 2.36 | 2.35 | 2.35 | 2.42 | 2.26 | 2.19 | 2.17 | 2.14 | 2.19 | 3 |
| 128Kx8 TSOP 12V | 2.80 | 2.54 | 2.44 | 2.43 | 2.55 | 2.24 | 2.21 | 2.18 | 2.18 | 2.20 | 4 |
| 128Kx8 TSOP 5V | 3.18 | 3.05 | 2.92 | 2.86 | 3.00 | 2.64 | 2.54 | 2.45 | 2.42 | 2.51 | 4 |
| 256Kx8 TSOP 12V | 5.57 | 5.00 | 4.91 | 4.81 | 5.07 | 4.51 | 4.42 | 4.32 | 4.09 | 4.33 | 4 |
| 256Kx8 TSOP/5V | 5.30 | 4.64 | 4.46 | 4.31 | 4.68 | 3.88 | 3.80 | 3.68 | 3.51 | 3.72 | 4 |
| 512Kx8 PDIP/PLCC | 5.60 | 5.17 | 4.88 | 4.68 | 5.08 | 4.29 | 4.17 | 4.01 | 3.82 | 4.07 | 4 |
| 512Kx8 TSOP 12V | 6.20 | 5.90 | 5.63 | 5.53 | 5.82 | 4.71 | 4.39 | 4.39 | 4.25 | 4.43 | 4 |
| 512Kx8 TSOP/5V | 6.28 | 5.75 | 5.38 | 5.23 | 5.66 | 4.63 | 4.31 | 4.26 | 4.11 | 4.33 | 4 |
| 512Kx8 SSOP/3V | 7.63 | 5.70 | 4.77 | 4.61 | 5.68 | 4.37 | 4.07 | 4.04 | 4.01 | 4.12 | 4 |
| 1Mbx8 TSOP/12V | 10.07 | 8.64 | 8.34 | 7.85 | 8.73 | 7.41 | 7.13 | 6.94 | 6.59 | 7.02 | 4 |
| 1Mbx8 TSOP/5V | 10.20 | 8.60 | 8.22 | 7.77 | 8.70 | 7.32 | 6.93 | 6.64 | 6.27 | 6.79 | 4 |
| 1Mbx8 TSOP/3V | 12.00 | 9.18 | 8.12 | 7.70 | 9.25 | 7.18 | 6.84 | 6.52 | 6.19 | 6.68 | 4 |
| 2Mbx8 TSOP/12V | 18.15 | 17.16 | 16.12 | 15.22 | 16.66 | 13.89 | 13.42 | 12.89 | 12.22 | 13.10 | 4 |
| 2Mbx8 TSOP/5V | 18.50 | 16.97 | 15.96 | 15.04 | 16.62 | 13.81 | 13.27 | 12.73 | 12.10 | 12.98 | 4 |
| 2Mbx8 TSOP/3V | 20.00 | 17.71 | 16.52 | 15.50 | 17.43 | 13.81 | 13.19 | 12.54 | 11.95 | 12.87 | 4 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (August 1997)


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## Table 2-14
## Estimated Long-Range Flash Memory Price Trends—North American Bookings (12V; Volume: 10,000 per Year; Speed: 150ns; Dollars)

| Product | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| 64Kx8 PDIP/PLCC | 2.53 | 2.16 | 2.15 | 2.14 | 2.14 |
| 64Kx8 TSOP | 2.68 | 2.32 | 2.18 | 2.17 | 2.16 |
| 128Kx8 PDIP/PLCC | 2.42 | 2.19 | 2.13 | 2.12 | 2.12 |
| 128Kx8 TSOP 12V | 2.55 | 2.20 | 2.16 | 2.15 | 2.15 |
| 128Kx8 TSOP 5V | 3.00 | 2.51 | 2.35 | 2.30 | 2.27 |
| 256Kx8 TSOP 12V | 5.07 | 4.33 | 4.00 | 3.90 | 3.86 |
| 256Kx8 TSOP/5V | 4.68 | 3.72 | 3.44 | 3.37 | 3.32 |
| 512Kx8 PDIP/PLCC | 5.08 | 4.07 | 3.72 | 3.60 | 3.54 |
| 512Kx8 TSOP 12V | 5.82 | 4.43 | 4.14 | 4.03 | 3.89 |
| 512Kx8 TSOP/5V | 5.66 | 4.33 | 4.00 | 3.88 | 3.77 |
| 512Kx8 SSOP/3V | 5.68 | 4.12 | 3.87 | 3.74 | 3.66 |
| 1Mbx8 TSOP/12V | 8.73 | 7.02 | 6.30 | 6.17 | 6.02 |
| 1Mbx8 TSOP/5V | 8.70 | 6.79 | 6.00 | 5.87 | 5.75 |
| 1Mbx8 TSOP/3V | 9.25 | 6.68 | 5.94 | 5.79 | 5.56 |
| 2Mbx8 TSOP/12V | 16.66 | 13.10 | 11.75 | 10.85 | 10.26 |
| 2Mbx8 TSOP/5V | 16.62 | 12.98 | 11.44 | 10.65 | 10.11 |
| 2Mbx8 TSOP/3V | 17.43 | 12.87 | 10.88 | 10.11 | 9.81 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (August 1997)


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## Table 2-15
## Estimated Gate Array Pricing—North American Production Bookings (Volume: 20,000 Units; Based on Utilized Gates Only; NRE = Netlist to Prototype; Millicents per Gate)

| Gate Count | 10-29.99K Gates | | | 30-59.99K Gates | | | 60-99.99K Gates | | | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|
| Technology | 1997 | 1998 | 1999 | 1997 | 1998 | 1999 | 1997 | 1998 | 1999 | (Weeks) |
| CMOS | | | | | | | | | | Production: |
| 0.8 Micron | 21.00 | 20.00 | 19.00 | 17.00 | 16.00 | 14.00 | 15.00 | 14.00 | 13.00 | 4-12 |
| 0.6 Micron | 24.00 | 23.00 | 22.00 | 17.00 | 15.00 | 14.00 | 17.00 | 16.00 | 15.00 | 4-12 |
| 0.5 Micron | 26.00 | 25.00 | 24.00 | 22.00 | 21.00 | 20.00 | 20.00 | 18.00 | 17.00 | 4-12 |
| 0.35 Micron | 36.00 | 34.00 | 34.00 | 33.00 | 29.00 | 28.00 | 21.00 | 20.00 | 19.00 | 4-12 |
| | | | | | | | | | | Prototypes: |
| NRE CMOS Average Charge ($K) | 44.00 | 44.00 | 43.00 | 54.00 | 52.00 | 52.00 | 74.00 | 73.00 | 73.00 | 1-4 |

| Gate Count | 100-299.99K Gates | | | >300K Gates | | | Lead Time |
|---|---|---|---|---|---|---|---|
| Technology | 1997 | 1998 | 1999 | 1997 | 1998 | 1999 | (Weeks) |
| CMOS | | | | | | | Production: |
| 0.8 Micron | 24.00 | 22.00 | 21.00 | NR | NR | NR | 4-12 |
| 0.6 Micron | 23.00 | 22.00 | 21.00 | 30.00 | 30.00 | 29.00 | 4-12 |
| 0.5 Micron | 27.00 | 24.00 | 22.00 | 33.00 | 32.00 | 32.00 | 4-12 |
| 0.35 Micron | 32.00 | 31.00 | 30.00 | 41.00 | 39.00 | 38.00 | 4-12 |
| | | | | | | | Prototypes: |
| NRE CMOS Average Charge ($K) | 107.00 | 106.00 | 105.00 | 123.00 | 120.00 | 120.00 | 1-4 |

NR = Not relevant
NRE = Nonrecurring engineering charge
Notes: The actual NRE may vary from these because of device amortization, testing, intellectual property rights, and other factors. Actual negotiated market prices may vary substantially from these because of manufacturer-specific factors such as intellectual property rights, alliances, service, package types, pad or core constraints, and volume discount. For volumes of 1 million or greater, discount the above prices by a further 50 to 60 percent. For core-limited solutions with volumes greater than 10,000 units, CBICs may be more cost-effective than gate arrays.
Source: Dataquest (August 1997)


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## Table 2-16
## Estimated CBIC Pricing—North American Production Bookings (Volume: 20,000 Units; Based on Utilized Gates Only; NRE = Netlist to Prototype; Millicents per Gate)

| Gate Count | 10-29.99K Gates | | | 30-59.99K Gates | | | 60-99.99K Gates | | | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|
| Technology | 1997 | 1998 | 1999 | 1997 | 1998 | 1999 | 1997 | 1998 | 1999 | (Weeks) |
| CMOS | | | | | | | | | | Production: |
| 0.8 Micron | 25.00 | 24.00 | 22.00 | 17.00 | 16.00 | 14.00 | 13.00 | 11.00 | 10.00 | 7-15 |
| 0.6 Micron | 26.00 | 25.00 | 24.00 | 18.00 | 16.00 | 15.00 | 13.00 | 12.00 | 10.00 | 7-15 |
| 0.5 Micron | 28.00 | 27.00 | 26.00 | 25.00 | 24.00 | 22.00 | 20.00 | 18.00 | 17.00 | 7-15 |
| 0.35 Micron | 40.00 | 39.00 | 38.00 | 38.00 | 35.00 | 34.00 | 25.00 | 24.00 | 22.00 | 7-15 |
| | | | | | | | | | | Prototypes: |
| NRE CMOS Average Charge ($K) | 68.00 | 67.00 | 65.00 | 72.00 | 72.00 | 71.00 | 83.00 | 83.00 | 83.00 | 3-6 |

| Gate Count | 100-299.99K Gates | | | >300K Gates | | | Lead Time |
|---|---|---|---|---|---|---|---|
| Technology | 1997 | 1998 | 1999 | 1997 | 1998 | 1999 | (Weeks) |
| CMOS | | | | | | | Production: |
| 0.8 Micron | 17.00 | 15.00 | 14.00 | NR | NR | NR | 7-15 |
| 0.6 Micron | 15.00 | 14.00 | 13.00 | 19.00 | 18.00 | 17.00 | 7-15 |
| 0.5 Micron | 14.00 | 12.00 | 10.00 | 17.00 | 15.00 | 14.00 | 7-15 |
| 0.35 Micron | 12.00 | 11.00 | 10.00 | 11.00 | 9.00 | 8.00 | 7-15 |
| | | | | | | | Prototypes: |
| NRE CMOS Average Charge ($K) | 133.00 | 132.00 | 132.00 | 163.00 | 161.00 | 160.00 | 3-6 |

NR = Not relevant
NRE = Nonrecurring engineering charge
Notes: The actual NRE may vary from these because of device amortization, testing, intellectual property rights, and other factors. Actual negotiated market prices may vary substantially from these because of manufacturer-specific factors such as intellectual property rights, alliances, service, package types, pad or core constraints, and volume discount. For volumes of 1 million or greater, discount the above prices by a further 50 to 60 percent. For core-limited solutions with volumes greater than 10,000 units, CBICs may be more cost-effective than gate arrays.
Source: Dataquest (August 1997)


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**For More Information...**

Evelyn Cronin, Senior Industry Analyst..... (408) 468-8075
Internet address..... evelyn.cronin@dataquest.com
Via fax..... (408) 954-1780
Dataquest Interactive..... http://www.dataquest.com

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## DATAQUEST WORLDWIDE OFFICES


**NORTH AMERICA**

**Worldwide Headquarters**
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: 1-408-468-8000
Facsimile: 1-408-954-1780

**East Coast Research Center**
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6262

**Dataquest Global Events**
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

**EUROPE**

**European Headquarters**
Tamesis, The Glanty
Egham, Surrey TW20 9AW
United Kingdom
Phone: +44 1784 431 611
Facsimile: +44 1784 488 980

**Dataquest France**
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: +33 1 41 35 13 00
Facsimile: +33 1 41 35 13 13

**Dataquest Germany**
Martin-Kollar-Strasse 15
D-81829 München
Germany
Phone: +49 89 42 70 4-0
Facsimile: +49 89 42 70 4-270

**JAPAN**

**Japan Headquarters**
Aobadai Hills 4-7-7
Aobadai
Meguro-ku, Tokyo 153
Japan
Phone: 81-3-3481-3670
Facsimile: 81-3-3481-3644

**ASIA/PACIFIC**

**Asia/Pacific Headquarters**
Suite 5904-7, Central Plaza
18 Harbour Road, Wanchai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

**Dataquest Korea**
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

**Dataquest Taiwan**
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

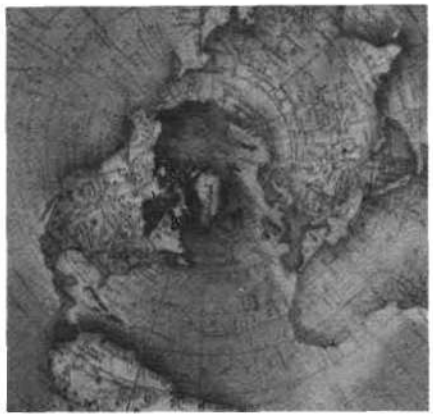
**Dataquest Singapore**
105 Cecil Street
#06-01/02 The Octagon
Singapore 069534
Phone: 65-227-1213
Facsimile: 65-227-4607

**Dataquest Thailand**
12/F, Vanissa Building
29 Soi Chidlom
Ploenchit Road
Patumwan, Bangkok 10330
Thailand
Phone: 662-655-0577
Facsimile: 662-655-0576

**Dataquest Australia**
80 Alfred Street
Milsons Point NSW 2061
Australia
Phone: 61-2-9941-4860
Facsimile: 61-2-9941-4868


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# North American Semiconductor Price Outlook—Third Quarter 1997

Market Statistics

**Program:** Semiconductor Supply and Pricing Worldwide
**Product Code:** SSPS-WW-MS-9703
**Publication Date:** June 23, 1997
**Filing:** Market Statistics

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# Table of Contents

Page

1. North American Semiconductor Price Outlook—Third Quarter 1997 1
   Methodology and Sources ..... 1
   Price Variations ..... 1
2. Market Statistics Tables ..... 3

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# List of Tables


| Table | | Page |
|---|---|---|
| 2-1 | Estimated Standard Logic Price Trends—North American Bookings | 3 |
| 2-2 | Estimated Long-Range Standard Logic Price Trends—North American Bookings | 4 |
| 2-3 | Estimated Microprocessor Price Trends—North American Bookings | 5 |
| 2-4 | Estimated Long-Range Microprocessor Price Trends—North American Bookings | 6 |
| 2-5 | Estimated DRAM Price Trends—North American Bookings | 7 |
| 2-6 | Estimated Long-Range DRAM Price Trends—North American Bookings | 9 |
| 2-7 | Estimated Static RAM Price Trends—North American Bookings | 10 |
| 2-8 | Estimated Long-Range Static RAM Price Trends—North American Bookings | 11 |
| 2-9 | Estimated ROM Price Trends—North American Bookings | 12 |
| 2-10 | Estimated Long-Range ROM Price Trends—North American Bookings | 12 |
| 2-11 | Estimated EPROM Price Trends—North American Bookings | 13 |
| 2-12 | Estimated Long-Range EPROM Price Trends—North American Bookings | 13 |
| 2-13 | Estimated Flash Memory Price Trends—North American ookings | 14 |
| 2-14 | Estimated Long-Range Flash Memory Price Trends—North American Bookings | 15 |
| 2-15 | Estimated Gate Array Pricing—North American Production Bookings | 16 |
| 2-16 | Estimated CBIC Pricing—North American Production Bookings | 17 |


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# Chapter 1
# North American Semiconductor Price Outlook—Third Quarter 1997

## Methodology and Sources

This document provides information on and forecasts for the North American bookings prices of more than 200 semiconductor devices. Dataquest collects price information on a quarterly basis from North American suppliers and major buyers of these products. North American bookings price information is analyzed by Semiconductor Supply and Pricing Worldwide (SSPS) analysts for consistency and reconciliation. The information finally is rationalized with worldwide billings price data in association with product analysts, resulting in the current forecast. This document includes associated long-range forecasts.

For SSPS clients that use the SSPS online service through CompuServe, the prices presented here correlate with the quarterly and long-range price tables dated June 1997 in the SSPS online service. Clients who want to access the information via the World Wide Web can pay extra for a Dataquest Interactive subscription, which allows users to access all their deliverables at their desktops. For additional product coverage and more detailed product specifications, please refer to those sources.

### Price Variations

Actual negotiated market prices may vary from these prices 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 value of a company's product. These prices are intended for use as price guidelines.


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# Chapter 2
# Market Statistics Tables

## Table 2-1
## Estimated Standard Logic Price Trends—North American Bookings
## (Volume: 100,000 per Year; Package: PLCC; Dollars)

| Product | 1997 Q1 | Q2 | Q3 | Q4 | 1997 Year | 1998 Q1 | Q2 | Q3 | Q4 | 1998 Year | Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 74LS TTL | | | | | | | | | | | |
| 74LS00 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 3-6 |
| 74LS74 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 3-6 |
| 74LS138 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 3-6 |
| 74LS244 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 3-6 |
| 74AC TTL | | | | | | | | | | | |
| 74AC00 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 3-6 |
| 74AC74 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.19 | 0.19 | 0.18 | 0.18 | 0.19 | 3-6 |
| 74AC138 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.28 | 0.28 | 0.27 | 0.27 | 0.28 | 3-6 |
| 74AC244 | 0.40 | 0.40 | 0.39 | 0.39 | 0.39 | 0.36 | 0.35 | 0.35 | 0.35 | 0.35 | 3-6 |
| 74F TTL | | | | | | | | | | | |
| 74F00 | 0.13 | 0.13 | 0.14 | 0.14 | 0.14 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 3-6 |
| 74F74 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 3-6 |
| 74F138 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 3-6 |
| 74F244 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 3-6 |
| 74HC CMOS | | | | | | | | | | | |
| 74HC00 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 3-6 |
| 74HC74 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 3-6 |
| 74HC138 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 3-6 |
| 74HC244 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 3-6 |
| 74ALS TTL | | | | | | | | | | | |
| 74ALS00 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 3-6 |
| 74ALS74 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 3-6 |
| 74ALS138 | 0.22 | 0.21 | 0.21 | 0.21 | 0.21 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 3-6 |
| 74ALS244 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 3-6 |
| 74AS TTL | | | | | | | | | | | |
| 74AS00 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 3-6 |
| 74AS74 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 3-6 |
| 74AS138 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 3-6 |
| 74AS244 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 3-6 |
| 74BC* | | | | | | | | | | | |
| 74BC00 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.19 | 0.19 | 0.18 | 0.18 | 0.19 | 3-6 |
| 74BC244 | 0.53 | 0.53 | 0.53 | 0.53 | 0.53 | 0.48 | 0.47 | 0.46 | 0.46 | 0.47 | 3-6 |
| 74BC373 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.50 | 0.49 | 0.46 | 0.46 | 0.48 | 3-6 |
| 74ACT244 | 0.42 | 0.42 | 0.41 | 0.41 | 0.41 | 0.39 | 0.37 | 0.37 | 0.36 | 0.37 | 3-6 |
| 74ACT245 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.40 | 0.39 | 0.39 | 0.37 | 0.39 | 3-6 |
| 74ABT244 | 0.58 | 0.58 | 0.58 | 0.57 | 0.58 | 0.53 | 0.53 | 0.51 | 0.48 | 0.51 | 3-6 |
| 74ABT245 | 0.62 | 0.62 | 0.62 | 0.61 | 0.62 | 0.57 | 0.56 | 0.55 | 0.52 | 0.55 | 3-6 |

*Pricing for 74BC excludes 74ABT and 74BCT.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (June 1997)


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## Table 2-2
## Estimated Long-Range Standard Logic Price Trends—North American Bookings (Volume: 100,000 per Year; Package: PLCC; Dollars)

| Product | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| 74LS TTL | | | | | |
| 74LS00 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| 74LS74 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |
| 74LS138 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| 74LS244 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 |
| 74AC TTL | | | | | |
| 74AC00 | 0.17 | 0.15 | 0.14 | 0.14 | 0.13 |
| 74AC74 | 0.20 | 0.19 | 0.18 | 0.17 | 0.17 |
| 74AC138 | 0.29 | 0.28 | 0.26 | 0.25 | 0.24 |
| 74AC244 | 0.39 | 0.35 | 0.34 | 0.32 | 0.32 |
| 74F TTL | | | | | |
| 74F00 | 0.14 | 0.13 | 0.13 | 0.13 | 0.13 |
| 74F74 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| 74F138 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |
| 74F244 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 |
| 74HC CMOS | | | | | |
| 74HC00 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| 74HC74 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 |
| 74HC138 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| 74HC244 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| 74ALS TTL | | | | | |
| 74ALS00 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| 74ALS74 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |
| 74ALS138 | 0.21 | 0.20 | 0.19 | 0.19 | 0.19 |
| 74ALS244 | 0.30 | 0.27 | 0.25 | 0.24 | 0.24 |
| 74AS TTL | | | | | |
| 74AS00 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| 74AS74 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| 74AS138 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| 74AS244 | 0.63 | 0.62 | 0.61 | 0.6 | 0.6 |
| 74BC* | | | | | |
| 74BC00 | 0.20 | 0.19 | 0.18 | 0.17 | 0.17 |
| 74BC244 | 0.53 | 0.47 | 0.45 | 0.44 | 0.43 |
| 74BC373 | 0.55 | 0.48 | 0.44 | 0.42 | 0.41 |
| 74ACT244 | 0.41 | 0.37 | 0.35 | 0.33 | 0.32 |
| 74ACT245 | 0.44 | 0.39 | 0.36 | 0.35 | 0.35 |
| 74ABT244 | 0.58 | 0.51 | 0.47 | 0.45 | 0.44 |
| 74ABT245 | 0.62 | 0.55 | 0.51 | 0.49 | 0.48 |

*Pricing for 74BC excludes 74ABT and 74BCT.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (June 1997)

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## Table 2-3
## Estimated Microprocessor Price Trends—North American Bookings
## (Volume: 25,000 per Year; Dollars) (Package: 32/64-Bit Devices—Ceramic PGA; Exceptions Noted)

| Product | 1997 Q1 | Q2 | Q3 | Q4 | 1997 Year | 1998 Q1 | Q2 | Q3 | Q4 | 1998 Year | Lead Times (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 68EC020-25 PQFP | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 2-8 |
| 68EC030-25 PQFP | 19.00 | 18.75 | 18.75 | 18.75 | 18.81 | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 | 2-8 |
| 68040-25 | 25.00 | 24.00 | 24.00 | 22.00 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 2-8 |
| 68LC040-25 CQFP 184 | 25.00 | 24.00 | 24.00 | 22.00 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 2-8 |
| Pentium-75 | 70.00 | 70.00 | 70.00 | 70.00 | 70.00 | EOL | EOL | EOL | EOL | EOL | 2-8 |
| Pentium-90 | 70.00 | 70.00 | 70.00 | 70.00 | 70.00 | EOL | EOL | EOL | EOL | EOL | 2-8 |
| Pentium-100 3.3V | 75.00 | 75.00 | 70.00 | 70.00 | 72.50 | 70.00 | 70.00 | EOL | EOL | EOL | 2-8 |
| Pentium-100 2.9V | 90.00 | 90.00 | 85.00 | 85.00 | 87.50 | 85.00 | 85.00 | EOL | EOL | EOL | 2-8 |
| Pentium-120 3.3V | 90.00 | 85.00 | 85.00 | 85.00 | 86.25 | 85.00 | 85.00 | EOL | EOL | EOL | 2-8 |
| Pentium-120 2.9V | 90.00 | 85.00 | 85.00 | 85.00 | 86.25 | 85.00 | 85.00 | EOL | EOL | EOL | 2-8 |
| Pentium-133 3.3V | 110.00 | 100.00 | 100.00 | 100.00 | 102.50 | 100.00 | 100.00 | EOL | EOL | EOL | 2-8 |
| Pentium-133 2.9V | 150.00 | 140.00 | 100.00 | 100.00 | 122.50 | 100.00 | 100.00 | EOL | EOL | EOL | 2-8 |
| Pentium-150 3.3V | 140.00 | 140.00 | 100.00 | 100.00 | 120.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 2-8 |
| Pentium-150 2.9V | 250.00 | 225.00 | 130.00 | 115.00 | 180.00 | 115.00 | 115.00 | 115.00 | 115.00 | 115.00 | 2-8 |
| Pentium-166 3.3V | 295.00 | 200.00 | 120.00 | 100.00 | 178.75 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 2-8 |
| Pentium-200 3.3V | 450.00 | 250.00 | 145.00 | 120.00 | 241.25 | 120.00 | 120.00 | 120.00 | 120.00 | 120.00 | 2-8 |
| Pentium MMX 166-MHz 2.8V PGA | 350.00 | 260.00 | 200.00 | 150.00 | 240.00 | 150.00 | 150.00 | 150.00 | 150.00 | 150.00 | 2-8 |
| Pentium MMX 200-MHz 2.8V PGA | 500.00 | 400.00 | 330.00 | 260.00 | 372.50 | 260.00 | 260.00 | 260.00 | 260.00 | 260.00 | 2-8 |
| Pentium MMX 233-MHz 2.8V PGA | NA | 600.00 | 430.00 | 380.00 | 470.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 2-8 |
| Pentium Pro-166C | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 | EOL | EOL | EOL | EOL | EOL | 2-8 |
| Pentium Pro-180 256K Cache | 410.00 | 330.00 | 330.00 | 330.00 | 350.00 | 330.00 | 330.00 | 330.00 | 330.00 | 330.00 | 2-8 |
| Pentium Pro-200 256K Cache | 475.00 | 475.00 | 450.00 | 450.00 | 462.50 | 450.00 | 450.00 | 450.00 | 450.00 | 450.00 | 2-8 |
| Pentium Pro-200 512K Cache | 993.00 | 993.00 | 985.00 | 985.00 | 989.00 | 985.00 | 985.00 | 985.00 | 985.00 | 985.00 | 2-8 |
| Pentium II 233-MHz 512K Cache | NA | 600.00 | 500.00 | 450.00 | 516.67 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 2-8 |
| Pentium II 266-MHz 512K Cache | NA | 750.00 | 650.00 | 600.00 | 666.67 | 550.00 | 550.00 | 550.00 | 550.00 | 550.00 | 2-8 |
| Pentium II 300-MHz 512K Cache | NA | 1,900.00 | 1,900.00 | 1,800.00 | 1,866.67 | 1,700.00 | 1,700.00 | 1,700.00 | 1,700.00 | 1,700.00 | 2-8 |
| PowerPC 601-80 | 70.00 | 68.00 | 68.00 | 68.00 | 68.50 | EOL | EOL | EOL | EOL | EOL | 2-8 |
| PowerPC 601-100 | 80.00 | 75.00 | 75.00 | 75.00 | 76.25 | EOL | EOL | EOL | EOL | EOL | 2-8 |
| PowerPC 603-80 | 63.00 | 61.00 | 61.00 | 60.00 | 61.25 | 60.00 | 60.00 | 60.00 | 60.00 | 60.00 | 2-8 |
| Powe PC 603-133 | 125.00 | 113.00 | 110.00 | 100.00 | 112.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 2-8 |
| PowerPC 604-166 | 200.00 | 167.00 | 167.00 | 160.00 | 173.50 | 130.00 | 130.00 | 130.00 | 130.00 | 130.00 | 2-8 |
| PowerPC 604-225 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 370.00 | 270.00 | 250.00 | 250.00 | 285.00 | 2-8 |
| PowerPC 604-240 | 500.00 | 450.00 | 400.00 | 400.00 | 437.50 | 400.00 | 375.00 | 375.00 | 350.00 | 375.00 | 2-8 |

EOL = End of life
NA = Not available
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (June 1997)


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**Table 2-4**
**Estimated Long-Range Microprocessor Price Trends—North American Bookings**
**(Volume: 25,000 per Year; Dollars)**
**(Package: 32/64 Bit Devices—Ceramic PGA; Exceptions Noted)**

| Product | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| 68EC020-25 PQFP | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 |
| 68EC030-25 PQFP | 18.81 | 18.75 | 18.75 | 18.75 | 18.75 |
| 68040-25 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 |
| 68LC040-25 CQFP 184 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 |
| Pentium-75 | 70.00 | EOL | EOL | EOL | EOL |
| Pentium-90 | 70.00 | EOL | EOL | EOL | EOL |
| Pentium-100 3.3V | 72.50 | EOL | EOL | EOL | EOL |
| Pentium-100 2.9V | 87.50 | EOL | EOL | EOL | EOL |
| Pentium-120 3.3V | 86.25 | EOL | EOL | EOL | EOL |
| Pentium-120 2.9V | 86.25 | EOL | EOL | EOL | EOL |
| Pentium-133 3.3V | 102.50 | EOL | EOL | EOL | EOL |
| Pentium-133 2.9V | 122.50 | EOL | EOL | EOL | EOL |
| Pentium-150 3.3V | 120.00 | 100.00 | EOL | EOL | EOL |
| Pentium-150 2.9V | 180.00 | 115.00 | EOL | EOL | EOL |
| Pentium-166 3.3V | 178.75 | 100.00 | 100.00 | EOL | EOL |
| Pentium-200 3.3V | 241.25 | 120.00 | 120.00 | EOL | EOL |
| Pentium MMX 166 MHz 2.8V PGA | 240.00 | 150.00 | 150.00 | EOL | EOL |
| Pentium MMX 200 MHz 2.8V PGA | 372.50 | 260.00 | 200.00 | EOL | EOL |
| Pentium MMX 233-MHz 2.8V PGA | 470.00 | 300.00 | 275.00 | EOL | EOL |
| Pentium Pro-166C | 600.00 | EOL | EOL | EOL | EOL |
| Pentium Pro-180 256K Cache | 350.00 | 330.00 | 225.00 | EOL | EOL |
| Pentium Pro-200 256K Cache | 462.50 | 450.00 | 375.00 | EOL | EOL |
| Pentium Pro-200 512K Cache | 989.00 | 985.00 | 635.00 | EOL | EOL |
| Pentium II 233-MHz 512K Cache | 516.67 | 400.00 | 330.00 | 300.00 | EOL |
| Pentium II 266-MHz 512K Cache | 666.67 | 550.00 | 450.00 | 450.00 | EOL |
| Pentium II 300-MHz 512K Cache | 1,866.67 | 1,700.00 | 1,600.00 | 1,600.00 | EOL |
| PowerPC 601-80 | 68.50 | EOL | EOL | EOL | EOL |
| PowerPC 601-100 | 76.25 | EOL | EOL | EOL | EOL |
| PowerPC 603-80 | 61.25 | 60.00 | EOL | EOL | EOL |
| Power PC 603-133 | 112.00 | 90.00 | EOL | EOL | EOL |
| Power PC 604-166 | 173.5 | 130 | EOL | EOL | EOL |
| Power PC 604-225 | 400 | 285 | EOL | EOL | EOL |
| Power PC 604-240 | 437.5 | 375 | EOL | EOL | EOL |

EOL = End of life
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (June 1997)

## Table 2-5
## Estimated DRAM Price Trends—North American Bookings (Contract Volume; U.S. Dollars)*

| Product | 1997 Q1 | Q2 | Q3 | Q4 | 1997 Year | 1998 Q1 | Q2 | Q3 | Q4 | 1998 Year | Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4Mbx1 DRAM 70ns SOJ 5V | 2.60 | 2.55 | 2.50 | 2.50 | 2.54 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 3-8 |
| 1Mbx4 DRAM 60ns SOJ 5V FPM | 2.40 | 2.35 | 2.32 | 2.35 | 2.36 | 2.38 | 2.38 | 2.38 | 2.40 | 2.39 | 3-8 |
| 1Mbx4 DRAM 60ns SOJ 5V EDO | 2.40 | 2.35 | 2.30 | 2.30 | 2.34 | 2.30 | 2.30 | 2.30 | 2.30 | 2.30 | 3-8 |
| 512Kx8 DRAM 70ns 5V | 2.82 | 2.66 | 2.60 | 2.55 | 2.66 | 2.49 | 2.47 | 2.44 | 2.44 | 2.46 | 3-8 |
| 256Kx16 DRAM 70ns SOJ 5V | 3.36 | 3.30 | 3.25 | 3.21 | 3.28 | 3.24 | 3.24 | 3.25 | 3.25 | 3.25 | 3-8 |
| 4Mbx4 DRAM 60 ns SOJ 5V FPM | 8.66 | 8.73 | 8.09 | 8.00 | 8.37 | 7.92 | 7.80 | 7.75 | 7.67 | 7.79 | 3-8 |
| 4Mbx4 DRAM 60ns SOJ 5V EDO | 8.66 | 8.52 | 8.04 | 7.93 | 8.29 | 7.84 | 7.74 | 7.69 | 7.59 | 7.72 | 3-8 |
| 1Mbx16 DRAM 60ns TSOP 5V FPM | 8.03 | 8.48 | 8.09 | 8.00 | 8.15 | 7.92 | 7.80 | 7.75 | 7.67 | 7.79 | 3-8 |
| 1Mbx16 DRAM 60ns TSOP 5V EDO | 8.03 | 8.46 | 8.01 | 7.90 | 8.10 | 7.82 | 7.74 | 7.69 | 7.59 | 7.71 | 3-8 |
| 1Mbx16 3.3V SDRAM | 10.25 | 9.73 | 9.53 | 9.30 | 9.70 | 8.69 | 8.40 | 8.29 | 8.19 | 8.39 | 3-8 |
| 2Mbx8 DRAM 60ns TSOP 5V FPM | 9.00 | 8.86 | 8.11 | 8.01 | 8.50 | 7.92 | 7.80 | 7.75 | 7.67 | 7.79 | 3-8 |
| 16Mbx4 DRAM SOJ 60ns 3.3V EDO | 75.00 | 57.00 | 48.88 | 44.30 | 56.29 | 39.18 | 38.00 | 34.66 | 30.00 | 35.46 | 3-8 |
| 16Mbx4 DRAM SOJ 3.3V SDRAM | 75.00 | 56.75 | 48.36 | 43.05 | 55.79 | 37.43 | 37.29 | 32.44 | 28.00 | 33.79 | 3-8 |
| 8Mbx8 DRAM SOJ 60ns 3.3V EDO | 75.00 | 57.00 | 48.88 | 44.30 | 56.29 | 39.18 | 38.00 | 34.66 | 30.00 | 35.46 | 3-8 |
| 8Mbx8 DRAM SOJ 3.3V SDRAM | 75.00 | 56.75 | 48.36 | 43.05 | 55.79 | 37.43 | 37.29 | 32.44 | 28.00 | 33.79 | 3-8 |
| 1Mbx32 SIMM 60ns 5V FPM | 19.00 | 19.88 | 19.38 | 19.29 | 19.39 | 18.69 | 18.63 | 18.35 | 18.29 | 18.49 | 3-8 |
| 1Mbx36 SIMM 60ns 5V FPM | 21.00 | 21.80 | 21.51 | 21.44 | 21.44 | 20.80 | 20.69 | 20.58 | 20.36 | 20.61 | 3-8 |
| 2Mbx32 SIMM 60ns 5V FPM | 36.12 | 39.16 | 38.44 | 37.52 | 37.81 | 36.06 | 35.70 | 35.27 | 34.96 | 35.50 | 3-8 |
| 2Mbx36 SIMM 60ns 5V FPM | 41.50 | 43.38 | 42.98 | 42.71 | 42.64 | 40.06 | 39.90 | 39.67 | 39.43 | 39.77 | 3-8 |
| 4Mbx32 SIMM 60ns 5V FPM | 72.20 | 73.22 | 72.46 | 71.71 | 72.40 | 68.56 | 67.26 | 66.31 | 65.87 | 67.00 | 3-8 |
| 4Mbx36 SIMM 60ns 5V FPM | 82.75 | 83.41 | 82.94 | 82.07 | 82.79 | 77.95 | 76.78 | 75.59 | 74.57 | 76.22 | 3-8 |
| 8Mbx32 SIMM 60ns 5V FPM | 141.20 | 145.28 | 142.79 | 141.52 | 142.70 | 134.74 | 132.20 | 130.61 | 129.27 | 131.71 | 3-8 |
| 8Mbx36 SIMM 60ns 5V FPM | 164.25 | 166.52 | 159.13 | 157.33 | 161.81 | 155.29 | 152.82 | 149.22 | 147.08 | 151.10 | 3-8 |
| 1Mbx32 SIMM 60ns 5V EDO | 19.00 | 19.81 | 19.32 | 19.14 | 19.32 | 18.60 | 18.54 | 18.28 | 18.25 | 18.42 | 3-8 |
| 1Mbx36 SIMM 60ns 5V EDO | 21.00 | 21.76 | 21.49 | 21.39 | 21.41 | 20.74 | 20.56 | 20.46 | 20.22 | 20.50 | 3-8 |
| 2Mbx32 SIMM 60ns 5V EDO | 36.12 | 38.16 | 37.48 | 37.10 | 37.22 | 35.65 | 35.24 | 34.77 | 34.43 | 35.02 | 3-8 |
| 2Mbx36 SIMM 60ns 5V EDO | 41.50 | 43.18 | 41.97 | 40.79 | 41.86 | 39.91 | 39.69 | 39.57 | 39.22 | 39.60 | 3-8 |
| 4Mbx32 SIMM 60ns 5V EDO | 72.20 | 72.20 | 71.69 | 70.97 | 71.77 | 68.09 | 67.09 | 66.17 | 65.25 | 66.65 | 3-8 |
| 4Mbx36 SIMM 60ns 5V EDO | 82.75 | 83.21 | 82.09 | 80.62 | 82.17 | 77.65 | 76.40 | 75.25 | 73.91 | 75.80 | 3-8 |


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## Table 2-5 (Continued)
## Estimated DRAM Price Trends—North American Bookings (Contract Volume; U.S. Dollars)*

| Product | 1997 Q1 | Q2 | Q3 | Q4 | 1997 Year | 1998 Q1 | Q2 | Q3 | Q4 | 1998 Year | Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8Mbx32 SIMM 60ns 5V EDO | 141.20 | 143.07 | 140.13 | 136.24 | 140.16 | 131.19 | 129.63 | 127.58 | 127.58 | 129.00 | 3-8 |
| 8Mbx36 SIMM 60ns 5V EDO | 164.25 | 165.12 | 159.63 | 157.60 | 161.65 | 154.19 | 151.21 | 148.53 | 145.76 | 149.92 | 3-8 |
| 1Mbx64 60ns 3.3V EDO | 41.38 | 39.62 | 37.15 | 35.86 | 38.50 | 34.92 | 34.30 | 33.89 | 33.27 | 34.09 | 3-8 |
| 2Mbx64 60ns 3.3V EDO | 75.75 | 72.53 | 69.62 | 68.02 | 71.48 | 66.81 | 65.20 | 63.92 | 62.44 | 64.59 | 3-8 |
| 4Mbx64 60ns 3.3V EDO | 146.24 | 140.17 | 134.82 | 133.60 | 138.71 | 129.52 | 126.42 | 124.06 | 121.66 | 125.42 | 3-8 |
| 1Mbx64 3.3V SDRAM | 42.13 | 40.58 | 39.03 | 38.15 | 39.97 | 34.87 | 34.20 | 33.69 | 33.23 | 34.00 | 3-8 |
| 2Mbx64 3.3V SDRAM | 79.25 | 78.60 | 71.01 | 68.21 | 74.27 | 67.01 | 64.96 | 63.20 | 61.44 | 64.15 | 3-8 |
| 4Mbx64 3.3V SDRAM | 149.00 | 141.00 | 136.88 | 133.93 | 140.20 | 129.44 | 126.00 | 123.45 | 121.25 | 125.04 | 3-8 |
| 256Kx16 VRAM 70ns SOP | 11.60 | 10.05 | 9.75 | 9.15 | 10.14 | 9.10 | 9.05 | 9.00 | 8.90 | 9.01 | 3-8 |
| 256Kx32 66MHz 3.3V SGRAM | 10.00 | 8.04 | 7.30 | 6.75 | 8.02 | 6.40 | 6.25 | 5.88 | 5.80 | 6.08 | 3-8 |

*Contract volume is at least 100,000 per order, except for VRAMs.

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.

Source: Dataquest (June 1997)



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## Table 2-6
## Estimated Long-Range DRAM Price Trends—North American Bookings (Contract Volume; U.S. Dollars)*

| Product | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| 4Mbx1 DRAM 70ns SOJ 5V | 2.54 | 2.45 | 2.45 | 2.50 | 2.55 |
| 1Mbx4 DRAM 60ns SOJ 5V FPM | 2.36 | 2.39 | 2.43 | 2.50 | 2.55 |
| 1Mbx4 DRAM 60ns SOJ 5V EDO | 2.34 | 2.30 | 2.32 | 2.40 | 2.45 |
| 512Kx8 DRAM 70ns 5V | 2.66 | 2.46 | 2.44 | 2.49 | 2.55 |
| 256Kx16 DRAM 70ns SOJ 5V | 3.28 | 3.25 | 3.30 | 3.60 | 3.85 |
| 4Mbx4 DRAM 60 ns SOJ 5V FPM | 8.37 | 7.79 | 7.75 | 8.10 | 8.50 |
| 4Mbx4 DRAM 60ns SOJ 5V EDO | 8.29 | 7.72 | 7.61 | 7.90 | 8.30 |
| 1Mbx16 DRAM 60ns TSOP 5V FPM | 8.15 | 7.79 | 7.75 | 7.99 | 8.25 |
| 1Mbx16 DRAM 60ns TSOP 5V EDO | 8.10 | 7.71 | 7.65 | 7.90 | 8.25 |
| 1Mbx16 3.3V SDRAM | 9.70 | 8.39 | 8.00 | 7.89 | 8.15 |
| 2Mbx8 DRAM 60ns TSOP 5V FPM | 8.50 | 7.79 | 7.75 | 8.10 | 8.36 |
| 16Mbx4 DRAM SOJ 60ns 3.3V EDO | 56.29 | 35.46 | 27.00 | 26.00 | 24.00 |
| 16Mbx4 DRAM SOJ 3.3V SDRAM | 55.79 | 33.79 | 26.80 | 25.75 | 23.90 |
| 8Mbx8 DRAM SOJ 60ns 3.3V EDO | 56.29 | 35.46 | 27.00 | 26.00 | 24.00 |
| 8Mbx8 DRAM SOJ 3.3V SDRAM | 55.79 | 33.79 | 26.80 | 25.75 | 23.90 |
| 1Mbx32 SIMM 60ns 5V FPM | 19.39 | 18.49 | 18.35 | 18.90 | 19.20 |
| 1Mbx36 SIMM 60ns 5V FPM | 21.44 | 20.61 | 20.50 | 21.10 | 22.65 |
| 2Mbx32 SIMM 60ns 5V FPM | 37.81 | 35.50 | 35.35 | 36.05 | 37.19 |
| 2Mbx36 SIMM 60ns 5V FPM | 42.64 | 39.77 | 39.50 | 40.97 | 42.03 |
| 4Mbx32 SIMM 60ns 5V FPM | 72.40 | 67.00 | 66.50 | 67.75 | 69.00 |
| 4Mbx36 SIMM 60ns 5V FPM | 82.79 | 76.22 | 75.80 | 77.05 | 79.09 |
| 8Mbx32 SIMM 60ns 5V FPM | 142.70 | 131.71 | 130.90 | 132.48 | 134.57 |
| 8Mbx36 SIMM 60ns 5V FPM | 161.81 | 151.10 | 149.88 | 152.67 | 156.89 |
| 1Mbx32 SIMM 60ns 5V EDO | 19.32 | 18.42 | 18.30 | 18.77 | 19.11 |
| 1Mbx36 SIMM 60ns 5V EDO | 21.41 | 20.50 | 20.35 | 21.01 | 22.59 |
| 2Mbx32 SIMM 60ns 5V EDO | 37.22 | 35.02 | 34.99 | 35.87 | 37.11 |
| 2Mbx36 SIMM 60ns 5V EDO | 41.86 | 39.60 | 39.39 | 40.69 | 42.01 |
| 4Mbx32 SIMM 60ns 5V EDO | 71.77 | 66.65 | 65.75 | 67.25 | 68.88 |
| 4Mbx36 SIMM 60ns 5V EDO | 82.17 | 75.80 | 74.11 | 76.95 | 79.03 |
| 8Mbx32 SIMM 60ns 5V EDO | 140.16 | 129.00 | 128.00 | 131.99 | 134.48 |
| 8Mbx36 SIMM 60ns 5V EDO | 161.65 | 149.92 | 146.20 | 151.84 | 155.55 |
| 1Mbx64 60ns 3.3V EDO | 38.50 | 34.09 | 33.20 | 31.21 | 30.56 |
| 2Mbx64 60ns 3.3V EDO | 71.48 | 64.59 | 61.06 | 59.79 | 58.09 |
| 4Mbx64 60ns 3.3V EDO | 138.71 | 125.42 | 120.25 | 118.77 | 117.71 |
| 1Mbx64 3.3V SDRAM | 39.97 | 34.00 | 33.01 | 31.03 | 30.26 |
| 2Mbx64 3.3V SDRAM | 74.27 | 64.15 | 60.89 | 59.49 | 57.77 |
| 4Mbx64 3.3V SDRAM | 140.20 | 125.04 | 119.75 | 117.89 | 116.61 |
| 256Kx16 VRAM 70ns SOP | 10.14 | 9.01 | 8.50 | 9.10 | 9.30 |
| 256Kx32 66MHz 3.3V SGRAM | 8.02 | 6.08 | 5.94 | 5.77 | 5.60 |

*Contract volume is at least 100,000 per order, except for VRAMs.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (June 1997)

## Table 2-7
## Estimated Static RAM Price Trends—North American Bookings
## (Volume: Slow SRAM—50,000 per Year; Fast SRAM—20,000 per Year; Package: PDIP; Dollars)

| Product | 1997 Q1 | 1997 Q2 | 1997 Q3 | 1997 Q4 | 1997 Year | 1998 Q1 | 1998 Q2 | 1998 Q3 | 1998 Q4 | 1998 Year | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 16Kx4 35ns | 2.19 | 2.17 | 2.16 | 2.14 | 2.17 | 2.09 | 2.09 | 2.09 | 2.11 | 2.10 | 2-4 |
| 8Kx8 25ns | 1.18 | 1.16 | 1.14 | 1.12 | 1.15 | 1.11 | 1.10 | 1.10 | 1.10 | 1.10 | 2-4 |
| 8Kx8 100-120ns | 1.39 | 1.31 | 1.30 | 1.30 | 1.33 | 1.29 | 1.29 | 1.26 | 1.26 | 1.28 | 2-4 |
| 64Kx4 10ns | 7.00 | 6.28 | 5.74 | 5.40 | 6.11 | 5.04 | 4.89 | 4.83 | 4.83 | 4.90 | 2-4 |
| 64Kx4 25ns | 2.06 | 1.90 | 1.84 | 1.80 | 1.90 | 1.70 | 1.70 | 1.60 | 1.60 | 1.65 | 2-4 |
| 32Kx8 12ns | 1.50 | 1.42 | 1.39 | 1.39 | 1.42 | 1.38 | 1.38 | 1.37 | 1.37 | 1.38 | 2-4 |
| 32Kx9 12ns Burst | 3.67 | 3.42 | 3.34 | 3.31 | 3.44 | 3.33 | 3.30 | 3.26 | 3.22 | 3.28 | 2-4 |
| 32Kx8, 15ns, 5V | 1.21 | 1.17 | 1.13 | 1.12 | 1.16 | 1.10 | 1.10 | 1.09 | 1.09 | 1.10 | 2-4 |
| 32Kx8, 15ns, 3.3V | 1.26 | 1.18 | 1.14 | 1.14 | 1.18 | 1.10 | 1.10 | 1.10 | 1.10 | 1.10 | 2-4 |
| 32Kx8 25ns | 1.20 | 1.16 | 1.12 | 1.12 | 1.15 | 1.10 | 1.10 | 1.09 | 1.09 | 1.10 | 2-4 |
| 32Kx8 70-100ns SOJ | 1.53 | 1.40 | 1.34 | 1.30 | 1.39 | 1.27 | 1.26 | 1.24 | 1.24 | 1.25 | 2-4 |
| 64Kx8 12ns Burst | 15.15 | 14.10 | 14.03 | 13.50 | 14.20 | 13.35 | 12.20 | 11.80 | 11.35 | 12.18 | 2-4 |
| 256Kx4 20ns | 5.22 | 4.74 | 4.48 | 4.23 | 4.67 | 4.02 | 3.94 | 3.81 | 3.73 | 3.88 | 3-6 |
| 128Kx8, 15 ns | 4.67 | 4.30 | 4.10 | 3.88 | 4.24 | 3.73 | 3.59 | 3.46 | 3.33 | 3.53 | 3-6 |
| 128Kx8, 20 ns | 4.82 | 4.50 | 4.19 | 4.01 | 4.38 | 3.71 | 3.63 | 3.50 | 3.41 | 3.56 | 3-6 |
| 128Kx8 25ns | 4.82 | 4.50 | 4.19 | 4.01 | 4.38 | 3.71 | 3.63 | 3.50 | 3.41 | 3.56 | 3-6 |
| 128Kx8 70-100ns SOJ | 4.65 | 3.78 | 3.63 | 3.50 | 3.89 | 3.47 | 3.44 | 3.37 | 3.28 | 3.39 | 3-6 |
| 32Kx32 15ns, 3.3V PQFP | 3.59 | 3.46 | 3.40 | 3.27 | 3.43 | 3.14 | 3.09 | 2.95 | 2.90 | 3.02 | 3-6 |
| 32Kx32 8ns 3.3V PBSynch | 3.29 | 3.17 | 3.02 | 2.94 | 3.11 | 2.83 | 2.80 | 2.75 | 2.70 | 2.77 | 3-6 |
| 64Kx32 8ns 3.3V PBSynch | 6.29 | 5.80 | 5.51 | 5.32 | 5.73 | 5.10 | 5.04 | 4.80 | 4.62 | 4.89 | 3-6 |
| 256Kx16 70-100ns | 19.15 | 17.90 | 16.38 | 15.70 | 17.28 | 15.22 | 14.30 | 13.85 | 13.20 | 14.14 | 3-6 |
| 256Kx16 25ns | 20.41 | 18.70 | 18.21 | 17.79 | 18.78 | 17.11 | 16.70 | 15.50 | 15.00 | 16.08 | 3-6 |
| 512Kx8 70ns | 17.96 | 16.52 | 16.20 | 15.62 | 16.57 | 15.21 | 14.79 | 14.26 | 13.62 | 14.47 | 3-6 |
| 512Kx8 25ns | 22.00 | 20.72 | 19.48 | 18.53 | 20.18 | 17.23 | 16.25 | 15.49 | 14.29 | 15.82 | 3-6 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (June 1997)

## Table 2-8
## Estimated Long-Range Static RAM Price Trends—North American Bookings (Volume: Slow SRAM—50,000 per Year; Fast SRAM—20,000 per Year; Package: PDIP; Dollars)

| Product | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| 16Kx4 35ns | 2.17 | 2.10 | 2.12 | 2.12 | 2.16 |
| 8Kx8 25ns | 1.15 | 1.10 | 1.12 | 1.22 | 1.30 |
| 8Kx8 100-120ns | 1.33 | 1.28 | 1.29 | 1.32 | 1.40 |
| 64Kx4 10ns | 6.11 | 4.90 | 5.8 | 6.40 | 6.59 |
| 64Kx4 25ns | 1.90 | 1.65 | 1.80 | 1.89 | 1.98 |
| 32Kx8 12ns | 1.42 | 1.38 | 1.46 | 1.55 | 1.70 |
| 32Kx9 12ns Burst | 3.44 | 3.28 | 3.21 | 3.30 | 3.50 |
| 32Kx8, 15ns, 5V | 1.16 | 1.10 | 1.15 | 1.25 | 1.30 |
| 32Kx8, 15ns, 3.3V | 1.18 | 1.10 | 1.2 | 1.29 | 1.40 |
| 32Kx8 25ns | 1.15 | 1.10 | 1.19 | 1.30 | 1.46 |
| 32Kx8 70-100ns SOJ | 1.39 | 1.25 | 1.30 | 1.35 | 1.40 |
| 64Kx8 12ns Burst | 14.20 | 12.18 | 11.1 | 12.00 | 12.25 |
| 256Kx4 20ns | 4.67 | 3.88 | 3.50 | 3.70 | 4.10 |
| 128Kx8, 15ns | 4.24 | 3.53 | 3.25 | 3.23 | 3.55 |
| 128Kx8, 20ns | 4.38 | 3.56 | 3.36 | 3.28 | 3.59 |
| 128Kx8 25ns | 4.38 | 3.56 | 3.36 | 3.28 | 3.59 |
| 128Kx8 70-100ns SOJ | 3.89 | 3.39 | 3.26 | 3.23 | 3.41 |
| 32Kx32 15ns, 3.3V PQFP | 3.43 | 3.02 | 2.86 | 3.20 | 3.85 |
| 32Kx32 8ns 3.3V PBSynch | 3.11 | 2.77 | 2.90 | 3.20 | 3.60 |
| 64Kx32 8ns 3.3V PBSynch | 5.73 | 4.89 | 4.50 | 4.29 | 5.35 |
| 256Kx16 70-100ns | 17.28 | 14.14 | 12.87 | 12.15 | 11.94 |
| 256Kx16 25ns | 18.78 | 16.08 | 13.86 | 12.10 | 11.90 |
| 512Kx8 70ns | 16.57 | 14.47 | 12.60 | 11.84 | 11.55 |
| 512Kx8 25ns | 20.18 | 15.82 | 12.98 | 11.98 | 11.66 |

EOL = End of life
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (June 1997)


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## Table 2-9
## Estimated ROM Price Trends—North American Bookings (Speed/Package: ≤1Mb Density—150ns and Above; 28-pin PDIP; ≥2Mb Density—200ns and Above; 32-pin PDIP) (Volume: 50,000 per Year; Dollars)

| | 1997 | | | | 1997 | 1998 | | | | 1998 | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Q1 | Q2 | Q3 | Q4 | Year | Q1 | Q2 | Q3 | Q4 | Year | (Weeks) |
| 128Kx8 ROM | 1.74 | 1.69 | 1.69 | 1.64 | 1.69 | 1.58 | 1.58 | 1.51 | 1.51 | 1.55 | 4-8 |
| 64Kx16 ROM | 2.00 | 1.92 | 1.88 | 1.80 | 1.90 | 1.73 | 1.73 | 1.66 | 1.66 | 1.70 | 4-8 |
| 256Kx8 ROM | 2.20 | 2.18 | 2.14 | 2.14 | 2.17 | 2.10 | 2.10 | 2.05 | 2.05 | 2.08 | 4-8 |
| 512Kx8 ROM | 3.10 | 3.00 | 2.90 | 2.80 | 2.95 | 2.70 | 2.70 | 2.66 | 2.66 | 2.68 | 4-8 |
| 256Kx16 ROM | 3.10 | 3.00 | 2.90 | 2.80 | 2.95 | 2.70 | 2.70 | 2.66 | 2.66 | 2.68 | 4-8 |
| 1MbX8 ROM | 4.00 | 3.90 | 3.80 | 3.70 | 3.85 | 3.62 | 3.62 | 3.53 | 3.53 | 3.58 | 4-8 |
| 1Mbx16 ROM | 6.00 | 5.80 | 5.70 | 5.65 | 5.79 | 5.55 | 5.55 | 5.46 | 5.46 | 5.51 | 4-8 |
| 2Mbx8 ROM | 5.87 | 5.72 | 5.70 | 5.65 | 5.74 | 5.55 | 5.55 | 5.46 | 5.46 | 5.51 | 4-8 |
| 2Mbx16 ROM | 12.00 | 11.75 | 11.50 | 11.30 | 11.64 | 11.00 | 11.00 | 10.74 | 10.74 | 10.87 | 4-8 |
| 4Mbx8 ROM | 12.00 | 11.60 | 11.40 | 11.30 | 11.58 | 11.00 | 11.00 | 10.74 | 10.74 | 10.87 | 4-8 |
| 4Mbx16 ROM | 16.00 | 15.80 | 15.40 | 15.00 | 15.55 | 14.50 | 14.50 | 14.00 | 14.00 | 14.25 | 4-9 |
| 8Mbx8 ROM | 15.50 | 15.30 | 15.20 | 14.90 | 15.23 | 14.40 | 14.40 | 13.90 | 13.90 | 14.15 | 4-9 |

[1]256Kx16 ROM: 150ns and above; 40-pin PDIP
[2]1Mbx8 ROM: 150ns and above; 32-pin SOP
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (June 1997)

## Table 2-10
## Estimated Long-Range ROM Price Trends—North American Bookings (Speed/Package: ≤1Mb Density—150ns and Above; 28-pin PDIP; ≥2Mb Density—200ns and Above; 32-pin PDIP) (Volume: 50,000 per Year; Dollars)

| Product | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| 128Kx8 ROM | 1.69 | 1.55 | 1.50 | 1.47 | 1.44 |
| 64Kx16 ROM | 1.90 | 1.70 | 1.63 | 1.61 | 1.59 |
| 256Kx8 ROM | 2.17 | 2.08 | 2.01 | 1.98 | 1.96 |
| 512Kx8 ROM | 2.95 | 2.68 | 2.60 | 2.56 | 2.52 |
| 256Kx16 ROM[1] | 2.95 | 2.68 | 2.60 | 2.56 | 2.52 |
| 1Mbx8 ROM[2] | 3.85 | 3.58 | 3.48 | 3.45 | 3.39 |
| 1Mbx16 ROM | 5.79 | 5.51 | 5.38 | 5.30 | 5.22 |
| 2Mbx8 ROM | 5.74 | 5.51 | 5.40 | 5.30 | 5.22 |
| 2Mbx16 ROM | 11.64 | 10.87 | 10.60 | 10.50 | 10.35 |
| 4Mbx8 ROM | 11.58 | 10.87 | 10.60 | 10.50 | 10.35 |
| 4Mbx16 ROM | 15.55 | 14.25 | 13.80 | 13.50 | 13.50 |
| 8Mbx8 ROM | 15.23 | 14.15 | 13.65 | 13.40 | 13.27 |

[1]256Kx16 ROM: 150ns and above; 40-pin PDIP
[2]1Mbx8 ROM: 150ns and above; 32-pin SOP
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (June 1997)

## Table 2-11
## Estimated EPROM Price Trends—North American Bookings
## (Volume: 50,000 per Year; Package: Windowed CERDIP; Speed: 150ns and Above; Dollars)

| | 1997 | | | | 1997 | 1998 | | | | 1998 | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Q1 | Q2 | Q3 | Q4 | Year | Q1 | Q2 | Q3 | Q4 | Year | (Weeks) |
| 32Kx8 EPROM | 1.37 | 1.36 | 1.33 | 1.32 | 1.35 | 1.32 | 1.29 | 1.28 | 1.27 | 1.29 | 2-3 |
| 64Kx8 EPROM | 1.43 | 1.43 | 1.39 | 1.39 | 1.41 | 1.38 | 1.36 | 1.33 | 1.31 | 1.34 | 2-3 |
| 128Kx8 EPROM | 1.93 | 1.90 | 1.83 | 1.80 | 1.87 | 1.73 | 1.73 | 1.70 | 1.70 | 1.72 | 2-3 |
| 256Kx8 EPROM | 2.77 | 2.77 | 2.75 | 2.73 | 2.76 | 2.68 | 2.66 | 2.52 | 2.50 | 2.59 | 2-3 |
| 128Kx16 EPROM | 3.65 | 3.31 | 3.20 | 3.13 | 3.32 | 3.08 | 3.03 | 2.82 | 2.80 | 2.93 | 2-3 |
| 512Kx8 EPROM | 4.97 | 4.68 | 4.58 | 4.51 | 4.69 | 4.38 | 4.32 | 4.20 | 4.17 | 4.26 | 2-3 |
| 256Kx16 EPROM | 7.58 | 6.38 | 6.24 | 6.15 | 6.59 | 6.10 | 5.78 | 5.43 | 5.08 | 5.59 | 2-3 |
| 1Mbx8 EPROM | 8.50 | 8.40 | 8.30 | 8.20 | 8.35 | 8.15 | 8.10 | 8.05 | 8.00 | 8.08 | 2-3 |
| 512Kx16 EPROM | 9.50 | 9.45 | 9.40 | 9.30 | 9.41 | 9.20 | 9.15 | 9.10 | 9.05 | 9.13 | 2-3 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (June 1997)

## Table 2-12
## Estimated Long-Range EPROM Price Trends—North American Bookings
## (Volume: 50,000 per Year; Package: Windowed CERDIP; Speed: 150ns and Above; Dollars)

| Product | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| 32Kx8 EPROM | 1.35 | 1.29 | 1.22 | 1.20 | 1.20 |
| 64Kx8 EPROM | 1.41 | 1.34 | 1.29 | 1.26 | 1.25 |
| 128Kx8 EPROM | 1.87 | 1.72 | 1.68 | 1.63 | 1.60 |
| 256Kx8 EPROM | 2.76 | 2.59 | 2.45 | 2.39 | 2.37 |
| 128Kx16 EPROM | 3.32 | 2.93 | 2.79 | 2.72 | 2.65 |
| 512Kx8 EPROM | 4.69 | 4.26 | 4.14 | 4.08 | 4.01 |
| 256Kx16 EPROM | 6.59 | 5.59 | 5.01 | 4.93 | 4.88 |
| 1Mbx8 EPROM | 8.35 | 8.08 | 7.98 | 7.89 | 7.81 |
| 512Kx16 EPROM | 9.41 | 9.13 | 8.94 | 8.87 | 8.79 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (June 1997)

## Table 2-13
## Estimated Flash Memory Price Trends—North American Bookings
## (12V; Volume: 10,000 per Year; Speed: 150ns; Dollars)

| Product | 1997 Q1 | 1997 Q2 | 1997 Q3 | 1997 Q4 | 1997 Year | 1998 Q1 | 1998 Q2 | 1998 Q3 | 1998 Q4 | 1998 Year | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 64Kx8 PDIP/PLCC | 2.75 | 2.61 | 2.44 | 2.34 | 2.53 | 2.19 | 2.15 | 2.15 | 2.15 | 2.16 | 5 |
| 64Kx8 TSOP | 2.83 | 2.68 | 2.63 | 2.59 | 2.68 | 2.43 | 2.38 | 2.29 | 2.19 | 2.32 | 5 |
| 128Kx8 PDIP/PLCC | 2.58 | 2.36 | 2.31 | 2.31 | 2.39 | 2.19 | 2.19 | 2.19 | 2.19 | 2.19 | 3 |
| 128Kx8 TSOP 12V | 2.80 | 2.54 | 2.44 | 2.44 | 2.55 | 2.29 | 2.24 | 2.24 | 2.24 | 2.25 | 4 |
| 128Kx8 TSOP 5V | 3.18 | 3.05 | 2.92 | 2.86 | 3.00 | 2.64 | 2.54 | 2.45 | 2.42 | 2.51 | 4 |
| 256Kx8 TSOP 12V | 5.57 | 5.00 | 4.91 | 4.81 | 5.07 | 4.51 | 4.42 | 4.32 | 4.09 | 4.33 | 4 |
| 256Kx8 TSOP/5V | 5.30 | 4.64 | 4.49 | 4.37 | 4.70 | 3.94 | 3.82 | 3.71 | 3.52 | 3.75 | 4 |
| 512Kx8 PDIP/PLCC | 5.60 | 5.17 | 4.88 | 4.68 | 5.08 | 4.38 | 4.23 | 4.07 | 3.88 | 4.14 | 4 |
| 512Kx8 TSOP 12V | 6.20 | 5.90 | 5.63 | 5.53 | 5.82 | 4.71 | 4.39 | 4.39 | 4.25 | 4.43 | 4 |
| 512Kx8 TSOP/5V | 6.28 | 5.75 | 5.47 | 5.34 | 5.71 | 4.70 | 4.37 | 4.32 | 4.16 | 4.39 | 4 |
| 512Kx8 SSOP/3V | 7.63 | 5.70 | 4.77 | 4.61 | 5.68 | 4.33 | 4.09 | 4.09 | 4.07 | 4.14 | 4 |
| 1Mbx8 TSOP/12V | 10.07 | 8.64 | 8.34 | 7.85 | 8.73 | 7.41 | 7.13 | 6.94 | 6.59 | 7.02 | 4 |
| 1Mbx8 TSOP/5V | 10.20 | 8.60 | 8.22 | 7.78 | 8.70 | 7.34 | 7.05 | 6.86 | 6.53 | 6.94 | 4 |
| 1Mbx8 TSOP/3V | 12.00 | 9.18 | 8.12 | 7.70 | 9.25 | 7.18 | 6.90 | 6.71 | 6.41 | 6.80 | 4 |
| 2Mbx8 TSOP/12V | 18.15 | 17.16 | 16.33 | 15.45 | 16.77 | 14.19 | 13.72 | 13.35 | 12.79 | 13.51 | 4 |
| 2Mbx8 TSOP/5V | 18.50 | 16.97 | 16.00 | 15.30 | 16.69 | 14.15 | 13.61 | 13.26 | 12.67 | 13.42 | 4 |
| 2Mbx8 TSOP/3V | 20.00 | 17.71 | 16.94 | 15.93 | 17.64 | 14.05 | 13.41 | 12.87 | 12.33 | 13.17 | 4 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (June 1997)

## Table 2-14
## Estimated Long-Range Flash Memory Price Trends—North American Bookings (12V; Volume: 10,000 per Year; Speed: 150ns; Dollars)

| Product | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| 64Kx8 PDIP/PLCC | 2.53 | 2.16 | 2.15 | 2.14 | 2.14 |
| 64Kx8 TSOP | 2.68 | 2.32 | 2.18 | 2.17 | 2.16 |
| 128Kx8 PDIP/PLCC | 2.39 | 2.19 | 2.18 | 2.17 | 2.16 |
| 128Kx8 TSOP 12V | 2.55 | 2.25 | 2.23 | 2.21 | 2.20 |
| 128Kx8 TSOP 5V | 3.00 | 2.51 | 2.39 | 2.35 | 2.30 |
| 256Kx8 TSOP 12V | 5.07 | 4.33 | 4.05 | 4.00 | 3.90 |
| 256Kx8 TSOP/5V | 4.70 | 3.75 | 3.49 | 3.44 | 3.38 |
| 512Kx8 PDIP/PLCC | 5.08 | 4.14 | 3.84 | 3.80 | 3.74 |
| 512Kx8 TSOP 12V | 5.82 | 4.43 | 4.22 | 4.09 | 3.92 |
| 512Kx8 TSOP/5V | 5.71 | 4.39 | 4.13 | 4.04 | 3.90 |
| 512Kx8 SSOP/3V | 5.68 | 4.14 | 4.04 | 3.94 | 3.87 |
| 1Mbx8 TSOP/12V | 8.73 | 7.02 | 6.55 | 6.49 | 6.45 |
| 1Mbx8 TSOP/5V | 8.70 | 6.94 | 6.49 | 6.44 | 6.40 |
| 1Mbx8 TSOP/3V | 9.25 | 6.80 | 6.37 | 6.33 | 6.30 |
| 2Mbx8 TSOP/12V | 16.77 | 13.51 | 12.08 | 11.48 | 10.59 |
| 2Mbx8 TSOP/5V | 16.69 | 13.42 | 12.04 | 11.39 | 10.44 |
| 2Mbx8 TSOP/3V | 17.64 | 13.17 | 12.00 | 11.34 | 10.38 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (June 1997)


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## Table 2-15
## Estimated Gate Array Pricing—North American Production Bookings
## (Volume: 20,000 Units; Based on Utilized Gates Only; NRE = Netlist to Prototype; Millicents per Gate)

| | 10-29.99K Gates | | | 30-59.99K Gates | | | 60-99.99K Gates | | | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|
| Gate Count Technology | 1997 | 1998 | 1999 | 1997 | 1998 | 1999 | 1997 | 1998 | 1999 | (Weeks) |
| CMOS | | | | | | | | | | Production: |
| 0.8 Micron | 21.00 | 20.00 | 19.00 | 17.00 | 16.00 | 14.00 | 15.00 | 14.00 | 13.00 | 4-12 |
| 0.6 Micron | 24.00 | 23.00 | 22.00 | 17.00 | 15.00 | 14.00 | 17.00 | 16.00 | 15.00 | 4-12 |
| 0.5 Micron | 26.00 | 25.00 | 24.00 | 22.00 | 21.00 | 20.00 | 20.00 | 18.00 | 17.00 | 4-12 |
| 0.35 Micron | 36.00 | 34.00 | 34.00 | 33.00 | 29.00 | 28.00 | 21.00 | 20.00 | 19.00 | 4-12 |
| | | | | | | | | | | Prototypes: |
| NRE CMOS Average Charge ($K) | 44.00 | 44.00 | 43.00 | 54.00 | 52.00 | 52.00 | 74.00 | 73.00 | 73.00 | 1-4 |

| | 100-299.99K Gates | | | ≥300K Gates | | | Lead Time |
|---|---|---|---|---|---|---|---|
| Gate Count Technology | 1997 | 1998 | 1999 | 1997 | 1998 | 1999 | (Weeks) |
| CMOS (Average) | | | | | | | Production: |
| 0.8 Micron | 24.00 | 22.00 | 21.00 | NR | NR | NR | 4-12 |
| 0.6 Micron | 23.00 | 22.00 | 21.00 | 30.00 | 30.00 | 29.00 | 4-12 |
| 0.5 Micron | 27.00 | 24.00 | 22.00 | 33.00 | 32.00 | 32.00 | 4-12 |
| 0.35 Micron | 32.00 | 31.00 | 30.00 | 41.00 | 39.00 | 38.00 | 4-12 |
| | | | | | | | Prototypes: |
| NRE CMOS Average Charge ($K) | 107.00 | 106.00 | 105.00 | 123.00 | 120.00 | 120.00 | 1-4 |

NR = Not relevant

NRE = Nonreccuring engineering charge

Notes: The actual NRE may vary from these because of device amortization, testing, intellectual property rights, and other factors. Actual negotiated market prices may vary substantially from these because of manufacturer-specific factors such as intellectual property rights, alliances, service, package types, pad or core constraints, and volume discount. These prices are intended for use as price guidelines. For volumes of 1 million units or greater, discount the above prices by a further 50 to 60 percent. For core-limited solutions with volumes greater than 10,000 units, CBICs may be more cost-effective than gate arrays.

Source: Dataquest (June 1997)



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## Table 2-16
## Estimated CBIC Pricing—North American Production Bookings
## (Volume: 20,000 Units; Based on Utilized Gates Only; NRE = Netlist to Prototype; Millicents per Gate)

| Gate Count Technology | 10-29.99K Gates 1997 | 1998 | 1999 | 30-59.99K Gates 1997 | 1998 | 1999 | 60-99.99K Gates 1997 | 1998 | 1999 | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|
| CMOS | | | | | | | | | | **Production:** |
| 0.8 Micron | 25.00 | 24.00 | 22.00 | 17.00 | 16.00 | 14.00 | 13.00 | 11.00 | 10.00 | 7-15 |
| 0.6 Micron | 26.00 | 25.00 | 24.00 | 18.00 | 16.00 | 15.00 | 13.00 | 12.00 | 10.00 | 7-15 |
| 0.5 Micron | 28.00 | 27.00 | 26.00 | 25.00 | 24.00 | 22.00 | 20.00 | 18.00 | 17.00 | 7-15 |
| 0.35 Micron | 40.00 | 39.00 | 38.00 | 38.00 | 35.00 | 34.00 | 25.00 | 24.00 | 22.00 | 7-15 |
| | | | | | | | | | | **Prototypes:** |
| NRE CMOS Average Charge ($K) | 68.00 | 67.00 | 65.00 | 72.00 | 72.00 | 71.00 | 83.00 | 83.00 | 83.00 | 3-6 |

| Gate Count Technology | 100-299.99K Gates 1997 | 1998 | 1999 | ≥300K Gates 1997 | 1998 | 1999 | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|
| CMOS | | | | | | | **Production:** |
| 0.8 Micron | 17.00 | 15.00 | 14.00 | NR | NR | NR | 7-15 |
| 0.6 Micron | 15.00 | 14.00 | 13.00 | 19.00 | 18.00 | 17.00 | 7-15 |
| 0.5 Micron | 14.00 | 12.00 | 10.00 | 17.00 | 15.00 | 14.00 | 7-15 |
| 0.35 Micron | 12.00 | 11.00 | 10.00 | 11.00 | 9.00 | 8.00 | 7-15 |
| | | | | | | | **Prototypes:** |
| NRE CMOS Average Charge ($K) | 133.00 | 132.00 | 132.00 | 163.00 | 161.00 | 160.00 | 3-6 |

NR = Not relevant

NRE = Nonrecurring engineering charge

Notes: The actual NRE may vary from these because of device amortization, testing, intellectual property rights, and other factors. Actual negotiated market prices may vary substantially from these because of manufacturer-specific factors such as intellectual property rights, alliances, service, package types, pad or core constraints, and volume discount. These prices are intended for use as price guidelines. For volumes of 1 million units or greate, discount the above prices by a further 50 to 60 percent. For core-limited solutions with volumes greater than 10,000 units, CBICs may be more cost-effective than gate arrays.

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**For More Information...**

Evelyn Cronin, Senior Industry Analyst..... (408) 468-8075
Internet address..... evelyn.cronin@dataquest.com
Via fax..... (408) 954-1780
Dataquest Interactive..... http://www.dataquest.com

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## DATAQUEST WORLDWIDE OFFICES


**NORTH AMERICA**

**Worldwide Headquarters**
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: 1-408-468-8000
Facsimile: 1-408-954-1780

**East Coast Headquarters**
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6262

**Dataquest Global Events**
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

Sales Offices:
Washington, DC (Federal)
New York, NY (Financial)
Dallas, TX

**LATIN AMERICA**
Research Affiliates and Sales Offices:
Buenos Aires, Argentina
Sao Paulo, Brazil
Santiago, Chile
Mexico City, Mexico

**EUROPE**

**European Headquarters**
Tamesis, The Glanty
Egham, Surrey TW20 9AW
United Kingdom
Phone: +44 1784 431 611
Facsimile: +44 1784 488 980

**Dataquest France**
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: +33 1 41 35 13 00
Facsimile: +33 1 41 35 13 13

**Dataquest Germany**
Kronstadter Strasse 9
81677 München
Germany
Phone: +49 89 93 09 09 0
Facsimile: +49 89 93 03 27 7

Sales Offices:
Brussels, Belgium
Kfar Saba, Israel
Milan, Italy
Randburg, South Africa
Madrid, Spain

**JAPAN**

**Japan Headquarters**
Aobadai Hills 4-7-7
Aobadai
Meguro-ku, Tokyo 153
Japan
Phone: 81-3-3481-3670
Facsimile: 81-3-3481-3644

**ASIA/PACIFIC**

**Asia/Pacific Headquarters**
Suite 5904-7, Central Plaza
18 Harbour Road, Wanchai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

**Dataquest Korea**
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

**Dataquest Taiwan**
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

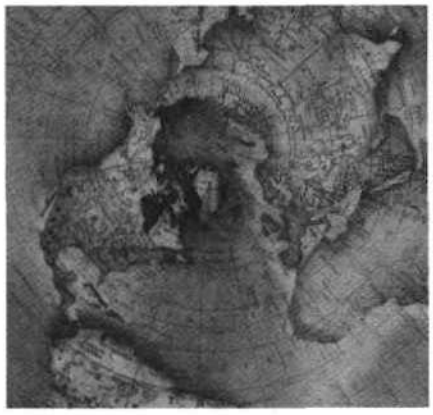
**Dataquest Singapore**
105 Cecil Street
#06-01/02 The Octagon
Singapore 069534
Phone: 65-227-1213
Facsimile: 65-227-4607

**Dataquest Thailand**
12/F, Vanissa Building
29 Soi Chidlom
Ploenchit Road
Patumwan, Bangkok 10330
Thailand
Phone: 662-655-0577
Facsimile: 662-655-0576

Research Affiliates and Sales Offices:
Melbourne, Australia
Beijing, China


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# Final 1996 Worldwide Semiconductor Market Share

Market Statistics

**Program:** Semiconductor Supply and Pricing Worldwide
**Product Code:** SSPS-WW-MS-9702
**Publication Date:** May 12, 1997
**Filing:** Market Statistics

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# Table of Contents

Page

Final 1996 Worldwide Semiconductor Market Share ..... 1
Introduction ..... 1
Segmentation ..... 1
Definitions ..... 2
Product Definitions ..... 2
Regional Definitions ..... 4
Line Item Definitions ..... 4
Market Share Methodology ..... 4
Notes on Market Share ..... 5
Notes to Market Share Tables ..... 5
Exchange Rates ..... 7
Section 1: 1996 Worldwide Market Share ..... 8
Section 2: 1996 Worldwide Market Share Rankings ..... 51

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# List of Tables


| Table | | Page |
|---|---|---|
| 1 | Exchange Rates | 7 |
| 1-1 | Each Company's Factory Revenue from Shipments of Total Semiconductors Worldwide (Including Hybrid) | 8 |
| 1-2 | Each Company's Factory Revenue from Shipments of Total Semiconductors Worldwide (Excluding Hybrid) | 13 |
| 1-3 | Each Company's Factory Revenue from Shipments of Total ICs Worldwide (Including Hybrid) | 18 |
| 1-4 | Each Company's Factory Revenue from Shipments of Total Integrated Circuits Worldwide (Excluding Hybrid) | 23 |
| 1-5 | Each Company's Factory Revenue from Shipments of Bipolar Digital Worldwide | 28 |
| 1-6 | Each Company's Factory Revenue from Shipments of Bipolar Logic Worldwide | 29 |
| 1-7 | Each Company's Factory Revenue from Shipments of Other Bipolar Logic/Memory/Microcomponents Worldwide | 30 |
| 1-8 | Each Company's Factory Revenue from Shipments of MOS Digital ICs Worldwide | 31 |
| 1-9 | Each Company's Factory Revenue from Shipments of MOS Memory Worldwide | 35 |
| 1-10 | Each Company's Factory Revenue from Shipments of MOS Microcomponents Worldwide | 37 |
| 1-11 | Each Company's Factory Revenue from Shipments of MOS Digital Logic Worldwide | 40 |
| 1-12 | Each Company's Factory Revenue from Shipments of Analog-Monolithic Worldwide | 43 |
| 1-13 | Each Company's Factory Revenue from Shipments of Total Discrete Worldwide | 46 |
| 1-14 | Each Company's Factory Revenue from Shipments of Total Optical Semiconductors Worldwide | 48 |
| 1-15 | Each Company's Factory Revenue from Shipments of Hybrid Analog Worldwide | 50 |
| 2-1 | Top 40 Worldwide Companies' Factory Revenue from Shipments of Total Semiconductors Worldwide (Including Hybrid) | 51 |
| 2-2 | Top 40 Worldwide Companies' Factory Revenue from Shipments of Total Semiconductors Worldwide (Excluding Hybrid) | 53 |
| 2-3 | Top 40 Worldwide Companies' Factory Revenue from Shipments of Total ICs Worldwide (Including Hybrid) | 55 |
| 2-4 | Top 40 Worldwide Companies' Factory Revenue from Shipments of Total Integrated Circuits Worldwide (Excluding Hybrid) | 57 |
| 2-5 | Top 20 Worldwide Companies' Factory Revenue from Shipments of Bipolar Digital Worldwide | 59 |


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# List of Tables (Continued)


| Table | | Page |
|---|---|---|
| 2-6 | Top 20 Worldwide Companies' Factory Revenue from Shipments of Bipolar Logic Worldwide | 60 |
| 2-7 | Top 13 Worldwide Companies' Factory Revenue from Shipments of Other Bipolar Logic/Memory/Microcomponents Worldwide | 61 |
| 2-8 | Top 40 Worldwide Companies' Factory Revenue from Shipments of MOS Digital ICs Worldwide | 62 |
| 2-9 | Top 40 Worldwide Companies' Factory Revenue from Shipments of MOS Memory Worldwide | 64 |
| 2-10 | Top 40 Worldwide Companies' Factory Revenue from Shipments of MOS Microcomponents Worldwide | 66 |
| 2-11 | Top 40 Worldwide Companies' Factory Revenue from Shipments of MOS Digital Logic Worldwide | 68 |
| 2-12 | Top 40 Worldwide Companies' Factory Revenue from Shipments of Analog-Monolithic Worldwide | 70 |
| 2-13 | Top 40 Worldwide Companies' Factory Revenue from Shipments of Total Discrete Worldwide | 72 |
| 2-14 | Top 349 Worldwide Companies' Factory Revenue from Shipments of Total Optical Semiconductors Worldwide | 74 |
| 2-15 | Top 29 Worldwide Companies' Factory Revenue from Shipments of Hybrid Analog Worldwide | 76 |


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# Final 1996 Worldwide Semiconductor Market Share

## Introduction

This document contains detailed information on Dataquest's view of the semiconductor market. Included in this document are the following:

- 1994-1996 market share estimates
- 1995-1996 market share rankings

Worldwide market share estimates combine data from many countries, each of which has a different and fluctuating exchange rate. Estimates of non-U.S. market consumption or revenue are based on 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, Dataquest's estimates are calculated in local currencies and then converted to U.S. dollars.

More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of this data is provided in the Dataquest Perspectives.

## Segmentation

This section outlines the market segments that are specific to this document. Dataquest's objective is to provide data along lines of segmentation that is logical, appropriate to the industry in question, and immediately useful to clients.

Dataquest defines the semiconductor industry as the group of competing companies primarily engaged in manufacturing semiconductors and related solid-state devices. Important products of the semiconductor industry include integrated circuits, discrete devices, and optoelectronics devices.

For market share purposes, Dataquest defines the semiconductor market according to the following functional segmentation scheme:

- Total Semiconductor (Including Hybrids)
- Total Semiconductor (Excluding Hybrids)
  - Total Monolithic Integrated Circuit (Including Hybrids)
  - Total Monolithic Integrated Circuit (Excluding Hybrids)
    - Bipolar Digital IC
      - Bipolar Logic
      - Other Bipolar Memory/Microcomponent/Logic
  - MOS Digital IC
    - MOS Memory
    - MOS Microcomponent
    - MOS Logic


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- Monolithic Analog IC
- Hybrid IC
- Discrete Semiconductor
- Optoelectronic Semiconductor

## Definitions

This section lists the definitions that are used by Dataquest to present the data in this document. For a complete listing of all semiconductor market segments tracked by Dataquest, please refer to the Dataquest Semiconductor Market Definitions Guide.

### Product Definitions

Total Semiconductor (Total Monolithic Integrated Circuit + Total Discrete + Total Optoelectronic). Defined as an active semiconductor product that contains semiconducting material (such as silicon, germanium, or gallium arsenide, but excluding ceramics) and reacts dynamically to an input signal, either by modifying its shape or adding energy to it. This definition excludes standalone passive components, such as capacitors, resistors, inductors, oscillators, crystals, transformers, and relays.

Total Monolithic Integrated Circuit (Digital Monolithic Bipolar IC + Digital Monolithic MOS IC + Analog IC). An IC is defined as a large number of passive and/or active discrete semiconductor circuits integrated into a single package. A monolithic IC is one in which discrete circuits are integrated onto a single die.

Bipolar Digital IC (Bipolar Digital Memory + Bipolar Digital Microcomponent + Bipolar Digital Logic). A bipolar digital IC is defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, 100 percent of the die area is manufactured using bipolar semiconductor technology. A digital function is one in which data-carrying signals vary in discrete values.

Bipolar Digital Logic (Bipolar Application-Specific IC + Bipolar Digital Standard Logic + Other Bipolar Logic). Defined as a bipolar digital semiconductor product in which more than 50 percent of the die area performs logic functions. Excludes bipolar digital microcomponent ICs.

Other Bipolar Digital Memory/Microcomponent/Logic. Defined as a bipolar digital semiconductor product in which binary data is stored and electronically retrieved. Includes ECL random-access memory (RAM), read-only memory (ROM), programmable ROM (PROM), last-in/first-out (LIFO) memory, and first-in/first-out (FIFO) memory. Not included are products made with mixed bipolar CMOS (that is, BiCMOS) with TTL or ECL outputs, which are classified as MOS.

MOS Digital IC (MOS Digital Memory + MOS Digital Microcomponent + MOS Digital Logic). Defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and, concurrently, where any portion of the die area is manufactured using metal oxide semiconductor (MOS) technology. A digital function is one in which

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data-carrying signals vary in discrete values. Includes mixed technology manufacturing, such as BiMOS and BiCMOS, where there is some MOS technology employed.

MOS Digital Memory (DRAM + SRAM + EPROM + EEPROM + Flash Memory + Mask ROM + Other MOS Digital Memory). Defined as a MOS digital IC in which binary data is stored and electronically retrieved.

MOS Digital Microcomponent IC (MOS Digital Microprocessor + MOS Digital Microcontroller + MOS Digital Microperipheral + Programmable Digital Signal Processor). Defined as a MOS digital IC that contains a data processing unit or serves as an interface to such a unit.

MOS Digital Logic IC (MOS Digital Logic Application-Specific IC + MOS Digital Standard Logic IC + Other MOS Digital Logic IC). Defined as a MOS digital IC in which more than 50 percent of the die area performs logic functions. Excludes MOS digital microcomponent ICs.

Total Analog IC (Amplifier/Comparator IC + Voltage Regulator/reference IC + Data Converter/Switch/Multiplexer IC + Interface IC + Telecom IC + Disk Drive IC + Other Special-Function IC + Linear Array/ASIC + Mixed-Signal ASIC + Total Special Consumer IC + Special Automotive IC + Smart Power IC). An analog IC is a semiconductor product that deals in the realm of electrical signal processing, power control, or electrical drive capability. It is one in which some of the inputs or outputs can be defined in terms of continuously or linearly variable voltages, currents, or frequencies. Includes only monolithic analog ICs manufactured using bipolar, MOS, or BiCMOS technologies. A monolithic IC is a single die contained in a single package.

Hybrid Integrated Circuit. Defined as a semiconductor product consisting of more than one die contained in a single package. A hybrid IC may perform 100 percent linear, 100 percent digital, or mixed-signal (both linear and digital) functions. Includes hybrid implementation of all monolithic IC functions described in the following categories. Includes all hybrid ICs manufactured using bipolar, MOS, or BiCMOS technologies.

Total Discrete (Transistor + Diode + Thyristor + Other Discrete). A discrete semiconductor is defined as a unit building block performing a fundamental semiconductor function.

Total Optoelectronic (LED Lamp/Display + Optocoupler + CCD + Laser Diode + Photosensor + Other Optoelectronic). Defined as a semiconductor product in which photons induce the flow of electrons, or vice versa. Other functions may also be integrated onto the product. This category does not include LCD, incandescent displays, fluorescent displays, cathode ray tubes (CRTs), or plasma displays.

### Regional Definitions

#### 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, Moldova, 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, dies, or wafers to another semiconductor vendor for resale is attributed to the semiconductor vendor that sells the product to a distributor or equipment manufacturer.

Merchant versus captive consumption: Dataquest includes all revenue, both merchant and captive, for semiconductor suppliers selling to the merchant market. The data excludes completely captive suppliers where devices are manufactured solely for the company's own use. A product that is used internally is valued at market price rather than at transfer or factory price.

## Market Share Methodology

Dataquest uses 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

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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 used 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.

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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.

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## Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar amounts. Table 1 outlines these rates for 1994 through 1996.

**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)


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# Section 1: 1996 Worldwide Market Share

**Table 1-1**
**Each Company's Factory Revenue from Shipments of Total Semiconductors Worldwide (Including Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Total Market | 110,513 | 151,262 | 141,690 | 100.0 | 100.0 | 100.0 |
| Americas Companies | 46,052 | 60,021 | 63,617 | 41.7 | 39.7 | 44.9 |
| ACC Microelectronics | 49 | 40 | 45 | 0 | 0 | 0 |
| Actel | 76 | 109 | 149 | 0 | 0 | 0.1 |
| Adaptec | 125 | 124 | 214 | 0.1 | 0 | 0.2 |
| Advanced Micro Devices | 2,134 | 2,337 | 1,947 | 1.9 | 1.5 | 1.4 |
| Allegro MicroSystems | 148 | 185 | 200 | 0.1 | 0.1 | 0.1 |
| Alliance Semiconductor | 90 | 220 | 76 | 0 | 0.1 | 0 |
| Altera | 199 | 402 | 497 | 0.2 | 0.3 | 0.4 |
| Analog Devices | 739 | 983 | 1,260 | 0.7 | 0.6 | 0.9 |
| Appian Technology | 7 | 9 | 10 | 0 | 0 | 0 |
| Applied Micro Circuits Corp. | 48 | 49 | 56 | 0 | 0 | 0 |
| ATI Technologies | 0 | 0 | 130 | 0 | 0 | 0 |
| Atmel | 375 | 589 | 1,024 | 0.3 | 0.4 | 0.7 |
| Brooktree | 109 | 120 | 0 | 0 | 0 | 0 |
| Burr-Brown | 165 | 186 | 207 | 0.1 | 0.1 | 0.1 |
| California Micro Devices | 10 | 13 | 8 | 0 | 0 | 0 |
| Catalyst | 50 | 48 | 54 | 0 | 0 | 0 |
| C-Cube | 0 | 0 | 150 | 0 | 0 | 0.1 |
| Cherry Semiconductor | 77 | 87 | 100 | 0 | 0 | 0 |
| Chip Express | 0 | 0 | 25 | 0 | 0 | 0 |
| Chips & Technologies | 89 | 138 | 150 | 0 | 0 | 0.1 |
| CID Technologies | 4 | 5 | 6 | 0 | 0 | 0 |
| Cirrus Logic | 781 | 1,003 | 891 | 0.7 | 0.7 | 0.6 |
| Comlinear | 16 | 0 | 0 | 0 | 0 | 0 |
| Crosspoint Solutions | 0 | 2 | 2 | 0 | 0 | 0 |
| Cypress Semiconductor | 400 | 553 | 516 | 0.4 | 0.4 | 0.4 |
| Cyrix | 241 | 212 | 160 | 0.2 | 0.1 | 0.1 |
| Dallas Semiconductor | 154 | 228 | 277 | 0.1 | 0.2 | 0.2 |
| Digital | 0 | 0 | 271 | 0 | 0 | 0.2 |
| DSP Group | 18 | 60 | 67 | 0 | 0 | 0 |
| Eastman Kodak | 3 | 3 | 3 | 0 | 0 | 0 |
| Elantec | 24 | 25 | 35 | 0 | 0 | 0 |
| Electronic Designs | 26 | 43 | 51 | 0 | 0 | 0 |
| ETEQ Microsystems | 6 | 7 | 4 | 0 | 0 | 0 |

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**Table 1-1 (Continued)**
**Each Company's Factory Revenue from Shipments of Total Semiconductors Worldwide (Including Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Exar | 169 | 147 | 96 | 0.2 | 0 | 0 |
| General Instrument | 262 | 413 | 362 | 0.2 | 0.3 | 0.3 |
| Gennum | 31 | 34 | 37 | 0 | 0 | 0 |
| G-Link USA | 0 | 14 | 15 | 0 | 0 | 0 |
| Gould AMI | 136 | 72 | 95 | 0.1 | 0 | 0 |
| Harris | 665 | 685 | 629 | 0.6 | 0.5 | 0.4 |
| Hewlett-Packard | 714 | 648 | 945 | 0.6 | 0.4 | 0.7 |
| Holt | 9 | 11 | 0 | 0 | 0 | 0 |
| Honeywell | 55 | 64 | 71 | 0 | 0 | 0 |
| Hughes | 40 | 36 | 39 | 0 | 0 | 0 |
| IBM | 2,532 | 3,522 | 2,740 | 2.3 | 2.3 | 1.9 |
| IC Sensors | 5 | 6 | 7 | 0 | 0 | 0 |
| IMI | 20 | 35 | 39 | 0 | 0 | 0 |
| IMP | 49 | 54 | 35 | 0 | 0 | 0 |
| Integrated Circuit Systems | 81 | 97 | 79 | 0 | 0 | 0 |
| Integrated Device Technology | 385 | 617 | 554 | 0.3 | 0.4 | 0.4 |
| Integrated Information Tech. | 35 | 44 | 51 | 0 | 0 | 0 |
| Integrated Silicon Solutions | 60 | 158 | 111 | 0 | 0.1 | 0 |
| Intel | 10,099 | 13,172 | 17,781 | 9.1 | 8.7 | 12.5 |
| International CMOS Technology | 12 | 16 | 12 | 0 | 0 | 0 |
| International Rectifier | 361 | 486 | 520 | 0.3 | 0.3 | 0.4 |
| ITT | 241 | 316 | 274 | 0.2 | 0.2 | 0.2 |
| IXYS | 55 | 65 | 66 | 0 | 0 | 0 |
| Kulite | 20 | 24 | 0 | 0 | 0 | 0 |
| Lattice | 134 | 186 | 200 | 0.1 | 0.1 | 0.1 |
| Level One Communications | 0 | 78 | 112 | 0 | 0 | 0 |
| Linear Technology | 225 | 305 | 365 | 0.2 | 0.2 | 0.3 |
| Linfinity | 44 | 50 | 51 | 0 | 0 | 0 |
| Logic Devices | 14 | 17 | 14 | 0 | 0 | 0 |
| LSI Logic | 901 | 1,269 | 1,239 | 0.8 | 0.8 | 0.9 |
| Lucent Technologies | 1,307 | 1,615 | 2,110 | 1.2 | 1.1 | 1.5 |
| Maxim | 169 | 189 | 387 | 0.2 | 0.1 | 0.3 |
| Micrel | 25 | 26 | 24 | 0 | 0 | 0 |
| Micro Linear | 41 | 54 | 54 | 0 | 0 | 0 |
| Micro Power Systems | 23 | 0 | 0 | 0 | 0 | 0 |
| Microchip Technology | 212 | 271 | 330 | 0.2 | 0.2 | 0.2 |
| Micron Technology | 1,492 | 2,601 | 1,558 | 1.4 | 1.7 | 1.1 |
| Microsemi | 100 | 118 | 146 | 0 | 0 | 0.1 |

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**Table 1-1 (Continued)**
**Each Company's Factory Revenue from Shipments of Total Semiconductors Worldwide (Including Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Mitel | 100 | 88 | 145 | 0 | 0 | 0.1 |
| Motorola | 7,238 | 8,722 | 8,076 | 6.5 | 5.8 | 5.7 |
| National Semiconductor | 2,127 | 2,408 | 2,380 | 1.9 | 1.6 | 1.7 |
| Novasensor | 13 | 15 | 0 | 0 | 0 | 0 |
| Oak Technology | 62 | 84 | 172 | 0 | 0 | 0.1 |
| Optek | 56 | 62 | 69 | 0 | 0 | 0 |
| OPTi | 130 | 167 | 119 | 0.1 | 0.1 | 0 |
| Paradigm | 36 | 55 | 23 | 0 | 0 | 0 |
| Performance Semiconductor | 20 | 28 | 0 | 0 | 0 | 0 |
| Powerex | 76 | 98 | 98 | 0 | 0 | 0 |
| Q Logic | 45 | 61 | 67 | 0 | 0 | 0 |
| Quality Semiconductor | 22 | 46 | 45 | 0 | 0 | 0 |
| Quality Technologies | 49 | 61 | 52 | 0 | 0 | 0 |
| QuickLogic | 8 | 16 | 25 | 0 | 0 | 0 |
| Ramtron | 15 | 25 | 14 | 0 | 0 | 0 |
| Raytheon | 108 | 125 | 131 | 0 | 0 | 0 |
| Rockwell | 514 | 744 | 1,351 | 0.5 | 0.5 | 1.0 |
| S3 | 130 | 315 | 464 | 0.1 | 0.2 | 0.3 |
| Seeq Technology | 22 | 27 | 32 | 0 | 0 | 0 |
| Semtech | 25 | 48 | 66 | 0 | 0 | 0 |
| Sensym | 8 | 0 | 0 | 0 | 0 | 0 |
| Sierra Semiconductor | 120 | 143 | 188 | 0.1 | 0 | 0.1 |
| Silicon Storage Technology | 0 | 35 | 91 | 0 | 0 | 0 |
| Silicon Systems | 298 | 369 | 0 | 0.3 | 0.2 | 0 |
| Sipex | 16 | 16 | 13 | 0 | 0 | 0 |
| Solitron | 7 | 8 | 9 | 0 | 0 | 0 |
| Spectra Diode Labs | 10 | 15 | 17 | 0 | 0 | 0 |
| Standard Microsystems | 100 | 150 | 153 | 0 | 0 | 0.1 |
| Sun Microsystems | 0 | 0 | 170 | 0 | 0 | 0.1 |
| Supertex | 30 | 35 | 33 | 0 | 0 | 0 |
| Symbios | 354 | 395 | 458 | 0.3 | 0.3 | 0.3 |
| Symphony Laboratories | 12 | 15 | 17 | 0 | 0 | 0 |
| Teccor Electronics | 60 | 68 | 84 | 0 | 0 | 0 |
| Telcom | 18 | 17 | 18 | 0 | 0 | 0 |
| Texas Instruments | 5,548 | 7,831 | 7,064 | 5.0 | 5.2 | 5.0 |
| Trident Microsystems | 87 | 139 | 180 | 0 | 0 | 0.1 |
| Tseng Labs | 83 | 105 | 26 | 0 | 0 | 0 |
| Unitrode | 88 | 103 | 98 | 0 | 0 | 0 |

**Table 1-1 (Continued)**
**Each Company's Factory Revenue from Shipments of Total Semiconductors Worldwide (Including Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Universal | 13 | 15 | 0 | 0 | 0 | 0 |
| VLSI Technology | 588 | 672 | 672 | 0.5 | 0.4 | 0.5 |
| VTC | 70 | 155 | 172 | 0 | 0.1 | 0.1 |
| WaferScale Integration | 21 | 36 | 48 | 0 | 0 | 0 |
| Weitek | 28 | 37 | 0 | 0 | 0 | 0 |
| Western Digital | 184 | 240 | 0 | 0.2 | 0.2 | 0 |
| Xicor | 100 | 114 | 123 | 0 | 0 | 0 |
| Xilinx | 321 | 520 | 566 | 0.3 | 0.3 | 0.4 |
| Zilog | 222 | 265 | 286 | 0.2 | 0.2 | 0.2 |
| Zoran | 0 | 0 | 29 | 0 | 0 | 0 |
| Other Americas | 39 | 33 | 40 | 0 | 0 | 0 |
| Japanese Companies | 44,778 | 60,599 | 50,884 | 40.5 | 40.1 | 35.9 |
| Fuji Electric | 446 | 566 | 486 | 0.4 | 0.4 | 0.3 |
| Fujitsu | 3,869 | 5,535 | 4,427 | 3.5 | 3.7 | 3.1 |
| Hitachi | 6,644 | 9,135 | 8,071 | 6.0 | 6.0 | 5.7 |
| Matsushita | 2,896 | 3,474 | 3,003 | 2.6 | 2.3 | 2.1 |
| Mitsubishi | 3,772 | 5,274 | 4,100 | 3.4 | 3.5 | 2.9 |
| NEC | 7,961 | 11,314 | 10,428 | 7.2 | 7.5 | 7.4 |
| New JRC | 218 | 237 | 200 | 0.2 | 0.2 | 0.1 |
| Nippon Steel Semiconductor | 160 | 549 | 198 | 0.1 | 0.4 | 0.1 |
| Oki | 1,471 | 2,028 | 1,177 | 1.3 | 1.3 | 0.8 |
| Ricoh | 182 | 213 | 168 | 0.2 | 0.1 | 0.1 |
| Rohm | 1,345 | 1,934 | 1,731 | 1.2 | 1.3 | 1.2 |
| Sanken | 608 | 733 | 622 | 0.6 | 0.5 | 0.4 |
| Sanyo | 2,321 | 2,714 | 2,491 | 2.1 | 1.8 | 1.8 |
| Seiko Epson | 273 | 313 | 256 | 0.2 | 0.2 | 0.2 |
| Sharp | 2,188 | 2,592 | 2,124 | 2.0 | 1.7 | 1.5 |
| Shindengen Electric | 242 | 329 | 298 | 0.2 | 0.2 | 0.2 |
| Sony | 1,876 | 2,333 | 1,983 | 1.7 | 1.5 | 1.4 |
| Stanley Electric | 0 | 301 | 0 | 0 | 0.2 | 0 |
| Toko | 91 | 113 | 94 | 0 | 0 | 0 |
| Toshiba | 7,556 | 10,076 | 8,065 | 6.8 | 6.7 | 5.7 |
| Yamaha | 382 | 444 | 295 | 0.3 | 0.3 | 0.2 |
| Other Japanese | 277 | 392 | 667 | 0.3 | 0.3 | 0.5 |
| European Companies | 9,834 | 12,837 | 13,681 | 8.9 | 8.5 | 9.7 |
| ABB-Hafo | 40 | 38 | 0 | 0 | 0 | 0 |
| Austria Mikro Systeme | 110 | 149 | 140 | 0 | 0 | 0 |
| Elex | 20 | 33 | 34 | 0 | 0 | 0 |

**Table 1-1 (Continued)**
**Each Company's Factory Revenue from Shipments of Total Semiconductors Worldwide (Including Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Elmos | 15 | 19 | 7 | 0 | 0 | 0 |
| EM Microelectronics Marin | 65 | 77 | 85 | 0 | 0 | 0 |
| Ericsson | 113 | 120 | 170 | 0.1 | 0 | 0.1 |
| Eupec | 98 | 120 | 160 | 0 | 0 | 0.1 |
| European Silicon Structures | 40 | 59 | 0 | 0 | 0 | 0 |
| Fagor | 27 | 38 | 0 | 0 | 0 | 0 |
| GEC Plessey | 314 | 368 | 338 | 0.3 | 0.2 | 0.2 |
| Micronas | 20 | 43 | 33 | 0 | 0 | 0 |
| Mietec | 178 | 179 | 190 | 0.2 | 0.1 | 0.1 |
| Philips | 2,920 | 3,900 | 4,219 | 2.6 | 2.6 | 3.0 |
| Semikron | 112 | 125 | 109 | 0.1 | 0 | 0 |
| SGS-Thomson | 2,640 | 3,398 | 4,112 | 2.4 | 2.2 | 2.9 |
| Siemens | 2,090 | 3,063 | 3,029 | 1.9 | 2.0 | 2.1 |
| TCS | 78 | 100 | 83 | 0 | 0 | 0 |
| TEMIC | 719 | 773 | 813 | 0.7 | 0.5 | 0.6 |
| Thesys | 15 | 20 | 0 | 0 | 0 | 0 |
| Westcode | 41 | 54 | 0 | 0 | 0 | 0 |
| Zetex | 40 | 56 | 54 | 0 | 0 | 0 |
| Other European | 84 | 105 | 105 | 0 | 0 | 0 |
| Asia/Pacific Companies | 9,849 | 17,805 | 13,508 | 8.9 | 11.8 | 9.5 |
| Acer | 70 | 80 | 50 | 0 | 0 | 0 |
| Daewoo | 38 | 49 | 45 | 0 | 0 | 0 |
| Holtek | 70 | 87 | 99 | 0 | 0 | 0 |
| Hualon Microelectronics Corp. | 89 | 107 | 47 | 0 | 0 | 0 |
| Hyundai | 1,521 | 4,132 | 2,247 | 1.4 | 2.7 | 1.6 |
| Korean Electronic Co. | 225 | 287 | 268 | 0.2 | 0.2 | 0.2 |
| LG Semicon | 1,697 | 2,863 | 2,243 | 1.5 | 1.9 | 1.6 |
| Macronix | 221 | 271 | 354 | 0.2 | 0.2 | 0.2 |
| Mosel Vitelic | 259 | 502 | 398 | 0.2 | 0.3 | 0.3 |
| Samsung | 4,832 | 8,332 | 6,464 | 4.4 | 5.5 | 4.6 |
| Silicon Integrated Systems | 101 | 127 | 127 | 0 | 0 | 0 |
| United Microelectronics Corp. | 418 | 477 | 492 | 0.4 | 0.3 | 0.3 |
| Vanguard | 0 | 0 | 225 | 0 | 0 | 0.2 |
| VIA | 0 | 0 | 110 | 0 | 0 | 0 |
| Winbond Electronics | 308 | 491 | 339 | 0.3 | 0.3 | 0.2 |

Source: Dataquest (April 1997)

**Table 1-2**
**Each Company's Factory Revenue from Shipments of Total Semiconductors Worldwide (Excluding Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Total Market | 108,848 | 149,607 | 140,222 | 100.0 | 100.0 | 100.0 |
| Americas Companies | 45,627 | 59,835 | 63,468 | 41.9 | 40.0 | 45.3 |
| ACC Microelectronics | 49 | 40 | 45 | 0 | 0 | 0 |
| Actel | 76 | 109 | 149 | 0 | 0 | 0.1 |
| Adaptec | 125 | 124 | 214 | 0.1 | 0 | 0.2 |
| Advanced Micro Devices | 2,134 | 2,337 | 1,947 | 2.0 | 1.6 | 1.4 |
| Allegro MicroSystems | 148 | 173 | 185 | 0.1 | 0.1 | 0.1 |
| Alliance Semiconductor | 90 | 220 | 76 | 0 | 0.1 | 0 |
| Altera | 199 | 402 | 497 | 0.2 | 0.3 | 0.4 |
| Analog Devices | 687 | 925 | 1,218 | 0.6 | 0.6 | 0.9 |
| Appian Technology | 7 | 9 | 10 | 0 | 0 | 0 |
| Applied Micro Circuits Corp. | 48 | 49 | 56 | 0 | 0 | 0 |
| ATI Technologies | 0 | 0 | 130 | 0 | 0 | 0 |
| Atmel | 375 | 589 | 1,024 | 0.3 | 0.4 | 0.7 |
| Brooktree | 109 | 120 | 0 | 0.1 | 0 | 0 |
| Burr-Brown | 105 | 126 | 157 | 0 | 0 | 0.1 |
| California Micro Devices | 10 | 13 | 8 | 0 | 0 | 0 |
| Catalyst | 50 | 48 | 54 | 0 | 0 | 0 |
| C-Cube | 0 | 0 | 150 | 0 | 0 | 0.1 |
| Cherry Semiconductor | 77 | 87 | 100 | 0 | 0 | 0 |
| Chip Express | 0 | 0 | 25 | 0 | 0 | 0 |
| Chips & Technologies | 89 | 138 | 150 | 0 | 0 | 0.1 |
| CID Technologies | 4 | 5 | 6 | 0 | 0 | 0 |
| Cirrus Logic | 781 | 1,003 | 891 | 0.7 | 0.7 | 0.6 |
| Comlinear | 9 | 0 | 0 | 0 | 0 | 0 |
| Crosspoint Solutions | 0 | 2 | 2 | 0 | 0 | 0 |
| Cypress Semiconductor | 400 | 553 | 516 | 0.4 | 0.4 | 0.4 |
| Cyrix | 241 | 212 | 160 | 0.2 | 0.1 | 0.1 |
| Dallas Semiconductor | 154 | 228 | 277 | 0.1 | 0.2 | 0.2 |
| Digital | 0 | 0 | 271 | 0 | 0 | 0.2 |
| DSP Group | 18 | 60 | 67 | 0 | 0 | 0 |
| Eastman Kodak | 3 | 3 | 3 | 0 | 0 | 0 |
| Elantec | 21 | 22 | 32 | 0 | 0 | 0 |
| Electronic Designs | 26 | 43 | 51 | 0 | 0 | 0 |
| ETEQ Microsystems | 6 | 7 | 4 | 0 | 0 | 0 |
| Exar | 169 | 147 | 96 | 0.2 | 0 | 0 |
| General Instrument | 262 | 413 | 362 | 0.2 | 0.3 | 0.3 |
| Gennum | 29 | 32 | 37 | 0 | 0 | 0 |


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**Table 1-2 (Continued)**
**Each Company's Factory Revenue from Shipments of Total Semiconductors Worldwide (Excluding Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| G-Link USA | 0 | 14 | 15 | 0 | 0 | 0 |
| Gould AMI | 136 | 72 | 95 | 0.1 | 0 | 0 |
| Harris | 665 | 685 | 629 | 0.6 | 0.5 | 0.4 |
| Hewlett-Packard | 714 | 648 | 945 | 0.7 | 0.4 | 0.7 |
| Holt | 9 | 11 | 0 | 0 | 0 | 0 |
| Honeywell | 55 | 64 | 71 | 0 | 0 | 0 |
| Hughes | 40 | 36 | 39 | 0 | 0 | 0 |
| IBM | 2,532 | 3,522 | 2,740 | 2.3 | 2.4 | 2.0 |
| IC Sensors | 5 | 6 | 7 | 0 | 0 | 0 |
| IMI | 20 | 35 | 39 | 0 | 0 | 0 |
| IMP | 49 | 54 | 35 | 0 | 0 | 0 |
| Integrated Circuit Systems | 81 | 97 | 79 | 0 | 0 | 0 |
| Integrated Device Technology | 385 | 617 | 554 | 0.4 | 0.4 | 0.4 |
| Integrated Information Tech. | 35 | 44 | 51 | 0 | 0 | 0 |
| Integrated Silicon Solutions | 60 | 158 | 111 | 0 | 0.1 | 0 |
| Intel | 10,099 | 13,172 | 17,781 | 9.3 | 8.8 | 12.7 |
| International CMOS Technology | 12 | 16 | 12 | 0 | 0 | 0 |
| International Rectifier | 361 | 486 | 520 | 0.3 | 0.3 | 0.4 |
| ITT | 241 | 316 | 274 | 0.2 | 0.2 | 0.2 |
| IXYS | 55 | 65 | 66 | 0 | 0 | 0 |
| Kulite | 20 | 24 | 0 | 0 | 0 | 0 |
| Lattice | 134 | 186 | 200 | 0.1 | 0.1 | 0.1 |
| Level One Communications | 0 | 78 | 112 | 0 | 0 | 0 |
| Linear Technology | 225 | 305 | 365 | 0.2 | 0.2 | 0.3 |
| Linfinity | 41 | 47 | 48 | 0 | 0 | 0 |
| Logic Devices | 14 | 17 | 14 | 0 | 0 | 0 |
| LSI Logic | 901 | 1,269 | 1,239 | 0.8 | 0.8 | 0.9 |
| Lucent Technologies | 1,307 | 1,615 | 2,110 | 1.2 | 1.1 | 1.5 |
| Maxim | 165 | 185 | 383 | 0.2 | 0.1 | 0.3 |
| Micrel | 25 | 26 | 24 | 0 | 0 | 0 |
| Micro Linear | 41 | 54 | 54 | 0 | 0 | 0 |
| Micro Power Systems | 23 | 0 | 0 | 0 | 0 | 0 |
| Microchip Technology | 212 | 271 | 330 | 0.2 | 0.2 | 0.2 |
| Micron Technology | 1,492 | 2,601 | 1,558 | 1.4 | 1.7 | 1.1 |
| Microsemi | 100 | 118 | 146 | 0 | 0 | 0.1 |
| Mitel | 70 | 68 | 129 | 0 | 0 | 0 |
| Motorola | 7,012 | 8,722 | 8,076 | 6.4 | 5.8 | 5.8 |
| National Semiconductor | 2,120 | 2,400 | 2,380 | 1.9 | 1.6 | 1.7 |

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**Table 1-2 (Continued)**
**Each Company's Factory Revenue from Shipments of Total Semiconductors Worldwide (Excluding Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Novasensor | 13 | 15 | 0 | 0 | 0 | 0 |
| Oak Technology | 62 | 84 | 172 | 0 | 0 | 0.1 |
| Optek | 56 | 62 | 69 | 0 | 0 | 0 |
| OPTi | 130 | 167 | 119 | 0.1 | 0.1 | 0 |
| Paradigm | 36 | 55 | 23 | 0 | 0 | 0 |
| Performance Semiconductor | 20 | 28 | 0 | 0 | 0 | 0 |
| Powerex | 76 | 98 | 98 | 0 | 0 | 0 |
| Q Logic | 45 | 61 | 67 | 0 | 0 | 0 |
| Quality Semiconductor | 22 | 46 | 45 | 0 | 0 | 0 |
| Quality Technologies | 49 | 61 | 52 | 0 | 0 | 0 |
| QuickLogic | 8 | 16 | 25 | 0 | 0 | 0 |
| Ramtron | 15 | 25 | 14 | 0 | 0 | 0 |
| Raytheon | 108 | 125 | 131 | 0 | 0 | 0 |
| Rockwell | 514 | 744 | 1,351 | 0.5 | 0.5 | 1.0 |
| S3 | 130 | 315 | 464 | 0.1 | 0.2 | 0.3 |
| Seeq Technology | 22 | 27 | 32 | 0 | 0 | 0 |
| Semtech | 25 | 48 | 66 | 0 | 0 | 0 |
| Sensym | 8 | 0 | 0 | 0 | 0 | 0 |
| Sierra Semiconductor | 120 | 143 | 188 | 0.1 | 0 | 0.1 |
| Silicon Storage Technology | 0 | 35 | 91 | 0 | 0 | 0 |
| Silicon Systems | 298 | 369 | 0 | 0.3 | 0.2 | 0 |
| Sipex | 2 | 2 | 0 | 0 | 0 | 0 |
| Solitron | 5 | 6 | 6 | 0 | 0 | 0 |
| Spectra Diode Labs | 10 | 15 | 17 | 0 | 0 | 0 |
| Standard Microsystems | 100 | 150 | 153 | 0 | 0.1 | 0.1 |
| Sun Microsystems | 0 | 0 | 170 | 0 | 0 | 0.1 |
| Supertex | 30 | 35 | 33 | 0 | 0 | 0 |
| Symbios | 354 | 395 | 458 | 0.3 | 0.3 | 0.3 |
| Symphony Laboratories | 12 | 15 | 17 | 0 | 0 | 0 |
| Teccor Electronics | 60 | 68 | 84 | 0 | 0 | 0 |
| Telcom | 18 | 17 | 18 | 0 | 0 | 0 |
| Texas Instruments | 5,548 | 7,831 | 7,064 | 5.1 | 5.2 | 5.0 |
| Trident Microsystems | 87 | 139 | 180 | 0 | 0 | 0.1 |
| Tseng Labs | 83 | 105 | 26 | 0 | 0 | 0 |
| Unitrode | 73 | 103 | 98 | 0 | 0 | 0 |
| Universal | 13 | 15 | 0 | 0 | 0 | 0 |
| VLSI Technology | 588 | 672 | 672 | 0.5 | 0.4 | 0.5 |
| VTC | 70 | 155 | 172 | 0 | 0.1 | 0.1 |

**Table 1-2 (Continued)**
**Each Company's Factory Revenue from Shipments of Total Semiconductors Worldwide (Excluding Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| WaferScale Integration | 21 | 36 | 48 | 0 | 0 | 0 |
| Weitek | 28 | 37 | 0 | 0 | 0 | 0 |
| Western Digital | 184 | 240 | 0 | 0.2 | 0.2 | 0 |
| Xicor | 100 | 114 | 123 | 0 | 0 | 0 |
| Xilinx | 321 | 520 | 566 | 0.3 | 0.3 | 0.4 |
| Zilog | 222 | 265 | 286 | 0.2 | 0.2 | 0.2 |
| Zoran | 0 | 0 | 29 | 0 | 0 | 0 |
| Other Americas | 39 | 33 | 40 | 0 | 0 | 0 |
| Japanese Companies | 43,642 | 59,230 | 49,639 | 40.1 | 39.6 | 35.4 |
| Fuji Electric | 424 | 543 | 465 | 0.4 | 0.4 | 0.3 |
| Fujitsu | 3,753 | 5,386 | 4,293 | 3.4 | 3.6 | 3.1 |
| Hitachi | 6,508 | 8,998 | 7,953 | 6.0 | 6.0 | 5.7 |
| Matsushita | 2,896 | 3,474 | 3,003 | 2.7 | 2.3 | 2.1 |
| Mitsubishi | 3,663 | 5,076 | 3,913 | 3.4 | 3.4 | 2.8 |
| NEC | 7,863 | 11,184 | 10,303 | 7.2 | 7.5 | 7.3 |
| New JRC | 218 | 237 | 200 | 0.2 | 0.2 | 0.1 |
| Nippon Steel Semiconductor | 160 | 549 | 198 | 0.1 | 0.4 | 0.1 |
| Oki | 1,458 | 2,015 | 1,164 | 1.3 | 1.3 | 0.8 |
| Ricoh | 182 | 213 | 168 | 0.2 | 0.1 | 0.1 |
| Rohm | 1,273 | 1,856 | 1,658 | 1.2 | 1.2 | 1.2 |
| Sanken | 368 | 450 | 368 | 0.3 | 0.3 | 0.3 |
| Sanyo | 2,147 | 2,521 | 2,314 | 2.0 | 1.7 | 1.7 |
| Seiko Epson | 273 | 313 | 256 | 0.3 | 0.2 | 0.2 |
| Sharp | 2,188 | 2,592 | 2,124 | 2.0 | 1.7 | 1.5 |
| Shindengen Electric | 194 | 301 | 277 | 0.2 | 0.2 | 0.2 |
| Sony | 1,835 | 2,292 | 1,918 | 1.7 | 1.5 | 1.4 |
| Stanley Electric | 0 | 301 | 0 | 0 | 0.2 | 0 |
| Toko | 83 | 105 | 86 | 0 | 0 | 0 |
| Toshiba | 7,497 | 10,002 | 8,029 | 6.9 | 6.7 | 5.7 |
| Yamaha | 382 | 444 | 295 | 0.4 | 0.3 | 0.2 |
| Other Japanese | 277 | 378 | 654 | 0.3 | 0.3 | 0.5 |
| European Companies | 9,730 | 12,737 | 13,607 | 8.9 | 8.5 | 9.7 |
| ABB-Hafo | 32 | 33 | 0 | 0 | 0 | 0 |
| Austria Mikro Systeme | 110 | 149 | 140 | 0.1 | 0 | 0 |
| Elex | 20 | 33 | 34 | 0 | 0 | 0 |
| Elmos | 15 | 19 | 7 | 0 | 0 | 0 |
| EM Microelectronics Marin | 65 | 77 | 85 | 0 | 0 | 0 |
| Ericsson | 94 | 105 | 157 | 0 | 0 | 0.1 |

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**Table 1-2 (Continued)**
**Each Company's Factory Revenue from Shipments of Total Semiconductors Worldwide (Excluding Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Eupec | 98 | 120 | 160 | 0 | 0 | 0.1 |
| European Silicon Structures | 40 | 59 | 0 | 0 | 0 | 0 |
| Fagor | 27 | 38 | 0 | 0 | 0 | 0 |
| GEC Plessey | 308 | 365 | 338 | 0.3 | 0.2 | 0.2 |
| Micronas | 20 | 33 | 33 | 0 | 0 | 0 |
| Mietec | 178 | 179 | 190 | 0.2 | 0.1 | 0.1 |
| Philips | 2,866 | 3,854 | 4,179 | 2.6 | 2.6 | 3.0 |
| Semikron | 112 | 125 | 109 | 0.1 | 0 | 0 |
| SGS-Thomson | 2,640 | 3,398 | 4,112 | 2.4 | 2.3 | 2.9 |
| Siemens | 2,090 | 3,063 | 3,029 | 1.9 | 2.0 | 2.2 |
| TCS | 78 | 100 | 83 | 0 | 0 | 0 |
| TEMIC | 719 | 773 | 813 | 0.7 | 0.5 | 0.6 |
| Thesys | 15 | 20 | 0 | 0 | 0 | 0 |
| Westcode | 41 | 54 | 0 | 0 | 0 | 0 |
| Zetex | 40 | 56 | 54 | 0 | 0 | 0 |
| Other European | 67 | 84 | 84 | 0 | 0 | 0 |
| Asia/Pacific Companies | 9,849 | 17,805 | 13,508 | 9.0 | 11.9 | 9.6 |
| Acer | 70 | 80 | 50 | 0 | 0 | 0 |
| Daewoo | 38 | 49 | 45 | 0 | 0 | 0 |
| Holtek | 70 | 87 | 99 | 0 | 0 | 0 |
| Hualon Microelectronics Corp. | 89 | 107 | 47 | 0 | 0 | 0 |
| Hyundai | 1,521 | 4,132 | 2,247 | 1.4 | 2.8 | 1.6 |
| Korean Electronic Co. | 225 | 287 | 268 | 0.2 | 0.2 | 0.2 |
| LG Semicon | 1,697 | 2,863 | 2,243 | 1.6 | 1.9 | 1.6 |
| Macronix | 221 | 271 | 354 | 0.2 | 0.2 | 0.3 |
| Mosel Vitelic | 259 | 502 | 398 | 0.2 | 0.3 | 0.3 |
| Samsung | 4,832 | 8,332 | 6,464 | 4.4 | 5.6 | 4.6 |
| Silicon Integrated Systems | 101 | 127 | 127 | 0 | 0 | 0 |
| United Microelectronics Corp. | 418 | 477 | 492 | 0.4 | 0.3 | 0.4 |
| Vanguard | 0 | 0 | 225 | 0 | 0 | 0.2 |
| VIA | 0 | 0 | 110 | 0 | 0 | 0 |
| Winbond Electronics | 308 | 491 | 339 | 0.3 | 0.3 | 0.2 |

Source: Dataquest (April 1997)


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**Table 1-3**
**Each Company's Factory Revenue from Shipments of Total ICs Worldwide (Including Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Total Market | 95,861 | 132,136 | 123,300 | 100.0 | 100.0 | 100.0 |
| Americas Companies | 42,814 | 55,754 | 59,376 | 44.7 | 42.2 | 48.2 |
| ACC Microelectronics | 49 | 40 | 45 | 0 | 0 | 0 |
| Actel | 76 | 109 | 149 | 0 | 0 | 0.1 |
| Adaptec | 125 | 124 | 214 | 0.1 | 0 | 0.2 |
| Advanced Micro Devices | 2,134 | 2,337 | 1,947 | 2.2 | 1.8 | 1.6 |
| Allegro MicroSystems | 139 | 156 | 181 | 0.1 | 0.1 | 0.1 |
| Alliance Semiconductor | 90 | 220 | 76 | 0 | 0.2 | 0 |
| Altera | 199 | 402 | 497 | 0.2 | 0.3 | 0.4 |
| Analog Devices | 739 | 983 | 1,260 | 0.8 | 0.7 | 1.0 |
| Appian Technology | 7 | 9 | 10 | 0 | 0 | 0 |
| Applied Micro Circuits Corp. | 48 | 49 | 56 | 0 | 0 | 0 |
| ATI Technologies | 0 | 0 | 130 | 0 | 0 | 0.1 |
| Atmel | 375 | 589 | 1,024 | 0.4 | 0.4 | 0.8 |
| Brooktree | 109 | 120 | 0 | 0.1 | 0 | 0 |
| Burr-Brown | 165 | 186 | 207 | 0.2 | 0.1 | 0.2 |
| California Micro Devices | 10 | 13 | 8 | 0 | 0 | 0 |
| Catalyst | 50 | 48 | 54 | 0 | 0 | 0 |
| C-Cube | 0 | 0 | 150 | 0 | 0 | 0.1 |
| Cherry Semiconductor | 77 | 87 | 100 | 0 | 0 | 0 |
| Chip Express | 0 | 0 | 25 | 0 | 0 | 0 |
| Chips & Technologies | 89 | 138 | 150 | 0 | 0.1 | 0.1 |
| Cirrus Logic | 781 | 1,003 | 891 | 0.8 | 0.8 | 0.7 |
| Comlinear | 16 | 0 | 0 | 0 | 0 | 0 |
| Crosspoint Solutions | 0 | 2 | 2 | 0 | 0 | 0 |
| Cypress Semiconductor | 400 | 553 | 516 | 0.4 | 0.4 | 0.4 |
| Cyrix | 241 | 212 | 160 | 0.3 | 0.2 | 0.1 |
| Dallas Semiconductor | 154 | 228 | 277 | 0.2 | 0.2 | 0.2 |
| Digital | 0 | 0 | 271 | 0 | 0 | 0.2 |
| DSP Group | 18 | 60 | 67 | 0 | 0 | 0 |
| Elantec | 24 | 25 | 35 | 0 | 0 | 0 |
| Electronic Designs | 26 | 43 | 51 | 0 | 0 | 0 |
| ETEQ Microsystems | 6 | 7 | 4 | 0 | 0 | 0 |
| Exar | 169 | 147 | 96 | 0.2 | 0.1 | 0 |
| Gennum | 31 | 34 | 37 | 0 | 0 | 0 |
| G-Link USA | 0 | 14 | 15 | 0 | 0 | 0 |
| Gould AMI | 136 | 72 | 95 | 0.1 | 0 | 0 |
| Harris | 478 | 457 | 397 | 0.5 | 0.3 | 0.3 |


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**Table 1-3 (Continued)**
**Each Company's Factory Revenue from Shipments of Total ICs Worldwide (Including Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Hewlett-Packard | 255 | 342 | 380 | 0.3 | 0.3 | 0.3 |
| Holt | 9 | 11 | 0 | 0 | 0 | 0 |
| Honeywell | 23 | 27 | 30 | 0 | 0 | 0 |
| Hughes | 40 | 36 | 39 | 0 | 0 | 0 |
| IBM | 2,532 | 3,522 | 2,740 | 2.6 | 2.7 | 2.2 |
| IMI | 20 | 35 | 39 | 0 | 0 | 0 |
| IMP | 49 | 54 | 35 | 0 | 0 | 0 |
| Integrated Circuit Systems | 81 | 97 | 79 | 0 | 0 | 0 |
| Integrated Device Technology | 385 | 617 | 554 | 0.4 | 0.5 | 0.4 |
| Integrated Information Tech. | 35 | 44 | 51 | 0 | 0 | 0 |
| Integrated Silicon Solutions | 60 | 158 | 111 | 0 | 0.1 | 0 |
| Intel | 10,099 | 13,172 | 17,781 | 10.5 | 10.0 | 14.4 |
| International CMOS Technology | 12 | 16 | 12 | 0 | 0 | 0 |
| International Rectifier | 8 | 18 | 27 | 0 | 0 | 0 |
| ITT | 127 | 124 | 193 | 0.1 | 0 | 0.2 |
| Kulite | 20 | 24 | 0 | 0 | 0 | 0 |
| Lattice | 134 | 186 | 200 | 0.1 | 0.1 | 0.2 |
| Level One Communications | 0 | 78 | 112 | 0 | 0 | 0 |
| Linear Technology | 225 | 305 | 365 | 0.2 | 0.2 | 0.3 |
| Linfinity | 44 | 50 | 51 | 0 | 0 | 0 |
| Logic Devices | 14 | 17 | 14 | 0 | 0 | 0 |
| LSI Logic | 901 | 1,269 | 1,239 | 0.9 | 1.0 | 1.0 |
| Lucent Technologies | 1,250 | 1,534 | 2,020 | 1.3 | 1.2 | 1.6 |
| Maxim | 169 | 189 | 387 | 0.2 | 0.1 | 0.3 |
| Micrel | 25 | 26 | 24 | 0 | 0 | 0 |
| Micro Linear | 41 | 54 | 54 | 0 | 0 | 0 |
| Micro Power Systems | 23 | 0 | 0 | 0 | 0 | 0 |
| Microchip Technology | 212 | 271 | 330 | 0.2 | 0.2 | 0.3 |
| Micron Technology | 1,492 | 2,601 | 1,558 | 1.6 | 2.0 | 1.3 |
| Mitel | 100 | 88 | 123 | 0.1 | 0 | 0 |
| Motorola | 6,096 | 7,022 | 6,584 | 6.4 | 5.3 | 5.3 |
| National Semiconductor | 2,028 | 2,244 | 2,223 | 2.1 | 1.7 | 1.8 |
| Novasensor | 13 | 15 | 0 | 0 | 0 | 0 |
| Oak Technology | 62 | 84 | 172 | 0 | 0 | 0.1 |
| Optek | 7 | 8 | 9 | 0 | 0 | 0 |
| OPTi | 130 | 167 | 119 | 0.1 | 0.1 | 0 |
| Paradigm | 36 | 55 | 23 | 0 | 0 | 0 |
| Performance Semiconductor | 20 | 28 | 0 | 0 | 0 | 0 |

**Table 1-3 (Continued)**
**Each Company's Factory Revenue from Shipments of Total ICs Worldwide (Including Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Q Logic | 45 | 61 | 67 | 0 | 0 | 0 |
| Quality Semiconductor | 22 | 46 | 45 | 0 | 0 | 0 |
| QuickLogic | 8 | 16 | 25 | 0 | 0 | 0 |
| Ramtron | 15 | 25 | 14 | 0 | 0 | 0 |
| Raytheon | 100 | 112 | 118 | 0.1 | 0 | 0 |
| Rockwell | 514 | 744 | 1,351 | 0.5 | 0.6 | 1.1 |
| S3 | 130 | 315 | 464 | 0.1 | 0.2 | 0.4 |
| Seeq Technology | 22 | 27 | 32 | 0 | 0 | 0 |
| Semtech | 5 | 19 | 42 | 0 | 0 | 0 |
| Sierra Semiconductor | 120 | 143 | 188 | 0.1 | 0.1 | 0.2 |
| Silicon Storage Technology | 0 | 35 | 91 | 0 | 0 | 0 |
| Silicon Systems | 298 | 369 | 0 | 0.3 | 0.3 | 0 |
| Sipex | 16 | 16 | 13 | 0 | 0 | 0 |
| Solitron | 2 | 2 | 4 | 0 | 0 | 0 |
| Standard Microsystems | 100 | 150 | 153 | 0.1 | 0.1 | 0.1 |
| Sun Microsystems | 0 | 0 | 170 | 0 | 0 | 0.1 |
| Supertex | 19 | 19 | 17 | 0 | 0 | 0 |
| Symbios | 354 | 395 | 458 | 0.4 | 0.3 | 0.4 |
| Symphony Laboratories | 12 | 15 | 17 | 0 | 0 | 0 |
| Telcom | 18 | 17 | 18 | 0 | 0 | 0 |
| Texas Instruments | 5,471 | 7,772 | 6,974 | 5.7 | 5.9 | 5.7 |
| Trident Microsystems | 87 | 139 | 180 | 0 | 0.1 | 0.1 |
| Tseng Labs | 83 | 105 | 26 | 0 | 0 | 0 |
| Unitrode | 88 | 103 | 98 | 0 | 0 | 0 |
| Universal | 13 | 15 | 0 | 0 | 0 | 0 |
| VLSI Technology | 588 | 672 | 672 | 0.6 | 0.5 | 0.5 |
| VTC | 70 | 155 | 172 | 0 | 0.1 | 0.1 |
| WaferScale Integration | 21 | 36 | 48 | 0 | 0 | 0 |
| Weitek | 28 | 37 | 0 | 0 | 0 | 0 |
| Western Digital | 184 | 240 | 0 | 0.2 | 0.2 | 0 |
| Xicor | 100 | 114 | 123 | 0.1 | 0 | 0 |
| Xilinx | 321 | 520 | 566 | 0.3 | 0.4 | 0.5 |
| Zilog | 222 | 265 | 286 | 0.2 | 0.2 | 0.2 |
| Zoran | 0 | 0 | 29 | 0 | 0 | 0 |
| Other Americas | 0 | 0 | 40 | 0 | 0 | 0 |
| Japanese Companies | 36,288 | 49,722 | 40,568 | 37.9 | 37.6 | 32.9 |
| Fuji Electric | 89 | 98 | 85 | 0 | 0 | 0 |
| Fujitsu | 3,542 | 5,084 | 3,986 | 3.7 | 3.8 | 3.2 |


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**Table 1-3 (Continued)**
**Each Company's Factory Revenue from Shipments of Total ICs Worldwide (Including Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Hitachi | 5,757 | 8,162 | 6,973 | 6.0 | 6.2 | 5.7 |
| Matsushita | 1,968 | 2,347 | 1,988 | 2.1 | 1.8 | 1.6 |
| Mitsubishi | 3,172 | 4,644 | 3,504 | 3.3 | 3.5 | 2.8 |
| NEC | 7,159 | 10,281 | 9,354 | 7.5 | 7.8 | 7.6 |
| New JRC | 205 | 223 | 188 | 0.2 | 0.2 | 0.2 |
| Nippon Steel Semiconductor | 160 | 549 | 198 | 0.2 | 0.4 | 0.2 |
| Oki | 1,437 | 1,988 | 1,138 | 1.5 | 1.5 | 0.9 |
| Ricoh | 182 | 213 | 168 | 0.2 | 0.2 | 0.1 |
| Rohm | 643 | 877 | 757 | 0.7 | 0.7 | 0.6 |
| Sanken | 240 | 283 | 254 | 0.3 | 0.2 | 0.2 |
| Sanyo | 1,782 | 2,059 | 1,902 | 1.9 | 1.6 | 1.5 |
| Seiko Epson | 273 | 313 | 256 | 0.3 | 0.2 | 0.2 |
| Sharp | 1,678 | 1,956 | 1,507 | 1.8 | 1.5 | 1.2 |
| Shindengen Electric | 48 | 28 | 21 | 0 | 0 | 0 |
| Sony | 1,513 | 1,898 | 1,567 | 1.6 | 1.4 | 1.3 |
| Toko | 40 | 45 | 39 | 0 | 0 | 0 |
| Toshiba | 5,931 | 8,025 | 6,204 | 6.2 | 6.1 | 5.0 |
| Yamaha | 382 | 444 | 295 | 0.4 | 0.3 | 0.2 |
| Other Japanese | 87 | 205 | 184 | 0 | 0.2 | 0.1 |
| European Companies | 7,278 | 9,418 | 10,380 | 7.6 | 7.1 | 8.4 |
| ABB-Hafo | 28 | 24 | 0 | 0 | 0 | 0 |
| Austria Mikro Systeme | 110 | 149 | 140 | 0.1 | 0.1 | 0.1 |
| Elex | 20 | 31 | 34 | 0 | 0 | 0 |
| Elmos | 15 | 19 | 7 | 0 | 0 | 0 |
| EM Microelectronics Marin | 65 | 77 | 85 | 0 | 0 | 0 |
| Ericsson | 83 | 84 | 119 | 0 | 0 | 0 |
| European Silicon Structures | 40 | 59 | 0 | 0 | 0 | 0 |
| GEC Plessey | 286 | 332 | 303 | 0.3 | 0.3 | 0.2 |
| Micronas | 20 | 43 | 33 | 0 | 0 | 0 |
| Mietec | 178 | 179 | 190 | 0.2 | 0.1 | 0.2 |
| Philips | 2,159 | 2,844 | 3,278 | 2.3 | 2.2 | 2.7 |
| SGS-Thomson | 2,207 | 2,807 | 3,526 | 2.3 | 2.1 | 2.9 |
| Siemens | 1,586 | 2,314 | 2,238 | 1.7 | 1.8 | 1.8 |
| TCS | 51 | 65 | 58 | 0 | 0 | 0 |
| TEMIC | 391 | 342 | 347 | 0.4 | 0.3 | 0.3 |
| Thesys | 15 | 20 | 0 | 0 | 0 | 0 |
| Zetex | 3 | 4 | 1 | 0 | 0 | 0 |
| Other European | 21 | 25 | 21 | 0 | 0 | 0 |

**Table 1-3 (Continued)**
**Each Company's Factory Revenue from Shipments of Total ICs Worldwide (Including Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Asia/Pacific Companies | 9,481 | 17,242 | 12,976 | 9.9 | 13.0 | 10.5 |
| Acer | 70 | 80 | 50 | 0 | 0 | 0 |
| Daewoo | 38 | 49 | 45 | 0 | 0 | 0 |
| Holtek | 70 | 87 | 99 | 0 | 0 | 0 |
| Hualon Microelectronics Corp. | 89 | 107 | 47 | 0 | 0 | 0 |
| Hyundai | 1,521 | 4,132 | 2,247 | 1.6 | 3.1 | 1.8 |
| Korean Electronic Co. | 47 | 45 | 51 | 0 | 0 | 0 |
| LG Semicon | 1,697 | 2,863 | 2,243 | 1.8 | 2.2 | 1.8 |
| Macronix | 221 | 271 | 354 | 0.2 | 0.2 | 0.3 |
| Mosel Vitelic | 259 | 502 | 398 | 0.3 | 0.4 | 0.3 |
| Samsung | 4,642 | 8,011 | 6,149 | 4.8 | 6.1 | 5.0 |
| Silicon Integrated Systems | 101 | 127 | 127 | 0.1 | 0 | 0.1 |
| United Microelectronics Corp. | 418 | 477 | 492 | 0.4 | 0.4 | 0.4 |
| Vanguard | 0 | 0 | 225 | 0 | 0 | 0.2 |
| VIA | 0 | 0 | 110 | 0 | 0 | 0 |
| Winbond Electronics | 308 | 491 | 339 | 0.3 | 0.4 | 0.3 |

Source: Dataquest (April 1997)


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**Table 1-4**
**Each Company's Factory Revenue from Shipments of Total Integrated Circuits Worldwide (Excluding Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Total Market | 94,196 | 130,481 | 121,832 | 100.0 | 100.0 | 100.0 |
| Americas Companies | 42,389 | 55,568 | 59,227 | 45.0 | 42.6 | 48.6 |
| ACC Microelectronics | 49 | 40 | 45 | 0 | 0 | 0 |
| Actel | 76 | 109 | 149 | 0 | 0 | 0.1 |
| Adaptec | 125 | 124 | 214 | 0.1 | 0 | 0.2 |
| Advanced Micro Devices | 2,134 | 2,337 | 1,947 | 2.3 | 1.8 | 1.6 |
| Allegro MicroSystems | 139 | 144 | 166 | 0.1 | 0.1 | 0.1 |
| Alliance Semiconductor | 90 | 220 | 76 | 0 | 0.2 | 0 |
| Altera | 199 | 402 | 497 | 0.2 | 0.3 | 0.4 |
| Analog Devices | 687 | 925 | 1,218 | 0.7 | 0.7 | 1.0 |
| Appian Technology | 7 | 9 | 10 | 0 | 0 | 0 |
| Applied Micro Circuits Corp. | 48 | 49 | 56 | 0 | 0 | 0 |
| ATI Technologies | 0 | 0 | 130 | 0 | 0 | 0.1 |
| Atmel | 375 | 589 | 1,024 | 0.4 | 0.5 | 0.8 |
| Brooktree | 109 | 120 | 0 | 0.1 | 0 | 0 |
| Burr-Brown | 105 | 126 | 157 | 0.1 | 0 | 0.1 |
| California Micro Devices | 10 | 13 | 8 | 0 | 0 | 0 |
| Catalyst | 50 | 48 | 54 | 0 | 0 | 0 |
| C-Cube | 0 | 0 | 150 | 0 | 0 | 0.1 |
| Cherry Semiconductor | 77 | 87 | 100 | 0 | 0 | 0 |
| Chip Express | 0 | 0 | 25 | 0 | 0 | 0 |
| Chips & Technologies | 89 | 138 | 150 | 0 | 0.1 | 0.1 |
| Cirrus Logic | 781 | 1,003 | 891 | 0.8 | 0.8 | 0.7 |
| Comlinear | 9 | 0 | 0 | 0 | 0 | 0 |
| Crosspoint Solutions | 0 | 2 | 2 | 0 | 0 | 0 |
| Cypress Semiconductor | 400 | 553 | 516 | 0.4 | 0.4 | 0.4 |
| Cyrix | 241 | 212 | 160 | 0.3 | 0.2 | 0.1 |
| Dallas Semiconductor | 154 | 228 | 277 | 0.2 | 0.2 | 0.2 |
| Digital | 0 | 0 | 271 | 0 | 0 | 0.2 |
| DSP Group | 18 | 60 | 67 | 0 | 0 | 0 |
| Elantec | 21 | 22 | 32 | 0 | 0 | 0 |
| Electronic Designs | 26 | 43 | 51 | 0 | 0 | 0 |
| ETEQ Microsystems | 6 | 7 | 4 | 0 | 0 | 0 |
| Exar | 169 | 147 | 96 | 0.2 | 0.1 | 0 |
| Gennum | 29 | 32 | 37 | 0 | 0 | 0 |
| G-Link USA | 0 | 14 | 15 | 0 | 0 | 0 |
| Gould AMI | 136 | 72 | 95 | 0.1 | 0 | 0 |
| Harris | 478 | 457 | 397 | 0.5 | 0.4 | 0.3 |

**Table 1-4 (Continued)**
**Each Company's Factory Revenue from Shipments of Total Integrated Circuits Worldwide (Excluding Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Hewlett-Packard | 255 | 342 | 380 | 0.3 | 0.3 | 0.3 |
| Holt | 9 | 11 | 0 | 0 | 0 | 0 |
| Honeywell | 23 | 27 | 30 | 0 | 0 | 0 |
| Hughes | 40 | 36 | 39 | 0 | 0 | 0 |
| IBM | 2,532 | 3,522 | 2,740 | 2.7 | 2.7 | 2.2 |
| IMI | 20 | 35 | 39 | 0 | 0 | 0 |
| IMP | 49 | 54 | 35 | 0 | 0 | 0 |
| Integrated Circuit Systems | 81 | 97 | 79 | 0 | 0 | 0 |
| Integrated Device Technology | 385 | 617 | 554 | 0.4 | 0.5 | 0.5 |
| Integrated Information Tech. | 35 | 44 | 51 | 0 | 0 | 0 |
| Integrated Silicon Solutions | 60 | 158 | 111 | 0 | 0.1 | 0 |
| Intel | 10,099 | 13,172 | 17,781 | 10.7 | 10.1 | 14.6 |
| International CMOS Technology | 12 | 16 | 12 | 0 | 0 | 0 |
| International Rectifier | 8 | 18 | 27 | 0 | 0 | 0 |
| ITT | 127 | 124 | 193 | 0.1 | 0 | 0.2 |
| Kulite | 20 | 24 | 0 | 0 | 0 | 0 |
| Lattice | 134 | 186 | 200 | 0.1 | 0.1 | 0.2 |
| Level One Communications | 0 | 78 | 112 | 0 | 0 | 0 |
| Linear Technology | 225 | 305 | 365 | 0.2 | 0.2 | 0.3 |
| Linfinity | 41 | 47 | 48 | 0 | 0 | 0 |
| Logic Devices | 14 | 17 | 14 | 0 | 0 | 0 |
| LSI Logic | 901 | 1,269 | 1,239 | 1.0 | 1.0 | 1.0 |
| Lucent Technologies | 1,250 | 1,534 | 2,020 | 1.3 | 1.2 | 1.7 |
| Maxim | 165 | 185 | 383 | 0.2 | 0.1 | 0.3 |
| Micrel | 25 | 26 | 24 | 0 | 0 | 0 |
| Micro Linear | 41 | 54 | 54 | 0 | 0 | 0 |
| Micro Power Systems | 23 | 0 | 0 | 0 | 0 | 0 |
| Microchip Technology | 212 | 271 | 330 | 0.2 | 0.2 | 0.3 |
| Micron Technology | 1,492 | 2,601 | 1,558 | 1.6 | 2.0 | 1.3 |
| Mitel | 70 | 68 | 107 | 0 | 0 | 0 |
| Motorola | 5,870 | 7,022 | 6,584 | 6.2 | 5.4 | 5.4 |
| National Semiconductor | 2,021 | 2,236 | 2,223 | 2.1 | 1.7 | 1.8 |
| Novasensor | 13 | 15 | 0 | 0 | 0 | 0 |
| Oak Technology | 62 | 84 | 172 | 0 | 0 | 0.1 |
| Optek | 7 | 8 | 9 | 0 | 0 | 0 |
| OPTi | 130 | 167 | 119 | 0.1 | 0.1 | 0 |
| Paradigm | 36 | 55 | 23 | 0 | 0 | 0 |
| Performance Semiconductor | 20 | 28 | 0 | 0 | 0 | 0 |


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**Table 1-4 (Continued)**
**Each Company's Factory Revenue from Shipments of Total Integrated Circuits Worldwide (Excluding Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Q Logic | 45 | 61 | 67 | 0 | 0 | 0 |
| Quality Semiconductor | 22 | 46 | 45 | 0 | 0 | 0 |
| QuickLogic | 8 | 16 | 25 | 0 | 0 | 0 |
| Ramtron | 15 | 25 | 14 | 0 | 0 | 0 |
| Raytheon | 100 | 112 | 118 | 0.1 | 0 | 0 |
| Rockwell | 514 | 744 | 1,351 | 0.5 | 0.6 | 1.1 |
| S3 | 130 | 315 | 464 | 0.1 | 0.2 | 0.4 |
| Seeq Technology | 22 | 27 | 32 | 0 | 0 | 0 |
| Semtech | 5 | 19 | 42 | 0 | 0 | 0 |
| Sierra Semiconductor | 120 | 143 | 188 | 0.1 | 0.1 | 0.2 |
| Silicon Storage Technology | 0 | 35 | 91 | 0 | 0 | 0 |
| Silicon Systems | 298 | 369 | 0 | 0.3 | 0.3 | 0 |
| Sipex | 2 | 2 | 0 | 0 | 0 | 0 |
| Solitron | 0 | 0 | 1 | 0 | 0 | 0 |
| Standard Microsystems | 100 | 150 | 153 | 0.1 | 0.1 | 0.1 |
| Sun Microsystems | 0 | 0 | 170 | 0 | 0 | 0.1 |
| Supertex | 19 | 19 | 17 | 0 | 0 | 0 |
| Symbios | 354 | 395 | 458 | 0.4 | 0.3 | 0.4 |
| Symphony Laboratories | 12 | 15 | 17 | 0 | 0 | 0 |
| Telcom | 18 | 17 | 18 | 0 | 0 | 0 |
| Texas Instruments | 5,471 | 7,772 | 6,974 | 5.8 | 6.0 | 5.7 |
| Trident Microsystems | 87 | 139 | 180 | 0 | 0.1 | 0.1 |
| Tseng Labs | 83 | 105 | 26 | 0 | 0 | 0 |
| Unitrode | 73 | 103 | 98 | 0 | 0 | 0 |
| Universal | 13 | 15 | 0 | 0 | 0 | 0 |
| VLSI Technology | 588 | 672 | 672 | 0.6 | 0.5 | 0.6 |
| VTC | 70 | 155 | 172 | 0 | 0.1 | 0.1 |
| WaferScale Integration | 21 | 36 | 48 | 0 | 0 | 0 |
| Weitek | 28 | 37 | 0 | 0 | 0 | 0 |
| Western Digital | 184 | 240 | 0 | 0.2 | 0.2 | 0 |
| Xicor | 100 | 114 | 123 | 0.1 | 0 | 0.1 |
| Xilinx | 321 | 520 | 566 | 0.3 | 0.4 | 0.5 |
| Zilog | 222 | 265 | 286 | 0.2 | 0.2 | 0.2 |
| Zoran | 0 | 0 | 29 | 0 | 0 | 0 |
| Other Americas | 0 | 0 | 40 | 0 | 0 | 0 |
| Japanese Companies | 35,152 | 48,353 | 39,323 | 37.3 | 37.1 | 32.3 |
| Fuji Electric | 67 | 75 | 64 | 0 | 0 | 0 |
| Fujitsu | 3,426 | 4,935 | 3,852 | 3.6 | 3.8 | 3.2 |

**Table 1-4 (Continued)**
**Each Company's Factory Revenue from Shipments of Total Integrated Circuits Worldwide (Excluding Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Hitachi | 5,621 | 8,025 | 6,855 | 6.0 | 6.2 | 5.6 |
| Matsushita | 1,968 | 2,347 | 1,988 | 2.1 | 1.8 | 1.6 |
| Mitsubishi | 3,063 | 4,446 | 3,317 | 3.3 | 3.4 | 2.7 |
| NEC | 7,061 | 10,151 | 9,229 | 7.5 | 7.8 | 7.6 |
| New JRC | 205 | 223 | 188 | 0.2 | 0.2 | 0.2 |
| Nippon Steel Semiconductor | 160 | 549 | 198 | 0.2 | 0.4 | 0.2 |
| Oki | 1,424 | 1,975 | 1,125 | 1.5 | 1.5 | 0.9 |
| Ricoh | 182 | 213 | 168 | 0.2 | 0.2 | 0.1 |
| Rohm | 571 | 799 | 684 | 0.6 | 0.6 | 0.6 |
| Sanyo | 1,608 | 1,866 | 1,725 | 1.7 | 1.4 | 1.4 |
| Seiko Epson | 273 | 313 | 256 | 0.3 | 0.2 | 0.2 |
| Sharp | 1,678 | 1,956 | 1,507 | 1.8 | 1.5 | 1.2 |
| Sony | 1,472 | 1,857 | 1,502 | 1.6 | 1.4 | 1.2 |
| Toko | 32 | 37 | 31 | 0 | 0 | 0 |
| Toshiba | 5,872 | 7,951 | 6,168 | 6.2 | 6.1 | 5.1 |
| Yamaha | 382 | 444 | 295 | 0.4 | 0.3 | 0.2 |
| Other Japanese | 87 | 191 | 171 | 0 | 0.1 | 0.1 |
| European Companies | 7,174 | 9,318 | 10,306 | 7.6 | 7.1 | 8.5 |
| ABB-Hafo | 20 | 19 | 0 | 0 | 0 | 0 |
| Austria Mikro Systeme | 110 | 149 | 140 | 0.1 | 0.1 | 0.1 |
| Elex | 20 | 31 | 34 | 0 | 0 | 0 |
| Elmos | 15 | 19 | 7 | 0 | 0 | 0 |
| EM Microelectronics Marin | 65 | 77 | 85 | 0 | 0 | 0 |
| Ericsson | 64 | 69 | 106 | 0 | 0 | 0 |
| European Silicon Structures | 40 | 59 | 0 | 0 | 0 | 0 |
| GEC Plessey | 280 | 329 | 303 | 0.3 | 0.3 | 0.2 |
| Micronas | 20 | 33 | 33 | 0 | 0 | 0 |
| Mietec | 178 | 179 | 190 | 0.2 | 0.1 | 0.2 |
| Philips | 2,105 | 2,798 | 3,238 | 2.2 | 2.1 | 2.7 |
| SGS-Thomson | 2,207 | 2,807 | 3,526 | 2.3 | 2.2 | 2.9 |
| Siemens | 1,586 | 2,314 | 2,238 | 1.7 | 1.8 | 1.8 |
| TCS | 51 | 65 | 58 | 0 | 0 | 0 |
| TEMIC | 391 | 342 | 347 | 0.4 | 0.3 | 0.3 |
| Thesys | 15 | 20 | 0 | 0 | 0 | 0 |
| Zetex | 3 | 4 | 1 | 0 | 0 | 0 |
| Other European | 4 | 4 | 0 | 0 | 0 | 0 |


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**Table 1-4 (Continued)**
**Each Company's Factory Revenue from Shipments of Total Integrated Circuits Worldwide (Excluding Hybrid) (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Asia/Pacific Companies | 9,481 | 17,242 | 12,976 | 10.1 | 13.2 | 10.7 |
| Acer | 70 | 80 | 50 | 0 | 0 | 0 |
| Daewoo | 38 | 49 | 45 | 0 | 0 | 0 |
| Holtek | 70 | 87 | 99 | 0 | 0 | 0 |
| Hualon Microelectronics Corp. | 89 | 107 | 47 | 0 | 0 | 0 |
| Hyundai | 1,521 | 4,132 | 2,247 | 1.6 | 3.2 | 1.8 |
| Korean Electronic Co. | 47 | 45 | 51 | 0 | 0 | 0 |
| LG Semicon | 1,697 | 2,863 | 2,243 | 1.8 | 2.2 | 1.8 |
| Macronix | 221 | 271 | 354 | 0.2 | 0.2 | 0.3 |
| Mosel Vitelic | 259 | 502 | 398 | 0.3 | 0.4 | 0.3 |
| Samsung | 4,642 | 8,011 | 6,149 | 4.9 | 6.1 | 5.0 |
| Silicon Integrated Systems | 101 | 127 | 127 | 0.1 | 0 | 0.1 |
| United Microelectronics Corp. | 418 | 477 | 492 | 0.4 | 0.4 | 0.4 |
| Vanguard | 0 | 0 | 225 | 0 | 0 | 0.2 |
| VIA | 0 | 0 | 110 | 0 | 0 | 0 |
| Winbond Electronics | 308 | 491 | 339 | 0.3 | 0.4 | 0.3 |

Source: Dataquest (April 1997)


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**Table 1-5**
**Each Company's Factory Revenue from Shipments of Bipolar Digital Worldwide**
**(Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Total Market | 2,912 | 2,455 | 1,849 | 100.0 | 100.0 | 100.0 |
| Americas Companies | 1,473 | 1,295 | 953 | 50.6 | 52.7 | 51.5 |
| Advanced Micro Devices | 143 | 100 | 62 | 4.9 | 4.1 | 3.4 |
| Applied Micro Circuits Corp. | 20 | 19 | 30 | 0.7 | 0.8 | 1.6 |
| Harris | 6 | 4 | 4 | 0.2 | 0.2 | 0.2 |
| Lucent Technologies | 63 | 50 | 70 | 2.2 | 2.0 | 3.8 |
| Motorola | 421 | 381 | 271 | 14.5 | 15.5 | 14.7 |
| National Semiconductor | 221 | 209 | 161 | 7.6 | 8.5 | 8.7 |
| Raytheon | 22 | 19 | 15 | 0.8 | 0.8 | 0.8 |
| Texas Instruments | 577 | 513 | 340 | 19.8 | 20.9 | 18.4 |
| Japanese Companies | 1,207 | 972 | 752 | 41.4 | 39.6 | 40.7 |
| Fujitsu | 395 | 203 | 90 | 13.6 | 8.3 | 4.9 |
| Hitachi | 465 | 442 | 451 | 16.0 | 18.0 | 24.4 |
| Matsushita | 29 | 29 | 19 | 1.0 | 1.2 | 1.0 |
| Mitsubishi | 23 | 37 | 25 | 0.8 | 1.5 | 1.4 |
| NEC | 194 | 109 | 90 | 6.7 | 4.4 | 4.9 |
| Oki | 33 | 36 | 4 | 1.1 | 1.5 | 0.2 |
| Toshiba | 68 | 116 | 73 | 2.3 | 4.7 | 3.9 |
| European Companies | 186 | 174 | 134 | 6.4 | 7.1 | 7.2 |
| GEC Plessey | 16 | 10 | 12 | 0.5 | 0.4 | 0.6 |
| Philips | 121 | 123 | 90 | 4.2 | 5.0 | 4.9 |
| SGS-Thomson | 12 | 6 | 0 | 0.4 | 0.2 | 0 |
| Siemens | 33 | 31 | 32 | 1.1 | 1.3 | 1.7 |
| Other European | 4 | 4 | 0 | 0.1 | 0.2 | 0 |
| Asia/Pacific Companies | 46 | 14 | 10 | 1.6 | 0.6 | 0.5 |
| LG Semicon | 46 | 14 | 10 | 1.6 | 0.6 | 0.5 |

Source: Dataquest (April 1997)


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**Table 1-6**
**Each Company's Factory Revenue from Shipments of Bipolar Logic Worldwide (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Total Market | 2,678 | 2,182 | 1,620 | 100.0 | 100.0 | 100.0 |
| Americas Companies | 1,402 | 1,154 | 922 | 52.4 | 52.9 | 56.9 |
| Advanced Micro Devices | 102 | 69 | 62 | 3.8 | 3.2 | 3.8 |
| Applied Micro Circuits Corp. | 20 | 19 | 30 | 0.7 | 0.9 | 1.9 |
| Harris | 6 | 4 | 4 | 0.2 | 0.2 | 0.2 |
| Lucent Technologies | 60 | 45 | 70 | 2.2 | 2.1 | 4.3 |
| Motorola | 420 | 359 | 251 | 15.7 | 16.5 | 15.5 |
| National Semiconductor | 212 | 138 | 157 | 7.9 | 6.3 | 9.7 |
| Raytheon | 17 | 15 | 12 | 0.6 | 0.7 | 0.7 |
| Texas Instruments | 565 | 505 | 336 | 21.1 | 23.1 | 20.7 |
| Japanese Companies | 1,058 | 854 | 577 | 39.5 | 39.1 | 35.6 |
| Fujitsu | 363 | 183 | 70 | 13.6 | 8.4 | 4.3 |
| Hitachi | 372 | 361 | 372 | 13.9 | 16.5 | 23.0 |
| Matsushita | 26 | 26 | 19 | 1.0 | 1.2 | 1.2 |
| Mitsubishi | 23 | 37 | 25 | 0.9 | 1.7 | 1.5 |
| NEC | 178 | 100 | 82 | 6.6 | 4.6 | 5.1 |
| Oki | 33 | 36 | 4 | 1.2 | 1.6 | 0.2 |
| Toshiba | 63 | 111 | 5 | 2.4 | 5.1 | 0.3 |
| European Companies | 172 | 160 | 111 | 6.4 | 7.3 | 6.9 |
| GEC Plessey | 16 | 10 | 0 | 0.6 | 0.5 | 0 |
| Philips | 107 | 109 | 79 | 4.0 | 5.0 | 4.9 |
| SGS-Thomson | 12 | 6 | 0 | 0.4 | 0.3 | 0 |
| Siemens | 33 | 31 | 32 | 1.2 | 1.4 | 2.0 |
| Other European | 4 | 4 | 0 | 0.1 | 0.2 | 0 |
| Asia/Pacific Companies | 46 | 14 | 10 | 1.7 | 0.6 | 0.6 |
| LG Semicon | 46 | 14 | 10 | 1.7 | 0.6 | 0.6 |

Source: Dataquest (April 1997)


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**Table 1-7**
**Each Company's Factory Revenue from Shipments of Other Bipolar Logic/Memory/ Microcomponents Worldwide (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Total Market | 234 | 273 | 229 | 100.0 | 100.0 | 100.0 |
| Americas Companies | 71 | 141 | 31 | 30.3 | 51.6 | 13.5 |
| Advanced Micro Devices | 41 | 31 | 0 | 17.5 | 11.4 | 0 |
| Lucent Technologies | 3 | 5 | 0 | 1.3 | 1.8 | 0 |
| Motorola | 1 | 22 | 20 | 0.4 | 8.1 | 8.7 |
| National Semiconductor | 9 | 71 | 4 | 3.8 | 26.0 | 1.7 |
| Raytheon | 5 | 4 | 3 | 2.1 | 1.5 | 1.3 |
| Texas Instruments | 12 | 8 | 4 | 5.1 | 2.9 | 1.7 |
| Japanese Companies | 149 | 118 | 175 | 63.7 | 43.2 | 76.4 |
| Fujitsu | 32 | 20 | 20 | 13.7 | 7.3 | 8.7 |
| Hitachi | 93 | 81 | 79 | 39.7 | 29.7 | 34.5 |
| Matsushita | 3 | 3 | 0 | 1.3 | 1.1 | 0 |
| NEC | 16 | 9 | 8 | 6.8 | 3.3 | 3.5 |
| Toshiba | 5 | 5 | 68 | 2.1 | 1.8 | 29.7 |
| European Companies | 14 | 14 | 23 | 6.0 | 5.1 | 10.0 |
| GEC Plessey | 0 | 0 | 12 | 0 | 0 | 5.2 |
| Philips | 14 | 14 | 11 | 6.0 | 5.1 | 4.8 |

Source: Dataquest (April 1997)


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**Table 1-8**
**Each Company's Factory Revenue from Shipments of MOS Digital ICs Worldwide**
**(Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Total Market | 76,021 | 110,410 | 100,683 | 100.0 | 100.0 | 100.0 |
| Americas Companies | 34,456 | 46,979 | 49,752 | 45.3 | 42.5 | 49.4 |
| ACC Microelectronics | 49 | 40 | 45 | 0 | 0 | 0 |
| Actel | 76 | 109 | 149 | 0 | 0 | 0.1 |
| Adaptec | 125 | 124 | 214 | 0.2 | 0.1 | 0.2 |
| Advanced Micro Devices | 1,804 | 2,064 | 1,770 | 2.4 | 1.9 | 1.8 |
| Allegro MicroSystems | 5 | 0 | 0 | 0 | 0 | 0 |
| Alliance Semiconductor | 90 | 220 | 76 | 0.1 | 0.2 | 0 |
| Altera | 199 | 402 | 497 | 0.3 | 0.4 | 0.5 |
| Analog Devices | 85 | 116 | 258 | 0.1 | 0.1 | 0.3 |
| Appian Technology | 7 | 9 | 10 | 0 | 0 | 0 |
| Applied Micro Circuits Corp. | 21 | 25 | 21 | 0 | 0 | 0 |
| ATI Technologies | 0 | 0 | 130 | 0 | 0 | 0.1 |
| Atmel | 363 | 573 | 988 | 0.5 | 0.5 | 1.0 |
| California Micro Devices | 5 | 6 | 5 | 0 | 0 | 0 |
| Catalyst | 49 | 48 | 54 | 0 | 0 | 0 |
| C-Cube | 0 | 0 | 150 | 0 | 0 | 0.1 |
| Chip Express | 0 | 0 | 25 | 0 | 0 | 0 |
| Chips & Technologies | 89 | 138 | 150 | 0.1 | 0.1 | 0.1 |
| Cirrus Logic | 681 | 887 | 741 | 0.9 | 0.8 | 0.7 |
| Crosspoint Solutions | 0 | 2 | 2 | 0 | 0 | 0 |
| Cypress Semiconductor | 400 | 553 | 516 | 0.5 | 0.5 | 0.5 |
| Cyrix | 241 | 212 | 160 | 0.3 | 0.2 | 0.2 |
| Dallas Semiconductor | 154 | 228 | 230 | 0.2 | 0.2 | 0.2 |
| Digital | 0 | 0 | 271 | 0 | 0 | 0.3 |
| DSP Group | 18 | 60 | 67 | 0 | 0 | 0 |
| Electronic Designs | 26 | 43 | 51 | 0 | 0 | 0 |
| ETEQ Microsystems | 6 | 7 | 4 | 0 | 0 | 0 |
| Exar | 0 | 16 | 9 | 0 | 0 | 0 |
| G-Link USA | 0 | 14 | 15 | 0 | 0 | 0 |
| Gould AMI | 105 | 72 | 95 | 0.1 | 0 | 0 |
| Harris | 188 | 193 | 162 | 0.2 | 0.2 | 0.2 |
| Hewlett-Packard | 255 | 342 | 380 | 0.3 | 0.3 | 0.4 |
| Holt | 2 | 3 | 0 | 0 | 0 | 0 |
| Hughes | 21 | 20 | 21 | 0 | 0 | 0 |
| IBM | 2,532 | 3,522 | 2,740 | 3.3 | 3.2 | 2.7 |
| IMI | 18 | 30 | 34 | 0 | 0 | 0 |
| IMP | 9 | 12 | 0 | 0 | 0 | 0 |

**Table 1-8 (Continued)**
**Each Company's Factory Revenue from Shipments of MOS Digital ICs Worldwide**
**(Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Integrated Circuit Systems | 42 | 52 | 50 | 0 | 0 | 0 |
| Integrated Device Technology | 385 | 617 | 554 | 0.5 | 0.6 | 0.6 |
| Integrated Information Tech. | 35 | 44 | 51 | 0 | 0 | 0 |
| Integrated Silicon Solutions | 60 | 158 | 111 | 0 | 0.1 | 0.1 |
| Intel | 10,079 | 13,163 | 17,781 | 13.3 | 11.9 | 17.7 |
| International CMOS Technology | 12 | 16 | 12 | 0 | 0 | 0 |
| ITT | 103 | 110 | 183 | 0.1 | 0 | 0.2 |
| Lattice | 134 | 186 | 200 | 0.2 | 0.2 | 0.2 |
| Logic Devices | 14 | 17 | 14 | 0 | 0 | 0 |
| LSI Logic | 901 | 1,269 | 1,239 | 1.2 | 1.1 | 1.2 |
| Lucent Technologies | 785 | 1,200 | 1,649 | 1.0 | 1.1 | 1.6 |
| Micrel | 7 | 7 | 6 | 0 | 0 | 0 |
| Micro Linear | 6 | 0 | 0 | 0 | 0 | 0 |
| Microchip Technology | 212 | 271 | 330 | 0.3 | 0.2 | 0.3 |
| Micron Technology | 1,492 | 2,601 | 1,558 | 2.0 | 2.4 | 1.5 |
| Motorola | 4,525 | 5,610 | 5,103 | 6.0 | 5.1 | 5.1 |
| National Semiconductor | 893 | 993 | 1,022 | 1.2 | 0.9 | 1.0 |
| Oak Technology | 62 | 84 | 172 | 0 | 0 | 0.2 |
| OPTi | 130 | 167 | 119 | 0.2 | 0.2 | 0.1 |
| Paradigm | 36 | 55 | 23 | 0 | 0 | 0 |
| Performance Semiconductor | 20 | 28 | 0 | 0 | 0 | 0 |
| Q Logic | 45 | 61 | 67 | 0 | 0 | 0 |
| Quality Semiconductor | 22 | 46 | 45 | 0 | 0 | 0 |
| QuickLogic | 8 | 16 | 25 | 0 | 0 | 0 |
| Ramtron | 15 | 25 | 14 | 0 | 0 | 0 |
| Rockwell | 514 | 744 | 1,230 | 0.7 | 0.7 | 1.2 |
| S3 | 130 | 315 | 464 | 0.2 | 0.3 | 0.5 |
| Seeq Technology | 22 | 27 | 12 | 0 | 0 | 0 |
| Sierra Semiconductor | 35 | 47 | 62 | 0 | 0 | 0 |
| Silicon Storage Technology | 0 | 35 | 91 | 0 | 0 | 0 |
| Standard Microsystems | 100 | 150 | 153 | 0.1 | 0.1 | 0.2 |
| Sun Microsystems | 0 | 0 | 170 | 0 | 0 | 0.2 |
| Supertex | 6 | 6 | 5 | 0 | 0 | 0 |
| Symbios | 298 | 293 | 306 | 0.4 | 0.3 | 0.3 |
| Symphony Laboratories | 12 | 15 | 17 | 0 | 0 | 0 |
| Texas Instruments | 4,052 | 6,325 | 4,904 | 5.3 | 5.7 | 4.9 |
| Trident Microsystems | 87 | 139 | 180 | 0.1 | 0.1 | 0.2 |
| Tseng Labs | 83 | 105 | 26 | 0.1 | 0 | 0 |


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**Table 1-8 (Continued)**
**Each Company's Factory Revenue from Shipments of MOS Digital ICs Worldwide**
**(Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Universal | 7 | 8 | 0 | 0 | 0 | 0 |
| VLSI Technology | 588 | 672 | 672 | 0.8 | 0.6 | 0.7 |
| WaferScale Integration | 21 | 36 | 48 | 0 | 0 | 0 |
| Weitek | 28 | 37 | 0 | 0 | 0 | 0 |
| Western Digital | 184 | 240 | 0 | 0.2 | 0.2 | 0 |
| Xicor | 100 | 114 | 123 | 0.1 | 0.1 | 0.1 |
| Xilinx | 321 | 520 | 566 | 0.4 | 0.5 | 0.6 |
| Zilog | 222 | 265 | 286 | 0.3 | 0.2 | 0.3 |
| Zoran | 0 | 0 | 29 | 0 | 0 | 0 |
| Other Americas | 0 | 0 | 40 | 0 | 0 | 0 |
| Japanese Companies | 29,034 | 41,677 | 33,361 | 38.2 | 37.7 | 33.1 |
| Fuji Electric | 40 | 46 | 41 | 0 | 0 | 0 |
| Fujitsu | 2,876 | 4,417 | 3,471 | 3.8 | 4.0 | 3.4 |
| Hitachi | 4,799 | 7,228 | 5,995 | 6.3 | 6.5 | 6.0 |
| Matsushita | 1,328 | 1,679 | 1,422 | 1.7 | 1.5 | 1.4 |
| Mitsubishi | 2,584 | 3,954 | 2,895 | 3.4 | 3.6 | 2.9 |
| NEC | 6,361 | 9,401 | 8,515 | 8.4 | 8.5 | 8.5 |
| New JRC | 32 | 40 | 28 | 0 | 0 | 0 |
| Nippon Steel Semiconductor | 160 | 549 | 198 | 0.2 | 0.5 | 0.2 |
| Oki | 1,365 | 1,911 | 1,103 | 1.8 | 1.7 | 1.1 |
| Ricoh | 168 | 175 | 118 | 0.2 | 0.2 | 0.1 |
| Rohm | 210 | 376 | 327 | 0.3 | 0.3 | 0.3 |
| Sanyo | 797 | 972 | 945 | 1.0 | 0.9 | 0.9 |
| Seiko Epson | 260 | 297 | 242 | 0.3 | 0.3 | 0.2 |
| Sharp | 1,582 | 1,851 | 1,415 | 2.1 | 1.7 | 1.4 |
| Sony | 1,007 | 1,303 | 1,050 | 1.3 | 1.2 | 1.0 |
| Toshiba | 5,015 | 6,920 | 5,186 | 6.6 | 6.3 | 5.2 |
| Yamaha | 363 | 416 | 289 | 0.5 | 0.4 | 0.3 |
| Other Japanese | 87 | 142 | 121 | 0.1 | 0.1 | 0.1 |
| European Companies | 3,499 | 4,931 | 5,040 | 4.6 | 4.5 | 5.0 |
| Austria Mikro Systeme | 46 | 68 | 54 | 0 | 0 | 0 |
| Elex | 20 | 23 | 13 | 0 | 0 | 0 |
| Elmos | 15 | 19 | 7 | 0 | 0 | 0 |
| EM Microelectronics Marin | 0 | 2 | 4 | 0 | 0 | 0 |
| Ericsson | 15 | 19 | 19 | 0 | 0 | 0 |
| European Silicon Structures | 40 | 48 | 0 | 0 | 0 | 0 |
| GEC Plessey | 129 | 164 | 128 | 0.2 | 0.1 | 0.1 |
| Mietec | 32 | 35 | 32 | 0 | 0 | 0 |

**Table 1-8 (Continued)**
**Each Company's Factory Revenue from Shipments of MOS Digital ICs Worldwide**
**(Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Philips | 1,027 | 1,418 | 1,857 | 1.4 | 1.3 | 1.8 |
| SGS-Thomson | 998 | 1,318 | 1,484 | 1.3 | 1.2 | 1.5 |
| Siemens | 1,007 | 1,591 | 1,226 | 1.3 | 1.4 | 1.2 |
| TCS | 31 | 41 | 44 | 0 | 0 | 0 |
| TEMIC | 124 | 165 | 172 | 0.2 | 0.1 | 0.2 |
| Thesys | 15 | 20 | 0 | 0 | 0 | 0 |
| Asia/Pacific Companies | 9,032 | 16,823 | 12,530 | 11.9 | 15.2 | 12.4 |
| Acer | 70 | 80 | 50 | 0 | 0 | 0 |
| Daewoo | 21 | 27 | 21 | 0 | 0 | 0 |
| Holtek | 70 | 87 | 99 | 0 | 0 | 0 |
| Hualon Microelectronics Corp. | 80 | 98 | 42 | 0.1 | 0 | 0 |
| Hyundai | 1,521 | 4,130 | 2,246 | 2.0 | 3.7 | 2.2 |
| LG Semicon | 1,606 | 2,807 | 2,193 | 2.1 | 2.5 | 2.2 |
| Macronix | 221 | 271 | 354 | 0.3 | 0.2 | 0.4 |
| Mosel Vitelic | 259 | 502 | 398 | 0.3 | 0.5 | 0.4 |
| Samsung | 4,409 | 7,775 | 5,889 | 5.8 | 7.0 | 5.8 |
| Silicon Integrated Systems | 101 | 127 | 127 | 0.1 | 0.1 | 0.1 |
| United Microelectronics Corp. | 418 | 477 | 492 | 0.5 | 0.4 | 0.5 |
| Vanguard | 0 | 0 | 225 | 0 | 0 | 0.2 |
| VIA | 0 | 0 | 110 | 0 | 0 | 0.1 |
| Winbond Electronics | 256 | 442 | 284 | 0.3 | 0.4 | 0.3 |

Source: Dataquest (April 1997)

## Table 1-9
## 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 |
| 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 |
| IMP | 1 | 0 | 0 | 0 | 0 | 0 |
| Integrated Device Technology | 252 | 444 | 378 | 0.8 | 0.8 | 1.0 |
| Integrated Silicon Solutions | 60 | 158 | 111 | 0.2 | 0.3 | 0.3 |
| Intel | 458 | 766 | 950 | 1.4 | 1.4 | 2.5 |
| ITT | 10 | 0 | 0 | 0 | 0 | 0 |
| Logic Devices | 2 | 5 | 2 | 0 | 0 | 0 |
| Lucent Technologies | 3 | 3 | 0 | 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 |
| 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 |


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**Table 1-9 (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 |
| 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 |
| Holtek | 0 | 0 | 2 | 0 | 0 | 0 |
| Hualon Microelectronics Corp. | 46 | 54 | 23 | 0.1 | 0 | 0 |
| Hyundai | 1,515 | 4,116 | 2,236 | 4.5 | 7.4 | 5.9 |
| LG Semicon | 1,525 | 2,635 | 2,021 | 4.6 | 4.8 | 5.3 |
| 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 (April 1997)


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## Table 1-10
## Each Company's Factory Revenue from Shipments of MOS Microcomponents Worldwide (Millions of U.S. Dollars)

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Total Market | 26,408 | 34,504 | 41,321 | 100.0 | 100.0 | 100.0 |
| Americas Companies | 18,843 | 24,204 | 30,302 | 71.4 | 70.1 | 73.3 |
| ACC Microelectronics | 49 | 40 | 45 | 0.2 | 0.1 | 0.1 |
| Adaptec | 125 | 124 | 214 | 0.5 | 0.4 | 0.5 |
| Advanced Micro Devices | 1,021 | 925 | 624 | 3.9 | 2.7 | 1.5 |
| Alliance Semiconductor | 0 | 10 | 10 | 0 | 0 | 0 |
| Analog Devices | 85 | 116 | 258 | 0.3 | 0.3 | 0.6 |
| Appian Technology | 7 | 9 | 10 | 0 | 0 | 0 |
| ATI Technologies | 0 | 0 | 130 | 0 | 0 | 0.3 |
| Atmel | 5 | 28 | 49 | 0 | 0 | 0.1 |
| California Micro Devices | 5 | 6 | 5 | 0 | 0 | 0 |
| C-Cube | 0 | 0 | 150 | 0 | 0 | 0.4 |
| Chips & Technologies | 89 | 138 | 150 | 0.3 | 0.4 | 0.4 |
| Cirrus Logic | 681 | 887 | 741 | 2.6 | 2.6 | 1.8 |
| Cypress Semiconductor | 40 | 50 | 64 | 0.2 | 0.1 | 0.2 |
| Cyrix | 241 | 212 | 160 | 0.9 | 0.6 | 0.4 |
| Dallas Semiconductor | 22 | 35 | 113 | 0 | 0.1 | 0.3 |
| Digital | 0 | 0 | 271 | 0 | 0 | 0.7 |
| DSP Group | 18 | 60 | 67 | 0 | 0.2 | 0.2 |
| Harris | 52 | 67 | 49 | 0.2 | 0.2 | 0.1 |
| Hughes | 3 | 3 | 3 | 0 | 0 | 0 |
| IBM | 399 | 703 | 741 | 1.5 | 2.0 | 1.8 |
| IMP | 8 | 1 | 0 | 0 | 0 | 0 |
| Integrated Device Technology | 51 | 63 | 70 | 0.2 | 0.2 | 0.2 |
| Integrated Information Tech. | 35 | 44 | 51 | 0.1 | 0.1 | 0.1 |
| Intel | 9,595 | 12,397 | 16,831 | 36.3 | 35.9 | 40.7 |
| ITT | 12 | 15 | 43 | 0 | 0 | 0.1 |
| LSI Logic | 78 | 107 | 103 | 0.3 | 0.3 | 0.2 |
| Lucent Technologies | 305 | 510 | 635 | 1.2 | 1.5 | 1.5 |
| Micro Linear | 6 | 0 | 0 | 0 | 0 | 0 |
| Microchip Technology | 130 | 169 | 213 | 0.5 | 0.5 | 0.5 |
| Motorola | 2,363 | 2,987 | 3,153 | 8.9 | 8.7 | 7.6 |
| National Semiconductor | 452 | 542 | 627 | 1.7 | 1.6 | 1.5 |
| Oak Technology | 62 | 84 | 172 | 0.2 | 0.2 | 0.4 |
| OPTi | 130 | 167 | 119 | 0.5 | 0.5 | 0.3 |
| Performance Semiconductor | 15 | 21 | 0 | 0 | 0 | 0 |
| Q Logic | 45 | 61 | 67 | 0.2 | 0.2 | 0.2 |
| Rockwell | 509 | 738 | 1,226 | 1.9 | 2.1 | 3.0 |

**Table 1-10 (Continued)**
**Each Company's Factory Revenue from Shipments of MOS Microcomponents Worldwide (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| S3 | 130 | 315 | 464 | 0.5 | 0.9 | 1.1 |
| Seeq Technology | 17 | 21 | 12 | 0 | 0 | 0 |
| Sierra Semiconductor | 35 | 47 | 62 | 0.1 | 0.1 | 0.2 |
| Standard Microsystems | 100 | 150 | 153 | 0.4 | 0.4 | 0.4 |
| Sun Microsystems | 0 | 0 | 170 | 0 | 0 | 0.4 |
| Supertex | 1 | 1 | 0 | 0 | 0 | 0 |
| Symbios | 81 | 85 | 102 | 0.3 | 0.2 | 0.2 |
| Symphony Laboratories | 12 | 15 | 17 | 0 | 0 | 0 |
| Texas Instruments | 1,006 | 1,254 | 1,550 | 3.8 | 3.6 | 3.8 |
| Trident Microsystems | 87 | 139 | 180 | 0.3 | 0.4 | 0.4 |
| Tseng Labs | 83 | 105 | 26 | 0.3 | 0.3 | 0 |
| VLSI Technology | 216 | 193 | 57 | 0.8 | 0.6 | 0.1 |
| WaferScale Integration | 3 | 18 | 30 | 0 | 0 | 0 |
| Weitek | 28 | 37 | 0 | 0.1 | 0.1 | 0 |
| Western Digital | 184 | 240 | 0 | 0.7 | 0.7 | 0 |
| Zilog | 222 | 265 | 286 | 0.8 | 0.8 | 0.7 |
| Zoran | 0 | 0 | 29 | 0 | 0 | 0 |
| Japanese Companies | 6,137 | 8,093 | 8,115 | 23.2 | 23.5 | 19.6 |
| Fuji Electric | 2 | 3 | 3 | 0 | 0 | 0 |
| Fujitsu | 390 | 650 | 677 | 1.5 | 1.9 | 1.6 |
| Hitachi | 998 | 1,441 | 1,629 | 3.8 | 4.2 | 3.9 |
| Matsushita | 460 | 555 | 534 | 1.7 | 1.6 | 1.3 |
| Mitsubishi | 698 | 982 | 901 | 2.6 | 2.8 | 2.2 |
| NEC | 1,678 | 2,061 | 2,179 | 6.4 | 6.0 | 5.3 |
| New JRC | 2 | 4 | 5 | 0 | 0 | 0 |
| Oki | 217 | 233 | 175 | 0.8 | 0.7 | 0.4 |
| Ricoh | 83 | 75 | 76 | 0.3 | 0.2 | 0.2 |
| Rohm | 50 | 71 | 66 | 0.2 | 0.2 | 0.2 |
| Sanyo | 161 | 187 | 164 | 0.6 | 0.5 | 0.4 |
| Seiko Epson | 21 | 28 | 22 | 0 | 0 | 0 |
| Sharp | 192 | 221 | 184 | 0.7 | 0.6 | 0.4 |
| Sony | 194 | 233 | 189 | 0.7 | 0.7 | 0.5 |
| Toshiba | 718 | 1,094 | 1,197 | 2.7 | 3.2 | 2.9 |
| Yamaha | 273 | 245 | 107 | 1.0 | 0.7 | 0.3 |
| Other Japanese | 0 | 10 | 7 | 0 | 0 | 0 |
| European Companies | 851 | 1,433 | 1,977 | 3.2 | 4.2 | 4.8 |
| Elex | 15 | 23 | 13 | 0 | 0 | 0 |
| EM Microelectronics Marin | 0 | 2 | 4 | 0 | 0 | 0 |


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**Table 1-10 (Continued)**
**Each Company's Factory Revenue from Shipments of MOS Microcomponents Worldwide (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| GEC Plessey | 11 | 10 | 10 | 0 | 0 | 0 |
| Philips | 403 | 662 | 1,085 | 1.5 | 1.9 | 2.6 |
| SGS-Thomson | 227 | 437 | 482 | 0.9 | 1.3 | 1.2 |
| Siemens | 128 | 209 | 284 | 0.5 | 0.6 | 0.7 |
| TCS | 16 | 22 | 21 | 0 | 0 | 0 |
| TEMIC | 51 | 68 | 78 | 0.2 | 0.2 | 0.2 |
| Asia/Pacific Companies | 577 | 774 | 927 | 2.2 | 2.2 | 2.2 |
| Acer | 68 | 77 | 50 | 0.3 | 0.2 | 0.1 |
| Daewoo | 17 | 23 | 18 | 0 | 0 | 0 |
| Holtek | 20 | 34 | 44 | 0 | 0 | 0.1 |
| Hyundai | 2 | 1 | 1 | 0 | 0 | 0 |
| LG Semicon | 29 | 56 | 59 | 0.1 | 0.2 | 0.1 |
| Macronix | 21 | 35 | 20 | 0 | 0.1 | 0 |
| Samsung | 44 | 87 | 99 | 0.2 | 0.3 | 0.2 |
| Silicon Integrated Systems | 101 | 127 | 127 | 0.4 | 0.4 | 0.3 |
| United Microelectronics Corp. | 227 | 274 | 315 | 0.9 | 0.8 | 0.8 |
| VIA | 0 | 0 | 110 | 0 | 0 | 0.3 |
| Winbond Electronics | 48 | 60 | 84 | 0.2 | 0.2 | 0.2 |

Source: Dataquest (April 1997)


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## Table 1-11
## Each Company's Factory Revenue from Shipments of MOS Digital Logic Worldwide (Millions of U.S. Dollars)

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Total Market | 16,108 | 20,619 | 21,555 | 100.0 | 100.0 | 100.0 |
| Americas Companies | 7,183 | 9,134 | 10,051 | 44.6 | 44.3 | 46.6 |
| Actel | 76 | 109 | 149 | 0.5 | 0.5 | 0.7 |
| Advanced Micro Devices | 341 | 420 | 435 | 2.1 | 2.0 | 2.0 |
| Allegro MicroSystems | 5 | 0 | 0 | 0 | 0 | 0 |
| Altera | 199 | 402 | 497 | 1.2 | 1.9 | 2.3 |
| Applied Micro Circuits Corp. | 21 | 25 | 21 | 0.1 | 0.1 | 0 |
| Atmel | 27 | 67 | 146 | 0.2 | 0.3 | 0.7 |
| Chip Express | 0 | 0 | 25 | 0 | 0 | 0.1 |
| Crosspoint Solutions | 0 | 2 | 2 | 0 | 0 | 0 |
| Cypress Semiconductor | 75 | 79 | 70 | 0.5 | 0.4 | 0.3 |
| Dallas Semiconductor | 102 | 137 | 117 | 0.6 | 0.7 | 0.5 |
| ETEQ Microsystems | 6 | 7 | 4 | 0 | 0 | 0 |
| Exar | 0 | 16 | 9 | 0 | 0 | 0 |
| Gould AMI | 61 | 72 | 95 | 0.4 | 0.3 | 0.4 |
| Harris | 124 | 108 | 104 | 0.8 | 0.5 | 0.5 |
| Hewlett-Packard | 255 | 342 | 380 | 1.6 | 1.7 | 1.8 |
| Holt | 2 | 3 | 0 | 0 | 0 | 0 |
| Hughes | 18 | 17 | 18 | 0.1 | 0 | 0 |
| IBM | 613 | 719 | 1,003 | 3.8 | 3.5 | 4.7 |
| IMI | 18 | 30 | 34 | 0.1 | 0.1 | 0.2 |
| IMP | 0 | 11 | 0 | 0 | 0 | 0 |
| Integrated Circuit Systems | 42 | 52 | 50 | 0.3 | 0.3 | 0.2 |
| Integrated Device Technology | 82 | 110 | 106 | 0.5 | 0.5 | 0.5 |
| Intel | 26 | 0 | 0 | 0.2 | 0 | 0 |
| International CMOS Technology | 12 | 16 | 12 | 0 | 0 | 0 |
| ITT | 81 | 95 | 140 | 0.5 | 0.5 | 0.6 |
| Lattice | 134 | 186 | 200 | 0.8 | 0.9 | 0.9 |
| Logic Devices | 12 | 12 | 12 | 0 | 0 | 0 |
| LSI Logic | 823 | 1,162 | 1,136 | 5.1 | 5.6 | 5.3 |
| Lucent Technologies | 477 | 687 | 1,014 | 3.0 | 3.3 | 4.7 |
| Micrel | 7 | 7 | 6 | 0 | 0 | 0 |
| Motorola | 1,214 | 1,386 | 1,123 | 7.5 | 6.7 | 5.2 |
| National Semiconductor | 262 | 263 | 268 | 1.6 | 1.3 | 1.2 |
| Quality Semiconductor | 15 | 32 | 44 | 0 | 0.2 | 0.2 |
| QuickLogic | 8 | 16 | 25 | 0 | 0 | 0.1 |
| Rockwell | 5 | 6 | 4 | 0 | 0 | 0 |
| Supertex | 5 | 5 | 5 | 0 | 0 | 0 |


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**Table 1-11 (Continued)**
**Each Company's Factory Revenue from Shipments of MOS Digital Logic Worldwide**
**(Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Symbios | 217 | 208 | 204 | 1.3 | 1.0 | 0.9 |
| Texas Instruments | 1,115 | 1,317 | 1,370 | 6.9 | 6.4 | 6.4 |
| Universal | 7 | 8 | 0 | 0 | 0 | 0 |
| VLSI Technology | 372 | 479 | 615 | 2.3 | 2.3 | 2.9 |
| WaferScale Integration | 3 | 1 | 2 | 0 | 0 | 0 |
| Xilinx | 321 | 520 | 566 | 2.0 | 2.5 | 2.6 |
| Other Americas | 0 | 0 | 40 | 0 | 0 | 0.2 |
| Japanese Companies | 7,378 | 9,522 | 9,538 | 45.8 | 46.2 | 44.2 |
| Fuji Electric | 38 | 43 | 38 | 0.2 | 0.2 | 0.2 |
| Fujitsu | 794 | 1,178 | 1,138 | 4.9 | 5.7 | 5.3 |
| Hitachi | 569 | 655 | 852 | 3.5 | 3.2 | 4.0 |
| Matsushita | 472 | 632 | 588 | 2.9 | 3.1 | 2.7 |
| Mitsubishi | 234 | 425 | 380 | 1.5 | 2.1 | 1.8 |
| NEC | 1,587 | 1,987 | 2,423 | 9.9 | 9.6 | 11.2 |
| New JRC | 30 | 36 | 23 | 0.2 | 0.2 | 0.1 |
| Oki | 451 | 450 | 387 | 2.8 | 2.2 | 1.8 |
| Ricoh | 66 | 94 | 39 | 0.4 | 0.5 | 0.2 |
| Rohm | 104 | 244 | 210 | 0.6 | 1.2 | 1.0 |
| Sanyo | 453 | 528 | 479 | 2.8 | 2.6 | 2.2 |
| Seiko Epson | 197 | 228 | 201 | 1.2 | 1.1 | 0.9 |
| Sharp | 523 | 600 | 504 | 3.2 | 2.9 | 2.3 |
| Sony | 426 | 581 | 531 | 2.6 | 2.8 | 2.5 |
| Toshiba | 1,279 | 1,562 | 1,476 | 7.9 | 7.6 | 6.8 |
| Yamaha | 89 | 170 | 181 | 0.6 | 0.8 | 0.8 |
| Other Japanese | 66 | 109 | 88 | 0.4 | 0.5 | 0.4 |
| European Companies | 1,164 | 1,475 | 1,394 | 7.2 | 7.2 | 6.5 |
| Austria Mikro Systeme | 46 | 68 | 54 | 0.3 | 0.3 | 0.3 |
| Elex | 5 | 0 | 0 | 0 | 0 | 0 |
| Elmos | 15 | 19 | 7 | 0 | 0 | 0 |
| Ericsson | 15 | 19 | 19 | 0 | 0 | 0 |
| European Silicon Structures | 40 | 48 | 0 | 0.2 | 0.2 | 0 |
| GEC Plessey | 118 | 154 | 118 | 0.7 | 0.7 | 0.5 |
| Mietec | 32 | 35 | 32 | 0.2 | 0.2 | 0.1 |
| Philips | 610 | 756 | 772 | 3.8 | 3.7 | 3.6 |
| SGS-Thomson | 182 | 235 | 264 | 1.1 | 1.1 | 1.2 |
| Siemens | 21 | 29 | 31 | 0.1 | 0.1 | 0.1 |
| TCS | 15 | 19 | 23 | 0 | 0 | 0.1 |
| TEMIC | 50 | 73 | 74 | 0.3 | 0.4 | 0.3 |

**Table 1-11 (Continued)**
**Each Company's Factory Revenue from Shipments of MOS Digital Logic Worldwide**
**(Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Thesys | 15 | 20 | 0 | 0 | 0 | 0 |
| Asia/Pacific Companies | 383 | 488 | 572 | 2.4 | 2.4 | 2.7 |
| Acer | 2 | 3 | 0 | 0 | 0 | 0 |
| Daewoo | 4 | 4 | 3 | 0 | 0 | 0 |
| Holtek | 50 | 53 | 53 | 0.3 | 0.3 | 0.2 |
| Hualon Microelectronics Corp. | 34 | 44 | 19 | 0.2 | 0.2 | 0 |
| Hyundai | 4 | 13 | 9 | 0 | 0 | 0 |
| LG Semicon | 52 | 116 | 113 | 0.3 | 0.6 | 0.5 |
| Macronix | 0 | 0 | 46 | 0 | 0 | 0.2 |
| Samsung | 171 | 190 | 289 | 1.1 | 0.9 | 1.3 |
| Winbond Electronics | 66 | 65 | 40 | 0.4 | 0.3 | 0.2 |

Source: Dataquest (April 1997)


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## Table 1-12
## Each Company's Factory Revenue from Shipments of Analog-Monolithic Worldwide (Millions of U.S. Dollars)

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Total Market | 15,263 | 17,616 | 19,300 | 100.0 | 100.0 | 100.0 |
| Americas Companies | 6,460 | 7,294 | 8,522 | 42.3 | 41.4 | 44.2 |
| Advanced Micro Devices | 187 | 173 | 115 | 1.2 | 1.0 | 0.6 |
| Allegro MicroSystems | 134 | 144 | 166 | 0.9 | 0.8 | 0.9 |
| Analog Devices | 602 | 809 | 960 | 3.9 | 4.6 | 5.0 |
| Applied Micro Circuits Corp. | 7 | 5 | 5 | 0 | 0 | 0 |
| Atmel | 12 | 16 | 36 | 0 | 0 | 0.2 |
| Brooktree | 109 | 120 | 0 | 0.7 | 0.7 | 0 |
| Burr-Brown | 105 | 126 | 157 | 0.7 | 0.7 | 0.8 |
| California Micro Devices | 5 | 7 | 3 | 0 | 0 | 0 |
| Catalyst | 1 | 0 | 0 | 0 | 0 | 0 |
| Cherry Semiconductor | 77 | 87 | 100 | 0.5 | 0.5 | 0.5 |
| Cirrus Logic | 100 | 116 | 150 | 0.7 | 0.7 | 0.8 |
| Comlinear | 9 | 0 | 0 | 0 | 0 | 0 |
| Dallas Semiconductor | 0 | 0 | 47 | 0 | 0 | 0.2 |
| Elantec | 21 | 22 | 32 | 0.1 | 0.1 | 0.2 |
| Exar | 169 | 131 | 87 | 1.1 | 0.7 | 0.5 |
| Gennum | 29 | 32 | 37 | 0.2 | 0.2 | 0.2 |
| Gould AMI | 31 | 0 | 0 | 0.2 | 0 | 0 |
| Harris | 284 | 260 | 231 | 1.9 | 1.5 | 1.2 |
| Holt | 7 | 8 | 0 | 0 | 0 | 0 |
| Honeywell | 23 | 27 | 30 | 0.2 | 0.2 | 0.2 |
| Hughes | 19 | 16 | 18 | 0.1 | 0 | 0 |
| IMI | 2 | 5 | 5 | 0 | 0 | 0 |
| IMP | 40 | 42 | 35 | 0.3 | 0.2 | 0.2 |
| Integrated Circuit Systems | 39 | 45 | 29 | 0.3 | 0.3 | 0.2 |
| Intel | 20 | 9 | 0 | 0.1 | 0 | 0 |
| International Rectifier | 8 | 18 | 27 | 0 | 0.1 | 0.1 |
| ITT | 24 | 14 | 10 | 0.2 | 0 | 0 |
| Kulite | 20 | 24 | 0 | 0.1 | 0.1 | 0 |
| Level One Communications | 0 | 78 | 112 | 0 | 0.4 | 0.6 |
| Linear Technology | 225 | 305 | 365 | 1.5 | 1.7 | 1.9 |
| Linfinity | 41 | 47 | 48 | 0.3 | 0.3 | 0.2 |
| Lucent Technologies | 402 | 284 | 301 | 2.6 | 1.6 | 1.6 |
| Maxim | 165 | 185 | 383 | 1.1 | 1.1 | 2.0 |
| Micrel | 18 | 19 | 18 | 0.1 | 0.1 | 0 |
| Micro Linear | 35 | 54 | 54 | 0.2 | 0.3 | 0.3 |
| Micro Power Systems | 23 | 0 | 0 | 0.2 | 0 | 0 |


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**Table 1-12 (Continued)**
**Each Company's Factory Revenue from Shipments of Analog-Monolithic Worldwide**
**(Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Mitel | 70 | 68 | 107 | 0.5 | 0.4 | 0.6 |
| Motorola | 924 | 1,031 | 1,210 | 6.1 | 5.9 | 6.3 |
| National Semiconductor | 907 | 1,034 | 1,040 | 5.9 | 5.9 | 5.4 |
| Novasensor | 13 | 15 | 0 | 0 | 0 | 0 |
| Optek | 7 | 8 | 9 | 0 | 0 | 0 |
| Raytheon | 78 | 93 | 103 | 0.5 | 0.5 | 0.5 |
| Rockwell | 0 | 0 | 121 | 0 | 0 | 0.6 |
| Seeq Technology | 0 | 0 | 20 | 0 | 0 | 0.1 |
| Semtech | 5 | 19 | 42 | 0 | 0.1 | 0.2 |
| Sierra Semiconductor | 85 | 96 | 126 | 0.6 | 0.5 | 0.7 |
| Silicon Systems | 298 | 369 | 0 | 2.0 | 2.1 | 0 |
| Sipex | 2 | 2 | 0 | 0 | 0 | 0 |
| Solitron | 0 | 0 | 1 | 0 | 0 | 0 |
| Supertex | 13 | 13 | 12 | 0 | 0 | 0 |
| Symbios | 56 | 102 | 152 | 0.4 | 0.6 | 0.8 |
| Telcom | 18 | 17 | 18 | 0.1 | 0 | 0 |
| Texas Instruments | 842 | 934 | 1,730 | 5.5 | 5.3 | 9.0 |
| Unitrode | 73 | 103 | 98 | 0.5 | 0.6 | 0.5 |
| Universal | 6 | 7 | 0 | 0 | 0 | 0 |
| VTC | 70 | 155 | 172 | 0.5 | 0.9 | 0.9 |
| Japanese Companies | 4,911 | 5,704 | 5,210 | 32.2 | 32.4 | 27.0 |
| Fuji Electric | 27 | 29 | 23 | 0.2 | 0.2 | 0.1 |
| Fujitsu | 155 | 315 | 291 | 1.0 | 1.8 | 1.5 |
| Hitachi | 357 | 355 | 409 | 2.3 | 2.0 | 2.1 |
| Matsushita | 611 | 639 | 547 | 4.0 | 3.6 | 2.8 |
| Mitsubishi | 456 | 455 | 397 | 3.0 | 2.6 | 2.1 |
| NEC | 506 | 641 | 624 | 3.3 | 3.6 | 3.2 |
| New JRC | 173 | 183 | 160 | 1.1 | 1.0 | 0.8 |
| Oki | 26 | 28 | 18 | 0.2 | 0.2 | 0 |
| Ricoh | 14 | 38 | 50 | 0 | 0.2 | 0.3 |
| Rohm | 361 | 423 | 357 | 2.4 | 2.4 | 1.8 |
| Sanyo | 811 | 894 | 780 | 5.3 | 5.1 | 4.0 |
| Seiko Epson | 13 | 16 | 14 | 0 | 0 | 0 |
| Sharp | 96 | 105 | 92 | 0.6 | 0.6 | 0.5 |
| Sony | 465 | 554 | 452 | 3.0 | 3.1 | 2.3 |
| Toko | 32 | 37 | 31 | 0.2 | 0.2 | 0.2 |
| Toshiba | 789 | 915 | 909 | 5.2 | 5.2 | 4.7 |
| Yamaha | 19 | 28 | 6 | 0.1 | 0.2 | 0 |
| Other Japanese | 0 | 49 | 50 | 0 | 0.3 | 0.3 |


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**Table 1-12 (Continued)**
**Each Company's Factory Revenue from Shipments of Analog-Monolithic Worldwide**
**(Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| European Companies | 3,489 | 4,213 | 5,132 | 22.9 | 23.9 | 26.6 |
| ABB-Hafo | 20 | 19 | 0 | 0.1 | 0.1 | 0 |
| Austria Mikro Systeme | 64 | 81 | 86 | 0.4 | 0.5 | 0.4 |
| Elex | 0 | 8 | 21 | 0 | 0 | 0.1 |
| EM Microelectronics Marin | 65 | 75 | 81 | 0.4 | 0.4 | 0.4 |
| Ericsson | 49 | 50 | 87 | 0.3 | 0.3 | 0.5 |
| European Silicon Structures | 0 | 11 | 0 | 0 | 0 | 0 |
| GEC Plessey | 135 | 155 | 163 | 0.9 | 0.9 | 0.8 |
| Micronas | 20 | 33 | 33 | 0.1 | 0.2 | 0.2 |
| Mietec | 146 | 144 | 158 | 1.0 | 0.8 | 0.8 |
| Philips | 957 | 1,257 | 1,291 | 6.3 | 7.1 | 6.7 |
| SGS-Thomson | 1,197 | 1,483 | 2,042 | 7.8 | 8.4 | 10.6 |
| Siemens | 546 | 692 | 980 | 3.6 | 3.9 | 5.1 |
| TCS | 20 | 24 | 14 | 0.1 | 0.1 | 0 |
| TEMIC | 267 | 177 | 175 | 1.7 | 1.0 | 0.9 |
| Zetex | 3 | 4 | 1 | 0 | 0 | 0 |
| Asia/Pacific Companies | 403 | 405 | 436 | 2.6 | 2.3 | 2.3 |
| Daewoo | 17 | 22 | 24 | 0.1 | 0.1 | 0.1 |
| Hualon Microelectronics Corp. | 9 | 9 | 5 | 0 | 0 | 0 |
| Hyundai | 0 | 2 | 1 | 0 | 0 | 0 |
| Korean Electronic Co. | 47 | 45 | 51 | 0.3 | 0.3 | 0.3 |
| LG Semicon | 45 | 42 | 40 | 0.3 | 0.2 | 0.2 |
| Samsung | 233 | 236 | 260 | 1.5 | 1.3 | 1.3 |
| Winbond Electronics | 52 | 49 | 55 | 0.3 | 0.3 | 0.3 |

Source: Dataquest (April 1997)

**Table 1-13**
**Each Company's Factory Revenue from Shipments of Total Discrete Worldwide**
**(Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Total Market | 10,763 | 14,314 | 13,475 | 100.0 | 100.0 | 100.0 |
| Americas Companies | 2,539 | 3,720 | 3,417 | 23.6 | 26.0 | 25.4 |
| Allegro MicroSystems | 9 | 29 | 19 | 0 | 0.2 | 0.1 |
| General Instrument | 262 | 413 | 362 | 2.4 | 2.9 | 2.7 |
| Harris | 187 | 228 | 232 | 1.7 | 1.6 | 1.7 |
| Hewlett-Packard | 99 | 146 | 140 | 0.9 | 1.0 | 1.0 |
| International Rectifier | 353 | 468 | 493 | 3.3 | 3.3 | 3.7 |
| ITT | 114 | 192 | 81 | 1.1 | 1.3 | 0.6 |
| IXYS | 55 | 65 | 66 | 0.5 | 0.5 | 0.5 |
| Lucent Technologies | 6 | 0 | 0 | 0 | 0 | 0 |
| Microsemi | 100 | 118 | 146 | 0.9 | 0.8 | 1.1 |
| Motorola | 1,097 | 1,650 | 1,452 | 10.2 | 11.5 | 10.8 |
| National Semiconductor | 99 | 164 | 157 | 0.9 | 1.1 | 1.2 |
| Optek | 1 | 1 | 1 | 0 | 0 | 0 |
| Powerex | 76 | 98 | 98 | 0.7 | 0.7 | 0.7 |
| Raytheon | 8 | 13 | 13 | 0 | 0 | 0 |
| Semtech | 20 | 29 | 24 | 0.2 | 0.2 | 0.2 |
| Solitron | 5 | 6 | 5 | 0 | 0 | 0 |
| Supertex | 11 | 16 | 16 | 0.1 | 0.1 | 0.1 |
| Teccor Electronics | 60 | 68 | 84 | 0.6 | 0.5 | 0.6 |
| Texas Instruments | 32 | 16 | 28 | 0.3 | 0.1 | 0.2 |
| Japanese Companies | 5,692 | 7,142 | 6,774 | 52.9 | 49.9 | 50.3 |
| Fuji Electric | 357 | 468 | 401 | 3.3 | 3.3 | 3.0 |
| Fujitsu | 192 | 283 | 290 | 1.8 | 2.0 | 2.2 |
| Hitachi | 798 | 889 | 977 | 7.4 | 6.2 | 7.3 |
| Matsushita | 511 | 631 | 565 | 4.7 | 4.4 | 4.2 |
| Mitsubishi | 424 | 479 | 452 | 3.9 | 3.3 | 3.4 |
| NEC | 652 | 831 | 818 | 6.1 | 5.8 | 6.1 |
| New JRC | 2 | 2 | 3 | 0 | 0 | 0 |
| Oki | 10 | 12 | 11 | 0 | 0 | 0 |
| Rohm | 524 | 771 | 681 | 4.9 | 5.4 | 5.1 |
| Sanken | 334 | 398 | 328 | 3.1 | 2.8 | 2.4 |
| Sanyo | 389 | 488 | 441 | 3.6 | 3.4 | 3.3 |
| Shindengen Electric | 194 | 301 | 277 | 1.8 | 2.1 | 2.1 |
| Sony | 50 | 53 | 43 | 0.5 | 0.4 | 0.3 |
| Toko | 51 | 68 | 55 | 0.5 | 0.5 | 0.4 |
| Toshiba | 1,204 | 1,428 | 1,390 | 11.2 | 10.0 | 10.3 |
| Other Japanese | 0 | 40 | 42 | 0 | 0.3 | 0.3 |


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**Table 1-13 (Continued)**
**Each Company's Factory Revenue from Shipments of Total Discrete Worldwide**
**(Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| European Companies | 2,178 | 2,915 | 2,784 | 20.2 | 20.4 | 20.7 |
| Elex | 0 | 2 | 0 | 0 | 0 | 0 |
| Ericsson | 15 | 20 | 28 | 0.1 | 0.1 | 0.2 |
| Eupec | 98 | 120 | 160 | 0.9 | 0.8 | 1.2 |
| Fagor | 27 | 38 | 0 | 0.3 | 0.3 | 0 |
| GEC Plessey | 28 | 36 | 35 | 0.3 | 0.3 | 0.3 |
| Philips | 761 | 1,056 | 941 | 7.1 | 7.4 | 7.0 |
| Semikron | 112 | 125 | 109 | 1.0 | 0.9 | 0.8 |
| SGS-Thomson | 433 | 591 | 586 | 4.0 | 4.1 | 4.3 |
| Siemens | 284 | 435 | 452 | 2.6 | 3.0 | 3.4 |
| TCS | 1 | 1 | 0 | 0 | 0 | 0 |
| TEMIC | 235 | 321 | 353 | 2.2 | 2.2 | 2.6 |
| Westcode | 41 | 54 | 0 | 0.4 | 0.4 | 0 |
| Zetex | 36 | 51 | 52 | 0.3 | 0.4 | 0.4 |
| Other European | 52 | 65 | 68 | 0.5 | 0.5 | 0.5 |
| Asia/Pacific Companies | 354 | 537 | 500 | 3.3 | 3.8 | 3.7 |
| Korean Electronic Co. | 167 | 220 | 193 | 1.6 | 1.5 | 1.4 |
| Samsung | 187 | 317 | 307 | 1.7 | 2.2 | 2.3 |

Source: Dataquest (April 1997)

**Table 1-14**
**Each Company's Factory Revenue from Shipments of Total Optical Semiconductors Worldwide (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Total Market | 3,889 | 4,812 | 4,915 | 100.0 | 100.0 | 100.0 |
| Americas Companies | 699 | 547 | 824 | 18.0 | 11.4 | 16.8 |
| CID Technologies | 4 | 5 | 6 | 0.1 | 0.1 | 0.1 |
| Eastman Kodak | 3 | 3 | 3 | 0 | 0 | 0 |
| Hewlett-Packard | 360 | 160 | 425 | 9.3 | 3.3 | 8.6 |
| Honeywell | 32 | 37 | 41 | 0.8 | 0.8 | 0.8 |
| IC Sensors | 5 | 6 | 7 | 0.1 | 0.1 | 0.1 |
| Lucent Technologies | 51 | 81 | 90 | 1.3 | 1.7 | 1.8 |
| Mitel | 0 | 0 | 22 | 0 | 0 | 0.4 |
| Motorola | 45 | 50 | 40 | 1.2 | 1.0 | 0.8 |
| Optek | 48 | 53 | 59 | 1.2 | 1.1 | 1.2 |
| Quality Technologies | 49 | 61 | 52 | 1.3 | 1.3 | 1.1 |
| Sensym | 8 | 0 | 0 | 0.2 | 0 | 0 |
| Spectra Diode Labs | 10 | 15 | 17 | 0.3 | 0.3 | 0.3 |
| Texas Instruments | 45 | 43 | 62 | 1.2 | 0.9 | 1.3 |
| Other Americas | 39 | 33 | 0 | 1.0 | 0.7 | 0 |
| Japanese Companies | 2,798 | 3,735 | 3,542 | 71.9 | 77.6 | 72.1 |
| Fujitsu | 135 | 168 | 151 | 3.5 | 3.5 | 3.1 |
| Hitachi | 89 | 84 | 121 | 2.3 | 1.7 | 2.5 |
| Matsushita | 417 | 496 | 450 | 10.7 | 10.3 | 9.2 |
| Mitsubishi | 176 | 151 | 144 | 4.5 | 3.1 | 2.9 |
| NEC | 150 | 202 | 256 | 3.9 | 4.2 | 5.2 |
| New JRC | 11 | 12 | 9 | 0.3 | 0.2 | 0.2 |
| Oki | 24 | 28 | 28 | 0.6 | 0.6 | 0.6 |
| Rohm | 178 | 286 | 293 | 4.6 | 5.9 | 6.0 |
| Sanken | 34 | 52 | 40 | 0.9 | 1.1 | 0.8 |
| Sanyo | 150 | 167 | 148 | 3.9 | 3.5 | 3.0 |
| Sharp | 510 | 636 | 617 | 13.1 | 13.2 | 12.6 |
| Sony | 313 | 382 | 373 | 8.0 | 7.9 | 7.6 |
| Stanley Electric | 0 | 301 | 0 | 0 | 6.3 | 0 |
| Toshiba | 421 | 623 | 471 | 10.8 | 12.9 | 9.6 |
| Other Japanese | 190 | 147 | 441 | 4.9 | 3.1 | 9.0 |
| European Companies | 378 | 504 | 517 | 9.7 | 10.5 | 10.5 |
| ABB-Hafo | 12 | 14 | 0 | 0.3 | 0.3 | 0 |
| Ericsson | 15 | 16 | 23 | 0.4 | 0.3 | 0.5 |
| Siemens | 220 | 314 | 339 | 5.7 | 6.5 | 6.9 |


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**Table 1-14 (Continued)**
**Each Company's Factory Revenue from Shipments of Total Optical Semiconductors Worldwide (Millions of U.S. Dollars)**

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| TCS | 26 | 34 | 25 | 0.7 | 0.7 | 0.5 |
| TEMIC | 93 | 110 | 113 | 2.4 | 2.3 | 2.3 |
| Zetex | 1 | 1 | 1 | 0 | 0 | 0 |
| Other European | 11 | 15 | 16 | 0.3 | 0.3 | 0.3 |
| Asia/Pacific Companies | 14 | 26 | 32 | 0.4 | 0.5 | 0.7 |
| Korean Electronic Co. | 11 | 22 | 24 | 0.3 | 0.5 | 0.5 |
| Samsung | 3 | 4 | 8 | 0 | 0 | 0.2 |

Source: Dataquest (April 1997)


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## Table 1-15
## Each Company's Factory Revenue from Shipments of Hybrid Analog Worldwide (Millions of U.S. Dollars)

| | Revenue | | | Market Share (%) | | |
|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Total Market | 1,665 | 1,655 | 1,468 | 100.0 | 100.0 | 100.0 |
| Americas Companies | 425 | 186 | 149 | 25.5 | 11.2 | 10.1 |
| Allegro MicroSystems | 0 | 12 | 15 | 0 | 0.7 | 1.0 |
| Analog Devices | 52 | 58 | 42 | 3.1 | 3.5 | 2.9 |
| Burr-Brown | 60 | 60 | 50 | 3.6 | 3.6 | 3.4 |
| Comlinear | 7 | 0 | 0 | 0.4 | 0 | 0 |
| Elantec | 3 | 3 | 3 | 0.2 | 0.2 | 0.2 |
| Gennum | 2 | 2 | 0 | 0.1 | 0.1 | 0 |
| Linfinity | 3 | 3 | 3 | 0.2 | 0.2 | 0.2 |
| Maxim | 4 | 4 | 4 | 0.2 | 0.2 | 0.3 |
| Mitel | 30 | 20 | 16 | 1.8 | 1.2 | 1.1 |
| Motorola | 226 | 0 | 0 | 13.6 | 0 | 0 |
| National Semiconductor | 7 | 8 | 0 | 0.4 | 0.5 | 0 |
| Sipex | 14 | 14 | 13 | 0.8 | 0.8 | 0.9 |
| Solitron | 2 | 2 | 3 | 0.1 | 0.1 | 0.2 |
| Unitrode | 15 | 0 | 0 | 0.9 | 0 | 0 |
| Japanese Companies | 1,136 | 1,369 | 1,245 | 68.2 | 82.7 | 84.8 |
| Fuji Electric | 22 | 23 | 21 | 1.3 | 1.4 | 1.4 |
| Fujitsu | 116 | 149 | 134 | 7.0 | 9.0 | 9.1 |
| Hitachi | 136 | 137 | 118 | 8.2 | 8.3 | 8.0 |
| Mitsubishi | 109 | 198 | 187 | 6.5 | 12.0 | 12.7 |
| NEC | 98 | 130 | 125 | 5.9 | 7.9 | 8.5 |
| Oki | 13 | 13 | 13 | 0.8 | 0.8 | 0.9 |
| Rohm | 72 | 78 | 73 | 4.3 | 4.7 | 5.0 |
| Sanken | 240 | 283 | 254 | 14.4 | 17.1 | 17.3 |
| Sanyo | 174 | 193 | 177 | 10.5 | 11.7 | 12.1 |
| Shindengen Electric | 48 | 28 | 21 | 2.9 | 1.7 | 1.4 |
| Sony | 41 | 41 | 65 | 2.5 | 2.5 | 4.4 |
| Toko | 8 | 8 | 8 | 0.5 | 0.5 | 0.5 |
| Toshiba | 59 | 74 | 36 | 3.5 | 4.5 | 2.5 |
| Other Japanese | 0 | 14 | 13 | 0 | 0.8 | 0.9 |
| European Companies | 104 | 100 | 74 | 6.2 | 6.0 | 5.0 |
| ABB-Hafo | 8 | 5 | 0 | 0.5 | 0.3 | 0 |
| Ericsson | 19 | 15 | 13 | 1.1 | 0.9 | 0.9 |
| GEC Plessey | 6 | 3 | 0 | 0.4 | 0.2 | 0 |
| Micronas | 0 | 10 | 0 | 0 | 0.6 | 0 |
| Philips | 54 | 46 | 40 | 3.2 | 2.8 | 2.7 |
| Other European | 17 | 21 | 21 | 1.0 | 1.3 | 1.4 |

Source: Dataquest (April 1997)

# Section 2: 1996 Worldwide Market Share Rankings

**Table 2-1**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of Total Semiconductors Worldwide (Including Hybrid) (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 1 | 1 | Intel | 13,172 | 17,781 | 35.0 | 12.5 |
| 2 | 2 | NEC | 11,314 | 10,428 | -7.8 | 7.4 |
| 5 | 3 | Motorola | 8,722 | 8,076 | -7.4 | 5.7 |
| 4 | 4 | Hitachi | 9,135 | 8,071 | -11.6 | 5.7 |
| 3 | 5 | Toshiba | 10,076 | 8,065 | -20.0 | 5.7 |
| 7 | 6 | Texas Instruments | 7,831 | 7,064 | -9.8 | 5.0 |
| 6 | 7 | Samsung | 8,332 | 6,464 | -22.4 | 4.6 |
| 8 | 8 | Fujitsu | 5,535 | 4,427 | -20.0 | 3.1 |
| 11 | 9 | Philips | 3,900 | 4,219 | 8.2 | 3.0 |
| 14 | 10 | SGS-Thomson | 3,398 | 4,112 | 21.0 | 2.9 |
| 9 | 11 | Mitsubishi | 5,274 | 4,100 | -22.3 | 2.9 |
| 15 | 12 | Siemens | 3,063 | 3,029 | -1.1 | 2.1 |
| 13 | 13 | Matsushita | 3,474 | 3,003 | -13.6 | 2.1 |
| 12 | 14 | IBM | 3,522 | 2,740 | -22.2 | 1.9 |
| 17 | 15 | Sanyo | 2,714 | 2,491 | -8.2 | 1.8 |
| 20 | 16 | National Semiconductor | 2,408 | 2,380 | -1.2 | 1.7 |
| 10 | 17 | Hyundai | 4,132 | 2,247 | -45.6 | 1.6 |
| 16 | 18 | LG Semicon | 2,863 | 2,243 | -21.7 | 1.6 |
| 19 | 19 | Sharp | 2,592 | 2,124 | -18.1 | 1.5 |
| 25 | 20 | Lucent Technologies | 1,615 | 2,110 | 30.7 | 1.5 |
| 22 | 21 | Sony | 2,333 | 1,983 | -15.0 | 1.4 |
| 21 | 22 | Advanced Micro Devices | 2,337 | 1,947 | -16.7 | 1.4 |
| 24 | 23 | Rohm | 1,934 | 1,731 | -10.5 | 1.2 |
| 18 | 24 | Micron Technology | 2,601 | 1,558 | -40.1 | 1.1 |
| 30 | 25 | Rockwell | 744 | 1,351 | 81.6 | 1.0 |
| 28 | 26 | Analog Devices | 983 | 1,260 | 28.2 | 0.9 |
| 26 | 27 | LSI Logic | 1,269 | 1,239 | -2.4 | 0.9 |
| 23 | 28 | Oki | 2,028 | 1,177 | -42.0 | 0.8 |
| 36 | 29 | Atmel | 589 | 1,024 | 73.9 | 0.7 |
| 34 | 30 | Hewlett-Packard | 648 | 945 | 45.8 | 0.7 |
| 27 | 31 | Cirrus Logic | 1,003 | 891 | -11.2 | 0.6 |
| 29 | 32 | TEMIC | 773 | 813 | 5.2 | 0.6 |
| 33 | 33 | VLSI Technology | 672 | 672 | 0 | 0.5 |
| 32 | 34 | Harris | 685 | 629 | -8.2 | 0.4 |

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**Table 2-1 (Continued)**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of Total Semiconductors Worldwide (Including Hybrid) (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 31 | 35 | Sanken | 733 | 622 | -15.1 | 0.4 |
| 40 | 36 | Xilinx | 520 | 566 | 8.8 | 0.4 |
| 35 | 37 | Integrated Device Technology | 617 | 554 | -10.2 | 0.4 |
| 43 | 38 | International Rectifier | 486 | 520 | 7.0 | 0.4 |
| 38 | 39 | Cypress Semiconductor | 553 | 516 | -6.7 | 0.4 |
| 47 | 40 | Altera | 402 | 497 | 23.6 | 0.4 |
| | | All Others | 16,280 | 16,021 | -1.6 | 11.3 |
| | | Americas Companies | 60,021 | 63,617 | 6.0 | 44.9 |
| | | Japanese Companies | 60,599 | 50,884 | -16.0 | 35.9 |
| | | European Companies | 12,837 | 13,681 | 6.6 | 9.7 |
| | | Asia/Pacific Companies | 17,805 | 13,508 | -24.1 | 9.5 |
| | | Total Market | 151,262 | 141,690 | -6.3 | 100.0 |

Source: Dataquest (April 1997)


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**Table 2-2**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of Total Semiconductors Worldwide (Excluding Hybrid) (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 1 | 1 | Intel | 13,172 | 17,781 | 35.0 | 12.7 |
| 2 | 2 | NEC | 11,184 | 10,303 | -7.9 | 7.3 |
| 5 | 3 | Motorola | 8,722 | 8,076 | -7.4 | 5.8 |
| 3 | 4 | Toshiba | 10,002 | 8,029 | -19.7 | 5.7 |
| 4 | 5 | Hitachi | 8,998 | 7,953 | -11.6 | 5.7 |
| 7 | 6 | Texas Instruments | 7,831 | 7,064 | -9.8 | 5.0 |
| 6 | 7 | Samsung | 8,332 | 6,464 | -22.4 | 4.6 |
| 8 | 8 | Fujitsu | 5,386 | 4,293 | -20.3 | 3.1 |
| 11 | 9 | Philips | 3,854 | 4,179 | 8.4 | 3.0 |
| 14 | 10 | SGS-Thomson | 3,398 | 4,112 | 21.0 | 2.9 |
| 9 | 11 | Mitsubishi | 5,076 | 3,913 | -22.9 | 2.8 |
| 15 | 12 | Siemens | 3,063 | 3,029 | -1.1 | 2.2 |
| 13 | 13 | Matsushita | 3,474 | 3,003 | -13.6 | 2.1 |
| 12 | 14 | IBM | 3,522 | 2,740 | -22.2 | 2.0 |
| 20 | 15 | National Semiconductor | 2,400 | 2,380 | -0.8 | 1.7 |
| 19 | 16 | Sanyo | 2,521 | 2,314 | -8.2 | 1.7 |
| 10 | 17 | Hyundai | 4,132 | 2,247 | -45.6 | 1.6 |
| 16 | 18 | LG Semicon | 2,863 | 2,243 | -21.7 | 1.6 |
| 18 | 19 | Sharp | 2,592 | 2,124 | -18.1 | 1.5 |
| 25 | 20 | Lucent Technologies | 1,615 | 2,110 | 30.7 | 1.5 |
| 21 | 21 | Advanced Micro Devices | 2,337 | 1,947 | -16.7 | 1.4 |
| 22 | 22 | Sony | 2,292 | 1,918 | -16.3 | 1.4 |
| 24 | 23 | Rohm | 1,856 | 1,658 | -10.7 | 1.2 |
| 17 | 24 | Micron Technology | 2,601 | 1,558 | -40.1 | 1.1 |
| 30 | 25 | Rockwell | 744 | 1,351 | 81.6 | 1.0 |
| 26 | 26 | LSI Logic | 1,269 | 1,239 | -2.4 | 0.9 |
| 28 | 27 | Analog Devices | 925 | 1,218 | 31.7 | 0.9 |
| 23 | 28 | Oki | 2,015 | 1,164 | -42.2 | 0.8 |
| 35 | 29 | Atmel | 589 | 1,024 | 73.9 | 0.7 |
| 33 | 30 | Hewlett-Packard | 648 | 945 | 45.8 | 0.7 |
| 27 | 31 | Cirrus Logic | 1,003 | 891 | -11.2 | 0.6 |
| 29 | 32 | TEMIC | 773 | 813 | 5.2 | 0.6 |
| 32 | 33 | VLSI Technology | 672 | 672 | 0 | 0.5 |
| 31 | 34 | Harris | 685 | 629 | -8.2 | 0.4 |
| 39 | 35 | Xilinx | 520 | 566 | 8.8 | 0.4 |
| 34 | 36 | Integrated Device Technology | 617 | 554 | -10.2 | 0.4 |
| 42 | 37 | International Rectifier | 486 | 520 | 7.0 | 0.4 |

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**Table 2-2 (Continued)**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of Total Semiconductors Worldwide (Excluding Hybrid) (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 36 | 38 | Cypress Semiconductor | 553 | 516 | -6.7 | 0.4 |
| 47 | 39 | Altera | 402 | 497 | 23.6 | 0.4 |
| 43 | 40 | United Microelectronics Corp. | 477 | 492 | 3.1 | 0.4 |
| | | All Others | 16,006 | 15,693 | -2.0 | 11.2 |
| | | Americas Companies | 59,835 | 63,468 | 6.1 | 45.3 |
| | | Japanese Companies | 59,230 | 49,639 | -16.2 | 35.4 |
| | | European Companies | 12,737 | 13,607 | 6.8 | 9.7 |
| | | Asia/Pacific Companies | 17,805 | 13,508 | -24.1 | 9.6 |
| | | Total Market | 149,607 | 140,222 | -6.3 | 100.0 |

Source: Dataquest (April 1997)


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**Table 2-3**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of Total ICs Worldwide (Including Hybrid) (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 1 | 1 | Intel | 13,172 | 17,781 | 35.0 | 14.4 |
| 2 | 2 | NEC | 10,281 | 9,354 | -9.0 | 7.6 |
| 6 | 3 | Texas Instruments | 7,772 | 6,974 | -10.3 | 5.7 |
| 3 | 4 | Hitachi | 8,162 | 6,973 | -14.6 | 5.7 |
| 7 | 5 | Motorola | 7,022 | 6,584 | -6.2 | 5.3 |
| 4 | 6 | Toshiba | 8,025 | 6,204 | -22.7 | 5.0 |
| 5 | 7 | Samsung | 8,011 | 6,149 | -23.2 | 5.0 |
| 8 | 8 | Fujitsu | 5,084 | 3,986 | -21.6 | 3.2 |
| 14 | 9 | SGS-Thomson | 2,807 | 3,526 | 25.6 | 2.9 |
| 9 | 10 | Mitsubishi | 4,644 | 3,504 | -24.5 | 2.8 |
| 13 | 11 | Philips | 2,844 | 3,278 | 15.3 | 2.7 |
| 11 | 12 | IBM | 3,522 | 2,740 | -22.2 | 2.2 |
| 10 | 13 | Hyundai | 4,132 | 2,247 | -45.6 | 1.8 |
| 12 | 14 | LG Semicon | 2,863 | 2,243 | -21.7 | 1.8 |
| 18 | 15 | Siemens | 2,314 | 2,238 | -3.3 | 1.8 |
| 19 | 16 | National Semiconductor | 2,244 | 2,223 | -0.9 | 1.8 |
| 24 | 17 | Lucent Technologies | 1,534 | 2,020 | 31.7 | 1.6 |
| 16 | 18 | Matsushita | 2,347 | 1,988 | -15.3 | 1.6 |
| 17 | 19 | Advanced Micro Devices | 2,337 | 1,947 | -16.7 | 1.6 |
| 20 | 20 | Sanyo | 2,059 | 1,902 | -7.6 | 1.5 |
| 23 | 21 | Sony | 1,898 | 1,567 | -17.4 | 1.3 |
| 15 | 22 | Micron Technology | 2,601 | 1,558 | -40.1 | 1.3 |
| 22 | 23 | Sharp | 1,956 | 1,507 | -23.0 | 1.2 |
| 29 | 24 | Rockwell | 744 | 1,351 | 81.6 | 1.1 |
| 27 | 25 | Analog Devices | 983 | 1,260 | 28.2 | 1.0 |
| 25 | 26 | LSI Logic | 1,269 | 1,239 | -2.4 | 1.0 |
| 21 | 27 | Oki | 1,988 | 1,138 | -42.8 | 0.9 |
| 32 | 28 | Atmel | 589 | 1,024 | 73.9 | 0.8 |
| 26 | 29 | Cirrus Logic | 1,003 | 891 | -11.2 | 0.7 |
| 28 | 30 | Rohm | 877 | 757 | -13.7 | 0.6 |
| 30 | 31 | VLSI Technology | 672 | 672 | 0 | 0.5 |
| 35 | 32 | Xilinx | 520 | 566 | 8.8 | 0.5 |
| 31 | 33 | Integrated Device Technology | 617 | 554 | -10.2 | 0.4 |
| 33 | 34 | Cypress Semiconductor | 553 | 516 | -6.7 | 0.4 |
| 41 | 35 | Altera | 402 | 497 | 23.6 | 0.4 |
| 38 | 36 | United Microelectronics Corp. | 477 | 492 | 3.1 | 0.4 |
| 47 | 37 | S3 | 315 | 464 | 47.3 | 0.4 |

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**Table 2-3 (Continued)**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of Total ICs Worldwide (Including Hybrid) (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 42 | 38 | Symbios | 395 | 458 | 15.9 | 0.4 |
| 36 | 39 | Mosel Vitelic | 502 | 398 | -20.7 | 0.3 |
| 39 | 40 | Harris | 457 | 397 | -13.1 | 0.3 |
| | | All Others | 12,142 | 12,133 | -0.1 | 9.8 |
| | | Americas Companies | 55,754 | 59,376 | 6.5 | 48.2 |
| | | Japanese Companies | 49,722 | 40,568 | -18.4 | 32.9 |
| | | European Companies | 9,418 | 10,380 | 10.2 | 8.4 |
| | | Asia/Pacific Companies | 17,242 | 12,976 | -24.7 | 10.5 |
| | | Total Market | 132,136 | 123,300 | -6.7 | 100.0 |

Source: Dataquest (April 1997)


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## Table 2-4
## Top 40 Worldwide Companies' Factory Revenue from Shipments of Total Integrated Circuits Worldwide (Excluding Hybrid) (Millions of U.S. Dollars)

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 1 | 1 | Intel | 13,172 | 17,781 | 35.0 | 14.6 |
| 2 | 2 | NEC | 10,151 | 9,229 | -9.1 | 7.6 |
| 6 | 3 | Texas Instruments | 7,772 | 6,974 | -10.3 | 5.7 |
| 3 | 4 | Hitachi | 8,025 | 6,855 | -14.6 | 5.6 |
| 7 | 5 | Motorola | 7,022 | 6,584 | -6.2 | 5.4 |
| 5 | 6 | Toshiba | 7,951 | 6,168 | -22.4 | 5.1 |
| 4 | 7 | Samsung | 8,011 | 6,149 | -23.2 | 5.0 |
| 8 | 8 | Fujitsu | 4,935 | 3,852 | -21.9 | 3.2 |
| 13 | 9 | SGS-Thomson | 2,807 | 3,526 | 25.6 | 2.9 |
| 9 | 10 | Mitsubishi | 4,446 | 3,317 | -25.4 | 2.7 |
| 14 | 11 | Philips | 2,798 | 3,238 | 15.7 | 2.7 |
| 11 | 12 | IBM | 3,522 | 2,740 | -22.2 | 2.2 |
| 10 | 13 | Hyundai | 4,132 | 2,247 | -45.6 | 1.8 |
| 12 | 14 | LG Semicon | 2,863 | 2,243 | -21.7 | 1.8 |
| 18 | 15 | Siemens | 2,314 | 2,238 | -3.3 | 1.8 |
| 19 | 16 | National Semiconductor | 2,236 | 2,223 | -0.6 | 1.8 |
| 24 | 17 | Lucent Technologies | 1,534 | 2,020 | 31.7 | 1.7 |
| 16 | 18 | Matsushita | 2,347 | 1,988 | -15.3 | 1.6 |
| 17 | 19 | Advanced Micro Devices | 2,337 | 1,947 | -16.7 | 1.6 |
| 22 | 20 | Sanyo | 1,866 | 1,725 | -7.6 | 1.4 |
| 15 | 21 | Micron Technology | 2,601 | 1,558 | -40.1 | 1.3 |
| 21 | 22 | Sharp | 1,956 | 1,507 | -23.0 | 1.2 |
| 23 | 23 | Sony | 1,857 | 1,502 | -19.1 | 1.2 |
| 29 | 24 | Rockwell | 744 | 1,351 | 81.6 | 1.1 |
| 25 | 25 | LSI Logic | 1,269 | 1,239 | -2.4 | 1.0 |
| 27 | 26 | Analog Devices | 925 | 1,218 | 31.7 | 1.0 |
| 20 | 27 | Oki | 1,975 | 1,125 | -43.0 | 0.9 |
| 32 | 28 | Atmel | 589 | 1,024 | 73.9 | 0.8 |
| 26 | 29 | Cirrus Logic | 1,003 | 891 | -11.2 | 0.7 |
| 28 | 30 | Rohm | 799 | 684 | -14.4 | 0.6 |
| 30 | 31 | VLSI Technology | 672 | 672 | 0 | 0.6 |
| 35 | 32 | Xilinx | 520 | 566 | 8.8 | 0.5 |
| 31 | 33 | Integrated Device Technology | 617 | 554 | -10.2 | 0.5 |
| 33 | 34 | Cypress Semiconductor | 553 | 516 | -6.7 | 0.4 |
| 41 | 35 | Altera | 402 | 497 | 23.6 | 0.4 |
| 38 | 36 | United Microelectronics Corp. | 477 | 492 | 3.1 | 0.4 |
| 47 | 37 | S3 | 315 | 464 | 47.3 | 0.4 |

**Table 2-4 (Continued)**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of Total Integrated Circuits Worldwide (Excluding Hybrid) (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 42 | 38 | Symbios | 395 | 458 | 15.9 | 0.4 |
| 36 | 39 | Mosel Vitelic | 502 | 398 | -20.7 | 0.3 |
| 39 | 40 | Harris | 457 | 397 | -13.1 | 0.3 |
| | | All Others | 11,612 | 11,675 | 0.5 | 9.6 |
| | | Americas Companies | 55,568 | 59,227 | 6.6 | 48.6 |
| | | Japanese Companies | 48,353 | 39,323 | -18.7 | 32.3 |
| | | European Companies | 9,318 | 10,306 | 10.6 | 8.5 |
| | | Asia/Pacific Companies | 17,242 | 12,976 | -24.7 | 10.7 |
| | | Total Market | 130,481 | 121,832 | -6.6 | 100.0 |

Source: Dataquest (April 1997)

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**Table 2-5**
**Top 20 Worldwide Companies' Factory Revenue from Shipments of Bipolar Digital Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 2 | 1 | Hitachi | 442 | 451 | 2.0 | 24.4 |
| 1 | 2 | Texas Instruments | 513 | 340 | -33.7 | 18.4 |
| 3 | 3 | Motorola | 381 | 271 | -28.9 | 14.7 |
| 4 | 4 | National Semiconductor | 209 | 161 | -23.0 | 8.7 |
| 5 | 5 | Fujitsu | 203 | 90 | -55.7 | 4.9 |
| 6 | 6 | Philips | 123 | 90 | -26.8 | 4.9 |
| 8 | 7 | NEC | 109 | 90 | -17.4 | 4.9 |
| 7 | 8 | Toshiba | 116 | 73 | -37.1 | 3.9 |
| 10 | 9 | Lucent Technologies | 50 | 70 | 40.0 | 3.8 |
| 9 | 10 | Advanced Micro Devices | 100 | 62 | -38.0 | 3.4 |
| 13 | 11 | Siemens | 31 | 32 | 3.2 | 1.7 |
| 16 | 12 | Applied Micro Circuits Corp. | 19 | 30 | 57.9 | 1.6 |
| 11 | 13 | Mitsubishi | 37 | 25 | -32.4 | 1.4 |
| 14 | 14 | Matsushita | 29 | 19 | -34.5 | 1.0 |
| 15 | 15 | Raytheon | 19 | 15 | -21.1 | 0.8 |
| 18 | 16 | GEC Plessey | 10 | 12 | 20.0 | 0.6 |
| 17 | 17 | LG Semicon | 14 | 10 | -28.6 | 0.5 |
| 12 | 18 | Oki | 36 | 4 | -88.9 | 0.2 |
| 20 | 19 | Harris | 4 | 4 | 0 | 0.2 |
| 19 | 20 | SGS-Thomson | 6 | 0 | -100.0 | 0 |
| | | All Others | 4 | - | -100.0 | 0 |
| | | Americas Companies | 1,295 | 953 | -26.4 | 51.5 |
| | | Japanese Companies | 972 | 752 | -22.6 | 40.7 |
| | | European Companies | 174 | 134 | -23.0 | 7.2 |
| | | Asia/Pacific Companies | 14 | 10 | -28.6 | 0.5 |
| | | Total Market | 2,455 | 1,849 | -24.7 | 100.0 |

Source: Dataquest (April 1997)


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**Table 2-6**
**Top 20 Worldwide Companies' Factory Revenue from Shipments of Bipolar Logic Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 2 | 1 | Hitachi | 361 | 372 | 3.0 | 23.0 |
| 1 | 2 | Texas Instruments | 505 | 336 | -33.5 | 20.7 |
| 3 | 3 | Motorola | 359 | 251 | -30.1 | 15.5 |
| 5 | 4 | National Semiconductor | 138 | 157 | 13.8 | 9.7 |
| 8 | 5 | NEC | 100 | 82 | -18.0 | 5.1 |
| 7 | 6 | Philips | 109 | 79 | -27.5 | 4.9 |
| 4 | 7 | Fujitsu | 183 | 70 | -61.7 | 4.3 |
| 10 | 8 | Lucent Technologies | 45 | 70 | 55.6 | 4.3 |
| 9 | 9 | Advanced Micro Devices | 69 | 62 | -10.1 | 3.8 |
| 13 | 10 | Siemens | 31 | 32 | 3.2 | 2.0 |
| 15 | 11 | Applied Micro Circuits Corp. | 19 | 30 | 57.9 | 1.9 |
| 11 | 12 | Mitsubishi | 37 | 25 | -32.4 | 1.5 |
| 14 | 13 | Matsushita | 26 | 19 | -26.9 | 1.2 |
| 16 | 14 | Raytheon | 15 | 12 | -20.0 | 0.7 |
| 17 | 15 | LG Semicon | 14 | 10 | -28.6 | 0.6 |
| 6 | 16 | Toshiba | 111 | 5 | -95.5 | 0.3 |
| 12 | 17 | Oki | 36 | 4 | -88.9 | 0.2 |
| 20 | 18 | Harris | 4 | 4 | 0 | 0.2 |
| 18 | 19 | GEC Plessey | 10 | 0 | -100.0 | 0 |
| 19 | 20 | SGS-Thomson | 6 | 0 | -100.0 | 0 |
| | | All Others | 4 | - | -100.0 | 0 |
| | | Americas Companies | 1,154 | 922 | -20.1 | 56.9 |
| | | Japanese Companies | 854 | 577 | -32.4 | 35.6 |
| | | European Companies | 160 | 111 | -30.6 | 6.9 |
| | | Asia/Pacific Companies | 14 | 10 | -28.6 | 0.6 |
| | | Total Market | 2,182 | 1,620 | -25.8 | 100.0 |

Source: Dataquest (April 1997)

## Table 2-7
## Top 13 Worldwide Companies' Factory Revenue from Shipments of Other Bipolar Logic/ Memory/Microcomponents Worldwide (Millions of U.S. Dollars)

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 1 | 1 | Hitachi | 81 | 79 | -2.5 | 34.5 |
| 10 | 2 | Toshiba | 5 | 68 | 1,260.0 | 29.7 |
| 4 | 3 | Motorola | 22 | 20 | -9.1 | 8.7 |
| 5 | 4 | Fujitsu | 20 | 20 | 0 | 8.7 |
| 19 | 5 | GEC Plessey | 0 | 12 | NA | 5.2 |
| 6 | 6 | Philips | 14 | 11 | -21.4 | 4.8 |
| 7 | 7 | NEC | 9 | 8 | -11.1 | 3.5 |
| 2 | 8 | National Semiconductor | 71 | 4 | -94.4 | 1.7 |
| 8 | 9 | Texas Instruments | 8 | 4 | -50.0 | 1.7 |
| 11 | 10 | Raytheon | 4 | 3 | -25.0 | 1.3 |
| 3 | 11 | Advanced Micro Devices | 31 | 0 | -100.0 | 0 |
| 9 | 12 | Lucent Technologies | 5 | 0 | -100.0 | 0 |
| 12 | 13 | Matsushita | 3 | 0 | -100.0 | 0 |
| | | All Others | - | - | NA | 0 |
| | | Americas Companies | 141 | 31 | -78.0 | 13.5 |
| | | Japanese Companies | 118 | 175 | 48.3 | 76.4 |
| | | European Companies | 14 | 23 | 64.3 | 10.0 |
| | | Asia/Pacific Companies | 0 | 0 | NA | 0 |
| | | Total Market | 273 | 229 | -16.1 | 100.0 |

NA = Not applicable
Source: Dataquest (April 1997)


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**Table 2-8**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of MOS Digital ICs Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 1 | 1 | Intel | 13,163 | 17,781 | 35.1 | 17.7 |
| 2 | 2 | NEC | 9,401 | 8,515 | -9.4 | 8.5 |
| 4 | 3 | Hitachi | 7,228 | 5,995 | -17.1 | 6.0 |
| 3 | 4 | Samsung | 7,775 | 5,889 | -24.3 | 5.8 |
| 5 | 5 | Toshiba | 6,920 | 5,186 | -25.1 | 5.2 |
| 7 | 6 | Motorola | 5,610 | 5,103 | -9.0 | 5.1 |
| 6 | 7 | Texas Instruments | 6,325 | 4,904 | -22.5 | 4.9 |
| 8 | 8 | Fujitsu | 4,417 | 3,471 | -21.4 | 3.4 |
| 10 | 9 | Mitsubishi | 3,954 | 2,895 | -26.8 | 2.9 |
| 11 | 10 | IBM | 3,522 | 2,740 | -22.2 | 2.7 |
| 9 | 11 | Hyundai | 4,130 | 2,246 | -45.6 | 2.2 |
| 12 | 12 | LG Semicon | 2,807 | 2,193 | -21.9 | 2.2 |
| 19 | 13 | Philips | 1,418 | 1,857 | 31.0 | 1.8 |
| 14 | 14 | Advanced Micro Devices | 2,064 | 1,770 | -14.2 | 1.8 |
| 23 | 15 | Lucent Technologies | 1,200 | 1,649 | 37.4 | 1.6 |
| 13 | 16 | Micron Technology | 2,601 | 1,558 | -40.1 | 1.5 |
| 20 | 17 | SGS-Thomson | 1,318 | 1,484 | 12.6 | 1.5 |
| 17 | 18 | Matsushita | 1,679 | 1,422 | -15.3 | 1.4 |
| 16 | 19 | Sharp | 1,851 | 1,415 | -23.6 | 1.4 |
| 22 | 20 | LSI Logic | 1,269 | 1,239 | -2.4 | 1.2 |
| 27 | 21 | Rockwell | 744 | 1,230 | 65.3 | 1.2 |
| 18 | 22 | Siemens | 1,591 | 1,226 | -22.9 | 1.2 |
| 15 | 23 | Oki | 1,911 | 1,103 | -42.3 | 1.1 |
| 21 | 24 | Sony | 1,303 | 1,050 | -19.4 | 1.0 |
| 24 | 25 | National Semiconductor | 993 | 1,022 | 2.9 | 1.0 |
| 30 | 26 | Atmel | 573 | 988 | 72.4 | 1.0 |
| 25 | 27 | Sanyo | 972 | 945 | -2.8 | 0.9 |
| 26 | 28 | Cirrus Logic | 887 | 741 | -16.5 | 0.7 |
| 28 | 29 | VLSI Technology | 672 | 672 | 0 | 0.7 |
| 33 | 30 | Xilinx | 520 | 566 | 8.8 | 0.6 |
| 29 | 31 | Integrated Device Technology | 617 | 554 | -10.2 | 0.6 |
| 31 | 32 | Cypress Semiconductor | 553 | 516 | -6.7 | 0.5 |
| 38 | 33 | Altera | 402 | 497 | 23.6 | 0.5 |
| 35 | 34 | United Microelectronics Corp. | 477 | 492 | 3.1 | 0.5 |
| 41 | 35 | S3 | 315 | 464 | 47.3 | 0.5 |
| 34 | 36 | Mosel Vitelic | 502 | 398 | -20.7 | 0.4 |
| 40 | 37 | Hewlett-Packard | 342 | 380 | 11.1 | 0.4 |

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**Table 2-8 (Continued)**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of MOS Digital ICs Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 44 | 38 | Macronix | 271 | 354 | 30.6 | 0.4 |
| 45 | 39 | Microchip Technology | 271 | 330 | 21.8 | 0.3 |
| 39 | 40 | Rohm | 376 | 327 | -13.0 | 0.3 |
| | | All Others | 7,466 | 7,516 | 0.7 | 7.5 |
| | | Americas Companies | 46,979 | 49,752 | 5.9 | 49.4 |
| | | Japanese Companies | 41,677 | 33,361 | -20.0 | 33.1 |
| | | European Companies | 4,931 | 5,040 | 2.2 | 5.0 |
| | | Asia/Pacific Companies | 16,823 | 12,530 | -25.5 | 12.4 |
| | | Total Market | 110,410 | 100,683 | -8.8 | 100.0 |

Source: Dataquest (April 1997)


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**Table 2-9**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of MOS Memory Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | 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 |
| 68 | 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 Solutions | 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 |

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**Table 2-9 (Continued)**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of MOS Memory Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 35 | 38 | Rohm | 61 | 51 | -16.4 | 0.1 |
| 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 |

Source: Dataquest (April 1997)


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**Table 2-10**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of MOS Microcomponents Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 1 | 1 | Intel | 12,397 | 16,831 | 35.8 | 40.7 |
| 2 | 2 | Motorola | 2,987 | 3,153 | 5.6 | 7.6 |
| 3 | 3 | NEC | 2,061 | 2,179 | 5.7 | 5.3 |
| 4 | 4 | Hitachi | 1,441 | 1,629 | 13.0 | 3.9 |
| 5 | 5 | Texas Instruments | 1,254 | 1,550 | 23.6 | 3.8 |
| 10 | 6 | Rockwell | 738 | 1,226 | 66.1 | 3.0 |
| 6 | 7 | Toshiba | 1,094 | 1,197 | 9.4 | 2.9 |
| 12 | 8 | Philips | 662 | 1,085 | 63.9 | 2.6 |
| 7 | 9 | Mitsubishi | 982 | 901 | -8.2 | 2.2 |
| 9 | 10 | Cirrus Logic | 887 | 741 | -16.5 | 1.8 |
| 11 | 11 | IBM | 703 | 741 | 5.4 | 1.8 |
| 13 | 12 | Fujitsu | 650 | 677 | 4.2 | 1.6 |
| 16 | 13 | Lucent Technologies | 510 | 635 | 24.5 | 1.5 |
| 15 | 14 | National Semiconductor | 542 | 627 | 15.7 | 1.5 |
| 8 | 15 | Advanced Micro Devices | 925 | 624 | -32.5 | 1.5 |
| 14 | 16 | Matsushita | 555 | 534 | -3.8 | 1.3 |
| 17 | 17 | SGS-Thomson | 437 | 482 | 10.3 | 1.2 |
| 18 | 18 | S3 | 315 | 464 | 47.3 | 1.1 |
| 19 | 19 | United Microelectronics Corp. | 274 | 315 | 15.0 | 0.8 |
| 20 | 20 | Zilog | 265 | 286 | 7.9 | 0.7 |
| 27 | 21 | Siemens | 209 | 284 | 35.9 | 0.7 |
| 100 | 22 | Digital | 0 | 271 | NA | 0.7 |
| 37 | 23 | Analog Devices | 116 | 258 | 122.4 | 0.6 |
| 36 | 24 | Adaptec | 124 | 214 | 72.6 | 0.5 |
| 30 | 25 | Microchip Technology | 169 | 213 | 26.0 | 0.5 |
| 24 | 26 | Sony | 233 | 189 | -18.9 | 0.5 |
| 25 | 27 | Sharp | 221 | 184 | -16.7 | 0.4 |
| 33 | 28 | Trident Microsystems | 139 | 180 | 29.5 | 0.4 |
| 23 | 29 | Oki | 233 | 175 | -24.9 | 0.4 |
| 42 | 30 | Oak Technology | 84 | 172 | 104.8 | 0.4 |
| 102 | 31 | Sun Microsystems | 0 | 170 | NA | 0.4 |
| 29 | 32 | Sanyo | 187 | 164 | -12.3 | 0.4 |
| 26 | 33 | Cyrix | 212 | 160 | -24.5 | 0.4 |
| 32 | 34 | Standard Microsystems | 150 | 153 | 2.0 | 0.4 |
| 34 | 35 | Chips & Technologies | 138 | 150 | 8.7 | 0.4 |
| 103 | 36 | C-Cube | 0 | 150 | NA | 0.4 |
| 105 | 37 | ATI Technologies | 0 | 130 | NA | 0.3 |


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**Table 2-10 (Continued)**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of MOS Microcomponents Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 35 | 38 | Silicon Integrated Systems | 127 | 127 | 0 | 0.3 |
| 31 | 39 | OPTi | 167 | 119 | -28.7 | 0.3 |
| 59 | 40 | Dallas Semiconductor | 35 | 113 | 222.9 | 0.3 |
| | | All Others | 2,281 | 1,868 | -18.1 | 4.5 |
| | | Americas Companies | 24,204 | 30,302 | 25.2 | 73.3 |
| | | Japanese Companies | 8,093 | 8,115 | 0.3 | 19.6 |
| | | European Companies | 1,433 | 1,977 | 38.0 | 4.8 |
| | | Asia/Pacific Companies | 774 | 927 | 19.8 | 2.2 |
| | | Total Market | 34,504 | 41,321 | 19.8 | 100.0 |

NA = Not applicable
Source: Dataquest (April 1997)


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**Table 2-11**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of MOS Digital Logic Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 1 | 1 | NEC | 1,987 | 2,423 | 21.9 | 11.2 |
| 2 | 2 | Toshiba | 1,562 | 1,476 | -5.5 | 6.8 |
| 4 | 3 | Texas Instruments | 1,317 | 1,370 | 4.0 | 6.4 |
| 5 | 4 | Fujitsu | 1,178 | 1,138 | -3.4 | 5.3 |
| 6 | 5 | LSI Logic | 1,162 | 1,136 | -2.2 | 5.3 |
| 3 | 6 | Motorola | 1,386 | 1,123 | -19.0 | 5.2 |
| 9 | 7 | Lucent Technologies | 687 | 1,014 | 47.6 | 4.7 |
| 8 | 8 | IBM | 719 | 1,003 | 39.5 | 4.7 |
| 10 | 9 | Hitachi | 655 | 852 | 30.1 | 4.0 |
| 7 | 10 | Philips | 756 | 772 | 2.1 | 3.6 |
| 16 | 11 | VLSI Technology | 479 | 615 | 28.4 | 2.9 |
| 11 | 12 | Matsushita | 632 | 588 | -7.0 | 2.7 |
| 15 | 13 | Xilinx | 520 | 566 | 8.8 | 2.6 |
| 13 | 14 | Sony | 581 | 531 | -8.6 | 2.5 |
| 12 | 15 | Sharp | 600 | 504 | -16.0 | 2.3 |
| 20 | 16 | Altera | 402 | 497 | 23.6 | 2.3 |
| 14 | 17 | Sanyo | 528 | 479 | -9.3 | 2.2 |
| 19 | 18 | Advanced Micro Devices | 420 | 435 | 3.6 | 2.0 |
| 17 | 19 | Oki | 450 | 387 | -14.0 | 1.8 |
| 18 | 20 | Mitsubishi | 425 | 380 | -10.6 | 1.8 |
| 21 | 21 | Hewlett-Packard | 342 | 380 | 11.1 | 1.8 |
| 27 | 22 | Samsung | 190 | 289 | 52.1 | 1.3 |
| 22 | 23 | National Semiconductor | 263 | 268 | 1.9 | 1.2 |
| 24 | 24 | SGS-Thomson | 235 | 264 | 12.3 | 1.2 |
| 23 | 25 | Rohm | 244 | 210 | -13.9 | 1.0 |
| 26 | 26 | Symbios | 208 | 204 | -1.9 | 0.9 |
| 25 | 27 | Seiko Epson | 228 | 201 | -11.8 | 0.9 |
| 28 | 28 | Lattice | 186 | 200 | 7.5 | 0.9 |
| 29 | 29 | Yamaha | 170 | 181 | 6.5 | 0.8 |
| 34 | 30 | Actel | 109 | 149 | 36.7 | 0.7 |
| 42 | 31 | Atmel | 67 | 146 | 117.9 | 0.7 |
| 36 | 32 | ITT | 95 | 140 | 47.4 | 0.6 |
| 30 | 33 | GEC Plessey | 154 | 118 | -23.4 | 0.5 |
| 31 | 34 | Dallas Semiconductor | 137 | 117 | -14.6 | 0.5 |
| 32 | 35 | LG Semicon | 116 | 113 | -2.6 | 0.5 |
| 33 | 36 | Integrated Device Technology | 110 | 106 | -3.6 | 0.5 |
| 35 | 37 | Harris | 108 | 104 | -3.7 | 0.5 |

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**Table 2-11 (Continued)**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of MOS Digital Logic Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 40 | 38 | Gould AMI | 72 | 95 | 31.9 | 0.4 |
| 39 | 39 | TEMIC | 73 | 74 | 1.4 | 0.3 |
| 38 | 40 | Cypress Semiconductor | 79 | 70 | -11.4 | 0.3 |
| | | All Others | 987 | 837 | -15.2 | 3.9 |
| | | Americas Companies | 9,134 | 10,051 | 10.0 | 46.6 |
| | | Japanese Companies | 9,522 | 9,538 | 0.2 | 44.2 |
| | | European Companies | 1,475 | 1,394 | -5.5 | 6.5 |
| | | Asia/Pacific Companies | 488 | 572 | 17.2 | 2.7 |
| | | Total Market | 20,619 | 21,555 | 4.5 | 100.0 |

Source: Dataquest (April 1997)


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**Table 2-12**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of Analog-Monolithic Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 1 | 1 | SGS-Thomson | 1,483 | 2,042 | 37.7 | 10.6 |
| 5 | 2 | Texas Instruments | 934 | 1,730 | 85.2 | 9.0 |
| 2 | 3 | Philips | 1,257 | 1,291 | 2.7 | 6.7 |
| 4 | 4 | Motorola | 1,031 | 1,210 | 17.4 | 6.3 |
| 3 | 5 | National Semiconductor | 1,034 | 1,040 | 0.6 | 5.4 |
| 9 | 6 | Siemens | 692 | 980 | 41.6 | 5.1 |
| 8 | 7 | Analog Devices | 809 | 960 | 18.7 | 5.0 |
| 6 | 8 | Toshiba | 915 | 909 | -0.7 | 4.7 |
| 7 | 9 | Sanyo | 894 | 780 | -12.8 | 4.0 |
| 10 | 10 | NEC | 641 | 624 | -2.7 | 3.2 |
| 11 | 11 | Matsushita | 639 | 547 | -14.4 | 2.8 |
| 12 | 12 | Sony | 554 | 452 | -18.4 | 2.3 |
| 16 | 13 | Hitachi | 355 | 409 | 15.2 | 2.1 |
| 13 | 14 | Mitsubishi | 455 | 397 | -12.7 | 2.1 |
| 22 | 15 | Maxim | 185 | 383 | 107.0 | 2.0 |
| 18 | 16 | Linear Technology | 305 | 365 | 19.7 | 1.9 |
| 14 | 17 | Rohm | 423 | 357 | -15.6 | 1.8 |
| 19 | 18 | Lucent Technologies | 284 | 301 | 6.0 | 1.6 |
| 17 | 19 | Fujitsu | 315 | 291 | -7.6 | 1.5 |
| 21 | 20 | Samsung | 236 | 260 | 10.2 | 1.3 |
| 20 | 21 | Harris | 260 | 231 | -11.2 | 1.2 |
| 24 | 22 | TEMIC | 177 | 175 | -1.1 | 0.9 |
| 27 | 23 | VTC | 155 | 172 | 11.0 | 0.9 |
| 29 | 24 | Allegro MicroSystems | 144 | 166 | 15.3 | 0.9 |
| 26 | 25 | GEC Plessey | 155 | 163 | 5.2 | 0.8 |
| 23 | 26 | New JRC | 183 | 160 | -12.6 | 0.8 |
| 28 | 27 | Mietec | 144 | 158 | 9.7 | 0.8 |
| 31 | 28 | Burr-Brown | 126 | 157 | 24.6 | 0.8 |
| 36 | 29 | Symbios | 102 | 152 | 49.0 | 0.8 |
| 33 | 30 | Cirrus Logic | 116 | 150 | 29.3 | 0.8 |
| 37 | 31 | Sierra Semiconductor | 96 | 126 | 31.3 | 0.7 |
| 109 | 32 | Rockwell | 0 | 121 | NA | 0.6 |
| 25 | 33 | Advanced Micro Devices | 173 | 115 | -33.5 | 0.6 |
| 41 | 34 | Level One Communications | 78 | 112 | 43.6 | 0.6 |
| 43 | 35 | Mitel | 68 | 107 | 57.4 | 0.6 |
| 38 | 36 | Raytheon | 93 | 103 | 10.8 | 0.5 |
| 39 | 37 | Cherry Semiconductor | 87 | 100 | 14.9 | 0.5 |


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**Table 2-12 (Continued)**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of Analog-Monolithic Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 35 | 38 | Unitrode | 103 | 98 | -4.9 | 0.5 |
| 34 | 39 | Sharp | 105 | 92 | -12.4 | 0.5 |
| 30 | 40 | Exar | 131 | 87 | -33.6 | 0.5 |
| | | All Others | 1,679 | 1,227 | -26.9 | 6.4 |
| | | Americas Companies | 7,294 | 8,522 | 16.8 | 44.2 |
| | | Japanese Companies | 5,704 | 5,210 | -8.7 | 27.0 |
| | | European Companies | 4,213 | 5,132 | 21.8 | 26.6 |
| | | Asia/Pacific Companies | 405 | 436 | 7.7 | 2.3 |
| | | Total Market | 17,616 | 19,300 | 9.6 | 100.0 |

Source: Dataquest (April 1997)


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**Table 2-13**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of Total Discrete Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 1 | 1 | Motorola | 1,650 | 1,452 | -12.0 | 10.8 |
| 2 | 2 | Toshiba | 1,428 | 1,390 | -2.7 | 10.3 |
| 4 | 3 | Hitachi | 889 | 977 | 9.9 | 7.3 |
| 3 | 4 | Philips | 1,056 | 941 | -10.9 | 7.0 |
| 5 | 5 | NEC | 831 | 818 | -1.6 | 6.1 |
| 6 | 6 | Rohm | 771 | 681 | -11.7 | 5.1 |
| 8 | 7 | SGS-Thomson | 591 | 586 | -0.8 | 4.3 |
| 7 | 8 | Matsushita | 631 | 565 | -10.5 | 4.2 |
| 11 | 9 | International Rectifier | 468 | 493 | 5.3 | 3.7 |
| 10 | 10 | Mitsubishi | 479 | 452 | -5.6 | 3.4 |
| 13 | 11 | Siemens | 435 | 452 | 3.9 | 3.4 |
| 9 | 12 | Sanyo | 488 | 441 | -9.6 | 3.3 |
| 12 | 13 | Fuji Electric | 468 | 401 | -14.3 | 3.0 |
| 14 | 14 | General Instrument | 413 | 362 | -12.3 | 2.7 |
| 16 | 15 | TEMIC | 321 | 353 | 10.0 | 2.6 |
| 15 | 16 | Sanken | 398 | 328 | -17.6 | 2.4 |
| 17 | 17 | Samsung | 317 | 307 | -3.2 | 2.3 |
| 19 | 18 | Fujitsu | 283 | 290 | 2.5 | 2.2 |
| 18 | 19 | Shindengen Electric | 301 | 277 | -8.0 | 2.1 |
| 20 | 20 | Harris | 228 | 232 | 1.8 | 1.7 |
| 21 | 21 | Korean Electronic Co. | 220 | 193 | -12.3 | 1.4 |
| 26 | 22 | Eupec | 120 | 160 | 33.3 | 1.2 |
| 23 | 23 | National Semiconductor | 164 | 157 | -4.3 | 1.2 |
| 27 | 24 | Microsemi | 118 | 146 | 23.7 | 1.1 |
| 24 | 25 | Hewlett-Packard | 146 | 140 | -4.1 | 1.0 |
| 25 | 26 | Semikron | 125 | 109 | -12.8 | 0.8 |
| 28 | 27 | Powerex | 98 | 98 | 0 | 0.7 |
| 30 | 28 | Teccor Electronics | 68 | 84 | 23.5 | 0.6 |
| 22 | 29 | ITT | 192 | 81 | -57.8 | 0.6 |
| 31 | 30 | IXYS | 65 | 66 | 1.5 | 0.5 |
| 29 | 31 | Toko | 68 | 55 | -19.1 | 0.4 |
| 34 | 32 | Zetex | 51 | 52 | 2.0 | 0.4 |
| 33 | 33 | Sony | 53 | 43 | -18.9 | 0.3 |
| 36 | 34 | GEC Plessey | 36 | 35 | -2.8 | 0.3 |
| 39 | 35 | Ericsson | 20 | 28 | 40.0 | 0.2 |
| 40 | 36 | Texas Instruments | 16 | 28 | 75.0 | 0.2 |
| 38 | 37 | Semtech | 29 | 24 | -17.2 | 0.2 |

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**Table 2-13 (Continued)**
**Top 40 Worldwide Companies' Factory Revenue from Shipments of Total Discrete Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 37 | 38 | Allegro MicroSystems | 29 | 19 | -34.5 | 0.1 |
| 41 | 39 | Supertex | 16 | 16 | 0 | 0.1 |
| 42 | 40 | Raytheon | 13 | 13 | 0 | 0 |
| | | All Others | 221 | 130 | -41.2 | 1.0 |
| | | Americas Companies | 3,720 | 3,417 | -8.1 | 25.4 |
| | | Japanese Companies | 7,142 | 6,774 | -5.2 | 50.3 |
| | | European Companies | 2,915 | 2,784 | -4.5 | 20.7 |
| | | Asia/Pacific Companies | 537 | 500 | -6.9 | 3.7 |
| | | Total Market | 14,314 | 13,475 | -5.9 | 100.0 |

Source: Dataquest (April 1997)


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**Table 2-14**
**Top 349 Worldwide Companies' Factory Revenue from Shipments of Total Optical Semiconductors Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 1 | 1 | Sharp | 636 | 617 | -3.0 | 12.6 |
| 2 | 2 | Toshiba | 623 | 471 | -24.4 | 9.6 |
| 3 | 3 | Matsushita | 496 | 450 | -9.3 | 9.2 |
| 11 | 4 | Hewlett-Packard | 160 | 425 | 165.6 | 8.6 |
| 4 | 5 | Sony | 382 | 373 | -2.4 | 7.6 |
| 5 | 6 | Siemens | 314 | 339 | 8.0 | 6.9 |
| 7 | 7 | Rohm | 286 | 293 | 2.4 | 6.0 |
| 8 | 8 | NEC | 202 | 256 | 26.7 | 5.2 |
| 9 | 9 | Fujitsu | 168 | 151 | -10.1 | 3.1 |
| 10 | 10 | Sanyo | 167 | 148 | -11.4 | 3.0 |
| 12 | 11 | Mitsubishi | 151 | 144 | -4.6 | 2.9 |
| 14 | 12 | Hitachi | 84 | 121 | 44.0 | 2.5 |
| 13 | 13 | TEMIC | 110 | 113 | 2.7 | 2.3 |
| 15 | 14 | Lucent Technologies | 81 | 90 | 11.1 | 1.8 |
| 20 | 15 | Texas Instruments | 43 | 62 | 44.2 | 1.3 |
| 17 | 16 | Optek | 53 | 59 | 11.3 | 1.2 |
| 16 | 17 | Quality Technologies | 61 | 52 | -14.8 | 1.1 |
| 21 | 18 | Honeywell | 37 | 41 | 10.8 | 0.8 |
| 18 | 19 | Sanken | 52 | 40 | -23.1 | 0.8 |
| 19 | 20 | Motorola | 50 | 40 | -20.0 | 0.8 |
| 23 | 21 | Oki | 28 | 28 | 0 | 0.6 |
| 22 | 22 | TCS | 34 | 25 | -26.5 | 0.5 |
| 24 | 23 | Korean Electronic Co. | 22 | 24 | 9.1 | 0.5 |
| 25 | 24 | Ericsson | 16 | 23 | 43.8 | 0.5 |
| 71 | 25 | Mitel | 0 | 22 | NA | 0.4 |
| 26 | 26 | Spectra Diode Labs | 15 | 17 | 13.3 | 0.3 |
| 28 | 27 | New JRC | 12 | 9 | -25.0 | 0.2 |
| 31 | 28 | Samsung | 4 | 8 | 100.0 | 0.2 |
| 29 | 29 | IC Sensors | 6 | 7 | 16.7 | 0.1 |
| 30 | 30 | CID Technologies | 5 | 6 | 20.0 | 0.1 |
| 32 | 31 | Eastman Kodak | 3 | 3 | 0 | 0 |
| 33 | 32 | Zetex | 1 | 1 | 0 | 0 |
| 6 | 33 | Stanley Electric | 301 | 0 | -100.0 | 0 |

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**Table 2-14 (Continued)**
**Top 349 Worldwide Companies' Factory Revenue from Shipments of Total Optical Semiconductors Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 27 | 34 | ABB-Hafo | 14 | 0 | -100.0 | 0 |
| | | All Others | 195 | 457 | 134.4 | 9.3 |
| | | Americas Companies | 547 | 824 | 50.6 | 16.8 |
| | | Japanese Companies | 3,735 | 3,542 | -5.2 | 72.1 |
| | | European Companies | 504 | 517 | 2.6 | 10.5 |
| | | Asia/Pacific Companies | 26 | 32 | 23.1 | 0.7 |
| | | Total Market | 4,812 | 4,915 | 2.1 | 100.0 |

Source: Dataquest (April 1997)

**Table 2-15**
**Top 29 Worldwide Companies' Factory Revenue from Shipments of Hybrid Analog Worldwide (Millions of U.S. Dollars)**

| 1995 Rank | 1996 Rank | | 1995 Revenue | 1996 Revenue | Percentage Change | 1996 Market Share (%) |
|---|---|---|---|---|---|---|
| 1 | 1 | Sanken | 283 | 254 | -10.2 | 17.3 |
| 2 | 2 | Mitsubishi | 198 | 187 | -5.6 | 12.7 |
| 3 | 3 | Sanyo | 193 | 177 | -8.3 | 12.1 |
| 4 | 4 | Fujitsu | 149 | 134 | -10.1 | 9.1 |
| 6 | 5 | NEC | 130 | 125 | -3.8 | 8.5 |
| 5 | 6 | Hitachi | 137 | 118 | -13.9 | 8.0 |
| 7 | 7 | Rohm | 78 | 73 | -6.4 | 5.0 |
| 12 | 8 | Sony | 41 | 65 | 58.5 | 4.4 |
| 9 | 9 | Burr-Brown | 60 | 50 | -16.7 | 3.4 |
| 10 | 10 | Analog Devices | 58 | 42 | -27.6 | 2.9 |
| 11 | 11 | Philips | 46 | 40 | -13.0 | 2.7 |
| 8 | 12 | Toshiba | 74 | 36 | -51.4 | 2.5 |
| 13 | 13 | Shindengen Electric | 28 | 21 | -25.0 | 1.4 |
| 14 | 14 | Fuji Electric | 23 | 21 | -8.7 | 1.4 |
| 15 | 15 | Mitel | 20 | 16 | -20.0 | 1.1 |
| 19 | 16 | Allegro MicroSystems | 12 | 15 | 25.0 | 1.0 |
| 16 | 17 | Ericsson | 15 | 13 | -13.3 | 0.9 |
| 17 | 18 | Sipex | 14 | 13 | -7.1 | 0.9 |
| 18 | 19 | Oki | 13 | 13 | 0 | 0.9 |
| 22 | 20 | Toko | 8 | 8 | 0 | 0.5 |
| 24 | 21 | Maxim | 4 | 4 | 0 | 0.3 |
| 26 | 22 | Linfinity | 3 | 3 | 0 | 0.2 |
| 27 | 23 | Elantec | 3 | 3 | 0 | 0.2 |
| 28 | 24 | Solitron | 2 | 3 | 50.0 | 0.2 |
| 20 | 25 | Micronas | 10 | 0 | -100.0 | 0 |
| 21 | 26 | National Semiconductor | 8 | 0 | -100.0 | 0 |
| 23 | 27 | ABB-Hafo | 5 | 0 | -100.0 | 0 |
| 25 | 28 | GEC Plessey | 3 | 0 | -100.0 | 0 |
| 29 | 29 | Gennum | 2 | 0 | -100.0 | 0 |
| | | All Others | 35 | 34 | -2.9 | 2.3 |
| | | Americas Companies | 186 | 149 | -19.9 | 10.1 |
| | | Japanese Companies | 1,369 | 1,245 | -9.1 | 84.8 |
| | | European Companies | 100 | 74 | -26.0 | 5.0 |
| | | Asia/Pacific Companies | 0 | - | NA | 0 |
| | | Total Market | 1,655 | 1,468 | -11.3 | 100.0 |

NA = Not applicable
Source: Dataquest (April 1997)

**For More Information...**

Kevin McClure, Market Research Analyst ..... (408) 468-8505
Internet address ..... kevin.mcclure@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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Dataquest
A Gartner Group Company

## DATAQUEST WORLDWIDE OFFICES


**NORTH AMERICA**

**Worldwide Headquarters**
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: 1-408-468-8000
Facsimile: 1-408-954-1780

**East Coast Headquarters**
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6262

**Dataquest Global Events**
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

Sales Offices:
Washington, DC (Federal)
New York, NY (Financial)
Dallas, TX

**LATIN AMERICA**
Research Affiliates and Sales Offices:
Buenos Aires, Argentina
Sao Paulo, Brazil
Santiago, Chile
Mexico City, Mexico

**EUROPE**

**European Headquarters**
Tamesis, The Glanty
Egham, Surrey TW20 9AW
United Kingdom
Phone: +44 1784 431 611
Facsimile: +44 1784 488 980

**Dataquest France**
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: +33 1 41 35 13 00
Facsimile: +33 1 41 35 13 13

**Dataquest Germany**
Kronstadter Strasse 9
81677 München
Germany
Phone: +49 89 93 09 09 0
Facsimile: +49 89 93 03 27 7

Sales Offices:
Brussels, Belgium
Kfar Saba, Israel
Milan, Italy
Randburg, South Africa
Madrid, Spain

**JAPAN**

**Japan Headquarters**
Aobadai Hills 4-7-7
Aobadai
Meguro-ku, Tokyo 153
Japan
Phone: 81-3-3481-3670
Facsimile: 81-3-3481-3644

**ASIA/PACIFIC**

**Asia/Pacific Headquarters**
Suite 5904-7, Central Plaza
18 Harbour Road, Wanchai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

**Dataquest Korea**
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

**Dataquest Taiwan**
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

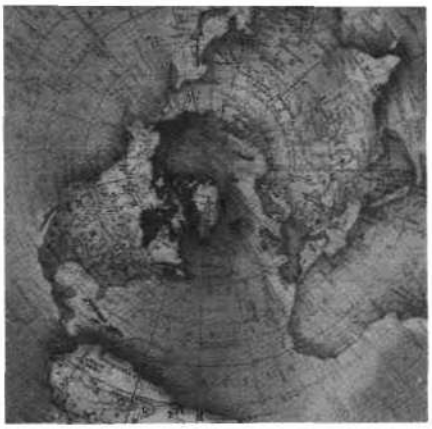
**Dataquest Singapore**
105 Cecil Street
#06-01/02 The Octagon
Singapore 069534
Phone: 65-227-1213
Facsimile: 65-227-4607

**Dataquest Thailand**
12/F, Vanissa Building
29 Soi Chidlom
Ploenchit Road
Patumwan, Bangkok 10330
Thailand
Phone: 662-655-0577
Facsimile: 662-655-0576

Research Affiliates and Sales Offices:
Melbourne, Australia
Beijing, China


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# North American Semiconductor Price Outlook—Second Quarter 1997

Market Statistics

**Program:** Semiconductor Supply and Pricing Worldwide
**Product Code:** SSPS-WW-MS-9701
**Publication Date:** March 10, 1997
**Filing:** Market Statistics

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# Table of Contents

Page

North American Semiconductor Price Outlook—
Second Quarter 1997 ..... 1
Methodology and Sources ..... 1
Price Variations ..... 1

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# List of Tables


| Table | | Page |
|---|---|---|
| 1 | Estimated Standard Logic Price Trends—North American Bookings | 2 |
| 2 | Estimated Long-Range Standard Logic Price Trends—North American Bookings | 3 |
| 3 | Estimated Microprocessor Price Trends—North American Bookings | 4 |
| 4 | Estimated Long-Range Microprocessor Price Trends—North American Bookings | 5 |
| 5 | Estimated DRAM Price Trends—North American Bookings | 6 |
| 6 | Estimated Long-Range DRAM Price Trends—North American Bookings | 8 |
| 7 | Estimated Static RAM Price Trends—North American Bookings | 9 |
| 8 | Estimated Long-Range Static RAM Price Trends—North American Bookings | 10 |
| 9 | Estimated ROM Price Trends—North American Bookings | 11 |
| 10 | Estimated Long-Range ROM Price Trends—North American Bookings | 11 |
| 11 | Estimated EPROM Price Trends—North American Bookings | 12 |
| 12 | Estimated Long-Range EPROM Price Trends—North American Bookings | 12 |
| 13 | Estimated Flash Memory Price Trends—North American Bookings | 13 |
| 14 | Estimated Long-Range Flash Memory Price Trends—North American Bookings | 14 |
| 15 | Estimated Gate Array Pricing—North American Production Bookings | 15 |
| 16 | Estimated CBIC Pricing—North American Production Bookings | 16 |



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# North American Semiconductor Price Outlook—Second Quarter 1997

## Methodology and Sources

This document provides information on and forecasts for the North American bookings prices of more than 200 semiconductor devices. Dataquest collects price information on a quarterly basis from North American suppliers and major buyers of these products. North American bookings price information is analyzed by Semiconductor Supply and Pricing Worldwide (SSPS) analysts for consistency and reconciliation. The information finally is rationalized with worldwide billings price data in association with product analysts, resulting in the current forecast. This document includes associated long-range forecasts.

For SSPS clients that use the SSPS online service through CompuServe, the prices presented here correlate with the quarterly and long-range price tables dated March 1997 in the SSPS online service. Clients who want to access the information via the World Wide Web can pay extra for a Dataquest Interactive subscription, which allows users to access all their deliverables at their desktops. For additional product coverage and more detailed product specifications, please refer to those sources.

### Price Variations

Actual negotiated market prices may vary from these prices 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 value of a company's product. These prices are intended for use as price guidelines.


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## Table 1
## Estimated Standard Logic Price Trends—North American Bookings
## (Volume: 100,000 per Year; Package: PLCC; Dollars)

| | 1996 | 1997 | | | | 1997 | 1998 | | | | 1998 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Q4 | Q1 | Q2 | Q3 | Q4 | Year | Q1 | Q2 | Q3 | Q4 | Year | Lead Times |
| 74LS TTL | | | | | | | | | | | | |
| 74LS00 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 2-6 |
| 74LS74 | 0.17 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 2-6 |
| 74LS138 | 0.18 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.16 | 0.16 | 0.17 | 2-6 |
| 74LS244 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 2-6 |
| 74AC TTL | | | | | | | | | | | | |
| 74AC00 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.15 | 0.15 | 0.15 | 0.14 | 0.15 | 2-6 |
| 74AC74 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.19 | 0.19 | 0.18 | 0.17 | 0.18 | 2-6 |
| 74AC138 | 0.31 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.28 | 0.28 | 0.27 | 0.27 | 0.27 | 2-6 |
| 74AC244 | 0.43 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.36 | 0.36 | 0.35 | 0.35 | 0.35 | 2-6 |
| 74F TTL | | | | | | | | | | | | |
| 74F00 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 2-6 |
| 74F74 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 2-6 |
| 74F138 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 2-6 |
| 74F244 | 0.23 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 2-6 |
| 74HC CMOS | | | | | | | | | | | | |
| 74HC00 | 0.12 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 2-6 |
| 74HC74 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 2-6 |
| 74HC138 | 0.18 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 2-6 |
| 74HC244 | 0.23 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 2-6 |
| 74ALS TTL | | | | | | | | | | | | |
| 74ALS00 | 0.16 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 2-6 |
| 74ALS74 | 0.18 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 2-6 |
| 74ALS138 | 0.23 | 0.22 | 0.21 | 0.21 | 0.21 | 0.21 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 2-6 |
| 74ALS244 | 0.31 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.27 | 0.27 | 0.26 | 0.26 | 0.26 | 2-6 |
| 74AS TTL | | | | | | | | | | | | |
| 74AS00 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 2-6 |
| 74AS74 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 2-6 |
| 74AS138 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 2-6 |
| 74AS244 | 0.65 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 2-6 |
| 74BC* | | | | | | | | | | | | |
| 74BC00 | 0.23 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.19 | 0.19 | 0.18 | 0.17 | 0.18 | 2-6 |
| 74BC244 | 0.55 | 0.53 | 0.53 | 0.53 | 0.53 | 0.53 | 0.48 | 0.47 | 0.46 | 0.44 | 0.46 | 2-6 |
| 74BC373 | 0.57 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.50 | 0.49 | 0.46 | 0.46 | 0.48 | 2-6 |
| 74ACT244 | 0.45 | 0.43 | 0.43 | 0.41 | 0.41 | 0.42 | 0.39 | 0.38 | 0.38 | 0.36 | 0.38 | 2-6 |
| 74ACT245 | 0.48 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.41 | 0.41 | 0.40 | 0.38 | 0.40 | 2-6 |
| 74ABT244 | 0.60 | 0.58 | 0.58 | 0.58 | 0.58 | 0.58 | 0.52 | 0.52 | 0.51 | 0.48 | 0.51 | 2-6 |
| 74ABT245 | 0.65 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.57 | 0.56 | 0.55 | 0.52 | 0.55 | 2-6 |

*Pricing for 74BC excludes 74ABT and 74BCT.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (March 1997)


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## Table 2
## Estimated Long-Range Standard Logic Price Trends—North American Bookings (Volume: 100,000 per Year; Package: PLCC; Dollars)

| Product | 1997 Year | 1998 Year | 1999 Year | 2000 Year | 2001 Year |
|---|---|---|---|---|---|
| 74LS TTL | | | | | |
| 74LS00 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| 74LS74 | 0.16 | 0.16 | 0.15 | 0.15 | 0.15 |
| 74LS138 | 0.17 | 0.17 | 0.16 | 0.15 | 0.15 |
| 74LS244 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 |
| 74AC TTL | | | | | |
| 74AC00 | 0.17 | 0.15 | 0.13 | 0.13 | 0.12 |
| 74AC74 | 0.21 | 0.18 | 0.16 | 0.15 | 0.15 |
| 74AC138 | 0.29 | 0.27 | 0.25 | 0.24 | 0.22 |
| 74AC244 | 0.40 | 0.35 | 0.31 | 0.28 | 0.27 |
| 74F TTL | | | | | |
| 74F00 | 0.14 | 0.13 | 0.13 | 0.12 | 0.12 |
| 74F74 | 0.15 | 0.15 | 0.14 | 0.14 | 0.14 |
| 74F138 | 0.18 | 0.18 | 0.17 | 0.17 | 0.17 |
| 74F244 | 0.22 | 0.22 | 0.21 | 0.20 | 0.20 |
| 74HC CMOS | | | | | |
| 74HC00 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| 74HC74 | 0.16 | 0.15 | 0.14 | 0.14 | 0.13 |
| 74HC138 | 0.17 | 0.17 | 0.16 | 0.16 | 0.16 |
| 74HC244 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| 74ALS TTL | | | | | |
| 74ALS00 | 0.14 | 0.14 | 0.13 | 0.13 | 0.13 |
| 74ALS74 | 0.16 | 0.16 | 0.16 | 0.15 | 0.15 |
| 74ALS138 | 0.21 | 0.20 | 0.20 | 0.20 | 0.20 |
| 74ALS244 | 0.30 | 0.26 | 0.25 | 0.24 | 0.24 |
| 74AS TTL | | | | | |
| 74AS00 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| 74AS74 | 0.19 | 0.19 | 0.19 | 0.20 | 0.20 |
| 74AS138 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| 74AS244 | 0.63 | 0.62 | 0.61 | 0.61 | 0.61 |
| 74BC* | | | | | |
| 74BC00 | 0.20 | 0.18 | 0.17 | 0.16 | 0.16 |
| 74BC244 | 0.53 | 0.46 | 0.43 | 0.42 | 0.41 |
| 74BC373 | 0.55 | 0.48 | 0.45 | 0.43 | 0.42 |
| 74ACT244 | 0.42 | 0.38 | 0.35 | 0.33 | 0.32 |
| 74ACT245 | 0.46 | 0.40 | 0.37 | 0.35 | 0.34 |
| 74ABT244 | 0.58 | 0.51 | 0.47 | 0.42 | 0.40 |
| 74ABT245 | 0.63 | 0.55 | 0.51 | 0.49 | 0.48 |

*Pricing for 74BC excludes 74ABT and 74BCT.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (March 1997)

## Table 3
## Estimated Microprocessor Price Trends—North American Bookings
## (Volume: 25,000 per Year; Dollars) (Package: 32/64-Bit Devices—Ceramic PGA; Exceptions Noted)

| Product | 1997 Q1 | Q2 | Q3 | Q4 | 1997 Year | 1998 Q1 | Q2 | Q3 | Q4 | 1998 Year | Lead Times (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 68EC020-25 PQFP | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 2-8 |
| 68EC030-25 PQFP | 19.00 | 18.75 | 18.75 | 18.75 | 18.81 | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 | 2-8 |
| 68040-25 | 25.00 | 24.00 | 24.00 | 22.00 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 2-8 |
| 68LC040-25 CQFP 184 | 25.00 | 24.00 | 24.00 | 22.00 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 2-8 |
| Pentium-75 | 70.00 | 70.00 | 70.00 | 70.00 | 70.00 | EOL | EOL | EOL | EOL | EOL | 2-8 |
| Pentium-90 | 70.00 | 70.00 | 70.00 | 70.00 | 70.00 | EOL | EOL | EOL | EOL | EOL | 2-8 |
| Pentium-100 3.3V | 75.00 | 75.00 | 70.00 | 70.00 | 72.50 | 70.00 | 70.00 | 70.00 | 70.00 | 70.00 | 2-8 |
| Pentium-100 2.9V | 90.00 | 90.00 | 85.00 | 85.00 | 87.50 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 2-8 |
| Pentium-120 3.3V | 90.00 | 85.00 | 85.00 | 85.00 | 86.25 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 2-8 |
| Pentium-120 2.9V | 90.00 | 85.00 | 85.00 | 85.00 | 86.25 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 2-8 |
| Pentium-133 3.3V | 110.00 | 100.00 | 100.00 | 90.00 | 100.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 2-8 |
| Pentium-133 2.9V | 150.00 | 140.00 | 140.00 | 110.00 | 135.00 | 110.00 | 110.00 | 110.00 | 110.00 | 110.00 | 2-8 |
| Pentium-150 3.3V | 140.00 | 140.00 | 130.00 | 130.00 | 135.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 2-8 |
| Pentium-150 2.9V | 250.00 | 200.00 | 150.00 | 150.00 | 187.50 | 150.00 | 150.00 | 150.00 | 150.00 | 150.00 | 2-8 |
| Pentium-166 3.3V | 295.00 | 200.00 | 200.00 | 175.00 | 217.50 | 140.00 | 140.00 | 140.00 | 140.00 | 140.00 | 2-8 |
| Pentium-200 3.3V | 450.00 | 400.00 | 300.00 | 300.00 | 362.50 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 2-8 |
| Pentium MMX 166-MHz 2.8V PGA | 350.00 | 300.00 | 200.00 | 200.00 | 262.50 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 2-8 |
| Pentium MMX 200-MHz 2.8V PGA | 500.00 | 400.00 | 350.00 | 300.00 | 387.50 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 2-8 |
| PentiumPRO-166C | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 | 2-8 |
| PentiumPRO-180 256k Cache | 410.00 | 330.00 | 280.00 | 280.00 | 325.00 | 225.00 | 225.00 | 225.00 | 225.00 | 225.00 | 2-8 |
| PentiumPRO-200 256k Cache | 475.00 | 475.00 | 425.00 | 375.00 | 437.50 | 375.00 | 375.00 | 375.00 | 375.00 | 375.00 | 2-8 |
| PentiumPRO-200 512k Cache | 993.00 | 993.00 | 895.00 | 895.00 | 944.00 | 700.00 | 700.00 | 635.00 | 635.00 | 667.50 | 2-8 |
| PowerPC601-80 | 70.00 | 68.00 | 68.00 | 68.00 | 68.50 | EOL | EOL | EOL | EOL | EOL | 2-8 |
| PowerPC601-100 | 80.00 | 75.00 | 75.00 | 75.00 | 76.25 | EOL | EOL | EOL | EOL | EOL | 2-8 |
| PowerPC603-80 | 63.00 | 61.00 | 61.00 | 60.00 | 61.25 | 60.00 | 60.00 | 60.00 | 60.00 | 60.00 | 2-8 |
| Powe PC603-133 | 125.00 | 115.00 | 110.00 | 110.00 | 115.00 | 100.00 | 90.00 | 90.00 | 90.00 | 92.50 | 2-8 |
| PowerPC604-166 | 200.00 | 180.00 | 180.00 | 170.00 | 182.50 | 170.00 | 170.00 | 150.00 | 150.00 | 160.00 | 2-8 |
| PowerPC604-225 | 400.00 | 360.00 | 330.00 | 330.00 | 355.00 | 300.00 | 300.00 | 280.00 | 280.00 | 290.00 | 2-8 |
| PowerPC604-240 | 500.00 | 450.00 | 400.00 | 400.00 | 437.50 | 400.00 | 375.00 | 375.00 | 350.00 | 375.00 | 2-8 |

EOL = End of life

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.

Source: Dataquest (March 1997)



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## Table 4
## Estimated Long-Range Microprocessor Price Trends—North American Bookings
## (Volume: 25,000 per Year; Dollars)
## (Package: 32/64 Bit Devices—Ceramic PGA; Exceptions Noted)

| Product | Year 1997 | Year 1998 | Year 1999 | Year 2000 | Year 2001 |
|---|---|---|---|---|---|
| 68EC020-25 PQFP | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 |
| 68EC030-25 VQFP | 18.81 | 18.75 | 18.75 | 18.75 | 18.75 |
| 68040-25 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 |
| 68LC040-25 CQFP 184 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 |
| Pentium-75 | 70.00 | EOL | EOL | EOL | EOL |
| Pentium-90 | 70.00 | EOL | EOL | EOL | EOL |
| Pentium-100 3.3V | 72.50 | 70.00 | EOL | EOL | EOL |
| Pentium-100 2.9V | 87.50 | 85.00 | EOL | EOL | EOL |
| Pentium-120 3.3V | 86.25 | 85.00 | EOL | EOL | EOL |
| Pentium-120 2.9V | 86.25 | 85.00 | EOL | EOL | EOL |
| Pentium-133 3.3V | 100.00 | 90.00 | EOL | EOL | EOL |
| Pentium-133 2.9V | 135.00 | 110.00 | EOL | EOL | EOL |
| Pentium-150 3.3V | 135.00 | 100.00 | EOL | EOL | EOL |
| Pentium-150 2.9V | 187.50 | 150.00 | 150.00 | EOL | EOL |
| Pentium-166 3.3V | 217.50 | 140.00 | 140.00 | EOL | EOL |
| Pentium-200 3.3V | 362.50 | 300.00 | 300.00 | EOL | EOL |
| Pentium MMX 166-MHz 2.8V PGA | 262.50 | 200.00 | 200.00 | EOL | EOL |
| Pentium MMX 200-MHz 2.8V PGA | 387.50 | 300.00 | 300.00 | EOL | EOL |
| PentiumPRO-166C | 600.00 | 600.00 | 600.00 | EOL | EOL |
| PentiumPRO-180 256k Cache | 325.00 | 225.00 | 225.00 | EOL | EOL |
| PentiumPRO-200 256k Cache | 437.50 | 375.00 | 375.00 | EOL | EOL |
| PentiumPRO-200 512k Cache | 944.00 | 667.50 | 667.50 | EOL | EOL |
| PowerPC601-80 | 68.50 | EOL | EOL | EOL | EOL |
| PowerPC601-100 | 76.25 | EOL | EOL | EOL | EOL |
| PowerPC603-80 | 61.25 | 60.00 | EOL | EOL | EOL |
| Powe PC603-133 | 115.00 | 92.50 | EOL | EOL | EOL |
| PowerPC604-166 | 182.50 | 160.00 | EOL | EOL | EOL |
| PowerPC604-225 | 355.00 | 290.00 | EOL | EOL | EOL |
| PowerPC604-240 | 437.50 | 375.00 | EOL | EOL | EOL |

EOL = End of life
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (March 1997)


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**Table 5**
**Estimated DRAM Price Trends—North American Bookings (Contract Volume; U.S. Dollars)***

| | 1997 | | | | 1997 | 1998 | | | | 1998 | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Q1 | Q2 | Q3 | Q4 | Year | Q1 | Q2 | Q3 | Q4 | Year | (Weeks) |
| 4Mbx1 DRAM 70ns SOJ 5V | 2.60 | 2.60 | 2.50 | 2.50 | 2.55 | 2.45 | 2.45 | 2.30 | 2.30 | 2.38 | 4-8 |
| 1Mbx4 DRAM 60ns SOJ 5V FPM | 2.40 | 2.35 | 2.35 | 2.30 | 2.35 | 2.30 | 2.30 | 2.28 | 2.28 | 2.29 | 4-8 |
| 1Mbx4 DRAM 60ns SOJ 5V EDO | 2.40 | 2.35 | 2.30 | 2.25 | 2.33 | 2.20 | 2.20 | 2.15 | 2.15 | 2.18 | 4-8 |
| 512Kx8 DRAM 70ns 5V FPM | 2.82 | 2.71 | 2.62 | 2.56 | 2.68 | 2.49 | 2.45 | 2.41 | 2.40 | 2.44 | 4-8 |
| 256Kx16 DRAM 70ns SOJ 5V FPM | 3.36 | 3.35 | 3.29 | 3.24 | 3.31 | 3.30 | 3.30 | 3.28 | 3.28 | 3.29 | 4-8 |
| 4Mb x 4 DRAM 60 ns SOJ 5V FPM | 8.66 | 8.00 | 7.80 | 7.72 | 8.05 | 7.66 | 7.54 | 7.45 | 7.39 | 7.51 | 4-8 |
| 4MbX4 DRAM 60ns SOJ 5V EDO | 8.66 | 8.00 | 7.73 | 7.58 | 7.99 | 7.47 | 7.35 | 7.31 | 7.22 | 7.34 | 4-8 |
| 1Mbx16 DRAM 60ns TSOP 5V FPM | 8.03 | 7.88 | 7.71 | 7.64 | 7.82 | 7.61 | 7.54 | 7.42 | 7.37 | 7.49 | 4-8 |
| 1Mbx16 DRAM 60ns TSOP 5V EDO | 8.03 | 7.88 | 7.69 | 7.56 | 7.79 | 7.53 | 7.41 | 7.33 | 7.28 | 7.39 | 4-8 |
| 1Mbx16 3.3V SDRAM | 10.25 | 10.00 | 9.65 | 9.33 | 9.81 | 8.68 | 8.35 | 8.27 | 8.17 | 8.37 | 4-8 |
| 2Mbx8 DRAM 60ns TSOP 5V FPM | 9.00 | 8.65 | 8.28 | 8.18 | 8.53 | 8.11 | 8.06 | 8.00 | 7.96 | 8.03 | 4-8 |
| 16Mbx4 DRAM SOJ 60ns 3.3V EDO | 75.00 | 65.00 | 60.00 | 55.00 | 63.75 | 45.00 | 40.00 | 35.00 | 30.00 | 37.50 | 4-8 |
| 16Mbx4 DRAM SOJ 3.3V SDRAM | 75.00 | 65.00 | 59.00 | 54.00 | 63.25 | 42.00 | 39.00 | 33.00 | 28.00 | 35.50 | 4-8 |
| 8Mbx8 DRAM SOJ 60ns 3.3V EDO | 75.00 | 65.00 | 60.00 | 55.00 | 63.75 | 45.00 | 40.00 | 35.00 | 30.00 | 37.50 | 4-8 |
| 8Mbx8 DRAM SOJ 3.3V SDRAM | 75.00 | 65.00 | 59.00 | 54.00 | 63.25 | 42.00 | 39.00 | 33.00 | 28.00 | 35.50 | 4-8 |
| 1Mbx32 SIMM 60ns 5V FPM | 19.00 | 18.68 | 18.00 | 17.86 | 18.39 | 17.68 | 17.59 | 17.40 | 17.33 | 17.50 | 4-8 |
| 1Mbx36 SIMM 60ns 5V FPM | 21.00 | 20.68 | 20.55 | 20.20 | 20.61 | 19.91 | 19.56 | 19.30 | 19.07 | 19.46 | 4-8 |
| 2Mbx32 SIMM 60ns 5V FPM | 36.12 | 35.58 | 34.15 | 33.99 | 34.96 | 33.74 | 33.23 | 33.02 | 32.91 | 33.23 | 4-8 |
| 2Mbx36 SIMM 60ns 5V FPM | 41.50 | 40.75 | 39.68 | 39.15 | 40.27 | 38.55 | 38.16 | 37.98 | 37.60 | 38.07 | 4-8 |
| 4Mbx32 SIMM 60ns 5V FPM | 72.20 | 69.08 | 68.01 | 67.40 | 69.17 | 66.45 | 64.98 | 64.46 | 63.94 | 64.96 | 4-8 |
| 4Mbx36 SIMM 60ns 5V FPM | 82.75 | 77.75 | 76.89 | 76.11 | 78.38 | 75.60 | 75.11 | 74.67 | 74.01 | 74.85 | 4-8 |
| 8Mbx32 SIMM 60ns 5V FPM | 141.20 | 134.86 | 132.56 | 132.02 | 135.16 | 131.88 | 131.11 | 129.50 | 129.11 | 130.40 | 4-8 |
| 8Mbx36 SIMM 60ns 5V FPM | 164.25 | 154.25 | 152.67 | 151.03 | 155.55 | 150.46 | 149.77 | 149.22 | 130.00 | 144.86 | 4-8 |
| 1Mbx32 SIMM 60ns 5V EDO | 19.00 | 18.68 | 17.90 | 17.56 | 18.29 | 17.50 | 17.33 | 17.15 | 17.02 | 17.25 | 4-8 |
| 1Mbx36 SIMM 60ns 5V EDO | 21.00 | 20.68 | 20.50 | 19.97 | 20.54 | 19.50 | 19.21 | 19.01 | 18.77 | 19.12 | 4-8 |
| 2Mbx32 SIMM 60ns 5V EDO | 36.12 | 35.58 | 34.07 | 33.89 | 34.92 | 33.50 | 33.06 | 32.88 | 32.69 | 33.03 | 4-8 |
| 2Mbx36 SIMM 60ns 5V EDO | 41.50 | 40.75 | 39.55 | 38.47 | 40.07 | 37.15 | 36.65 | 36.30 | 36.05 | 36.54 | 4-8 |


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## Table 5 (Continued)
## Estimated DRAM Price Trends—North American Bookings (Contract Volume; U.S. Dollars)*

| | 1997 | | | | 1997 | 1998 | | | | 1998 | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4Mbx32 SIMM 60ns 5V EDO | 72.20 | 69.08 | 67.64 | 66.80 | 68.93 | 64.98 | 63.77 | 62.49 | 62.11 | 63.34 | 4-8 |
| 4Mbx36 SIMM 60ns 5V EDO | 82.75 | 77.75 | 76.65 | 75.77 | 78.23 | 75.11 | 74.15 | 73.79 | 73.16 | 74.05 | 4-8 |
| 8Mbx32 SIMM 60ns 5V EDO | 141.20 | 134.86 | 132.08 | 131.67 | 134.95 | 129.50 | 125.72 | 124.75 | 123.70 | 125.92 | 4-8 |
| 8Mbx36 SIMM 60ns 5V EDO | 164.25 | 154.25 | 152.05 | 145.89 | 154.11 | 147.00 | 145.00 | 141.00 | 138.00 | 142.75 | 4-8 |
| 1Mbx64 60ns 3.3V EDO | 41.38 | 40.40 | 39.13 | 37.50 | 39.60 | 35.54 | 35.17 | 34.26 | 33.64 | 34.65 | 4-8 |
| 2Mbx64 60ns 3.3V EDO | 75.75 | 73.39 | 71.06 | 68.81 | 72.25 | 67.13 | 65.01 | 63.59 | 61.79 | 64.38 | 4-8 |
| 4Mbx64 60ns 3.3V EDO | 146.24 | 141.00 | 137.05 | 132.00 | 139.07 | 130.00 | 126.05 | 123.75 | 121.55 | 125.34 | 4-8 |
| 1Mbx64 3.3V SDRAM | 42.13 | 40.58 | 39.03 | 36.93 | 39.67 | 35.42 | 35.15 | 33.96 | 33.46 | 34.50 | 4-8 |
| 2Mbx64 3.3V SDRAM | 76.25 | 77.39 | 71.01 | 68.21 | 73.22 | 67.02 | 64.98 | 63.20 | 61.50 | 64.18 | 4-8 |
| 4Mbx64 3.3V SDRAM | 149.00 | 141.00 | 136.90 | 131.95 | 139.71 | 130.00 | 126.00 | 123.50 | 121.45 | 125.24 | 4-8 |
| 256Kx16 VRAM 70ns SOP | 11.60 | 10.67 | 10.30 | 8.80 | 9.70 | 9.20 | 9.20 | 9.00 | 8.90 | 9.08 | 4-8 |
| 256Kx32 66-MHz 3.3V SGRAM | 10.00 | 9.25 | 8.50 | 7.50 | 8.81 | 7.25 | 7.00 | 6.75 | 6.50 | 6.88 | 4-8 |

*Contract volume is at least 100,000 per order, except for VRAMs.

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines

Source: Dataquest (March 1997)

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## Table 6
## Estimated Long-Range DRAM Price Trends—North American Bookings (Contract Volume; U.S. Dollars)*

| Product | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| 4Mbx1 DRAM 70ns SOJ 5V | 2.55 | 2.38 | 2.38 | 2.45 | 2.66 |
| 1Mbx4 DRAM 60ns SOJ 5V FPM | 2.35 | 2.29 | 2.29 | 2.33 | 2.40 |
| 1Mbx4 DRAM 60ns SOJ 5V EDO | 2.33 | 2.18 | 2.20 | 2.33 | 2.40 |
| 512Kx8 DRAM 70ns 5V FPM | 2.68 | 2.44 | 2.44 | 2.55 | 2.80 |
| 256Kx16 DRAM 70ns SOJ 5V FPM | 3.31 | 3.29 | 3.31 | 3.50 | 3.60 |
| 4Mb x 4 DRAM 60ns SOJ 5V FPM | 8.05 | 7.51 | 7.51 | 7.77 | 8.10 |
| 4MbX4 DRAM 60ns SOJ 5V EDO | 7.99 | 7.34 | 7.35 | 7.66 | 8.00 |
| 1Mbx16 DRAM 60ns TSOP 5V FPM | 7.82 | 7.49 | 7.51 | 7.80 | 8.05 |
| 1Mbx16 DRAM 60ns TSOP 5V EDO | 7.79 | 7.39 | 7.39 | 7.66 | 8.00 |
| 1Mbx16 3.3V SDRAM | 9.81 | 8.37 | 8.15 | 8.00 | 8.10 |
| 2Mbx8 DRAM 60ns TSOP 5V FPM | 8.53 | 8.03 | 8.04 | 8.10 | 8.20 |
| 16Mbx4 DRAM SOJ 60ns 3.3V EDO | 63.75 | 37.50 | 30.00 | 29.00 | 28.00 |
| 16Mbx4 DRAM SOJ 3.3V SDRAM | 63.25 | 35.50 | 29.00 | 28.00 | 27.25 |
| 8Mbx8 DRAM SOJ 60ns 3.3V EDO | 63.75 | 37.50 | 30.00 | 29.00 | 28.00 |
| 8Mbx8 DRAM SOJ 3.3V SDRAM | 63.25 | 35.50 | 29.00 | 28.00 | 27.25 |
| 1Mbx32 SIMM 60ns 5V FPM | 18.39 | 17.50 | 17.70 | 18.20 | 18.40 |
| 1Mbx36 SIMM 60ns 5V FPM | 20.61 | 19.46 | 19.66 | 20.05 | 20.50 |
| 2Mbx32 SIMM 60ns 5V FPM | 34.96 | 33.23 | 33.25 | 33.70 | 34.20 |
| 2Mbx36 SIMM 60ns 5V FPM | 40.27 | 38.07 | 38.08 | 38.90 | 39.50 |
| 4Mbx32 SIMM 60ns 5V FPM | 69.17 | 64.96 | 64.99 | 65.60 | 66.10 |
| 4Mbx36 SIMM 60ns 5V FPM | 78.38 | 74.85 | 74.86 | 76.01 | 78.00 |
| 8Mbx32 SIMM 60ns 5V FPM | 135.16 | 130.40 | 130.40 | 132.00 | 135.00 |
| 8Mbx36 SIMM 60ns 5V FPM | 155.55 | 144.86 | 144.88 | 146.00 | 155.00 |
| 1Mbx32 SIMM 60ns 5V EDO | 18.29 | 17.25 | 17.25 | 17.40 | 18.00 |
| 1Mbx36 SIMM 60ns 5V EDO | 20.54 | 19.12 | 19.12 | 19.80 | 21.00 |
| 2Mbx32 SIMM 60ns 5V EDO | 34.92 | 33.03 | 33.04 | 33.40 | 34.80 |
| 2Mbx36 SIMM 60ns 5V EDO | 40.07 | 36.54 | 36.55 | 37.00 | 38.20 |
| 4Mbx32 SIMM 60ns 5V EDO | 68.93 | 63.34 | 63.34 | 64.00 | 65.20 |
| 4Mbx36 SIMM 60ns 5V EDO | 78.23 | 74.05 | 74.05 | 75.50 | 77.75 |
| 8Mbx32 SIMM 60ns 5V EDO | 134.95 | 125.92 | 125.93 | 127.00 | 135.00 |
| 8Mbx36 SIMM 60ns 5V EDO | 154.11 | 142.75 | 142.75 | 145.00 | 155.00 |
| 1Mbx64 60ns 3.3V EDO | 39.60 | 34.65 | 33.30 | 33.40 | 33.80 |
| 2Mbx64 60ns 3.3V EDO | 72.25 | 64.38 | 63.00 | 60.00 | 58.00 |
| 4Mbx64 60ns 3.3V EDO | 139.07 | 125.34 | 123.00 | 117.90 | 115.00 |
| 1Mbx64 3.3V SDRAM | 39.67 | 34.50 | 33.20 | 33.40 | 33.80 |
| 2Mbx64 3.3V SDRAM | 73.22 | 64.18 | 62.00 | 58.00 | 56.00 |
| 4Mbx64 3.3V SDRAM | 139.71 | 125.24 | 122.00 | 117.00 | 114.00 |
| 256Kx16 VRAM 70ns SOP | 9.70 | 9.08 | 9.08 | 9.15 | 9.30 |
| 256Kx32 66-MHz 3.3V SGRAM | 8.81 | 6.88 | 6.19 | 5.99 | 5.88 |

*Contract volume is at least 100,000 per order, except for VRAMs.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (March 1997)

## Table 7
## Estimated Static RAM Price Trends—North American Bookings
## (Volume: Slow SRAM—50,000 per Year; Fast SRAM—20,000 per Year; Package: PDIP; Dollars)

| Product | 1997 Q1 | 1997 Q2 | 1997 Q3 | 1997 Q4 | 1997 Year | 1998 Q1 | 1998 Q2 | 1998 Q3 | 1998 Q4 | 1998 Year | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 16Kx4 35ns | 2.19 | 2.17 | 2.16 | 2.14 | 2.17 | 2.09 | 2.09 | 2.06 | 2.06 | 2.08 | 2-4 |
| 8Kx8 25ns | 1.18 | 1.22 | 1.22 | 1.22 | 1.21 | 1.21 | 1.21 | 1.21 | 1.21 | 1.21 | 2-4 |
| 8Kx8 100-120ns | 1.39 | 1.38 | 1.36 | 1.33 | 1.36 | 1.29 | 1.29 | 1.26 | 1.26 | 1.28 | 2-4 |
| 64Kx4 10ns | 7.00 | 6.68 | 6.38 | 6.13 | 6.55 | 5.83 | 5.77 | 5.66 | 5.87 | 5.78 | 2-4 |
| 64Kx4 25ns | 2.06 | 1.92 | 1.89 | 1.89 | 1.94 | 1.76 | 1.77 | 1.73 | 1.74 | 1.75 | 2-4 |
| 32Kx8 12ns | 1.50 | 1.50 | 1.48 | 1.48 | 1.49 | 1.47 | 1.47 | 1.46 | 1.46 | 1.46 | 2-4 |
| 32Kx9 12ns Burst | 3.67 | 3.54 | 3.39 | 3.33 | 3.48 | 3.33 | 3.30 | 3.26 | 3.22 | 3.28 | 2-4 |
| 32Kx8, 15ns, 5V | 1.21 | 1.20 | 1.16 | 1.16 | 1.18 | 1.15 | 1.15 | 1.14 | 1.14 | 1.15 | 2-4 |
| 32Kx 8, 15ns, 3.3V | 1.26 | 1.24 | 1.22 | 1.22 | 1.23 | 1.20 | 1.20 | 1.19 | 1.19 | 1.20 | 2-4 |
| 32Kx8 25ns | 1.20 | 1.19 | 1.16 | 1.16 | 1.18 | 1.15 | 1.15 | 1.14 | 1.14 | 1.15 | 2-4 |
| 32Kx8 70-100ns SOJ | 1.53 | 1.40 | 1.30 | 1.27 | 1.37 | 1.20 | 1.18 | 1.17 | 1.17 | 1.18 | 2-4 |
| 64Kx8 12ns Burst | 15.15 | 14.20 | 14.13 | 13.55 | 14.26 | 13.41 | 12.51 | 11.96 | 11.66 | 12.39 | 2-4 |
| 256Kx4 20ns | 5.22 | 4.92 | 4.72 | 4.47 | 4.83 | 4.28 | 4.28 | 4.22 | 4.22 | 4.25 | 4-6 |
| 128Kx8, 15ns | 4.67 | 4.44 | 4.25 | 3.98 | 4.34 | 3.84 | 3.68 | 3.57 | 3.43 | 3.63 | 4-6 |
| 128Kx8, 20ns | 4.82 | 4.57 | 4.29 | 4.14 | 4.45 | 3.82 | 3.81 | 3.75 | 3.73 | 3.78 | 4-6 |
| 128Kx8 25ns | 4.82 | 4.57 | 4.29 | 4.14 | 4.45 | 3.82 | 3.81 | 3.75 | 3.73 | 3.78 | 4-6 |
| 128Kx8 70-100ns SOJ | 4.65 | 4.29 | 4.10 | 3.88 | 4.23 | 3.71 | 3.63 | 3.55 | 3.45 | 3.59 | 4-6 |
| 32Kx32 15ns, 3.3V PQFP | 3.59 | 3.46 | 3.44 | 3.31 | 3.45 | 3.17 | 3.12 | 2.98 | 2.95 | 3.05 | 4-6 |
| 32Kx32 8ns 3.3V PBSynch | 3.29 | 3.19 | 3.07 | 2.96 | 3.13 | 2.84 | 2.81 | 2.77 | 2.72 | 2.79 | 4-6 |
| 64Kx32 8ns 3.3V PBSynch | 6.29 | 5.82 | 5.58 | 5.38 | 5.77 | 5.16 | 5.07 | 4.85 | 4.69 | 4.94 | 4-6 |
| 256Kx16 70-100ns | 19.15 | 18.44 | 18.17 | 17.54 | 18.33 | 17.14 | 16.55 | 15.97 | 12.25 | 15.48 | 4-6 |
| 256Kx16 25ns | 20.41 | 18.98 | 18.27 | 17.88 | 18.89 | 16.15 | 16.45 | 16.06 | 15.99 | 16.16 | 4-6 |
| 512Kx8 70ns | 17.96 | 17.52 | 17.26 | 16.66 | 17.35 | 16.28 | 15.72 | 15.18 | 14.49 | 15.42 | 4-6 |
| 512Kx8 25ns | 22.00 | 20.76 | 19.95 | 19.56 | 20.57 | 18.45 | 17.50 | 16.97 | 15.58 | 17.13 | 4-6 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (March 1997)



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## Table 8
## Estimated Long-Range Static RAM Price Trends—North American Bookings (Volume: Slow SRAM—50,000 per Year; Fast SRAM—20,000 per Year; Package: PDIP; Dollars

| Product | 1997 Year | 1998 Year | 1999 Year | 2000 Year | 2001 Year |
|---|---|---|---|---|---|
| 16Kx4 35ns | 2.17 | 2.08 | 2.10 | 2.10 | 2.15 |
| 8Kx8 25ns | 1.21 | 1.21 | 1.22 | 1.25 | 1.30 |
| 8Kx8 100-120ns | 1.36 | 1.28 | 1.30 | 1.30 | 1.40 |
| 64Kx4 10ns | 6.55 | 5.78 | 6.40 | 6.45 | 6.50 |
| 64Kx4 25ns | 1.94 | 1.75 | 1.78 | 1.80 | 1.90 |
| 32Kx8 12ns | 1.49 | 1.46 | 1.48 | 1.55 | 1.66 |
| 32Kx9 12ns Burst | 3.48 | 3.28 | 3.22 | 3.25 | 3.30 |
| 32K x 8, 15ns, 5V | 1.18 | 1.15 | 1.18 | 1.20 | 1.25 |
| 32Kx8, 15ns, 3.3V | 1.23 | 1.20 | 1.22 | 1.25 | 1.30 |
| 32Kx8 25ns | 1.18 | 1.15 | 1.20 | 1.22 | 1.26 |
| 32Kx8 70-100ns SOJ | 1.37 | 1.18 | 1.25 | 1.30 | 1.38 |
| 64Kx8 12ns Burst | 14.26 | 12.39 | 11.20 | 12.00 | 12.20 |
| 256Kx4 20ns | 4.83 | 4.25 | 4.22 | 4.75 | 4.90 |
| 128Kx8, 15ns | 4.34 | 3.63 | 3.43 | 3.43 | 3.45 |
| 128Kx8, 20ns | 4.45 | 3.78 | 3.73 | 3.70 | 3.68 |
| 128Kx8 25ns | 4.45 | 3.78 | 3.73 | 3.70 | 3.68 |
| 128Kx8 70-100ns SOJ | 4.23 | 3.59 | 3.45 | 3.42 | 3.40 |
| 32Kx32 15ns, 3.3V PQFP | 3.45 | 3.05 | 3.00 | 3.00 | 3.05 |
| 32Kx32 8ns 3.3V PBSynch | 3.13 | 2.79 | 3.00 | 3.40 | 3.60 |
| 64Kx32 8ns 3.3V PBSynch | 5.77 | 4.94 | 4.82 | 4.82 | 4.84 |
| 256Kx16 70-100ns | 18.33 | 15.48 | 14.90 | 13.40 | 12.65 |
| 256Kx16 25ns | 18.89 | 16.16 | 15.10 | 14.10 | 13.00 |
| 512Kx8 70ns | 17.35 | 15.42 | 13.90 | 13.05 | 12.45 |
| 512Kx8 25ns | 20.57 | 17.13 | 14.90 | 13.60 | 12.60 |

EOL = End of life
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (March 1997)


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## Table 9
## Estimated ROM Price Trends—North American Bookings (Speed/Package: ≤1Mb Density—150ns and Above; 28-pin PDIP; ≥2Mb Density—200ns and Above; 32-pin PDIP) (Volume: 50,000 per Year; Dollars)

| | 1997 | | | | 1997 | 1998 | | | | 1998 | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Q1 | Q2 | Q3 | Q4 | Year | Q1 | Q2 | Q3 | Q4 | Year | (Weeks) |
| 128Kx8 ROM | 1.74 | 1.69 | 1.69 | 1.64 | 1.69 | 1.58 | 1.58 | 1.51 | 1.51 | 1.55 | 4-8 |
| 64Kx16 ROM | 2.00 | 1.92 | 1.88 | 1.80 | 1.90 | 1.73 | 1.73 | 1.66 | 1.66 | 1.70 | 4-8 |
| 256Kx8 ROM | 2.20 | 2.18 | 2.14 | 2.14 | 2.17 | 2.10 | 2.10 | 2.05 | 2.05 | 2.08 | 4-8 |
| 512Kx8 ROM | 3.10 | 3.00 | 2.90 | 2.80 | 2.95 | 2.70 | 2.70 | 2.66 | 2.66 | 2.68 | 4-8 |
| 256Kx16 ROM[1] | 3.10 | 3.00 | 2.90 | 2.80 | 2.95 | 2.70 | 2.70 | 2.66 | 2.66 | 2.68 | 4-8 |
| 1Mbx8 ROM[2] | 4.00 | 3.90 | 3.80 | 3.70 | 3.85 | 3.62 | 3.62 | 3.53 | 3.53 | 3.58 | 4-8 |
| 1Mbx16 ROM | 6.00 | 5.80 | 5.70 | 5.65 | 5.79 | 5.55 | 5.55 | 5.46 | 5.46 | 5.51 | 4-8 |
| 2Mbx8 ROM | 5.87 | 5.72 | 5.70 | 5.65 | 5.74 | 5.55 | 5.55 | 5.46 | 5.46 | 5.51 | 4-8 |
| 2Mbx16 ROM | 12.00 | 11.75 | 11.50 | 11.30 | 11.64 | 11.00 | 11.00 | 10.74 | 10.74 | 10.87 | 4-8 |
| 4Mbx8 ROM | 12.00 | 11.60 | 11.40 | 11.30 | 11.58 | 11.00 | 11.00 | 10.74 | 10.74 | 10.87 | 4-8 |
| 4Mbx16 ROM | 16.00 | 15.80 | 15.40 | 15.00 | 15.55 | 14.50 | 14.50 | 14.00 | 14.00 | 14.25 | 4-9 |
| 8Mbx8 ROM | 15.50 | 15.30 | 15.20 | 14.90 | 15.23 | 14.40 | 14.40 | 13.90 | 13.90 | 14.15 | 4-9 |

[1]256Kx16 ROM: 150ns and above; 40-pin PDIP
[2]1Mbx8 ROM: 150ns and above; 32-pin SOP
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (March 1997)

## Table 10
## Estimated Long-Range ROM Price Trends—North American Bookings (Speed/Package: ≤1Mb Density—150ns and Above; 28-pin PDIP; ≥2Mb Density—200ns and Above; 32-pin PDIP) (Volume: 50,000 per Year; Dollars)

| Product | 1997 Year | 1998 Year | 1999 Year | 2000 Year | 2001 Year |
|---|---|---|---|---|---|
| 128Kx8 ROM | 1.69 | 1.55 | 1.50 | 1.47 | 1.44 |
| 64Kx16 ROM | 1.90 | 1.70 | 1.65 | 1.61 | 1.59 |
| 256Kx8 ROM | 2.17 | 2.08 | 2.20 | 1.98 | 1.96 |
| 512Kx8 ROM | 2.95 | 2.68 | 2.60 | 2.56 | 2.52 |
| 256Kx16 ROM[1] | 2.95 | 2.68 | 2.60 | 2.56 | 2.52 |
| 1Mbx8 ROM[2] | 3.85 | 3.58 | 3.50 | 3.45 | 3.40 |
| 1Mbx16 ROM | 5.79 | 5.51 | 5.40 | 5.30 | 5.22 |
| 2Mbx8 ROM | 5.74 | 5.51 | 5.40 | 5.30 | 5.22 |
| 2Mbx16 ROM | 11.64 | 10.87 | 10.60 | 10.50 | 10.35 |
| 4Mbx8 ROM | 11.58 | 10.87 | 10.60 | 10.50 | 10.35 |
| 4Mbx16 ROM | 15.55 | 14.25 | 14.00 | 13.80 | 13.50 |
| 8Mbx8 ROM | 15.23 | 14.15 | 14.00 | 13.80 | 13.50 |

[1]256Kx16 ROM: 150ns and above; 40-pin PDIP
[2]1Mbx8 ROM: 150ns and above; 32-pin SOP
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (March 1997)

## Table 11
## Estimated EPROM Price Trends—North American Bookings (Volume: 50,000 per Year; Package: Windowed CERDIP; Speed: 150ns and Above; Dollars)

| | 1997 | | | | 1997 | 1998 | | | | 1998 | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Q1 | Q2 | Q3 | Q4 | Year | Q1 | Q2 | Q3 | Q4 | Year | (Weeks) |
| 32Kx8 EPROM | 1.37 | 1.37 | 1.37 | 1.36 | 1.37 | 1.35 | 1.33 | 1.32 | 1.33 | 1.33 | 2-3 |
| 64Kx8 EPROM | 1.43 | 1.45 | 1.43 | 1.43 | 1.44 | 1.42 | 1.42 | 1.37 | 1.37 | 1.39 | 2-3 |
| 128Kx8 EPROM | 1.93 | 1.90 | 1.83 | 1.80 | 1.87 | 1.73 | 1.73 | 1.70 | 1.70 | 1.72 | 2-3 |
| 256Kx8 EPROM | 2.77 | 2.77 | 2.75 | 2.73 | 2.75 | 2.68 | 2.67 | 2.52 | 2.50 | 2.59 | 2-3 |
| 128Kx16 EPROM | 3.65 | 3.59 | 3.47 | 3.40 | 3.53 | 3.33 | 3.20 | 2.98 | 2.95 | 3.11 | 2-3 |
| 512Kx8 EPROM | 4.97 | 4.97 | 4.87 | 4.77 | 4.89 | 4.60 | 4.48 | 4.40 | 4.33 | 4.45 | 2-3 |
| 256Kx16 EPROM | 7.58 | 7.10 | 6.63 | 6.15 | 6.86 | 6.50 | 6.00 | 5.50 | 5.00 | 5.75 | 2-3 |
| 1Mbx8 EPROM | 8.50 | 8.40 | 8.30 | 8.20 | 8.35 | 8.15 | 8.10 | 8.05 | 8.00 | 8.08 | 2-3 |
| 512Kx16 EPROM | 9.50 | 9.45 | 9.40 | 9.30 | 9.41 | 9.20 | 9.15 | 9.10 | 9.05 | 9.13 | 2-3 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (March 1997)

## Table 12
## Estimated Long-Range EPROM Price Trends—North American Bookings (Volume: 50,000 per Year; Package: Windowed CERDIP; Speed: 150ns and Above; Dollars)

| Product | 1997 Year | 1998 Year | 1999 Year | 2000 Year | 2001 Year |
|---|---|---|---|---|---|
| 32Kx8 EPROM | 1.37 | 1.23 | 1.22 | 1.20 | 1.20 |
| 64Kx8 EPROM | 1.44 | 1.27 | 1.27 | 1.26 | 1.26 |
| 128Kx8 EPROM | 1.87 | 1.55 | 1.52 | 1.49 | 1.48 |
| 256Kx8 EPROM | 2.75 | 2.39 | 2.10 | 2.00 | 1.95 |
| 128Kx16 EPROM | 3.53 | 2.38 | 2.25 | 2.19 | 2.12 |
| 512Kx8 EPROM | 4.89 | 4.23 | 3.96 | 3.85 | 3.70 |
| 256Kx16 EPROM | 6.86 | 4.61 | 4.49 | 4.35 | 4.22 |
| 1Mbx8 EPROM | 8.35 | 8.08 | 7.89 | 7.48 | 7.22 |
| 512Kx16 EPROM | 9.41 | 9.13 | 8.93 | 8.46 | 8.11 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (March 1997)

## Table 13
## Estimated Flash Memory Price Trends—North American Bookings
## (12V; Volume: 10,000 per Year; Speed: 150ns; Dollars)

| Product | 1997 Q1 | 1997 Q2 | 1997 Q3 | 1997 Q4 | 1997 Year | 1998 Q1 | 1998 Q2 | 1998 Q3 | 1998 Q4 | 1998 Year | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 64Kx8, PDIP/PLCC | 2.75 | 2.60 | 2.50 | 2.40 | 2.56 | 2.35 | 2.30 | 2.30 | 2.30 | 2.31 | 5 |
| 64Kx8, TSOP | 2.83 | 2.75 | 2.70 | 2.66 | 2.73 | 2.60 | 2.55 | 2.45 | 2.35 | 2.49 | 5 |
| 128Kx8, PDIP/PLCC | 2.58 | 2.40 | 2.35 | 2.35 | 2.42 | 2.30 | 2.30 | 2.30 | 2.30 | 2.30 | 3 |
| 128Kx8, TSOP 12V | 2.80 | 2.60 | 2.50 | 2.50 | 2.60 | 2.45 | 2.40 | 2.40 | 2.40 | 2.41 | 4 |
| 128Kx8, TSOP 5V | 3.18 | 3.08 | 3.00 | 2.95 | 3.05 | 2.80 | 2.70 | 2.60 | 2.60 | 2.68 | 4 |
| 256Kx8, TSOP 12V | 5.57 | 5.10 | 5.00 | 4.90 | 5.14 | 4.75 | 4.65 | 4.55 | 4.30 | 4.56 | 4 |
| 256Kx8, TSOP/5V | 5.30 | 4.73 | 4.63 | 4.53 | 4.80 | 4.20 | 4.10 | 4.00 | 3.85 | 4.04 | 4 |
| 512Kx8, PDIP/PLCC | 5.60 | 5.30 | 5.00 | 4.80 | 5.18 | 4.75 | 4.60 | 4.45 | 4.25 | 4.51 | 4 |
| 512Kx8, TSOP 12V | 6.20 | 6.05 | 5.78 | 5.68 | 5.93 | 5.05 | 4.70 | 4.70 | 4.55 | 4.75 | 4 |
| 512Kx8, TSOP/5V | 6.28 | 6.05 | 5.78 | 5.68 | 5.94 | 5.05 | 4.70 | 4.70 | 4.55 | 4.75 | 4 |
| 512Kx8, SSOP/3V | 7.63 | 6.65 | 5.30 | 5.10 | 6.17 | 5.05 | 4.70 | 4.70 | 4.55 | 4.75 | 4 |
| 1Mbx8 TSOP/12V | 10.07 | 8.80 | 8.50 | 8.00 | 8.84 | 7.80 | 7.50 | 7.30 | 6.90 | 7.38 | 4 |
| 1Mbx8 TSOP/5V | 10.20 | 8.85 | 8.50 | 8.00 | 8.89 | 7.80 | 7.50 | 7.30 | 6.90 | 7.38 | 4 |
| 1Mbx8 TSOP/3V | 12.00 | 10.00 | 8.50 | 8.00 | 9.63 | 7.80 | 7.50 | 7.30 | 6.90 | 7.38 | 4 |
| 2Mbx8 TSOP/12V | 18.15 | 17.55 | 16.75 | 15.85 | 17.08 | 15.20 | 14.70 | 14.30 | 13.70 | 14.48 | 4 |
| 2Mbx8 TSOP/5V | 18.50 | 17.75 | 16.75 | 16.00 | 17.25 | 15.50 | 14.90 | 14.30 | 13.70 | 14.60 | 4 |
| 2Mbx8 TSOP/3V | 20.00 | 18.40 | 17.60 | 16.55 | 18.14 | 15.90 | 14.90 | 14.30 | 13.70 | 14.70 | 4 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (March 1997)

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## Table 14
## Estimated Long-Range Flash Memory Price Trends—North American Bookings (12V; Volume: 10,000 per Year; Speed: 150ns; Dollars)

| Product | 1997 Year | 1998 Year | 1999 Year | 2000 Year | 2001 Year |
|---|---|---|---|---|---|
| 64Kx8, PDIP/PLCC | 2.56 | 2.31 | 2.29 | 2.28 | 2.27 |
| 64Kx8, TSOP | 2.73 | 2.49 | 2.44 | 2.43 | 2.41 |
| 128Kx8, PDIP/PLCC | 2.42 | 2.30 | 2.27 | 2.23 | 2.20 |
| 128Kx8, TSOP 12V | 2.60 | 2.41 | 2.34 | 2.29 | 2.26 |
| 128Kx8, TSOP 5V | 3.05 | 2.68 | 2.55 | 2.40 | 2.35 |
| 256Kx8, TSOP 12V | 5.14 | 4.56 | 4.10 | 4.00 | 3.91 |
| 256Kx8, TSOP/5V | 4.80 | 4.04 | 3.70 | 3.50 | 3.42 |
| 512Kx8, PDIP/PLCC | 5.18 | 4.51 | 4.15 | 4.02 | 3.85 |
| 512Kx8, TSOP 12V | 5.93 | 4.75 | 4.27 | 4.09 | 3.92 |
| 512Kx8, TSOP/5V | 5.94 | 4.75 | 4.27 | 4.09 | 3.92 |
| 512Kx8, SSOP/3V | 6.17 | 4.75 | 4.27 | 4.09 | 3.92 |
| 1Mbx8 TSOP/12V | 8.84 | 7.38 | 6.94 | 6.74 | 6.40 |
| 1Mbx8 TSOP/5V | 8.89 | 7.38 | 6.94 | 6.74 | 6.40 |
| 1Mbx8 TSOP/3V | 9.63 | 7.38 | 6.94 | 6.74 | 6.40 |
| 2Mbx8 TSOP/12V | 17.08 | 14.48 | 12.08 | 11.50 | 10.60 |
| 2Mbx8 TSOP/5V | 17.25 | 14.60 | 12.08 | 11.50 | 10.60 |
| 2Mbx8 TSOP/3V | 18.14 | 14.70 | 12.08 | 11.50 | 10.60 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (March 1997)


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## Table 15
## Estimated Gate Array Pricing—North American Production Bookings
## (Volume: 20,000 Units; Based on Utilized Gates Only; NRE = Netlist to Prototype; Millicents per Gate)

| Gate Count Technology | 10-29.99K Gates 1997 | 1998 | 1999 | 30-59.99K Gates 1997 | 1998 | 1999 | 60-99.99K Gates 1997 | 1998 | 1999 | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|
| CMOS (Average) | | | | | | | | | | Production: |
| 0.8 Micron | 21.00 | 20.00 | 19.00 | 17.00 | 16.00 | 14.00 | 15.00 | 14.00 | 13.00 | 4-12 |
| 0.6 Micron | 24.00 | 23.00 | 22.00 | 17.00 | 15.00 | 14.00 | 17.00 | 16.00 | 15.00 | 4-12 |
| 0.5 Micron | 26.00 | 25.00 | 24.00 | 22.00 | 21.00 | 20.00 | 20.00 | 18.00 | 17.00 | 4-12 |
| 0.35 Micron | 36.00 | 34.00 | 34.00 | 33.00 | 29.00 | 28.00 | 21.00 | 20.00 | 19.00 | 4-12 |
| | | | | | | | | | | Prototypes: |
| NRE CMOS Average Charge ($K) | 44.00 | 44.00 | 43.00 | 54.00 | 52.00 | 52.00 | 74.00 | 73.00 | 73.00 | 1-4 |

| Gate Count Technology | 100-299.99K Gates 1997 | 1998 | 1999 | ≥300K Gates 1997 | 1998 | 1999 | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|
| CMOS (Average) | | | | | | | Production: |
| 0.8 Micron | 24.00 | 22.00 | 21.00 | NR | NR | NR | 4-12 |
| 0.6 Micron | 23.00 | 22.00 | 21.00 | 30.00 | 30.00 | 29.00 | 4-12 |
| 0.5 Micron | 27.00 | 24.00 | 22.00 | 33.00 | 32.00 | 32.00 | 4-12 |
| 0.35 Micron | 32.00 | 31.00 | 30.00 | 41.00 | 39.00 | 38.00 | 4-12 |
| | | | | | | | Prototypes: |
| NRE CMOS Average Charge ($K) | 107.00 | 106.00 | 105.00 | 123.00 | 120.00 | 120.00 | 1-4 |

NR = Not relevant

NRE = Nonrecouring engineering charge

Notes: The actual NRE may vary from these because of device amortization, testing, intellectual property rights, and other factors. Actual negotiated market prices may vary substantially from these because of manufacturer-specific factors such as intellectual property rights, alliances, service, package types, pad or core constraints, and volume discount. These prices are intended for use as price guidelines. For volumes of 1 million units or greater discount the above prices by a further 50 to 60 percent. For core-limited solutions with volumes greater than than 10,000 units, CBICs may be more cost-effective than gate arrays.

*Source: Dataquest (March 1997)*


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## Table 16
## Estimated CBIC Pricing—North American Production Bookings
## (Volume: 20,000 Units; Based on Utilized Gates Only; NRE = Netlist to Prototype; Millicents per Gate)

| | 10-29.99K Gates | | | 30-59.99K Gates | | | 60-99.99K Gates | | | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|
| Gate Count Technology | 1997 | 1998 | 1999 | 1997 | 1998 | 1999 | 1997 | 1998 | 1999 | (Weeks) |
| CMOS | | | | | | | | | | Production: |
| 0.8 Micron | 25.00 | 24.00 | 22.00 | 17.00 | 16.00 | 14.00 | 13.00 | 11.00 | 10.00 | 7-15 |
| 0.6 Micron | 26.00 | 25.00 | 24.00 | 18.00 | 16.00 | 15.00 | 13.00 | 12.00 | 10.00 | 7-15 |
| 0.5 Micron | 28.00 | 27.00 | 26.00 | 25.00 | 24.00 | 22.00 | 20.00 | 18.00 | 17.00 | 7-15 |
| 0.35 Micron | 40.00 | 39.00 | 38.00 | 38.00 | 35.00 | 34.00 | 25.00 | 24.00 | 22.00 | 7-15 |
| | | | | | | | | | | Prototypes: |
| NRE CMOS Average Charge ($K) | 68.00 | 67.00 | 65.00 | 72.00 | 72.00 | 71.00 | 83.00 | 83.00 | 83.00 | 3-6 |

| | 100-299.99K Gates | | | ≥300K Gates | | | Lead Time |
|---|---|---|---|---|---|---|---|
| Gate Count Technology | 1997 | 1998 | 1999 | 1997 | 1998 | 1999 | (Weeks) |
| CMOS | | | | | | | Production: |
| 0.8 Micron | 17.00 | 15.00 | 14.00 | NR | NR | NR | 7-15 |
| 0.6 Micron | 15.00 | 14.00 | 13.00 | 19.00 | 18.00 | 17.00 | 7-15 |
| 0.5 Micron | 14.00 | 12.00 | 10.00 | 17.00 | 15.00 | 14.00 | 7-15 |
| 0.35 Micron | 12.00 | 11.00 | 10.00 | 11.00 | 9.00 | 8.00 | 7-15 |
| | | | | | | | Prototypes: |
| NRE CMOS Average Charge ($K) | 133.00 | 132.00 | 132.00 | 163.00 | 161.00 | 160.00 | 3-6 |

NR = Not relevant

NRE = Nonreccuring engineering charge

Notes: The actual NRE may vary from these because of device amortization, testing, intellectual property rights, and other factors. Actual negotiated market prices may vary substantially from these because of manufacturer-specific factors such as intellectual property rights, alliances, service, package types, pad or core constraints, and volume discount. These prices are intended for use as price guidelines. For volumes of 1 million units or greater discount the above prices by a further 50 to 60 percent. For core-limited solutions with volumes greater than than 10,000 units, CBICs may be more cost-effective than gate arrays.

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**For More Information...**

Evelyn Cronin, Senior Industry Analyst..... (408) 468-8075
Internet address..... evelyn.cronin@dataquest.com
Via fax..... (408) 954-1780

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## DATAQUEST WORLDWIDE OFFICES

### NORTH AMERICA

**Worldwide Headquarters**
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: 1-408-468-8000
Facsimile: 1-408-954-1780

**East Coast Headquarters**
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6262

**Dataquest Global Events**
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

Sales Offices:
- Washington, DC (Federal)
- New York, NY (Financial)
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### LATIN AMERICA

Research Affiliates and Sales Offices:
Buenos Aires, Argentina
Sao Paulo, Brazil
Santiago, Chile
Mexico City, Mexico

### EUROPE

**European Headquarters**
Tamesis, The Glanty
Egham, Surrey TW20 9AW
United Kingdom
Phone: +44 1784 431 611
Facsimile: +44 1784 488 980

**Dataquest France**
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: +33 1 41 35 13 00
Facsimile: +33 1 41 35 13 13

**Dataquest Germany**
Kronstadter Strasse 9
81677 München
Germany
Phone: +49 89 93 09 09 0
Facsimile: +49 89 93 03 27 7

Sales Offices:
- Brussels, Belgium
- Kfar Saba, Israel
- Milan, Italy
- Randburg, South Africa
- Madrid, Spain

### JAPAN

**Japan Headquarters**
Aobadai Hills 4-7-7
Aobadai
Meguro-ku, Tokyo 153
Japan
Phone: 81-3-3481-3670
Facsimile: 81-3-3481-3644

### ASIA/PACIFIC

**Asia/Pacific Headquarters**
Suite 5904-7, Central Plaza
18 Harbour Road, Wanchai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

**Dataquest Korea**
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

**Dataquest Taiwan**
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

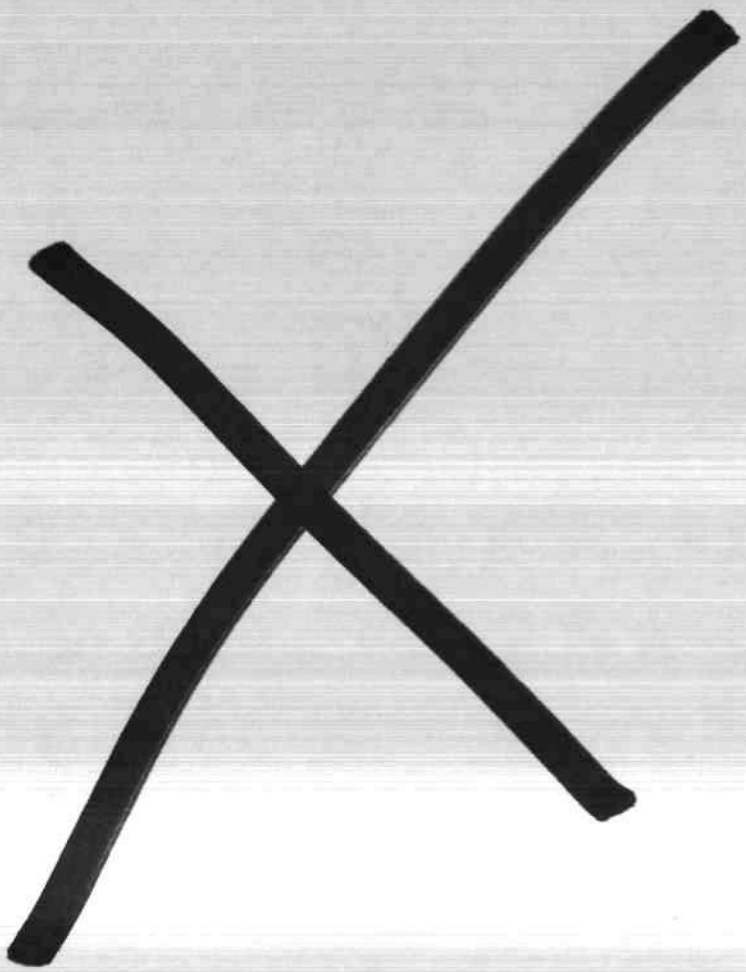
**Dataquest Singapore**
105 Cecil Street
#06-01/02 The Octagon
Singapore 069534
Phone: 65-227-1213
Facsimile: 65-227-4607

**Dataquest Thailand**
12/F, Vanissa Building
29 Soi Chidlom
Ploenchit Road
Patumwan, Bangkok 10330
Thailand
Phone: 662-655-0577
Facsimile: 662-655-0576

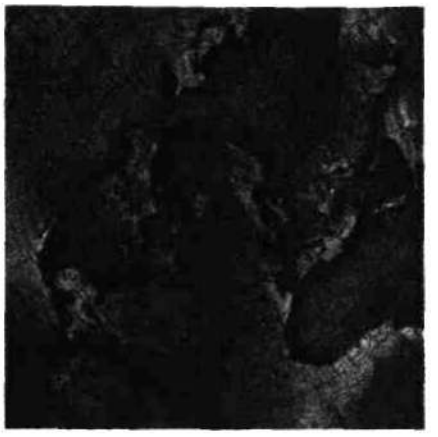
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# North American Semiconductor Price Outlook—First Quarter 1997

Market Statistics

**Program:** Semiconductor Supply and Pricing Worldwide
**Product Code:** SPSG-WW-MS-9605
**Publication Date:** January 6, 1997
**Filing:** Market Statistics

# North American Semiconductor Price Outlook: First Quarter 1997

## Methodology and Sources

This document provides information on and forecasts for the North American bookings prices of more than 200 semiconductor devices. Dataquest collects price information on a quarterly basis from North American suppliers and major buyers of these products. North American bookings price information is analyzed by Semiconductor Supply and Pricing Worldwide (SPSG) analysts for consistency and reconciliation. The information finally is rationalized with worldwide billings price data in association with product analysts, resulting in the current forecast. This document includes associated long-range forecasts.

For SPSG clients that use the SPSG online service, the prices presented here correlate with the quarterly and long-range price tables dated September 1996 in the SPSG online service. For additional product coverage and more detailed product specifications, please refer to those sources.

### Price Variations

Actual negotiated market prices may vary from these prices 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 value of a company's product. These prices are intended for use as price guidelines.


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## Table 1
## Estimated Standard Logic Price Trends—North American Bookings
## (Volume: 100,000 per Year; Package: PLCC; Dollars)

| Product | 1996 Q4 | 1997 Q1 | Q2 | Q3 | Q4 | 1997 Year | 1998 Q1 | Q2 | Q3 | Q4 | 1998 Year | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74LS TTL | | | | | | | | | | | | |
| 74LS00 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 2-6 |
| 74LS74 | 0.17 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 2-6 |
| 74LS138 | 0.18 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.16 | 0.16 | 0.17 | 2-6 |
| 74LS244 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 2-6 |
| 74AC TTL | | | | | | | | | | | | |
| 74AC00 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.15 | 0.15 | 0.15 | 0.14 | 0.15 | 2-6 |
| 74AC74 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.19 | 0.19 | 0.18 | 0.17 | 0.18 | 2-6 |
| 74AC138 | 0.31 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.28 | 0.28 | 0.27 | 0.27 | 0.27 | 2-6 |
| 74AC244 | 0.43 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.36 | 0.36 | 0.35 | 0.35 | 0.35 | 2-6 |
| 74F TTL | | | | | | | | | | | | |
| 74F00 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 2-6 |
| 74F74 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 2-6 |
| 74F138 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 2-6 |
| 74F244 | 0.23 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 2-6 |
| 74HC CMOS | | | | | | | | | | | | |
| 74HC00 | 0.12 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 2-6 |
| 74HC74 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 2-6 |
| 74HC138 | 0.18 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 2-6 |
| 74HC244 | 0.23 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 2-6 |
| 74ALS TTL | | | | | | | | | | | | |
| 74ALS00 | 0.16 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 2-6 |
| 74ALS74 | 0.18 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 2-6 |
| 74ALS138 | 0.23 | 0.22 | 0.21 | 0.21 | 0.21 | 0.21 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 2-6 |
| 74ALS244 | 0.31 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.27 | 0.27 | 0.26 | 0.26 | 0.26 | 2-6 |
| 74AS TTL | | | | | | | | | | | | |
| 74AS00 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 2-6 |
| 74AS74 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 2-6 |
| 74AS138 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 2-6 |
| 74AS244 | 0.65 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 2-6 |
| 74BC* | | | | | | | | | | | | |
| 74BC00 | 0.23 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.19 | 0.19 | 0.18 | 0.17 | 0.18 | 2-6 |
| 74BC244 | 0.55 | 0.53 | 0.53 | 0.53 | 0.53 | 0.53 | 0.48 | 0.47 | 0.46 | 0.44 | 0.46 | 2-6 |
| 74BC373 | 0.57 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.50 | 0.49 | 0.46 | 0.46 | 0.48 | 2-6 |
| 74ACT244 | 0.45 | 0.43 | 0.43 | 0.41 | 0.41 | 0.42 | 0.39 | 0.38 | 0.38 | 0.36 | 0.38 | 2-6 |
| 74ACT245 | 0.48 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.41 | 0.41 | 0.40 | 0.38 | 0.40 | 2-6 |
| 74ABT244 | 0.60 | 0.58 | 0.58 | 0.58 | 0.58 | 0.58 | 0.52 | 0.52 | 0.51 | 0.48 | 0.51 | 2-6 |
| 74ABT245 | 0.65 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.57 | 0.56 | 0.55 | 0.52 | 0.55 | 2-6 |

*Pricing for 74BC excludes 74ABT and 74BCT.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1996)


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## Table 2
## Estimated Long-Range Standard Logic Price Trends—North American Bookings (Volume: 100,000 per Year; Package: PLCC; Dollars)

| Product | 1997 Year | 1998 Year | 1999 Year | 2000 Year | 2001 Year |
|---|---|---|---|---|---|
| 74LS TTL | | | | | |
| 74LS00 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| 74LS74 | 0.16 | 0.16 | 0.15 | 0.15 | 0.15 |
| 74LS138 | 0.17 | 0.17 | 0.16 | 0.15 | 0.15 |
| 74LS244 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 |
| 74AC TTL | | | | | |
| 74AC00 | 0.17 | 0.15 | 0.13 | 0.13 | 0.12 |
| 74AC74 | 0.21 | 0.18 | 0.16 | 0.15 | 0.15 |
| 74AC138 | 0.29 | 0.27 | 0.25 | 0.24 | 0.22 |
| 74AC244 | 0.40 | 0.35 | 0.31 | 0.28 | 0.27 |
| 74F TTL | | | | | |
| 74F00 | 0.14 | 0.13 | 0.13 | 0.12 | 0.12 |
| 74F74 | 0.15 | 0.15 | 0.14 | 0.14 | 0.14 |
| 74F138 | 0.18 | 0.18 | 0.17 | 0.17 | 0.17 |
| 74F244 | 0.22 | 0.22 | 0.21 | 0.20 | 0.20 |
| 74HC CMOS | | | | | |
| 74HC00 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| 74HC74 | 0.16 | 0.15 | 0.14 | 0.14 | 0.13 |
| 74HC138 | 0.17 | 0.17 | 0.16 | 0.16 | 0.16 |
| 74HC244 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| 74ALS TTL | | | | | |
| 74ALS00 | 0.14 | 0.14 | 0.13 | 0.13 | 0.13 |
| 74ALS74 | 0.16 | 0.16 | 0.16 | 0.15 | 0.15 |
| 74ALS138 | 0.21 | 0.20 | 0.20 | 0.20 | 0.20 |
| 74ALS244 | 0.30 | 0.26 | 0.25 | 0.24 | 0.24 |
| 74AS TTL | | | | | |
| 74AS00 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| 74AS74 | 0.19 | 0.19 | 0.19 | 0.20 | 0.20 |
| 74AS138 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| 74AS244 | 0.63 | 0.62 | 0.61 | 0.61 | 0.61 |
| 74BC* | | | | | |
| 74BC00 | 0.20 | 0.18 | 0.17 | 0.16 | 0.16 |
| 74BC244 | 0.53 | 0.46 | 0.43 | 0.42 | 0.41 |
| 74BC373 | 0.55 | 0.48 | 0.45 | 0.43 | 0.42 |
| 74ACT244 | 0.42 | 0.38 | 0.35 | 0.33 | 0.32 |
| 74ACT245 | 0.46 | 0.40 | 0.37 | 0.35 | 0.34 |
| 74ABT244 | 0.58 | 0.51 | 0.47 | 0.42 | 0.40 |
| 74ABT245 | 0.63 | 0.55 | 0.51 | 0.49 | 0.48 |

*Pricing for 74BC excludes 74ABT and 74BCT.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1996)


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## Table 3
## Estimated Microprocessor Price Trends—North American Bookings
## (Volume: 8-Bit, 16-Bit, and 32-Bit—25,000 per Year; Dollars)
## (Package: 8/16-Bit Devices—PDIP; 32-Bit Devices—Ceramic PGA; Exceptions Noted)

| Product | 1996 Q4 | 1997 Q1 | Q2 | Q3 | Q4 | 1997 Year | 1998 Q1 | Q2 | Q3 | Q4 | 1998 Year | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 68EC020-25 PQFP | 9.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 4-8 |
| 68EC030-25 PQFP | 21.00 | 19.00 | 19.00 | 18.75 | 18.75 | 18.88 | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 | 4-8 |
| 68040-25 | 30.00 | 25.00 | 24.00 | 24.00 | 22.00 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 4-8 |
| 68LC040-25 CQFP 184 | 30.00 | 25.00 | 24.00 | 24.00 | 22.00 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 | 4-8 |
| Pentium-75 | 50.00 | 45.00 | 40.00 | 40.00 | 40.00 | 41.25 | 40.00 | 40.00 | 40.00 | 40.00 | 40.00 | 4-8 |
| Pentium-90 | 60.00 | 50.00 | 50.00 | 50.00 | 45.00 | 48.75 | 45.00 | 45.00 | 45.00 | 45.00 | 45.00 | 4-8 |
| Pentium-100 3.3V | 75.00 | 75.00 | 60.00 | 60.00 | 50.00 | 61.25 | 50.00 | 50.00 | 50.00 | 50.00 | 50.00 | 4-8 |
| Pentium-100 2.9V | 100.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 4-8 |
| Pentium-120 3.3V | 117.00 | 95.00 | 80.00 | 80.00 | 80.00 | 83.75 | 80.00 | 80.00 | 80.00 | 80.00 | 80.00 | 4-8 |
| Pentium-120 2.9V | 144.00 | 130.00 | 120.00 | 120.00 | 120.00 | 122.50 | 120.00 | 120.00 | 120.00 | 120.00 | 120.00 | 4-8 |
| Pentium-133 3.3V | 175.00 | 110.00 | 100.00 | 85.00 | 75.00 | 92.50 | 75.00 | 75.00 | 75.00 | 75.00 | 75.00 | 4-8 |
| Pentium-133 2.9V | 244.00 | 190.00 | 175.00 | 170.00 | 170.00 | 176.25 | 170.00 | 170.00 | 170.00 | 170.00 | 170.00 | 4-8 |
| Pentium-150 3.3V | 225.00 | 150.00 | 150.00 | 120.00 | 120.00 | 135.00 | 120.00 | 120.00 | 120.00 | 120.00 | 120.00 | 4-8 |
| Pentium-150 2.9V | 329.00 | 235.00 | 220.00 | 220.00 | 220.00 | 223.75 | 220.00 | 220.00 | 220.00 | 220.00 | 220.00 | 4-8 |
| Pentium-166 3.3V | 350.00 | 225.00 | 170.00 | 125.00 | 125.00 | 161.25 | 110.00 | 110.00 | 110.00 | 110.00 | 110.00 | 4-8 |
| Pentium-200 3.3V | 450.00 | 400.00 | 400.00 | 175.00 | 145.00 | 280.00 | 145.00 | 145.00 | 145.00 | 145.00 | 145.00 | 4-8 |
| Pentium Pro-166C | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 | 4-8 |
| Pentium Pro-180 | 400.00 | 350.00 | 325.00 | 300.00 | 300.00 | 318.75 | 270.00 | 270.00 | 270.00 | 270.00 | 270.00 | 4-8 |
| Pentium Pro-200 256K Cache | 500.00 | 475.00 | 400.00 | 400.00 | 400.00 | 418.75 | 350.00 | 350.00 | 350.00 | 350.00 | 350.00 | 4-8 |
| Pentium Pro-200 512K Cache | 1,035.00 | 993.00 | 993.00 | 895.00 | 895.00 | 944.00 | 700.00 | 700.00 | 700.00 | 700.00 | 700.00 | 4-8 |
| PowerPC 601-80 | 80.00 | 70.00 | 68.00 | 68.00 | 68.00 | 68.50 | 68.00 | 68.00 | 68.00 | 68.00 | 68.00 | 4-8 |
| PowerPC 601-100 | 90.00 | 80.00 | 75.00 | 75.00 | 75.00 | 76.25 | 75.00 | 75.00 | 75.00 | 75.00 | 75.00 | 4-8 |
| PowerPC 603-80 | 75.00 | 61.00 | 61.00 | 60.00 | 60.00 | 60.50 | 60.00 | 60.00 | 60.00 | 60.00 | 60.00 | 4-8 |
| PowerPC 603-133 | 125.00 | 125.00 | 115.00 | 80.00 | 80.00 | 100.00 | 75.00 | 75.00 | 75.00 | 75.00 | 75.00 | 4-8 |

Notes: Pricing excludes accessory parts like floating point and memory management.
Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (December 1996)

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## Table 4
## Estimated Long-Range Microprocessor Price Trends—North American Bookings
## (Volume: 8-Bit, 16-Bit, and 32-Bit—25,000 per Year; Dollars)
## (Package: 8/16-Bit Devices—PDIP; 32-Bit Devices—Ceramic PGA; Exceptions Noted)

| Product | 1997 Year | 1998 Year | 1999 Year | 2000 Year | 2001 Year |
|---|---|---|---|---|---|
| 68EC020-25 PQFP | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 |
| 68EC030-25 PQFP | 18.88 | 18.75 | 18.75 | 18.75 | 18.75 |
| 68040-25 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 |
| 68LC040-25 CQFP 184 | 23.75 | 22.00 | 22.00 | 22.00 | 22.00 |
| Pentium-75 | 41.25 | 40.00 | 40.00 | 40.00 | 40.00 |
| Pentium-90 | 48.75 | 45.00 | 45.00 | 45.00 | 45.00 |
| Pentium-100 3.3V | 61.25 | 50.00 | 50.00 | 50.00 | 50.00 |
| Pentium-100 2.9V | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 |
| Pentium-120 3.3V | 83.75 | 80.00 | 80.00 | 80.00 | 80.00 |
| Pentium-120 2.9V | 122.50 | 120.00 | 120.00 | 120.00 | 120.00 |
| Pentium-133 3.3V | 92.50 | 75.00 | 75.00 | 75.00 | 75.00 |
| Pentium-133 2.9V | 176.25 | 170.00 | 170.00 | 170.00 | 170.00 |
| Pentium-150 3.3V | 135.00 | 120.00 | 120.00 | 120.00 | 120.00 |
| Pentium-150 2.9V | 223.75 | 220.00 | 220.00 | 220.00 | 220.00 |
| Pentium-166 3.3V | 168.75 | 110.00 | 110.00 | 110.00 | 110.00 |
| Pentium-200 3.3V | 280.00 | 145.00 | 145.00 | 145.00 | 145.00 |
| Pentium Pro-166C | 600.00 | 600.00 | 600.00 | 600.00 | 600.00 |
| Pentium Pro-180 | 318.75 | 270.00 | 270.00 | 270.00 | 270.00 |
| Pentium Pro-200 256K Cache | 418.75 | 350.00 | 350.00 | 350.00 | 350.00 |
| Pentium Pro-200 512K Cache | 944.00 | 700.00 | 700.00 | 700.00 | 700.00 |
| PowerPC 601-80 | 68.50 | 68.00 | 68.00 | 68.00 | 68.00 |
| PowerPC 601-100 | 76.25 | 75.00 | 75.00 | 75.00 | 75.00 |
| PowerPC 603-80 | 60.50 | 60.00 | 60.00 | 60.00 | 60.00 |
| PowerPC 603-133 | 100.00 | 75.00 | 75.00 | 75.00 | 75.00 |

Notes: Pricing excludes accessory parts like floating point and memory management.
Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (December 1996)


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## Table 5
## Estimated DRAM Price Trends—North American Bookings
## (Contract Volume; U.S. Dollars)*

| Product | 1996 Q4 | 1997 Q1 | Q2 | Q3 | Q4 | 1997 Year | 1998 Q1 | Q2 | Q3 | Q4 | 1998 Year | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1Mbx1 DRAM 70-80ns (DIP/SOJ) 5V | 2.25 | 2.24 | 2.23 | 2.23 | 2.23 | 2.23 | 2.22 | 2.21 | 2.20 | 2.19 | 2.21 | 6-8 |
| 256Kx4 DRAM 60ns SOJ 5V | 2.15 | 2.12 | 2.08 | 2.07 | 2.08 | 2.09 | 2.02 | 2.01 | 2.01 | 1.99 | 2.01 | 6-8 |
| 4Mbx1 DRAM 70ns SOJ 5V | 2.97 | 2.72 | 2.67 | 2.64 | 2.62 | 2.66 | 2.58 | 2.39 | 2.38 | 2.30 | 2.41 | 2-6 |
| 1Mbx4 DRAM 60ns SOJ 5V FPM | 2.81 | 2.40 | 2.45 | 2.44 | 2.40 | 2.42 | 2.39 | 2.18 | 2.20 | 2.20 | 2.24 | 2-6 |
| 1Mbx4 DRAM 60ns SOJ 5V EDO | 2.84 | 2.42 | 2.45 | 2.44 | 2.40 | 2.43 | 2.38 | 2.18 | 2.20 | 2.20 | 2.24 | 2-6 |
| 512Kx8 DRAM 70ns 5V | 3.29 | 2.82 | 2.69 | 2.56 | 2.43 | 2.62 | 2.33 | 2.33 | 2.31 | 2.31 | 2.32 | 2-6 |
| 256Kx16 DRAM 70ns SOJ 5V | 3.67 | 3.36 | 3.40 | 3.34 | 3.24 | 3.33 | 3.17 | 3.10 | 3.00 | 2.95 | 3.06 | 2-6 |
| 4Mb x 4 DRAM 60 ns SOJ 5V FPM | 10.20 | 9.00 | 8.67 | 8.38 | 8.17 | 8.55 | 7.96 | 7.84 | 7.79 | 7.73 | 7.83 | 2-6 |
| 4MbX4 DRAM 60ns SOJ 5V EDO | 10.16 | 9.00 | 8.67 | 8.38 | 8.17 | 8.55 | 7.96 | 7.84 | 7.79 | 7.73 | 7.83 | 2-6 |
| 1Mbx16 DRAM 60ns TSOP 5V FPM | 9.00 | 8.94 | 8.74 | 8.44 | 8.06 | 8.54 | 7.75 | 7.56 | 7.43 | 7.29 | 7.51 | 2-6 |
| 1Mbx16 DRAM 60ns TSOP 5V EDO | 9.00 | 8.93 | 8.73 | 8.44 | 8.04 | 8.54 | 7.75 | 7.50 | 7.25 | 7.02 | 7.38 | 2-6 |
| 2Mbx8 DRAM 60ns TSOP 5V FPM | 9.56 | 9.06 | 8.65 | 8.04 | 7.96 | 8.43 | 7.53 | 7.36 | 7.27 | 7.18 | 7.34 | 2-6 |
| 16Mbx4 DRAM SOJ 60ns 3.3V EDO | 100.00 | 86.88 | 78.75 | 73.75 | 67.50 | 76.72 | 60.00 | 54.50 | 50.25 | 40.33 | 51.27 | 2-6 |
| 16Mbx4 DRAM SOJ 3.3V SDRAM | 85.00 | 85.83 | 81.25 | 68.50 | 59.00 | 73.65 | 51.25 | 45.75 | 41.75 | 38.50 | 44.31 | 2-6 |
| 1Mbx32 SIMM 60ns 5V FPM | 22.63 | 20.07 | 19.32 | 18.62 | 17.94 | 18.99 | 17.44 | 17.18 | 16.79 | 16.53 | 16.99 | 2-6 |
| 1Mbx36 SIMM 60ns 5V FPM | 26.00 | 22.75 | 21.50 | 20.25 | 19.50 | 21.00 | 19.00 | 19.00 | 18.75 | 18.50 | 18.81 | 2-6 |
| 2Mbx32 SIMM 60ns 5V FPM | 38.25 | 35.87 | 34.85 | 33.50 | 32.15 | 34.09 | 31.12 | 30.43 | 30.42 | 30.07 | 30.51 | 2-6 |
| 2Mbx36 SIMM 60ns 5V FPM | 41.93 | 40.80 | 39.22 | 38.63 | 37.00 | 38.91 | 34.87 | 34.62 | 34.55 | 34.10 | 34.53 | 2-6 |
| 4Mbx32 SIMM 60ns 5V FPM | 79.73 | 75.07 | 72.37 | 70.00 | 67.58 | 71.25 | 64.98 | 64.55 | 63.57 | 62.23 | 63.83 | 2-6 |
| 4Mbx36 SIMM 60ns 5V FPM | 84.85 | 82.60 | 80.43 | 76.25 | 73.08 | 78.09 | 70.73 | 69.55 | 68.88 | 67.70 | 69.21 | 2-6 |
| 8Mbx32 SIMM 60ns 5V FPM | 159.47 | 150.13 | 144.73 | 139.60 | 135.16 | 142.41 | 129.97 | 128.51 | 126.48 | 124.46 | 127.35 | 2-6 |
| 8Mbx36 SIMM 60ns 5V FPM | 175.87 | 166.00 | 160.34 | 155.01 | 150.37 | 157.93 | 144.65 | 143.22 | 141.29 | 138.34 | 141.88 | 2-6 |
| 1Mbx32 SIMM 60ns 5V EDO | 20.38 | 19.62 | 19.08 | 18.37 | 17.69 | 18.69 | 17.19 | 17.05 | 16.67 | 16.41 | 16.83 | 2-6 |
| 1Mbx36 SIMM 60ns 5V EDO | 24.89 | 23.08 | 22.75 | 21.90 | 21.12 | 22.21 | 20.80 | 20.60 | 19.40 | 19.06 | 19.97 | 2-6 |
| 2Mbx32 SIMM 60ns 5V EDO | 36.63 | 35.97 | 35.02 | 33.50 | 32.12 | 34.15 | 31.09 | 31.02 | 30.95 | 30.65 | 30.93 | 2-6 |
| 2Mbx36 SIMM 60ns 5V EDO | 42.19 | 41.02 | 39.45 | 38.62 | 36.98 | 39.02 | 34.87 | 34.59 | 34.30 | 34.05 | 34.45 | 2-6 |
| 4Mbx32 SIMM 60ns 5V EDO | 80.16 | 75.98 | 72.63 | 70.00 | 67.49 | 71.53 | 64.85 | 64.44 | 63.56 | 62.21 | 63.77 | 2-6 |
| 4Mbx36 SIMM 60ns 5V EDO | 85.26 | 82.85 | 80.67 | 76.23 | 73.02 | 78.19 | 70.59 | 69.52 | 68.88 | 67.70 | 69.17 | 2-6 |
| 8Mbx32 SIMM 60ns 5V EDO | 166.08 | 151.85 | 146.55 | 141.90 | 138.29 | 144.65 | 129.97 | 128.53 | 126.44 | 124.46 | 127.35 | 2-6 |


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## Table 5 (Continued)
## Estimated DRAM Price Trends—North American Bookings
## (Contract Volume; U.S. Dollars)*

| Product | 1996 Q4 | 1997 Q1 | Q2 | Q3 | Q4 | 1997 Year | 1998 Q1 | Q2 | Q3 | Q4 | 1998 Year | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8Mbx36 SIMM 60ns 5V EDO | 178.54 | 166.40 | 160.45 | 155.03 | 150.41 | 158.07 | 144.60 | 143.26 | 141.24 | 138.29 | 141.85 | 2-6 |
| 1Mbx64 60ns 3.3V EDO | 45.00 | 46.34 | 44.86 | 43.50 | 42.34 | 44.26 | 41.45 | 41.94 | 41.45 | 40.97 | 41.45 | 2-6 |
| 2Mbx64 60ns 3.3V EDO | 90.00 | 97.33 | 89.33 | 86.67 | 84.27 | 89.40 | 79.73 | 78.62 | 77.60 | 76.61 | 78.14 | 2-6 |
| 4Mbx64 60ns 3.3V EDO | 180.00 | 182.67 | 177.33 | 172.53 | 169.12 | 175.41 | 153.75 | 155.70 | 153.71 | 151.79 | 153.74 | 2-6 |
| 256Kx4 VRAM 70ns SOJ | 5.73 | 5.75 | 5.72 | 5.71 | 5.69 | 5.72 | 5.64 | 5.58 | 5.53 | 5.48 | 5.56 | 2-6 |
| 128Kx8 VRAM 70ns SOJ | 5.93 | 5.93 | 5.91 | 5.90 | 5.89 | 5.90 | 5.83 | 5.77 | 5.72 | 5.66 | 5.74 | 2-6 |
| 256Kx16 VRAM 70ns SOP | 12.00 | 11.33 | 10.67 | 10.33 | 9.97 | 10.58 | 9.25 | 9.01 | 8.78 | 8.55 | 8.90 | 2-6 |
| 256Kx32 66-MHz 3.3V SGRAM | 14.38 | 13.63 | 12.88 | 11.63 | 10.38 | 12.13 | 8.26 | 8.20 | 8.09 | 8.03 | 8.14 | 2-6 |

*Contract volume is at least 100,000 per order, except for VRAMs.

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.

Source: Dataquest (December 1996)



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## Table 6
## Estimated Long-Range DRAM Price Trends—North American Bookings (Contract Volume; U.S. Dollars)*

| Product | 1997 Year | 1998 Year | 1999 Year | 2000 Year | 2001 Year |
|---|---|---|---|---|---|
| 1Mbx1 DRAM 70-80ns (DIP/SOJ) 5V | 2.23 | 2.21 | 2.12 | 2.03 | 1.95 |
| 256Kx4 DRAM 60ns SOJ 5V | 2.09 | 2.01 | 1.93 | 1.85 | 1.78 |
| 4Mbx1 DRAM 70ns SOJ 5V | 2.66 | 2.41 | 2.32 | 2.22 | 2.13 |
| 1Mbx4 DRAM 60ns SOJ 5V FPM | 2.42 | 2.24 | 2.15 | 2.07 | 1.98 |
| 1Mbx4 DRAM 60ns SOJ 5V EDO | 2.43 | 2.24 | 2.15 | 2.07 | 1.98 |
| 512Kx8 DRAM 70ns 5V | 2.62 | 2.32 | 2.22 | 2.14 | 2.05 |
| 256Kx16 DRAM 70ns SOJ 5V | 3.33 | 3.06 | 2.93 | 2.82 | 2.70 |
| 4Mb x 4 DRAM 60 ns SOJ 5V FPM | 8.55 | 7.83 | 7.52 | 7.22 | 6.93 |
| 4MbX4 DRAM 60ns SOJ 5V EDO | 8.55 | 7.83 | 7.52 | 7.22 | 6.93 |
| 1Mbx16 DRAM 60ns TSOP 5V FPM | 8.54 | 7.51 | 7.21 | 6.92 | 6.64 |
| 1Mbx16 DRAM 60ns TSOP 5V EDO | 8.54 | 7.38 | 7.08 | 6.80 | 6.53 |
| 2Mbx8 DRAM 60ns TSOP 5V FPM | 8.43 | 7.34 | 7.04 | 6.76 | 6.49 |
| 16Mbx4 DRAM SOJ 60ns 3.3V EDO | 76.72 | 51.27 | 35.00 | 27.01 | 25.84 |
| 16Mbx4 DRAM SOJ 3.3V SDRAM | 73.65 | 44.31 | 31.00 | 27.00 | 25.11 |
| 1Mbx32 SIMM 60ns 5V FPM | 18.99 | 16.99 | 16.31 | 15.65 | 15.03 |
| 1Mbx36 SIMM 60ns 5V FPM | 21.00 | 18.81 | 18.06 | 17.34 | 16.64 |
| 2Mbx32 SIMM 60ns 5V FPM | 34.09 | 30.51 | 29.29 | 28.12 | 26.99 |
| 2Mbx36 SIMM 60ns 5V FPM | 38.91 | 34.53 | 33.15 | 31.83 | 30.55 |
| 4Mbx32 SIMM 60ns 5V FPM | 71.25 | 63.83 | 61.28 | 58.83 | 56.48 |
| 4Mbx36 SIMM 60ns 5V FPM | 78.09 | 69.21 | 66.44 | 63.79 | 61.23 |
| 8Mbx32 SIMM 60ns 5V FPM | 142.41 | 127.35 | 122.26 | 117.37 | 112.67 |
| 8Mbx36 SIMM 60ns 5V FPM | 157.93 | 141.88 | 136.20 | 130.75 | 125.52 |
| 1Mbx32 SIMM 60ns 5V EDO | 18.69 | 16.83 | 16.16 | 15.51 | 14.89 |
| 1Mbx36 SIMM 60ns 5V EDO | 22.21 | 19.97 | 19.17 | 18.40 | 17.66 |
| 2Mbx32 SIMM 60ns 5V EDO | 34.15 | 30.93 | 29.69 | 28.50 | 27.36 |
| 2Mbx36 SIMM 60ns 5V EDO | 39.02 | 34.45 | 33.07 | 31.75 | 30.48 |
| 4Mbx32 SIMM 60ns 5V EDO | 71.53 | 63.77 | 61.21 | 58.77 | 56.42 |
| 4Mbx36 SIMM 60ns 5V EDO | 78.19 | 69.17 | 66.41 | 63.75 | 61.20 |
| 8Mbx32 SIMM 60ns 5V EDO | 144.65 | 127.35 | 122.25 | 117.36 | 112.67 |
| 8Mbx36 SIMM 60ns 5V EDO | 158.07 | 141.85 | 136.18 | 130.73 | 125.50 |
| 1Mbx64 60ns 3.3V EDO | 44.26 | 41.45 | 32.97 | 29.00 | 27.46 |
| 2Mbx64 60ns 3.3V EDO | 89.40 | 78.14 | 61.01 | 58.21 | 56.09 |
| 4Mbx64 60ns 3.3V EDO | 175.41 | 153.74 | 123.00 | 117.09 | 111.97 |
| 256Kx4 VRAM 70ns SOJ | 5.72 | 5.56 | 5.34 | 5.12 | 4.92 |
| 128Kx8 VRAM 70ns SOJ | 5.90 | 5.74 | 5.51 | 5.29 | 5.08 |
| 256Kx16 VRAM 70ns SOP | 10.58 | 8.90 | 8.54 | 8.20 | 7.87 |
| 256Kx32 66-MHz 3.3V SGRAM | 12.13 | 8.14 | 5.88 | 5.40 | 5.10 |

*Contract volume is at least 100,000 per order, except for VRAMs.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (December 1996)


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## Table 7
## Estimated Static RAM Price Trends—North American Bookings
## (Volume: Slow SRAM—50,000 per Year; Fast SRAM—20,000 per Year; Package: PDIP; Dollars)

| Product | 1996 Q4 | 1997 Q1 | Q2 | Q3 | Q4 | 1997 Year | 1998 Q1 | Q2 | Q3 | Q4 | 1998 Year | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16Kx4 35ns | 2.30 | 2.29 | 2.26 | 2.24 | 2.21 | 2.25 | 2.15 | 2.19 | 2.09 | 2.13 | 2.14 | 2 |
| 8Kx8 25ns | 1.43 | 1.43 | 1.52 | 1.52 | 1.52 | 1.50 | 1.49 | 1.49 | 1.47 | 1.47 | 1.48 | 2 |
| 8Kx8 100-120ns | 1.48 | 1.48 | 1.48 | 1.49 | 1.49 | 1.49 | 1.40 | 1.40 | 1.37 | 1.36 | 1.38 | 2 |
| 64Kx4 10ns | 6.50 | 7.00 | 6.68 | 6.38 | 6.13 | 6.54 | 5.83 | 6.04 | 5.66 | 5.87 | 5.85 | 6 |
| 64Kx4 25ns | 2.19 | 2.13 | 2.13 | 2.08 | 2.08 | 2.10 | 2.02 | 2.04 | 1.95 | 1.97 | 1.99 | 6 |
| 32Kx8 12ns | 1.93 | 1.80 | 1.80 | 1.72 | 1.63 | 1.74 | 1.48 | 1.48 | 1.48 | 1.48 | 1.48 | 4 |
| 32Kx9 12ns Burst | 4.45 | 3.90 | 3.71 | 3.48 | 3.39 | 3.62 | 3.35 | 3.30 | 3.26 | 3.22 | 3.28 | 4 |
| 32K x 8 15ns 5V | 1.35 | 1.34 | 1.34 | 1.27 | 1.26 | 1.30 | 1.30 | 1.29 | 1.29 | 1.29 | 1.29 | 4 |
| 32K x 8 15ns 3.3V | 1.37 | 1.33 | 1.38 | 1.36 | 1.35 | 1.36 | 1.33 | 1.32 | 1.32 | 1.31 | 1.32 | 4 |
| 32Kx8 25ns | 1.32 | 1.32 | 1.33 | 1.26 | 1.26 | 1.29 | 1.29 | 1.28 | 1.28 | 1.28 | 1.28 | 4 |
| 32Kx8 70-100ns SOJ | 1.76 | 1.63 | 1.55 | 1.50 | 1.46 | 1.53 | 1.35 | 1.33 | 1.32 | 1.31 | 1.33 | 3 |
| 64Kx8 12ns Burst | 17.50 | 14.80 | 13.95 | 13.25 | 12.90 | 13.73 | 1.40 | 13.33 | 12.55 | 11.84 | 9.78 | 4 |
| 256Kx4 20ns | 5.50 | 5.83 | 5.50 | 5.33 | 5.08 | 5.44 | 4.92 | 4.92 | 4.83 | 4.83 | 4.88 | 4 |
| 128K x 8 15ns | 5.56 | 5.36 | 4.96 | 4.83 | 4.44 | 4.90 | 4.30 | 4.16 | 4.09 | 3.95 | 4.13 | 4 |
| 128K x 8 20ns | 5.50 | 5.23 | 4.87 | 4.68 | 4.58 | 4.84 | 4.23 | 4.22 | 4.12 | 4.10 | 4.17 | 4 |
| 128Kx8 25ns | 5.50 | 5.23 | 4.87 | 4.68 | 4.58 | 4.84 | 4.23 | 4.22 | 4.12 | 4.10 | 4.17 | 4 |
| 128Kx8 70-100ns SOJ | 5.00 | 4.86 | 4.61 | 4.54 | 4.38 | 4.60 | 4.28 | 4.14 | 3.99 | 3.81 | 4.06 | 3 |
| 32Kx32 15ns 3.3V PQFP | 3.48 | 3.47 | 3.35 | 3.33 | 3.20 | 3.34 | 3.07 | 3.02 | 2.88 | 2.85 | 2.95 | 5 |
| 32Kx32 8ns 3.3V PB Synch | 3.52 | 3.38 | 3.20 | 3.12 | 3.01 | 3.18 | 2.89 | 2.88 | 2.76 | 2.69 | 2.80 | 5 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1996)


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**Table 8**
**Estimated Long-Range Static RAM Price Trends—North American Bookings (Volume: Slow SRAM—50,000 per Year; Fast SRAM—20,000 per Year; Package: PDIP; Dollars)**

| Product | 1997 Year | 1998 Year | 1999 Year | 2000 Year | 2001 Year |
|---|---|---|---|---|---|
| 16Kx4 35ns | 2.25 | 2.14 | 2.11 | 2.08 | 2.06 |
| 8Kx8 25ns | 1.50 | 1.48 | 1.46 | 1.46 | 1.48 |
| 8Kx8 100-120ns | 1.49 | 1.38 | 1.33 | 1.29 | 1.27 |
| 64Kx4 10ns | 6.54 | 5.85 | 5.79 | 5.67 | 5.63 |
| 64Kx4 25ns | 2.10 | 1.99 | 1.92 | 1.85 | 1.81 |
| 32Kx8 12ns | 1.74 | 1.48 | 1.51 | 1.54 | 1.60 |
| 32Kx9 12ns Burst | 3.62 | 3.28 | 3.35 | 3.40 | 3.45 |
| 32K x 8 15ns 5V | 1.30 | 1.29 | 1.35 | 1.40 | 1.40 |
| 32K x 8 15ns 3.3V | 1.36 | 1.32 | 1.32 | 1.40 | 1.40 |
| 32Kx8 25ns | 1.29 | 1.28 | 1.30 | 1.35 | 1.45 |
| 32Kx8 70-100ns SOJ | 1.53 | 1.33 | 1.35 | 1.40 | 1.40 |
| 64Kx8 12ns Burst | 13.73 | 9.78 | 7.00 | 6.33 | 5.90 |
| 256Kx4 20ns | 5.44 | 4.88 | 4.42 | 4.10 | 3.93 |
| 128K x 8 15ns | 4.90 | 4.13 | 3.94 | 3.82 | 3.76 |
| 128K x 8 20ns | 4.84 | 4.17 | 3.95 | 3.85 | 3.81 |
| 128Kx8 25ns | 4.84 | 4.17 | 3.98 | 3.89 | 3.85 |
| 128Kx8 70-100ns SOJ | 4.60 | 4.20 | 4.00 | 3.91 | 3.88 |
| 32Kx32 15ns 3.3V PQFP | 3.34 | 2.95 | 2.50 | 2.50 | 2.50 |
| 32Kx32 8ns 3.3V PB Synch | 3.18 | 2.80 | 2.35 | 2.33 | 2.50 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1996)


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## Table 9
## Estimated ROM Price Trends—North American Bookings (Speed/Package: ≤1Mb Density—150ns and Above, 28-Pin PDIP; ≥2Mb Density—200ns and Above, 32-Pin PDIP) (Volume: 50,000 per Year; Dollars)

| Product | 1996 Q4 | 1997 Q1 | Q2 | Q3 | Q4 | 1997 Year | 1998 Q1 | Q2 | Q3 | Q4 | 1998 Year | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 128Kx8 | 1.90 | 1.74 | 1.65 | 1.60 | 1.56 | 1.64 | 1.54 | 1.52 | 1.48 | 1.45 | 1.50 | 4-8 |
| 64Kx16 | 2.00 | 2.00 | 1.98 | 1.97 | 1.97 | 1.98 | 1.95 | 1.93 | 1.93 | 1.92 | 1.93 | 4-8 |
| 256Kx8 | 2.25 | 2.20 | 2.19 | 2.17 | 2.17 | 2.18 | 2.15 | 2.15 | 2.14 | 2.14 | 2.15 | 4-8 |
| 512Kx8 | 3.20 | 3.10 | 2.90 | 2.70 | 2.50 | 2.80 | 2.35 | 2.30 | 2.24 | 2.19 | 2.27 | 4-8 |
| 256Kx16[1] | 3.20 | 3.10 | 2.90 | 2.70 | 2.50 | 2.80 | 2.35 | 2.28 | 2.21 | 2.14 | 2.25 | 4-8 |
| 1Mbx8[2] | 4.20 | 4.00 | 3.80 | 3.65 | 3.49 | 3.74 | 3.29 | 3.19 | 3.16 | 3.05 | 3.17 | 4-8 |
| 1Mbx16 | 7.00 | 6.00 | 5.20 | 4.10 | 3.80 | 4.78 | 3.57 | 3.46 | 3.36 | 3.26 | 3.41 | 4-8 |
| 2Mbx8 | 7.00 | 5.87 | 5.13 | 4.02 | 3.70 | 4.68 | 3.50 | 3.38 | 3.30 | 2.18 | 3.09 | 4-8 |

[1]256Kx16 ROM: 150ns and above; 40-pin PDIP
[2]1Mbx8 ROM: 150ns and above; 32-pin SOP
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1996)

## Table 10
## Estimated Long-Range ROM Price Trends—North American Bookings (Speed/Package: ≤1Mb Density—150ns and Above, 28-Pin PDIP; ≥2Mb Density—200ns and Above, 32-Pin PDIP) (Volume: 50,000 per Year; Dollars)

| Product | 1997 Year | 1998 Year | 1999 Year | 2000 Year | 2001 Year |
|---|---|---|---|---|---|
| 128Kx8 | 1.64 | 1.50 | 1.47 | 1.44 | 1.44 |
| 64Kx16 | 1.98 | 1.93 | 1.92 | 1.92 | 1.93 |
| 256Kx8 | 2.18 | 2.15 | 2.13 | 2.12 | 2.10 |
| 512Kx8 | 2.80 | 2.27 | 2.24 | 2.21 | 2.19 |
| 256Kx16[1] | 2.80 | 2.25 | 2.22 | 2.19 | 2.18 |
| 1Mbx8[2] | 3.74 | 3.17 | 3.09 | 3.05 | 3.00 |
| 1Mbx16 | 4.78 | 3.41 | 3.35 | 3.28 | 3.22 |
| 2Mbx8 | 4.68 | 3.09 | 3.05 | 3.02 | 3.00 |

[1]256Kx16 ROM: 150ns and above; 40-pin PDIP
[2]1Mbx8 ROM: 150ns and above; 32-pin SOP
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1996)


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**Table 11**
**Estimated EPROM Price Trends—North American Bookings (Volume: 50,000 per Year; Package: Windowed CERDIP; Speed: 150ns and Above; Dollars)**

| Product | 1996 Q4 | 1997 Q1 | 1997 Q2 | 1997 Q3 | 1997 Q4 | 1997 Year | 1998 Q1 | 1998 Q2 | 1998 Q3 | 1998 Q4 | 1998 Year | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32Kx8 | 1.80 | 1.75 | 1.75 | 1.70 | 1.70 | 1.73 | 1.65 | 1.65 | 1.60 | 1.60 | 1.63 | 2 |
| 64Kx8 | 1.90 | 1.85 | 1.85 | 1.80 | 1.80 | 1.83 | 1.75 | 1.75 | 1.70 | 1.70 | 1.73 | 2 |
| 128Kx8 | 2.60 | 2.50 | 2.40 | 2.30 | 2.20 | 2.40 | 2.10 | 2.10 | 2.00 | 2.00 | 2.05 | 2 |
| 256Kx8 | 3.80 | 3.70 | 3.60 | 3.50 | 3.40 | 3.55 | 3.30 | 3.30 | 3.20 | 3.20 | 3.25 | 2 |
| 128Kx16 | 5.80 | 5.00 | 4.80 | 4.60 | 4.40 | 4.70 | 4.20 | 4.00 | 3.80 | 3.60 | 3.90 | 2 |
| 512Kx8 | 6.85 | 6.30 | 5.90 | 5.60 | 5.40 | 5.93 | 5.20 | 5.00 | 4.80 | 4.60 | 4.90 | 2 |
| 256Kx16 | 9.00 | 8.50 | 8.00 | 7.50 | 7.00 | 7.75 | 6.50 | 6.00 | 5.50 | 5.00 | 5.75 | 2 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1996)

**Table 12**
**Estimated Long-Range EPROM Price Trends—North American Bookings (Volume: 50,000 per Year; Package: Windowed CERDIP; Speed: 150ns and Above; Dollars)**

| Product | 1997 Year | 1998 Year | 1999 Year | 2000 Year | 2001 Year |
|---|---|---|---|---|---|
| 32Kx8 | 1.73 | 1.63 | 1.60 | 1.58 | 1.58 |
| 64Kx8 | 1.83 | 1.73 | 1.69 | 1.66 | 1.64 |
| 128Kx8 | 2.40 | 2.05 | 2.00 | 1.94 | 1.91 |
| 256Kx8 | 3.55 | 3.25 | 3.15 | 3.08 | 3.01 |
| 128Kx16 | 4.70 | 3.90 | 3.79 | 3.65 | 3.55 |
| 512Kx8 | 5.93 | 4.90 | 4.75 | 4.62 | 4.30 |
| 256Kx16 | 7.75 | 5.75 | 4.95 | 4.70 | 4.50 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as price guidelines.
Source: Dataquest (December 1996)


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## Table 13
## Estimated Flash Memory Price Trends—North American Bookings
## (12V; Volume: 10,000 per Year; Speed: 150ns; Dollars)

| | Product | 1996 Q4 | 1997 Q1 | Q2 | Q3 | Q4 | 1997 Year | 1998 Q1 | Q2 | Q3 | Q4 | 1998 Year | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 64Kx8 PDIP/PLCC | 3.00 | 2.75 | 2.60 | 2.50 | 2.40 | 2.56 | 2.35 | 2.30 | 2.20 | 2.10 | 2.24 | 5 |
| 2 | 64Kx8 TSOP | 3.25 | 3.00 | 2.85 | 2.75 | 2.65 | 2.81 | 2.60 | 2.55 | 2.45 | 2.35 | 2.49 | 5 |
| 3 | 128Kx8 PDIP/PLCC | 2.85 | 2.65 | 2.55 | 2.45 | 2.40 | 2.51 | 2.35 | 2.30 | 2.20 | 2.10 | 2.24 | 3 |
| 4 | 128Kx8 TSOP 12V | 2.98 | 2.85 | 2.75 | 2.65 | 2.60 | 2.71 | 2.55 | 2.50 | 2.40 | 2.30 | 2.44 | 5 |
| 5 | 128Kx8 TSOP 5V | 5.05 | 3.90 | 3.70 | 3.60 | 3.50 | 3.68 | 3.45 | 3.40 | 3.30 | 3.15 | 3.33 | 3 |
| 6 | 256Kx8 TSOP 12V | 6.13 | 5.80 | 5.60 | 5.40 | 5.20 | 5.50 | 5.15 | 5.00 | 4.75 | 4.60 | 4.88 | 5 |
| 7 | 256Kx8 TSOP/5V | 6.00 | 5.50 | 5.30 | 5.00 | 4.80 | 5.15 | 4.70 | 4.50 | 4.30 | 4.10 | 4.40 | 3 |
| 8 | 512Kx8 PDIP/PLCC | 7.68 | 6.00 | 5.60 | 5.30 | 5.00 | 5.48 | 4.80 | 4.60 | 4.45 | 4.25 | 4.53 | 2 |
| 9 | 512Kx8 TSOP 12V | 7.90 | 6.25 | 5.80 | 5.50 | 5.10 | 5.66 | 5.00 | 4.80 | 4.70 | 4.50 | 4.75 | 4 |
| 10 | 512Kx8 TSOP/5V | 8.90 | 6.35 | 5.90 | 5.60 | 5.30 | 5.79 | 5.10 | 4.90 | 4.70 | 4.50 | 4.80 | 4 |
| 11 | 1Mbx8 TSOP/12V | 10.32 | 10.10 | 9.75 | 9.30 | 8.60 | 9.44 | 8.00 | 7.90 | 7.65 | 7.50 | 7.76 | 4 |
| 12 | 1Mbx8 TSOP/5V | 11.50 | 10.20 | 9.80 | 9.50 | 8.85 | 9.59 | 8.20 | 8.00 | 7.70 | 7.50 | 7.85 | 4 |
| 13 | 2Mbx8 TSOP/12V | 21.41 | 18.15 | 17.60 | 16.95 | 15.95 | 17.16 | 15.35 | 14.70 | 14.10 | 13.55 | 14.43 | 4 |
| 14 | 2Mbx8 TSOP/5V | 21.75 | 18.50 | 17.75 | 17.00 | 16.15 | 17.35 | 15.50 | 14.90 | 14.30 | 13.70 | 14.60 | 4 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (December 1996)

17 now

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## Table 14
## Estimated Long-Range Flash Memory Price Trends—North American Bookings (12V; Volume: 10,000 per Year; Speed: 150ns; Dollars)

| Product | 1997 Year | 1998 Year | 1999 Year | 2000 Year | 2001 Year |
|---|---|---|---|---|---|
| 64Kx8 PDIP/PLCC | 2.56 | 2.24 | 2.15 | 2.09 | 2.00 |
| 64Kx8 TSOP | 2.81 | 2.49 | 2.30 | 2.18 | 2.10 |
| 128Kx8 PDIP/PLCC | 2.51 | 2.24 | 2.12 | 2.02 | 1.98 |
| 128Kx8 TSOP 12V | 2.71 | 2.44 | 2.32 | 2.25 | 2.20 |
| 128Kx8 TSOP 5V | 3.68 | 3.33 | 3.16 | 3.06 | 3.00 |
| 256Kx8 TSOP 12V | 5.50 | 4.88 | 4.63 | 4.49 | 4.40 |
| 256Kx8 TSOP/5V | 5.15 | 4.40 | 4.00 | 3.76 | 3.61 |
| 512Kx8 PDIP/PLCC | 5.48 | 4.53 | 4.12 | 3.87 | 3.72 |
| 512Kx8 TSOP 12V | 5.66 | 4.75 | 4.32 | 4.06 | 3.90 |
| 512Kx8 TSOP/5V | 5.79 | 4.80 | 4.37 | 4.02 | 3.78 |
| 1Mbx8 TSOP/12V | 9.44 | 7.76 | 7.06 | 6.50 | 6.11 |
| 1Mbx8 TSOP/5V | 9.59 | 7.85 | 7.14 | 6.57 | 6.18 |
| 2Mbx8 TSOP/12V | 17.16 | 14.43 | 12.98 | 11.68 | 10.52 |
| 2Mbx8 TSOP/5V | 17.35 | 14.60 | 13.14 | 11.83 | 10.64 |

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (December 1996)


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## Table 15
## Estimated Gate Array Pricing—North American Production Bookings
## (Volume: 20,000 Units, Based on Utilized Gates Only; NRE = Netlist to Prototype, Millicents per Gate)

| | 10-29.99K Gates | | | 30-59.99K Gates | | | 60-99.99K Gates | | | Lead Time |
|---|---|---|---|---|---|---|---|---|---|---|
| **Gate Count Technology** | **1997** | **1998** | **1999** | **1997** | **1998** | **1999** | **1997** | **1998** | **1999** | **(Weeks)** |
| CMOS (Average) | | | | | | | | | | Production: |
| 1.0 Micron | 31.00 | 27.00 | 25.00 | 30.00 | 26.00 | 23.00 | 28.00 | 25.00 | 22.00 | 6-12 |
| 0.8 Micron | 27.00 | 23.00 | 22.00 | 23.00 | 20.00 | 18.00 | 23.00 | 19.00 | 17.00 | 6-12 |
| 0.6/0.5 Micron | 25.00 | 21.00 | 19.00 | 18.00 | 16.00 | 15.00 | 17.00 | 15.00 | 14.00 | 6-12 |
| 0.3 Micron | NR | NR | 24.00 | NR | NR | 20.00 | 16.00 | 14.00 | 13.00 | 6-12 |
| | | | | | | | | | | Prototypes: |
| NRE CMOS Average Charge ($K) | 44.00 | 44.00 | 43.00 | 54.00 | 52.00 | 52.00 | 74.00 | 73.00 | 73.00 | 2-8 |

| | 100-299.99K Gates | | | ≥300K Gates | | | Lead Time |
|---|---|---|---|---|---|---|---|
| **Gate Count Technology** | **1997** | **1998** | **1999** | **1997** | **1998** | **1999** | **(Weeks)** |
| CMOS (Average) | | | | | | | Production: |
| 1.0 Micron | NR | NR | 33.00 | NR | NR | 36.00 | 6-12 |
| 0.8 Micron | 24.00 | 21.00 | 19.00 | NR | NR | 34.00 | 6-12 |
| 0.6/0.5 Micron | 18.00 | 16.00 | 15.00 | 20.00 | 17.00 | 16.00 | 6-12 |
| 0.3 Micron | 17.00 | 15.00 | 14.00 | 19.00 | 16.00 | 15.00 | 6-12 |
| | | | | | | | Prototypes: |
| NRE CMOS Average Charge ($K) | 107.00 | 106.00 | 105.00 | 123.00 | 120.00 | 120.00 | 2-8 |

NR = Not relevant

Notes: The actual NRE charge may vary from these because of device amortization, testing, intellectual property rights, and other factors.

Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as intellectual property rights, alliances, service, package types, and volume discount. These prices are intended for use as price guidelines. For volumes of 100,000 units or greater, discount the above prices by a further 40 percent to 60 percent.

For high-density solutions with volumes greater than 150,000 units or for low-density solutions with volumes greater than 500 units, CBICs may be more cost-effective than gate arrays.

Source: Dataquest (December 1996)

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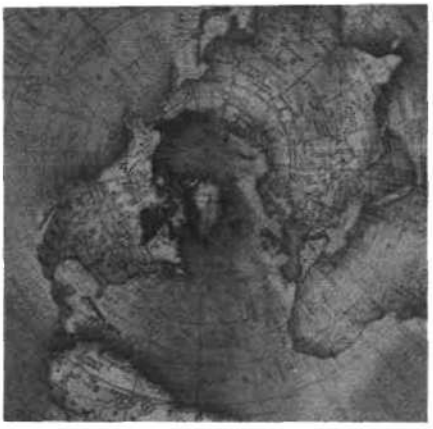
## Table 16
## Estimated CBIC Pricing—North American Production Bookings
## (Volume: 20,000 Units, Based on Utilized Gates Only; NRE = Netlist to Prototype, Millicents per Gate)

| Gate Count Technology | 10-29.99K Gates 1997 | 1998 | 1999 | 30-59.99K Gates 1997 | 1998 | 1999 | 60-99.99K Gates 1997 | 1998 | 1999 | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|---|---|---|
| CMOS | | | | | | | | | | Production: |
| 1.0 Micron | 37.00 | 30.00 | 27.00 | 33.00 | 28.00 | 24.00 | 31.00 | 27.00 | 25.00 | 7-13 |
| 0.8 Micron | 31.00 | 26.00 | 25.00 | 24.00 | 21.00 | 19.00 | 25.00 | 21.00 | 19.00 | 7-13 |
| 0.6/0.5 Micron | 26.00 | 22.00 | 19.00 | 21.00 | 18.00 | 17.00 | 20.00 | 17.00 | 16.00 | 7-13 |
| 0.3 Micron | NR | NR | 21.00 | NR | NR | 20.00 | 19.00 | 15.00 | 14.00 | NR |
| | | | | | | | | | | Prototypes: |
| NRE CMOS Average Charge ($K) | 68.00 | 67.00 | 65.00 | 72.00 | 72.00 | 71.00 | 83.00 | 83.00 | 83.00 | 4-8 |

| Gate Count Technology | 100-299K Gates 1997 | 1998 | 1999 | ≥300K Gates 1997 | 1998 | 1999 | Lead Time (Weeks) |
|---|---|---|---|---|---|---|---|
| CMOS | | | | | | | Production: |
| 1.0 Micron | NR | NR | 30.00 | NR | NR | 38.00 | 7-13 |
| 0.8 Micron | 26.00 | 22.00 | 20.00 | NR | NR | 36.00 | 7-13 |
| 0.6/0.5 Micron | 22.00 | 19.00 | 18.00 | 24.00 | 21.00 | 19.00 | 7-13 |
| 0.3 Micron | 21.00 | 17.00 | 16.00 | 22.00 | 19.00 | 18.00 | 7-13 |
| | | | | | | | Prototypes: |
| NRE CMOS Average Charge ($K) | 133.00 | 132.00 | 132.00 | 163.00 | 161.00 | 160.00 | 4-8 |

NR = Not relevant

Notes: The actual NRE charge may vary from these because of device amortization, testing, intellectual property rights, and other factors.
Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as intellectual property rights, alliances, service, package types, and volume discount. These prices are intended for use as price guidelines. For volumes of 100,000 units or greater, discount the above prices by a further 40 percent to 60 percent.
For high-density solutions with volumes greater than 150,000 units or for low-density solutions with volumes greater than 500 units, CBICs may be more cost-effective than gate arrays.
Source: Dataquest (December 1996)



Dataquest

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MARIA VALENZUELA

# 1997 Semiconductor User Wants and Needs: They Want More!



User Wants and Needs

**Program:** Semiconductor Supply and Pricing Worldwide
**Product Code:** SSPS-WW-UW-9701
**Publication Date:** December 8, 1997
**Filing:** Reports

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# Table of Contents


Page

1. Executive Summary ..... 1
   - Three Semiconductor Applications Categories ..... 1
   - Survey Objective ..... 2
2. Introduction ..... 3
   - Management Summary ..... 3
   - Report Contents ..... 5
3. Survey Participant Demographics ..... 7
   - Survey Methodology ..... 7
   - Respondents' Function Groups ..... 7
   - Respondents' Demographics ..... 9
   - Respondents' Market Size ..... 10
4. Show Me the Money: Spending and TCO ..... 13
   - Semiconductor Spending ..... 13
   - Survey Participants versus Total North America Market ..... 14
   - Targeted Semiconductor Inventory Holding ..... 15
   - Semiconductor Inventory Holding: Actual versus Target ..... 16
   - Future Semiconductor Inventory Holding Targets ..... 16
   - Total Cost of Ownership ..... 16
5. How Buyers Buy: Procurement Sourcing Channels ..... 19
   - Role of Distribution ..... 19
   - Pros and Cons of Distribution ..... 20
   - Spot Market ..... 20
   - Strategy toward the Spot Market ..... 21
   - Semiconductor Device Families Procured from the Spot Market ..... 22
6. Who Buyers Deal With: Supply Base Analysis ..... 25
   - Current Supply Base ..... 25
   - Changes from 1996 ..... 25
   - Changes Expected in 1998 ..... 27
   - Strategic Suppliers ..... 27
7. How They Are Doing: Vendor-of-Choice Programs and Trends ..... 29
   - Do They or Don't They? ..... 29
   - Frequency of VoC ..... 30
   - Suppliers That Are Tracked ..... 31
   - Management's View ..... 31
8. What Matters: Importance versus Satisfaction ..... 33
   - Delivery Issues ..... 33
   - Quality Issues ..... 34
   - Responsiveness Issues ..... 34
   - Technical Support Issues ..... 36
   - Flexibility Issues ..... 37
   - Total Cost of Ownership Issues ..... 38
   - Price Issues ..... 39
   - Summary ..... 40

# Table of Contents (Continued)

Page

9. Truth or Token? Supplier and Buyer Trust ..... 41
   - Vendor of Choice Feedback to Suppliers ..... 41
   - How Is Information Shared? ..... 42
   - Buyer and Vendor Trust ..... 44
   - Value and Goal Sharing ..... 46
10. Teamwork: Supplier and Buyer Joint Approval ..... 47
   - Joint Qualification: Yes or No ..... 47
   - Which Device Families ..... 48
   - If Not Now, What about the Future? ..... 49
11. Roundup: Conclusions and Comparisons ..... 51

# List of Figures


| Figure | | Page |
|---|---|---|
| 2-1 | Percentage of Buyers Surveyed Using the Spot Market for the Listed Semiconductor Device Families | 3 |
| 2-2 | Importance versus Satisfaction Ratings for Total Cost of Ownership | 4 |
| 3-1 | Type of Functional Group | 8 |
| 3-2 | Respondents' Semiconductor Purchases | 8 |
| 3-3 | Respondents' Application Markets | 9 |
| 3-4 | Level of Purchasing Responsibility | 10 |
| 3-5 | Sales of Respondents | 11 |
| 4-1 | Semiconductor Spending of Respondents, 1996 | 13 |
| 4-2 | Semiconductor Purchasing Power Growth | 14 |
| 4-3 | Current Targeted Semiconductor Inventory Holding Levels | 15 |
| 4-4 | Change Expected in Targeted Semiconductor Level, 1998 | 17 |
| 4-5 | Current Measurement of TCO | 17 |
| 5-1 | Percentage of Semiconductor Spending through Distribution Channels | 19 |
| 5-2 | Spot Market Purchases of Semiconductors | 21 |
| 5-3 | Percentage of Respondents Buying Each Device Family on the Spot Market | 23 |
| 6-1 | Number of Suppliers Used by Respondents in 1997 | 26 |
| 6-2 | Strategic Suppliers versus Regular Suppliers | 27 |
| 7-1 | Performance of Regular Vendor Evaluation | 29 |
| 7-2 | Frequency of Performance Evaluation | 30 |
| 7-3 | Priority of VoC Program for Nonpurchasing Management | 32 |
| 8-1 | Delivery Issues | 34 |
| 8-2 | Quality Issues | 35 |
| 8-3 | Responsiveness Issues | 35 |
| 8-4 | Technical Support Issues | 36 |
| 8-5 | Flexibility Issues | 37 |
| 8-6 | Total Cost of Ownership Issues | 38 |
| 8-7 | Pricing Issues | 39 |
| 9-1 | VoC Feedback to Vendors | 41 |
| 9-2 | Level of VoC Feedback to Vendors | 42 |
| 9-3 | Changes in VoC Feedback to Vendors | 43 |
| 9-4 | Level of Trust in Vendors | 44 |
| 9-5 | Change in Level of Trust in Vendors | 45 |
| 9-6 | Vendors' and Respondents' Shared Goals | 46 |
| 10-1 | Semiconductor Joint Qualification—Vendors and Respondents | 47 |
| 10-2 | Jointly Qualified Devices—Level of Participation | 48 |
| 10-3 | Plans for Joint Qualification | 49 |

# List of Tables


| Table | | Page |
|---|---|---|
| 4-1 | Semiconductor Inventory Levels: Current versus Target | 16 |
| 5-1 | Spot Market Strategies | 21 |
| 5-2 | Device Families Bought on the Spot Market | 22 |
| 6-1 | Change in Number of Suppliers since 1996 | 26 |
| 6-2 | Change in Number of Suppliers Expected in 1998 | 27 |
| 7-1 | Vendors Evaluated Regularly | 31 |



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# Chapter 1
# Executive Summary

## Three Semiconductor Applications Categories

For the purposes of estimating semiconductor consumption, Dataquest has segmented electronics equipment production into three broad groups. These three groups are data processing, communications, and others. These groups in turn are broken into narrower electronic product categories, as shown below:

- Data processing
  - Computers
  - Data storage
  - Input/output devices
  - Dedicated systems
  - Other data processing
- Communications
  - Premise telecom
  - Public telecom
  - Mobile communications
  - Broadcast and studio equipment
  - Other communications
- Others
  - Industrial
  - Consumer
  - Military/civil aerospace
  - Transportation

According to Dataquest's spring 1997 semiconductor application forecast, data processing accounts for 51 percent of 1996 semiconductor consumption (revenue-based), communications for 22 percent, and others for 27 percent.

For the purposes of this report, Dataquest selected the demographics of the companies participating so that 50 percent of respondents represented the data processing segment, 25 percent, communications, and the rest, others.


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## Survey Objective

Dataquest wanted to examine the buyer/supplier relationship from the procurement/user standpoint. Users of semiconductors, primarily buyers, were surveyed on various aspects of their supplier relationship.

The objective of the survey was to complete 100 surveys with the respondents' demographics: 50 percent data processing companies, 25 percent communications companies, and 25 percent industrial, military, medical, and consumer companies.

*Project Analysts: Evelyn Cronin and Mark Giudici*


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# Chapter 2
# Introduction

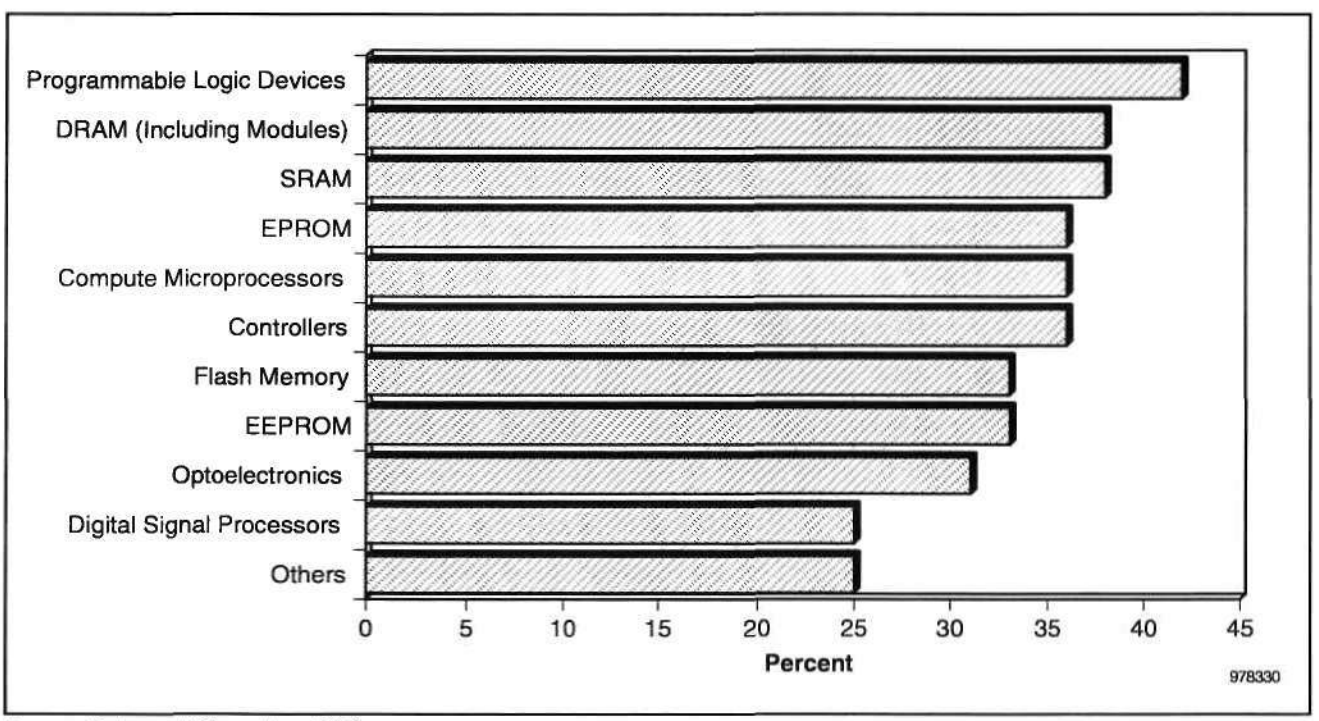
## Management Summary

Dataquest completed a survey of 104 semiconductor users that explored the relationship between users (buyers) and vendors and how procurement is conducted. Those surveyed account for over 15 percent of the total semiconductor spending for North America in 1996, based on Dataquest's total North American semiconductor market revenue. The results were very interesting.

For example, it was discovered that the device family most widely sourced in the spot market by the buyers surveyed was programmable logic devices (PLDs)—over 43 percent of all buyers who use the spot market source PLDs there. Figure 2-1 plots these results.

The next group consisted of two memory devices, DRAM and SRAM. Thirty-eight percent of buyers who use the spot market buy these devices there. EPROM, compute processors, and controllers form the next group, with 36 percent of spot market users selecting these categories.

**Figure 2-1**
**Percentage of Buyers Surveyed Using the Spot Market for the Listed Semiconductor Device Families**



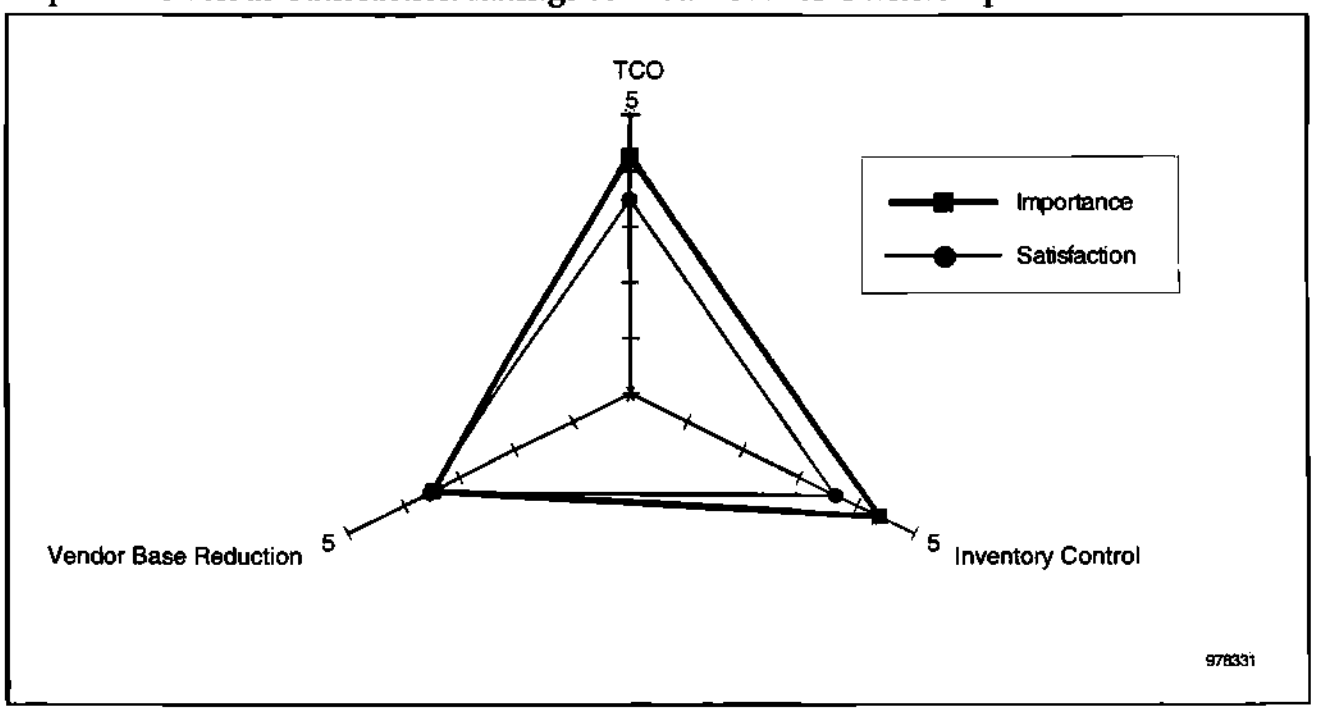

Source: Dataquest (November 1997)


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Close behind were flash and EEPROMs, which were bought by 33 percent of the group. Thirty-one percent of respondents who use the spot market buy or have bought optoelectronics there, while DSPs and others were bought by 25 percent. The "others" category is a mixed bag made up of clients who refused to state which devices they bought, those buying discretes, and those who bought a wide variety but would not specify.

Another area covered was the differences in importance and satisfaction rating for key purchasing criteria (see Figure 2-2). One of the criteria studied was total cost of ownership (TCO). The buyers have spoken—they are not satisfied with their vendors' efforts to reduce TCO. In fairness to vendors, though, TCO is probably the hardest of the three to pin down. It is subject to so many variations in itself, and the way it is tracked by buyers seems to be in a state of flux (according to the vendors). That said, however, any means by which the TCO can be reduced by vendors is appreciated by buyers, and the buyers certainly believe the vendors can and need to do more.

**Figure 2-2**
**Importance versus Satisfaction Ratings for Total Cost of Ownership**




Source: Dataquest (November 1997)


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## Report Contents

The report has been divided into 11 chapters. Chapter 1 is the executive summary, and Chapter 2 is the management summary. Chapter 3 covers the demographics of the survey participants. Chapter 4 looks at the users' areas of semiconductor spending and their relation to total market size as well as to inventory holding and total cost of ownership.

Chapter 5 covers procurement sourcing channels, specifically the distribution and spot market channels. It looks at advantages and disadvantages and sourcing strategies. Chapter 6 deals with supply base and the vendor trends. It also covers strategic versus nonstrategic suppliers. Chapter 7 looks at vendor measurement, its frequency, and its perception by non-procurement management.

Chapter 8 explores the importance versus satisfaction ratings for delivery, quality, responsiveness, technical support, flexibility, total cost of ownership, and price. Chapter 9 looks at information sharing between buyers and suppliers and also covers the issue of trust and goal sharing in the relationship. Chapter 10 deals with buyer and vendor joint approval of semiconductors. The report finishes with conclusions and comparisons in Chapter 11.

# Chapter 3
# Survey Participant Demographics

## Survey Methodology

Dataquest's 1997 Semiconductor Procurement study contains the results of a telephone survey conducted by Dataquest's Worldwide Research Operations group. The survey questionnaire was developed by analysts from Dataquest's Semiconductor Supply and Pricing Worldwide program (SSPS). The questionnaire comprises a total of 45 questions. Many of the questions allowed or required more than one response. On average, a respondent was asked to answer about 40 questions because not all questions applied to each respondent. Trained interviewers conducted the 20-minute survey using a computer-aided telephone interviewing (CATI) system. About 15 percent of each interviewer's work was monitored for validation. Worldwide Research Operations analysts tabulated the survey results using SPSS, a statistical analysis software package.

Dataquest conducted the study during September 1997. The sample list was obtained from a Computer Intelligence database. Dataquest obtained a total of 2,303 randomly selected names. The titles represented were president/general manager, senior financial executive, PC manager, and purchase manager in the computer and equipment, household appliance, household, communications, transportation, military and civil aerospace, medical, optical instrument, environment, and process control industries.

Dataquest placed a total of 3,056 calls. The sample disposition was as follows:

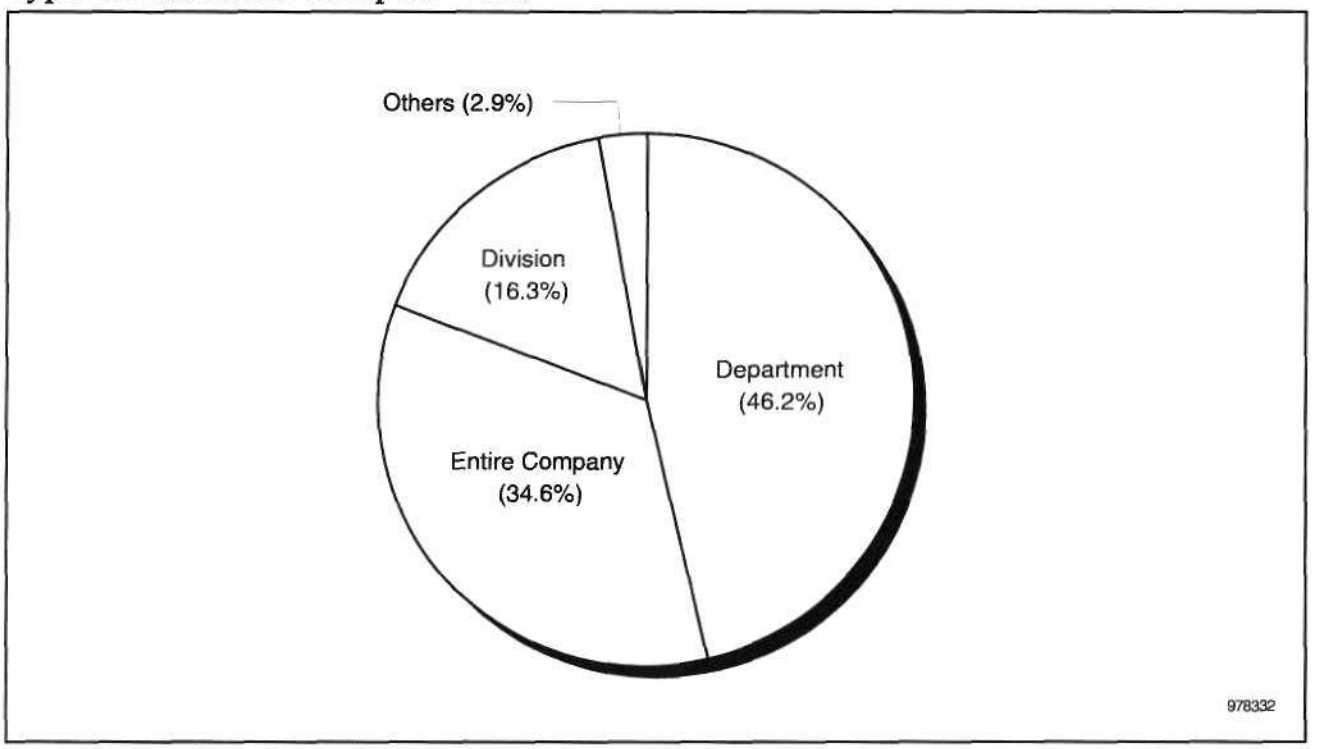
- 104 completed interviews
- 129 bad numbers
- 2,097 unable to contact subject, left message, or others
- 125 refused interview
- 601 did not qualify to participate in study

## Respondents' Function Groups

The functional groups of those responding to the survey ranged from the entire company to division and department levels. As shown in Figure 3-1, more than one-third (34.6 percent) of the sample purchased for their entire companies, over 15 percent (16.3 percent) represented divisions, and close to half (46.2 percent) represented their departments. The high percentage of department-level respondents accounts for the size of the purchases made. Figure 3-2 shows that, again, close to half the respondents (44.2 percent) bought up to $1 million in semiconductors in 1996, a quarter (25 percent) bought between $1 million and $9.9 million, and 25.9 percent bought over $10 million semiconductors last year. The total of semiconductors purchased in 1996 was $5.82 billion (12.98 percent of all 1996 semiconductors consumed in the Americas).

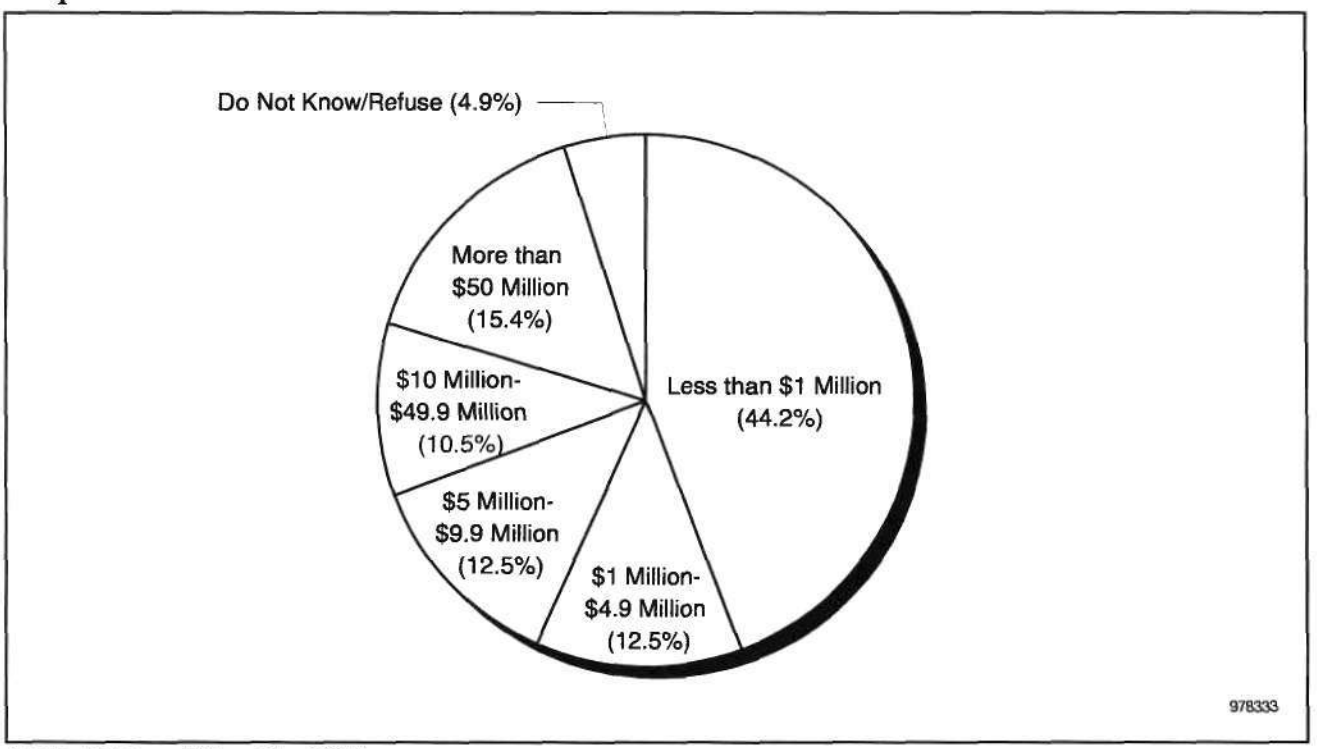

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**Figure 3-1**
**Type of Functional Group (N = 104)**




Source: Dataquest (November 1997)

**Figure 3-2**
**Respondents' Semiconductor Purchases**

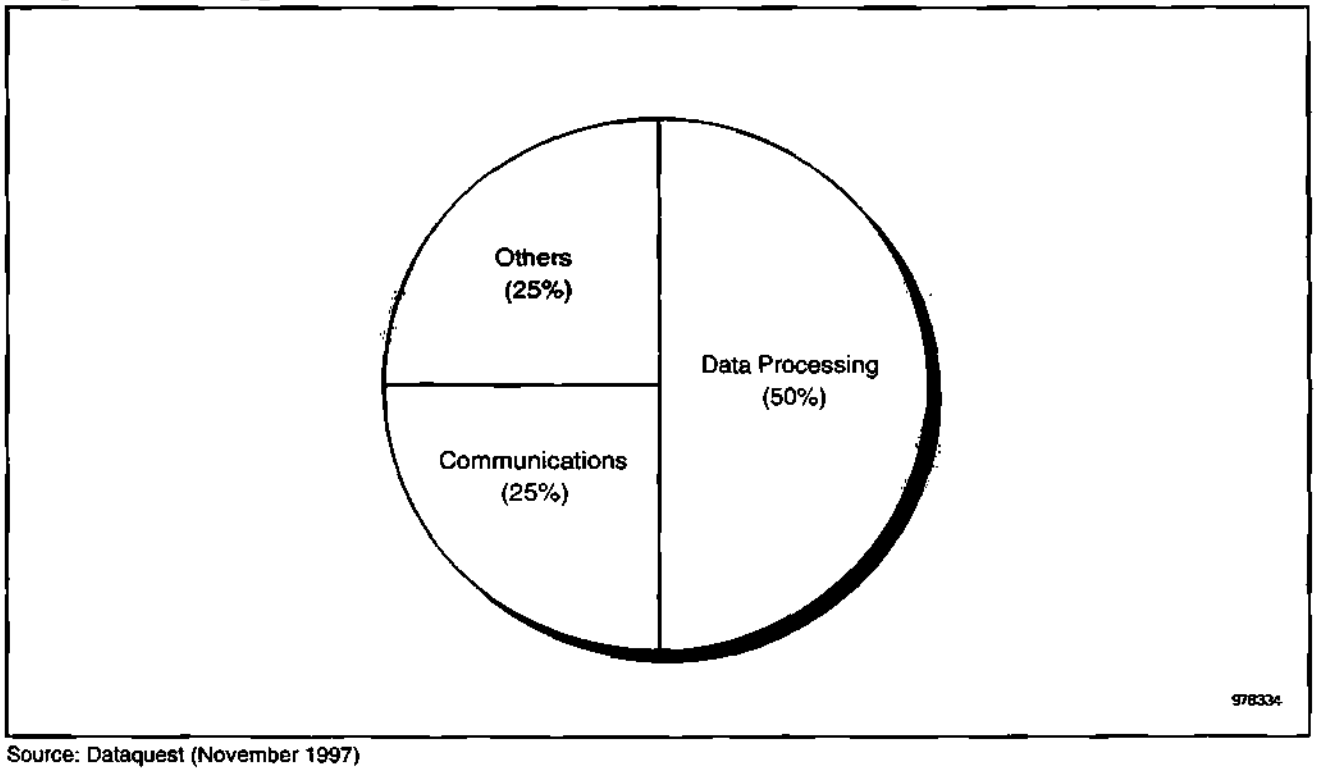



Source: Dataquest (November 1997)

## Respondents' Demographics

The makeup of the survey response closely reflects the North American electronics industry from which it was polled. As shown in Figure 3-3, respondents from the data processing industry (any nonsoftware company manufacturing or selling computers or equipment used with computers) make up 50 percent of the sample. One-quarter of the response came from communications companies, and the remaining 25 percent of the sample is made up of industrial, consumer, and military/civil aerospace companies. Based on the spring 1997 forecast for 1996 semiconductor revenue by application, 51 percent of the overall North American electronics industry is data processing companies, 22 percent is communications companies, and 27 percent is industrial, consumer, transportation, and military/civil aerospace companies.

**Figure 3-3**
**Respondents' Application Markets (N = 104)**

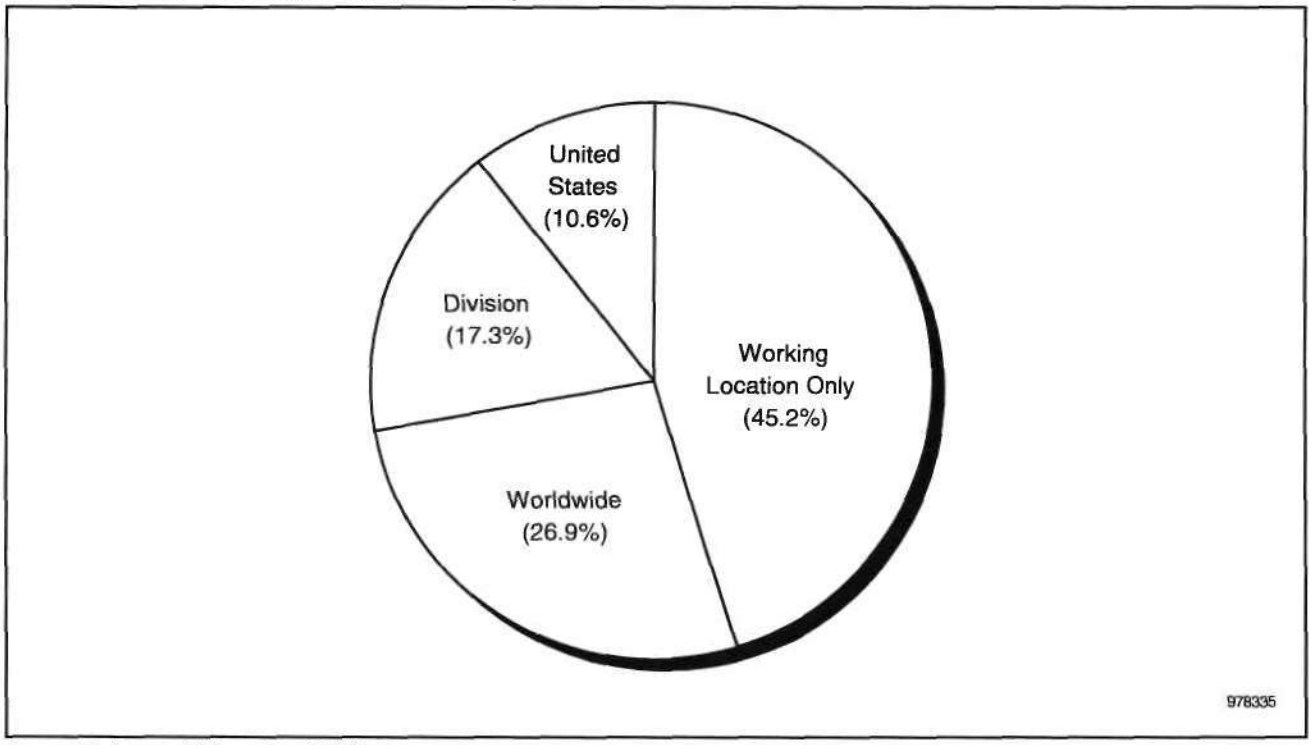



Source: Dataquest (November 1997)

## Respondents' Market Size

The level of purchasing control also ranged from large to small. The spectrum spanned from handling worldwide operations to handling only the location at which the respondent worked. As shown in Figure 3-4, over one-quarter (26.9 percent) of the respondents were responsible for worldwide semiconductor procurement, 10.6 percent were responsible for U.S. purchases, 17.3 percent handled divisional semiconductor procurement, and close to half (45.2 percent) were responsible for their work location. This response sample represents a good mix of tactical and strategic procurement requirements.

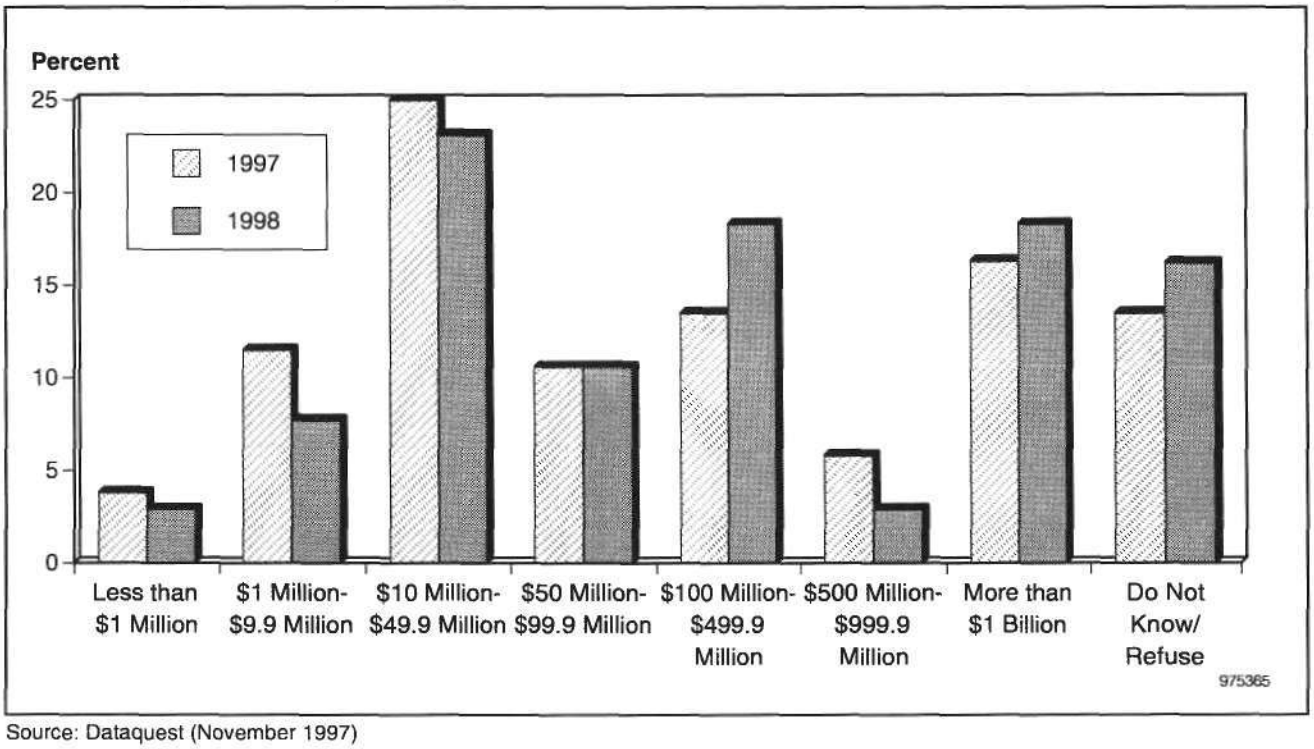
**Figure 3-4**
**Level of Purchasing Responsibility (N = 104)**




Source: Dataquest (November 1997)

There was a large spread in the size of the companies for which the respondents worked. The largest group (25 percent) came from companies ranging from $10 million to $49 million in sales; the next-largest group of respondents (16.3 percent) had sales of more than $1 billion. The full detail of 1997 and 1998 sales estimates is shown in Figure 3-5. Most companies with more than $100 million in sales (except those ranging from $500 million to $999 million) expected to grow from 1997 to 1998, while those under $100 million all expected either to shrink or stay the same.

**Figure 3-5**
**Sales of Respondents (N = 104)**




Source: Dataquest (November 1997)

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# Chapter 4
# Show Me the Money: Spending and TCO

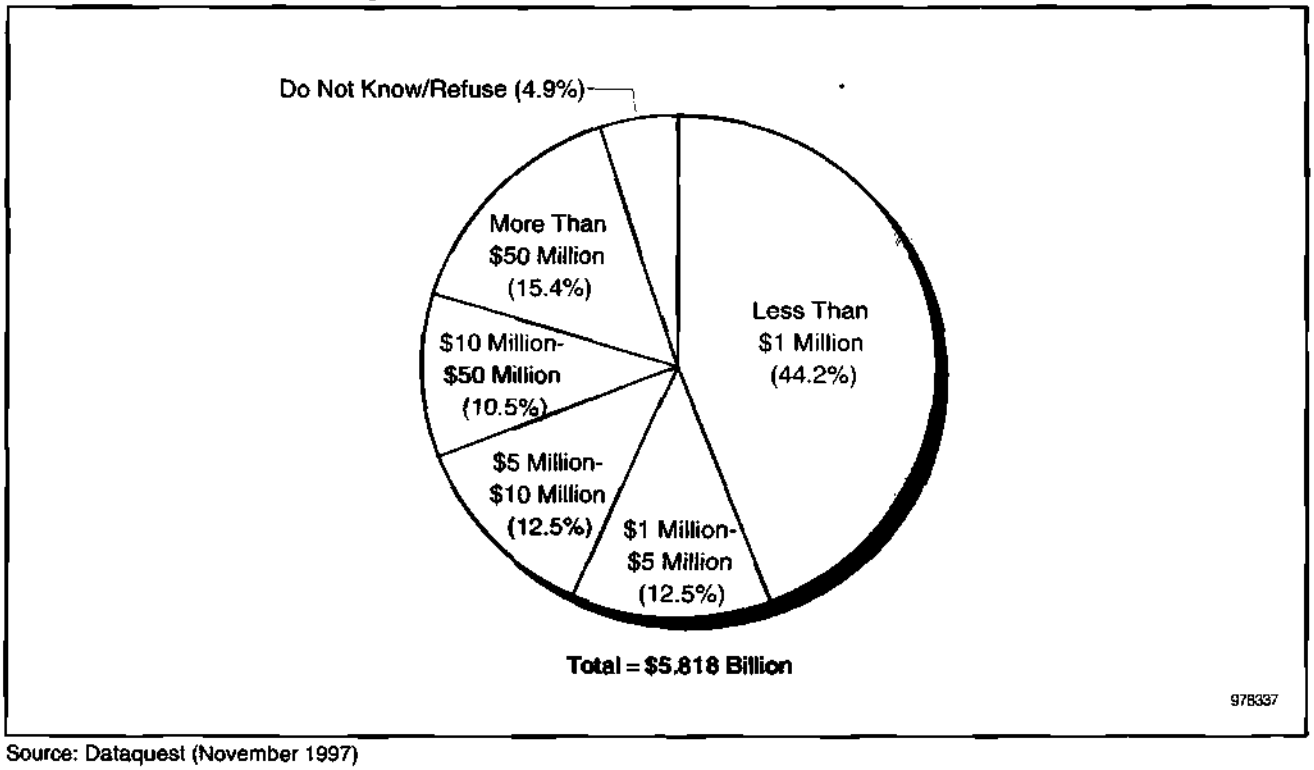
This chapter covers what many consider the backbone of the procurement function: semiconductor spending, inventory holding, and total cost of ownership.

## Semiconductor Spending

A survey is a useful tool for getting feedback on the mood of a given base on selected issues. However, the usefulness is largely related to the survey's relevance to the readers. Buyers always want to know the bottom line—are those surveyed big fish or little fish in the pond that is called procurement spending?

The participants were asked to state their actual 1996 semiconductor spending. Figure 4-1 shows that the survey included a good spread, from smaller companies to quite large organizations. The sum of the semiconductor spending by the respondents was $5.818 billion.

**Figure 4-1**
**Semiconductor Spending of Respondents, 1996 (N = 104)**



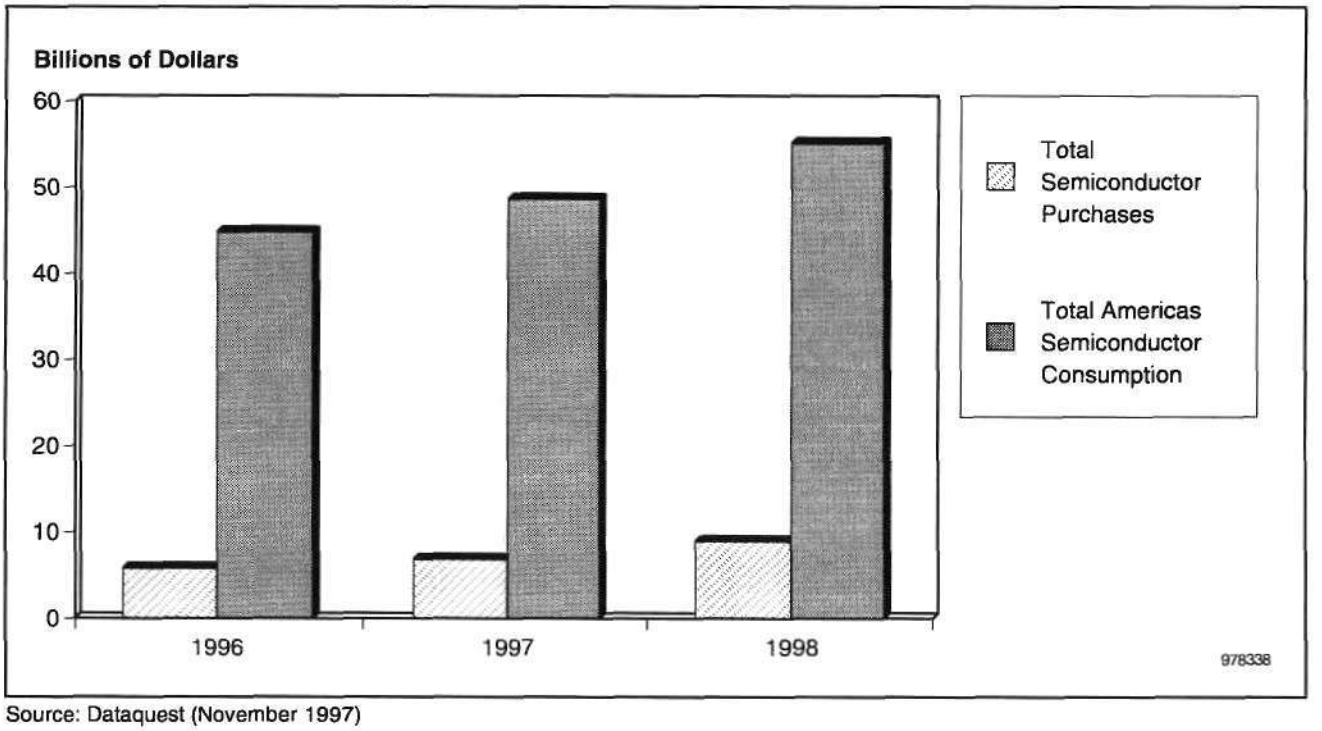

Source: Dataquest (November 1997)


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## Survey Participants versus Total North America Market

Putting the survey respondents into the context of their North American market, Figure 4-2 shows that the results are impressive. The purchasing power in 1996 of the surveyed 104 respondents represents 13 percent of all the semiconductors consumed in the Americas ($44.8 billion). The outlook of these respondents is to increase their purchases relative to Dataquest's forecast to 14.1 percent of 1997's semiconductor consumption and 16.2 percent of 1998's Americas semiconductor consumption.

**Figure 4-2**
**Semiconductor Purchasing Power Growth**




Source: Dataquest (November 1997)

## Targeted Semiconductor Inventory Holding

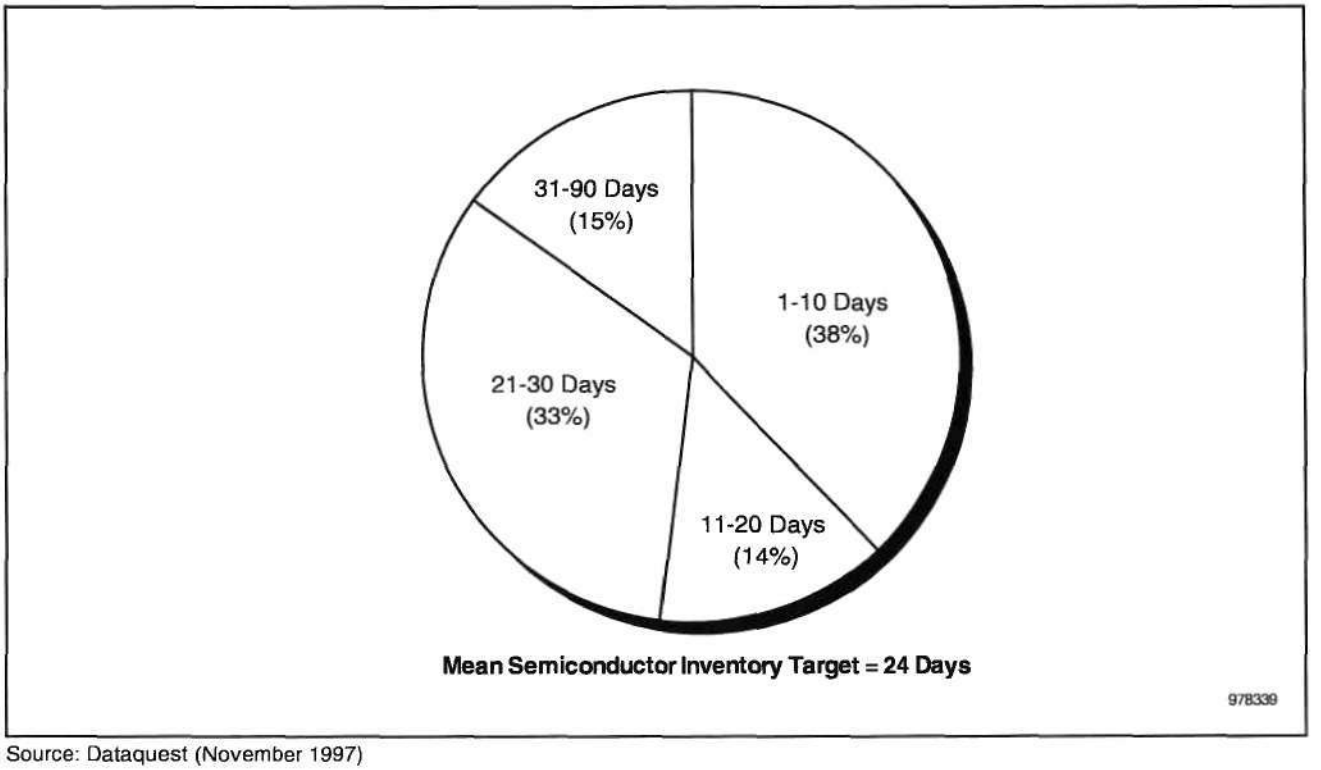
Dataquest next asked about semiconductor inventory holding levels. Buyers are usually set a targeted inventory holding level (in days) that they aim to achieve. However, there is often a difference between the inventory target goal and the actual semiconductor inventory levels maintained.

All 104 of the buyers surveyed responded to this question. Figure 4-3 shows the ranges of the targeted semiconductor inventory holding levels for the surveyed buyers in 1997. The largest group had the lowest target for inventory holding (between one and 10 days)—38 percent of respondents fell into this category.

The second-largest group had a targeted semiconductor holding level between 21 and 30 days—33 percent. Fourteen percent of respondents cited ranges of 11 to 20 days, and 15 percent named levels of 31 to 90 days.

Based on the target semiconductor inventory holding information given by the buyers surveyed, the mean inventory holding target was 24 days.

**Figure 4-3**
**Current Targeted Semiconductor Inventory Holding Levels (N = 84, Do Not Know/ Refused = 20)**




Source: Dataquest (November 1997)

## Semiconductor Inventory Holding: Actual versus Target

Theory and practice are often different. Dataquest asked buyers to state whether their current actual inventory holdings were at, below, or above their target inventory levels. The results of this are shown in Table 4-1.

Even though 8 percent of respondents maintained inventory levels lower than their targets, the vast majority of buyers surveyed did not exceed expectations! Although 43 percent of participants said that their actual semiconductor inventory holding level was the same as their target, a full 39 percent said that they were running with more inventory than their target. One-tenth of participants refused to comment.

**Table 4-1**
**Semiconductor Inventory Levels: Current versus Target**

| | Number of Respondents | Percentage |
|---|---|---|
| Same as Target | 45 | 43 |
| Higher than Target | 41 | 39 |
| Lower than Target | 8 | 8 |
| Do Not Know/Refuse | 10 | 10 |
| **Total** | **104** | **100** |

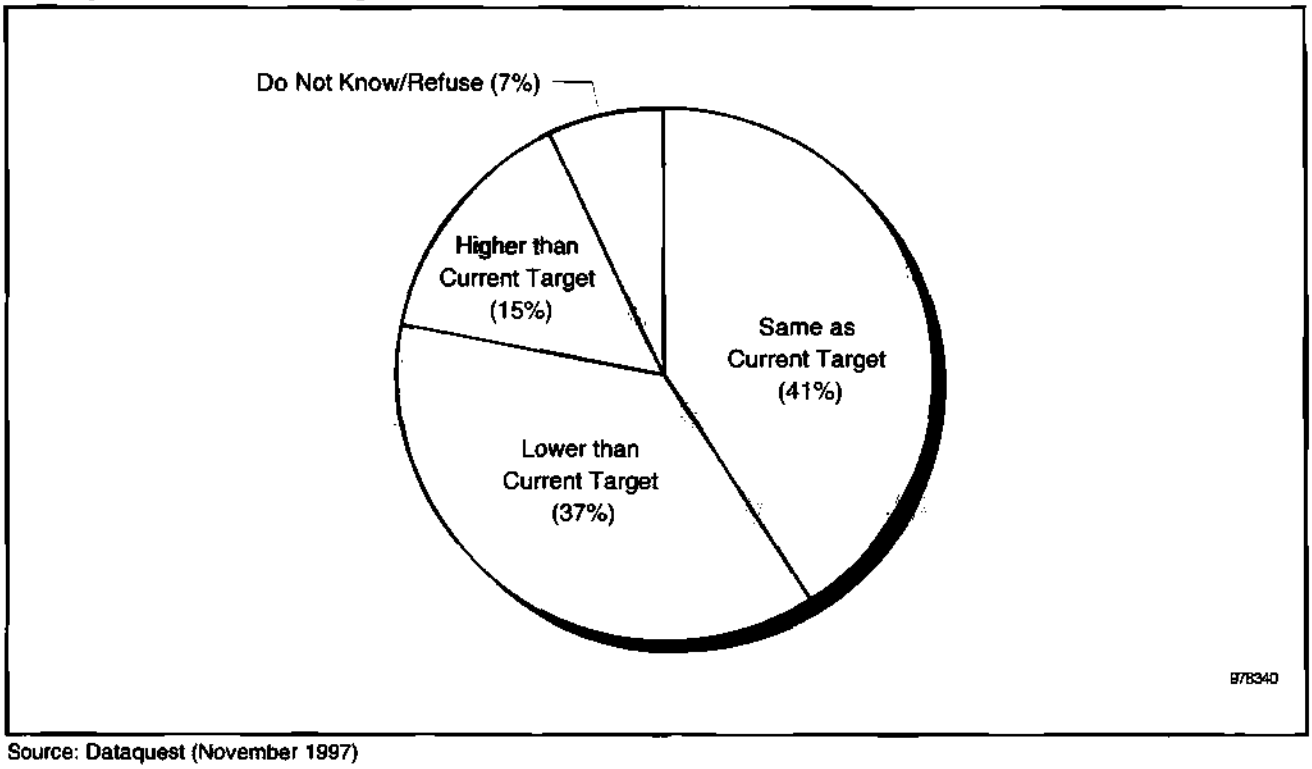
Source: Dataquest (November 1997)

## Future Semiconductor Inventory Holding Targets

Dataquest was interested to learn what would happen to the participants' targets for semiconductor inventory in the next 12 months. The buyers surveyed were asked how their 1998 inventory holding target would change compared to their present target. Figure 4-4 shows the results.

Over 40 percent of those participating in the survey said that their inventory target would remain the same for 1998 as it is for 1997. A further 37 percent, however, stated that next year's inventory target would be lower than their current target. However, 15 percent of the buyers surveyed acknowledged that their inventory holding target would be higher in 1998 than in 1997. The remaining respondents either refused to comment or did not know how next year's target would compare to this year's.

**Figure 4-4**
**Change Expected in Targeted Semiconductor Level, 1998 (N = 104)**



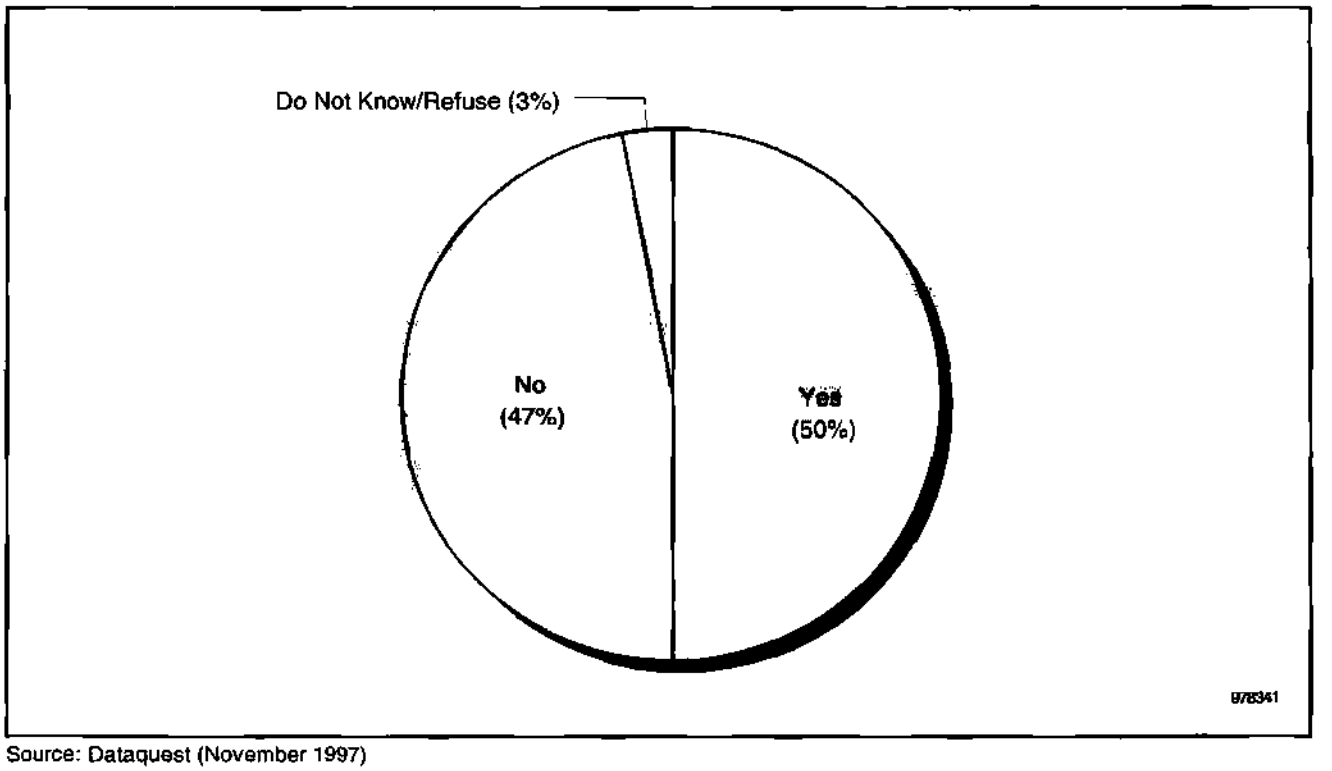

Source: Dataquest (November 1997)

## Total Cost of Ownership

The concept of TCO is often bandied about now. Pick up any procurement or logistics magazine and one will find articles that discuss this notion in varying depths. However, Dataquest wanted to see if there was any fire behind the smoke of TCO debate. The survey respondents were asked simply if their companies measured total cost of ownership of the semiconductor devices being purchased at present.

Figure 4-5 shows the results of TCO use by the buyers surveyed. It can be seen that the respondents were split almost down the middle. Half said they did measure TCO, while just under half said they did not measure it at the moment. It looks as if the jury is still out on TCO implementation for a lot of those surveyed. That said, though, it is very encouraging to see that half of the companies had implemented TCO within their organizations.

**Figure 4-5**
**Current Measurement of TCO (N = 104)**




Source: Dataquest (November 1997)

# Chapter 5
# How Buyers Buy: Procurement Sourcing Channels

When buyers want to obtain product, they have a number of sourcing channels open to them. These channels can be divided into three categories:

- From the device manufacturer (OEM)
- From a distributor
- From a redistributor or broker in the spot market

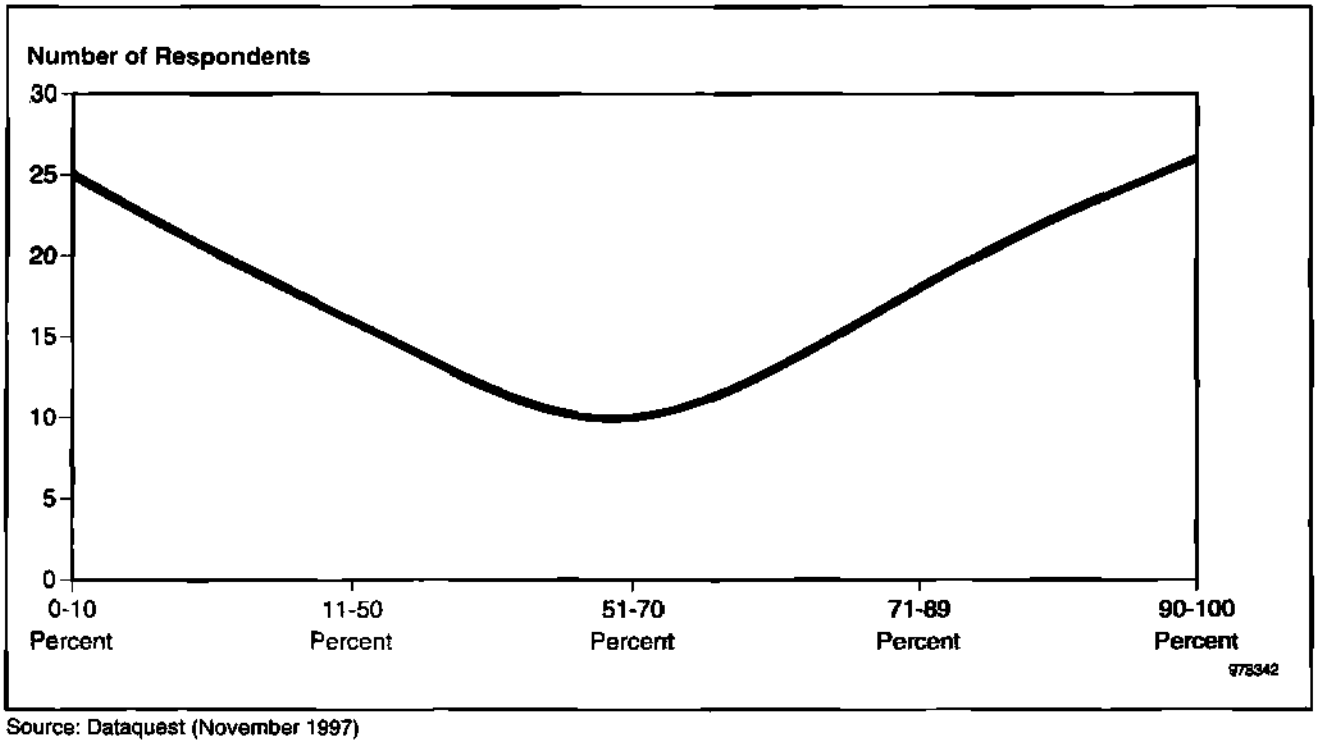
OEM procurement is direct procurement; the other two channels are indirect. That is about the only similarity between the distributor and redistributor channels. As any buyer will testify, there is a world of difference between buying from an authorized distributor and buying from the spot market.

In this chapter, Dataquest looks at the indirect sourcing channels—distribution and the spot market.

## Role of Distribution

Dataquest asked the buyers surveyed to state what percentage of their semiconductor spending was sourced through distribution channels. Figure 5-1 shows the results. Of the 95 respondents who answered this question, 10 said that they sourced no semiconductors from distribution (0 percent), while, on the opposite end of the spectrum, six buyers stated that all their semiconductors were sourced through distribution (100 percent).

**Figure 5-1**
**Percentage of Semiconductor Spending through Distribution Channels (N = 95)**




Source: Dataquest (November 1997)


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For ease of analysis, the responses have been grouped into five ranges. Figure 5-1 resembles a reverse bell curve, with the two largest groups falling within the 10 percent at either end of the spectrum. One-quarter sourced up to 10 percent from distribution, and just over one-quarter of those surveyed sourced 90 to 100 percent from distribution. Just over 40 percent of buyers sourced less than half of their semiconductor needs from distribution, but about 60 percent sourced more than half of their needs from distribution.

## Pros and Cons of Distribution

Dataquest wanted to obtain the buyers' views on the advantages and disadvantages of distribution. All survey respondents commented, and many chose more than one response.

The most commonly mentioned advantages of distribution were:

- Faster delivery
- Shorter lead times
- Greater flexibility
- Expected higher priority from distributor than OEM/felt more valued by distributor
- Greater support from distributor for inventory holding and stock support issues

The most commonly mentioned disadvantages of distribution were:

- Higher price
- Lack of in-depth technical support

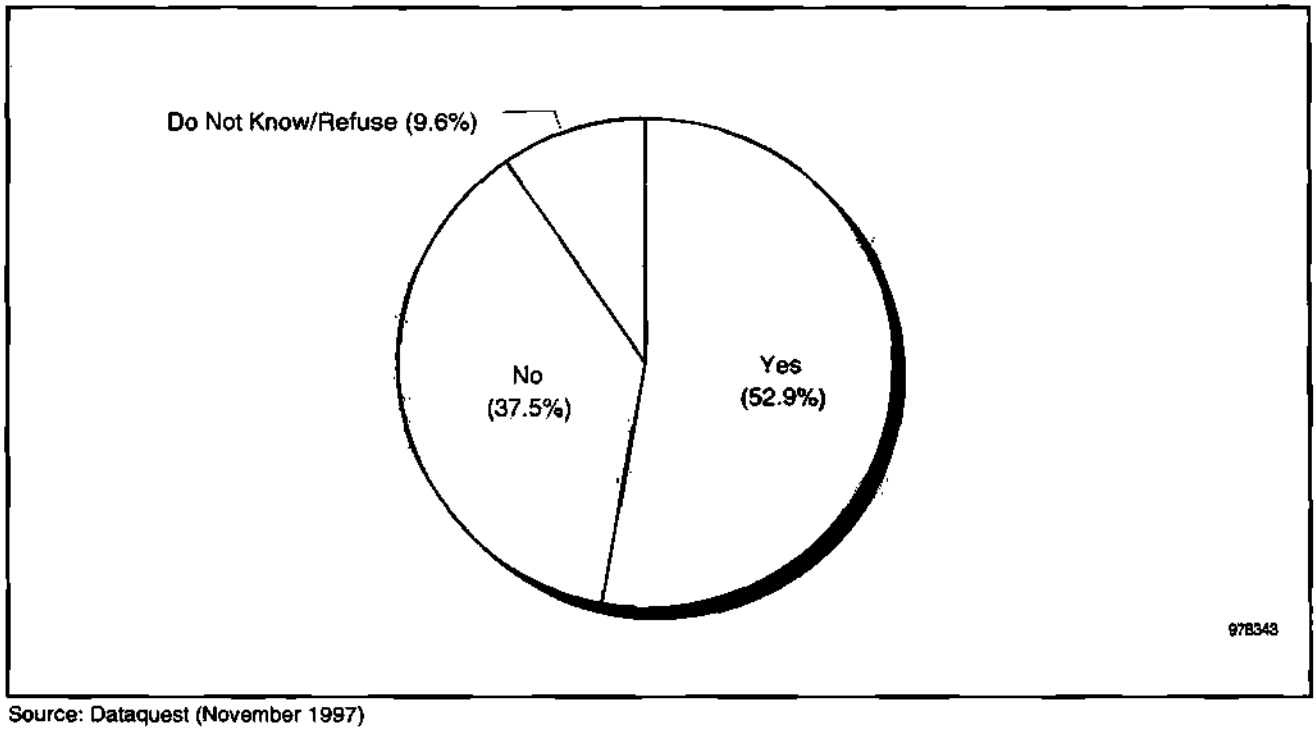
Thus, for many, the advantages outweighed the disadvantages.

## Spot Market

Because the spot market is a much-discussed area for product redistribution, Dataquest was interested to learn what percentage of buyers used this channel and what strategies they used. Also, Dataquest asked them to say which semiconductor device families they sourced from the spot market.

Dataquest first wanted to establish the percentage of buyers in the survey who used the spot market to source semiconductors. Figure 5-2 shows that about 53 percent of the respondents did use the spot market, and 38 percent said they did not use it. Over 9 percent either did not know if they used the spot market or refused to comment.

**Figure 5-2**
**Spot Market Purchases of Semiconductors (N = 104)**




Source: Dataquest (November 1997)

## Strategy toward the Spot Market

Those who admitted to using the spot market on occasion for semiconductor sourcing were asked for their strategy for using it. The results are shown in Table 5-1. Ninety percent said they use the spot market only when they have to. This means that they source product from the redistribution channel only as a last resort. Five percent were opportunistic—they source some product from the spot market if it is cheaper than their usual suppliers. The remaining 5 percent source product only from the spot market. One wonders how wise it is to single-source semiconductors from the spot market.

**Table 5-1**
**Spot Market Strategies**

| | Number of Respondents | Percentage |
|---|---|---|
| Use Only When Necessary | 49 | 90 |
| Use When the Spot Market Is Cheaper | 3 | 5 |
| Buy All Products from the Spot Market | 3 | 5 |
| **Total** | **55** | **100** |

Source: Dataquest (November 1997)

## Semiconductor Device Families Procured from the Spot Market

Dataquest sought to discover which semiconductor device families were sourced from the spot market. The buyers surveyed were asked to select which of a list of device families they bought from the spot market. The results of their selection are grouped in Table 5-2.

**Table 5-2**
**Device Families Bought on the Spot Market (N = 55)**

| | Number of Respondents | Percentage |
|---|---|---|
| Programmable Logic Devices | 23 | 42 |
| DRAM (Including Modules) | 21 | 38 |
| SRAM | 21 | 38 |
| EPROM | 20 | 36 |
| Compute Microprocessors | 20 | 36 |
| Controllers | 20 | 36 |
| Flash Memory | 18 | 33 |
| EEPROM | 18 | 33 |
| Optoelectronics | 17 | 31 |
| Digital Signal Processors | 14 | 25 |
| Others | 14 | 25 |

Source: Dataquest (November 1997)

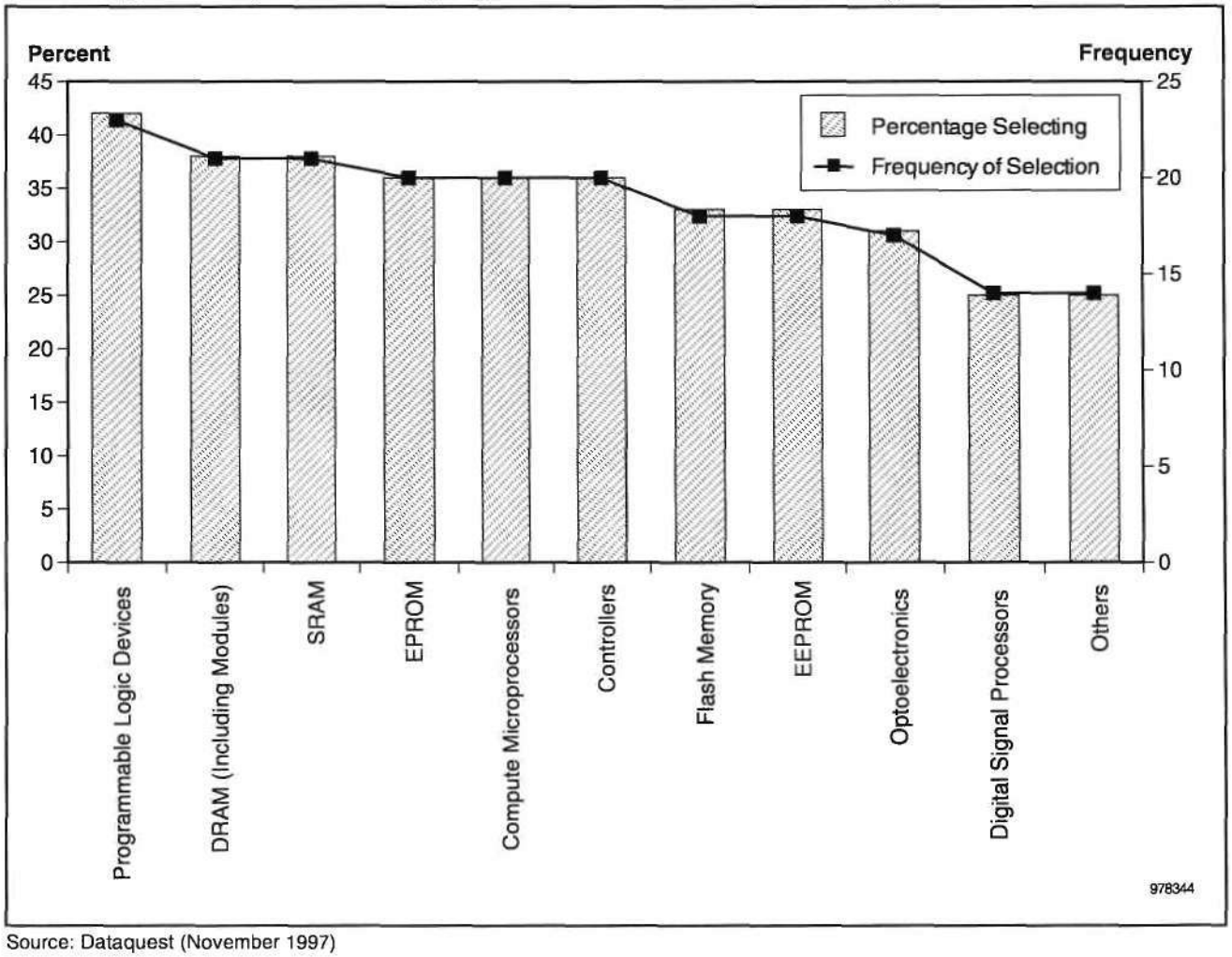
Please note that buyers were asked to select as many device families as were applicable, so each percentage shown in Table 5-2 is independent of the others. Each shows the percentage of the 55 participants who buy or have bought that device family from the spot market.

For ease of viewing, Figure 5-3 graphs the frequency with which each device was selected and its percentage. The device family most widely sourced in the spot market was PLDs—42 percent of all buyers who use the spot market source PLDs there.

The next group consisted of two memory devices, DRAM and SRAM. Of those buyers using the spot market, 38 percent buy these devices there. EPROM, compute processors, and controllers form the next group, with 36 percent of spot market users selecting these categories.

Close behind were flash and EEPROM, which were bought by 33 percent of the group. Thirty-one percent of respondents who use the spot market buy or have bought optoelectronics, while DSPs and other devices were bought by 25 percent. The "others" listing is a mixed bag made up of clients who refused to state what devices they bought, those who bought discretes, and those who bought a wide variety but would not specify.

**Figure 5-3**
**Percentage of Respondents Buying Each Device Family on the Spot Market**




Source: Dataquest (November 1997)

# Chapter 6
# Who Buyers Deal With: Supply Base Analysis

Talk to most buyers for any length and the question of vendor base reduction always surfaces as a concern. Buyers talk about adopting a scheme to maximize the commercial benefits to the company while minimizing the number of vendors employed. However, because of the variety of component needs of the end product and because of vendor specialization, buyers are often forced to deal with more vendors than they would like. It becomes a juggling act for buyers to manage all of the vendor interfaces to ensure that the best deal is being obtained.

Many talk about the concept of strategic vendors—vendors that have been deemed to be of the utmost importance to the buyer's company and integral to its continued success. In short, these are the suppliers that play a vital role in the life of the buyer's company.

This chapter examines the supply base trends of the 104 participants. It looks at how many vendors they currently deal with and how this has changed from 1996 and will change in 1998. Chapter 6 also explores the concept of strategic suppliers. Issues such as vendor-of-choice (VoC) programs, trust, and the sharing of information between buyers and suppliers are discussed in Chapters 7 and 9.

## Current Supply Base

Dataquest asked all survey participants how many vendors they currently use. Figure 6-1 shows the results. Nearly seven out of 10 buyers surveyed deal with fewer than 40 vendors. About two out of 10 buyers surveyed deal with 40 to 100 suppliers, while one out of 10 buyers has a total vendor base of between 101 and 700.

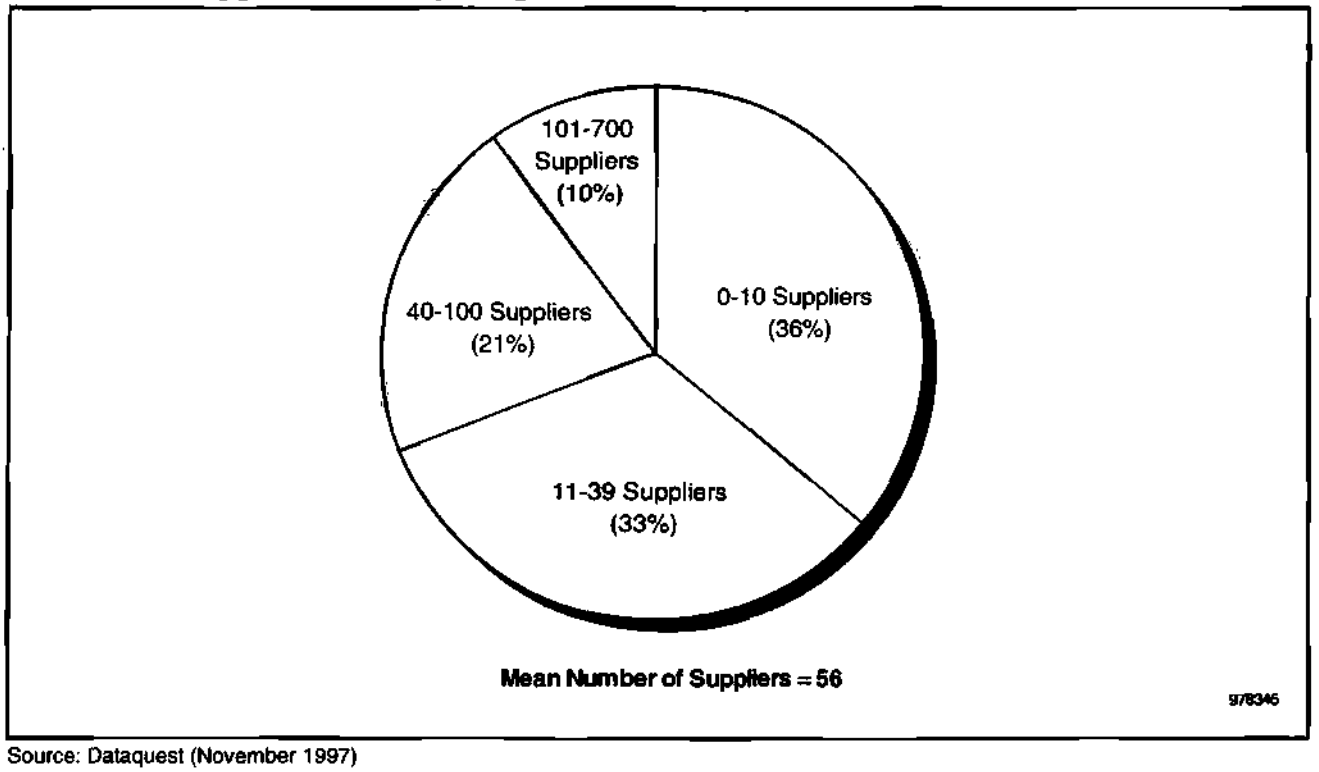
Most buyers have between two and 10 suppliers—36 percent of respondents fell into this range. Those with 11 to 39 vendors accounted for 33 percent of buyers surveyed. The rest of those surveyed deal with more than 40 different vendors. Based on the 104 completed responses gathered by Dataquest, the mean number of vendors used by buyers is 56.

However, given that a mere 10 percent of buyers deal with more than 100 vendors, the vendor base of 56 is artificially high. Removing these 10 respondents and reducing the sample size to 94 produces a different result. In this case the mean number of vendors used by the buyers is 29.

## Changes from 1996

Figure 6-1 details the current number of vendors with which buyers deal. However, Dataquest wanted to see if the vendor base strategy of the participating buyers had altered much from 1996, so the surveyed buyers were asked how their current vendor base has changed from 1996.

**Figure 6-1**
**Number of Suppliers Used by Respondents in 1997 (N = 104)**




Source: Dataquest (November 1997)

Table 6-1 shows how the current size of the supply base has changed from 1996. Well over half of the respondents stated that the size of their vendor base remained unchanged from 1996 to 1997. This would mean either that these buyers had conducted a vendor rationalization program before 1996 and reached a vendor base number with which they are satisfied or that these buyers have not done a vendor reduction exercise and are just using the previous year's supply base.

**Table 6-1**
**Change in Number of Suppliers since 1996**

| | Number of Respondents | Percentage |
|---|---|---|
| Same | 57 | 55 |
| Increased | 17 | 16 |
| Decreased | 27 | 26 |
| Do Not Know/Refuse | 3 | 3 |

Source: Dataquest (November 1997)

Interestingly, over one-quarter of the buyers surveyed said that they have decreased their vendor base from 1996. This would indicate that these buyers are in the process of vendor rationalization. This reduction program could be deliberate, through purchasing consolidation, or accidental, through product changes.

About 16 percent of surveyed buyers said that they have increased the number of vendors they deal with from 1996.

## Changes Expected in 1998

Dataquest also sought to discover what plans the buyers had for their vendor base size. Table 6-2 shows that about half of the participants have no plans to change their vendor size—in line with the results in Table 6-1. One-fifth of buyers in the survey plan to increase their vendor base size in 1998, and about one-third plan to decrease their vendor base size next year.

**Table 6-2**
**Change in Number of Suppliers Expected in 1998**

| | Number of Respondents | Percentage |
|---|---|---|
| Same | 49 | 47 |
| Increased | 21 | 20 |
| Decreased | 33 | 32 |
| Do Not Know/Refuse | 1 | 1 |

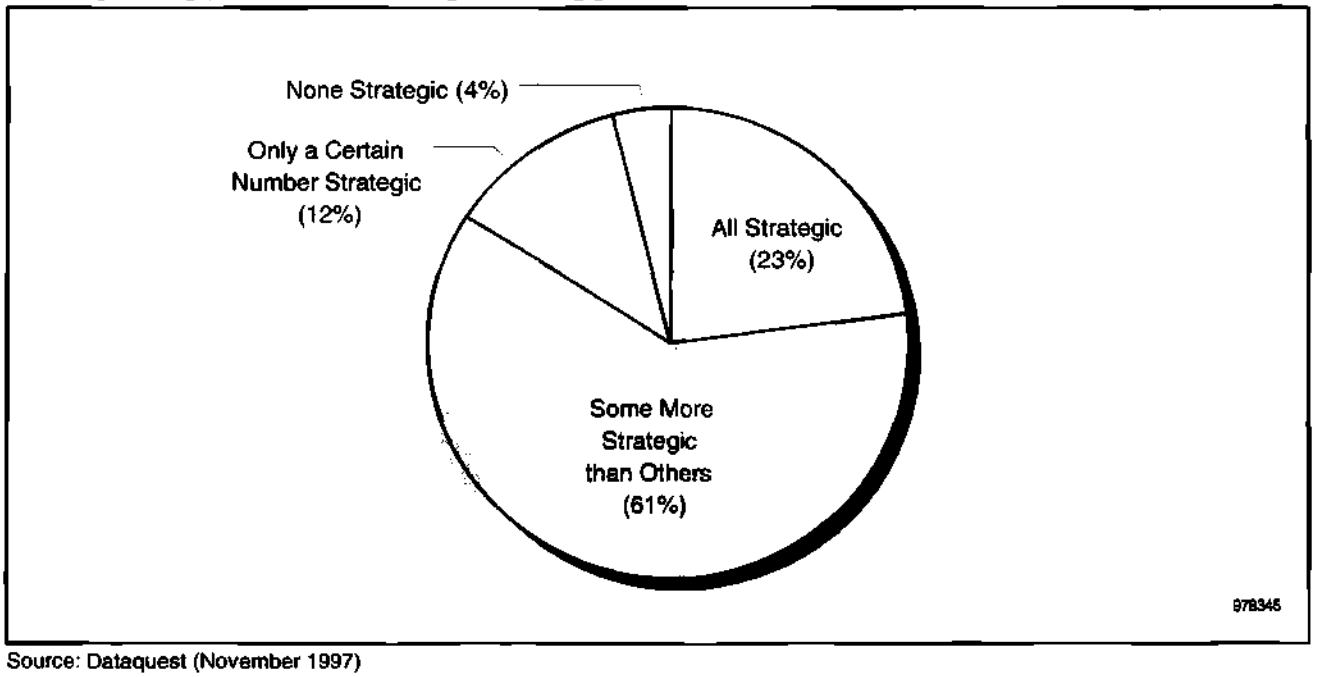
Source: Dataquest (November 1997)

## Strategic Suppliers

As was shown in Figure 6-1, all buyers surveyed deal with multiple suppliers. There has been a trend for buyers to rank vendors into strategic and nonstrategic categories. The reasons why one supplier is strategic and another is not are many and may include spending, component importance, technology access, corporate goals, and manufacturing capability.

Dataquest wanted to see if the buyers in this survey had strategic suppliers. Instead of asking the participants for a straight "yes or no" answer, Dataquest asked them to pick a statement that best fit their company's opinion on strategic suppliers. The results are shown in Figure 6-2.

**Figure 6-2**
**Strategic Suppliers versus Regular Suppliers**




Source: Dataquest (November 1997)

Only 4 percent of respondents stated that none of their current vendors was strategic, while an impressive 23 percent of respondents stated that all their suppliers were strategic.

Nearly three-quarters of participants had a certain number of strategic suppliers, although it is interesting to see which statement they chose of the two offered by the survey that would have been appropriate responses to the question. The two choices were "some suppliers are more strategic than others" and "only a certain number of suppliers is strategic." Both phrases have the same meaning but express it differently. The first phrase is more "touchy-feely" and less clearly defined, while the second phrase is more logical, more definite, and less open to interpretation. Interestingly, the majority of the surveyed buyers picked the first phrase. What does this say about the buyers? If only I were a psychologist and not an analyst, I could respond.

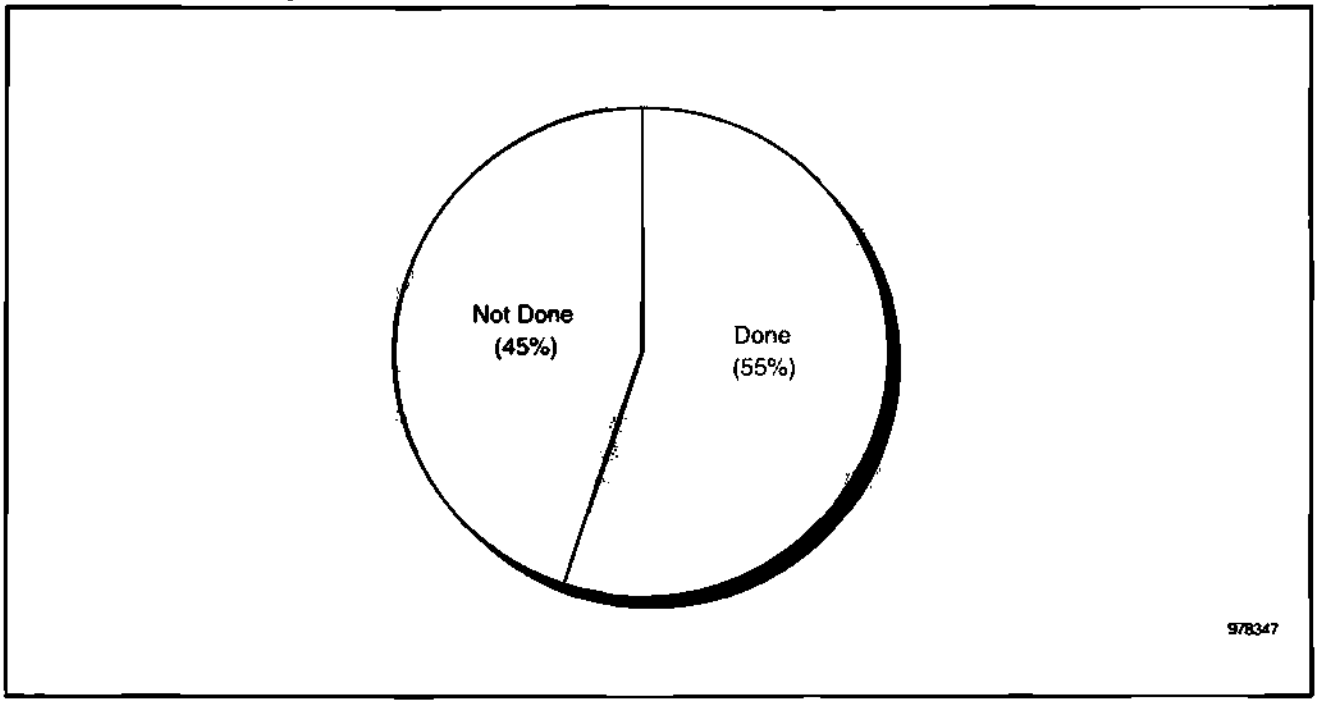
# Chapter 7
# How They Are Doing: Vendor-of-Choice Programs and Trends

One of the most far-reaching changes over the past five years impacting suppliers of all products are vendor-of-choice—or similar—programs. VoC programs involve a regular review of supplier compliance with agreed-to goals as part of efforts to improve supplier performance. The concepts of strategic vendors, vendor reduction, and total cost of ownership all involve VoC and are all dependent on a VoC program in one form or another.

## Do They or Don't They?

Dataquest wanted to see what percentage of the surveyed buyers actually conduct formalized, regular vendor measurement. In other words, Dataquest sought to discover whether buyers had a vendor-of-choice program. As shown in Figure 7-1, more than half (55 percent) of the respondents performed regular vendor reviews, highlighting both the importance and opportunity of this increasingly important practice. It is important in that many semiconductor suppliers are now being regularly reviewed for improvement, and it is an opportunity for users to lower total costs by beginning some sort of VoC program.

**Figure 7-1**
**Performance of Regular Vendor Evaluation**




Source: Dataquest (November 1997)

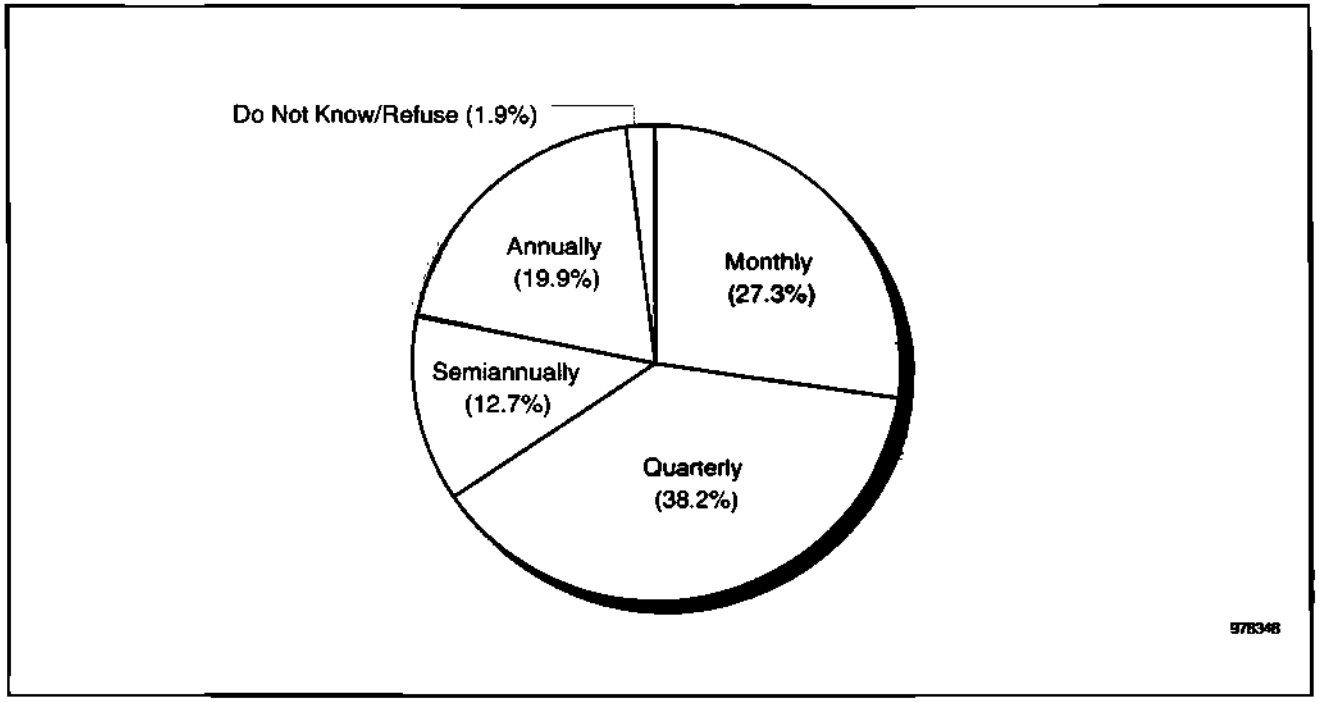

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## Frequency of VoC

The frequency of vendor review often is cited as a critical part of the overall review process. Reviews that are either too frequent are too time consuming for the benefits gained; those that are not regular enough can be so infrequent that they fail to reveal any meaningful improvement. Each company needs to determine the frequency of vendor review that will provide the most cost-effective improvement schedule for both supplier and user companies. Thus, Dataquest wanted to see what the frequency distribution was for the surveyed buyers.

Figure 7-2 shows that quarterly reviews are the most popular frequency for those respondents that perform reviews, with over one-third (38.2 percent) of the sample. The next-most-popular frequency is monthly reviews, with over one-quarter of the sample (27.3 percent) following this rigorous schedule. About one-third (32.6 percent) of those that review their supplier base do so every six months or annually—these companies either have very good relations with their suppliers or are in relatively stable markets that do not require frequent performance reviews. It was interesting to note that respondents were evenly split over which suppliers they reviewed. Emphasizing the need for each company to determine what is cost-effective, half of the respondents that performed reviews evaluated only strategic suppliers, while the other half reviewed all suppliers.

**Figure 7-2**
**Frequency of Performance Evaluation (N = 55)**




Source: Dataquest (November 1997)

## Suppliers That Are Tracked

The majority of buyers have strategic and nonstrategic vendors—a resounding 96 percent had either some strategic vendors or had only strategic vendors. However, only 55 percent of the sample also had a regularly conducted VoC program. Dataquest then asked this 55 percent to indicate the vendors with which they conducted this performance evaluation. Table 7-1 shows the results.

**Table 7-1**
**Vendors Evaluated Regularly**

| | Number of Respondents | Percentage |
|---|---|---|
| All Vendors | 28 | 49 |
| Only Strategic Vendors | 28 | 49 |
| Do Not Know/Refuse | 1 | 2 |

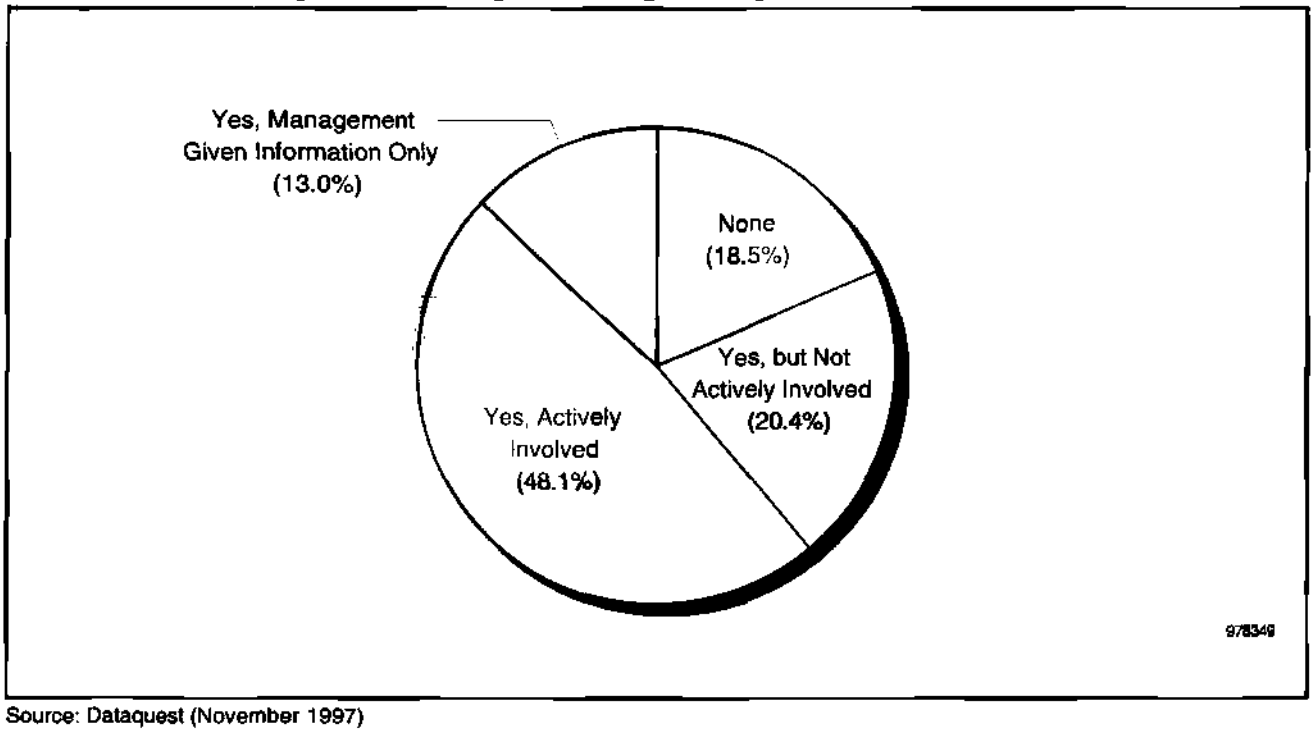
Source: Dataquest (November 1997)

It can be seen that the percentage of those who performed vendor-of-choice evaluations for their entire vendor base was the same as those who performed it only for their strategic vendors, 49 percent. The "do not know/refused" responses accounted for the remaining 2 percent.

## Management's View

Although VoC programs are critical to those directly involved, they are sometimes given only lip service by the rest of management within a participating company. We asked the sample whether their VoC program was a priority for the nonpurchasing management of their companies. Figure 7-3 shows that, for most, the rest of management is either actively (48.1 percent) or partly (20.4 percent) involved, while close to one-fifth (18.5 percent) of the respondents still had no outside management involvement in this critical area. Although it is encouraging that more than 80 percent of the sample saw management outside of purchasing take VoC programs as some sort of a priority, it is still disconcerting that close to 20 percent of companies that have VoC programs do not have buy-in from management outside of purchasing.

**Figure 7-3**
**Priority of VoC Program for Nonpurchasing Management**




Source: Dataquest (November 1997)

# Chapter 8
# What Matters: Importance versus Satisfaction

There are many factors that create a good working relationship between the buyer and the seller, and the vendors' ability to perform what's needed by their customers when it matters is crucial. However, it is often difficult for vendors to assess how they're doing and which of many issues matters most to their customers (the buyers). In other words, it is sometimes difficult to see the forest for the trees—of all the issues floating out there, which are the most important to buyers, and how do the vendors shape up? This chapter attempts to gauge the importance to buyers of key procurement issues and to measure their satisfaction levels.

For ease of analysis, this chapter has been broken into seven subsections. Each subsection covers a key purchasing topic, and the survey participants were asked to rate importance and satisfaction levels for a list of related criteria. The seven subsections are: delivery issues, quality issues, responsiveness issues, technical support issues, flexibility issues, total cost of ownership issues, and price issues.

The participating buyers were asked to rate the importance of a criterion and also how satisfied they were with their vendors on that criterion. The scale of measurement was 1 to 5, with 1 being the least important or least satisfied and 5 being the most important or most satisfied. All 104 survey participants responded, and their mean score is plotted.

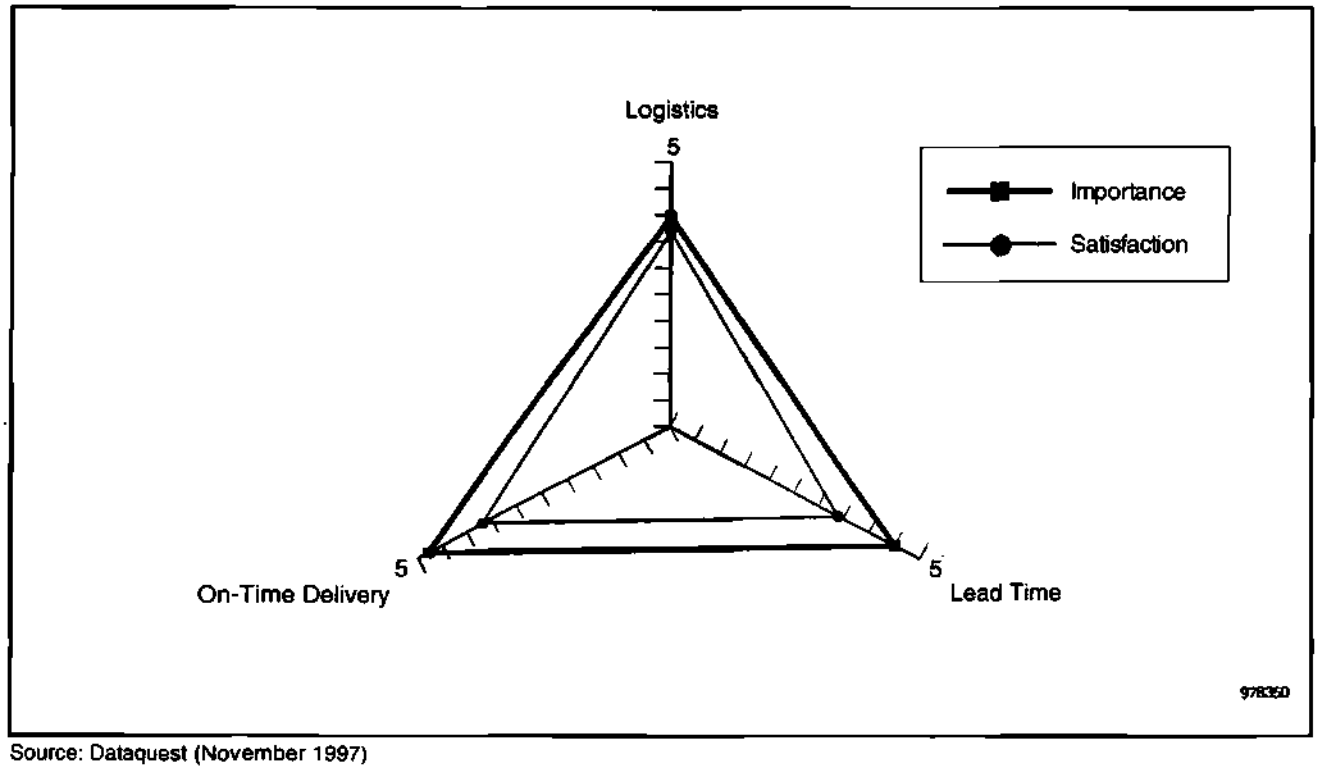
## Delivery Issues

Dataquest broke delivery into three issues: logistics, lead times, and on-time delivery. Figure 8-1 plots the mean score given by buyers on importance versus satisfaction levels for these issues. From this it can be seen that vendors were underachieving on each of the three delivery issues—that is, the mean satisfaction score was lower than the mean importance score.

For logistics, the importance and satisfactions levels were relatively close. However, according to the buyers surveyed, logistics was the least important of the three delivery issues. Ironically, it received the highest satisfaction score.

On-time delivery was the most important of the delivery issues, followed closely by lead times. This is not surprising. If buyers cannot trust the accuracy of vendors' delivery schedules, what can they trust? If buyers cannot procure product within a reasonable time, how do they survive? However, it is clear from the results that most buyers believe that their vendors have some work to do on these fronts. The difference between the mean importance score and the mean satisfaction score was 1.12 and 1.1 for on-time delivery and lead times, respectively, with satisfaction lagging importance in both cases.

**Figure 8-1**
**Delivery Issues**




Source: Dataquest (November 1997)

## Quality Issues

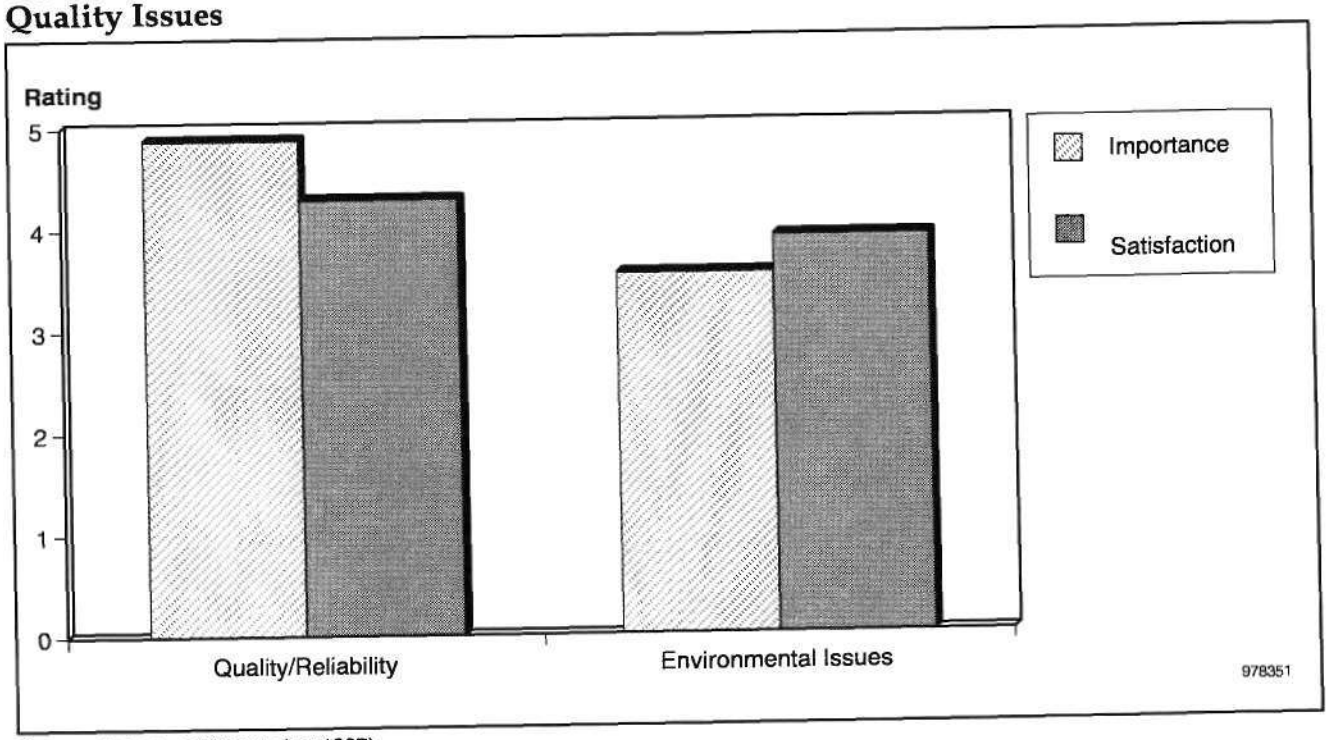
Quality issues were divided into two parts: product reliability and environmental issues. From Figure 8-2 it can be seen that the results are some what mixed. Buyers are less concerned about environmental issues than reliability issues. However, the satisfaction level on the environmental issues exceeds the importance level. Clearly, vendors have done more than enough on this front, and buyers are happy.

For quality and reliability, the mean score was 4.88 (of a maximum of 5). Product reliability is crucial in the buyer/seller relationship, a fact that buyers clearly recognize. Product reliability is the foundation on which the relationship is built. No matter how tall a building the buyers and sellers build, without solid product reliability, it will topple and fall. Buyers are fairly pleased with the results of their vendors giving a mean satisfaction rating of 4.29 (just 0.59 behind the mean importance score). However, this is a key issue sellers can keep working on—there is no such thing as a product that is too reliable in the minds of customers!

## Responsiveness Issues

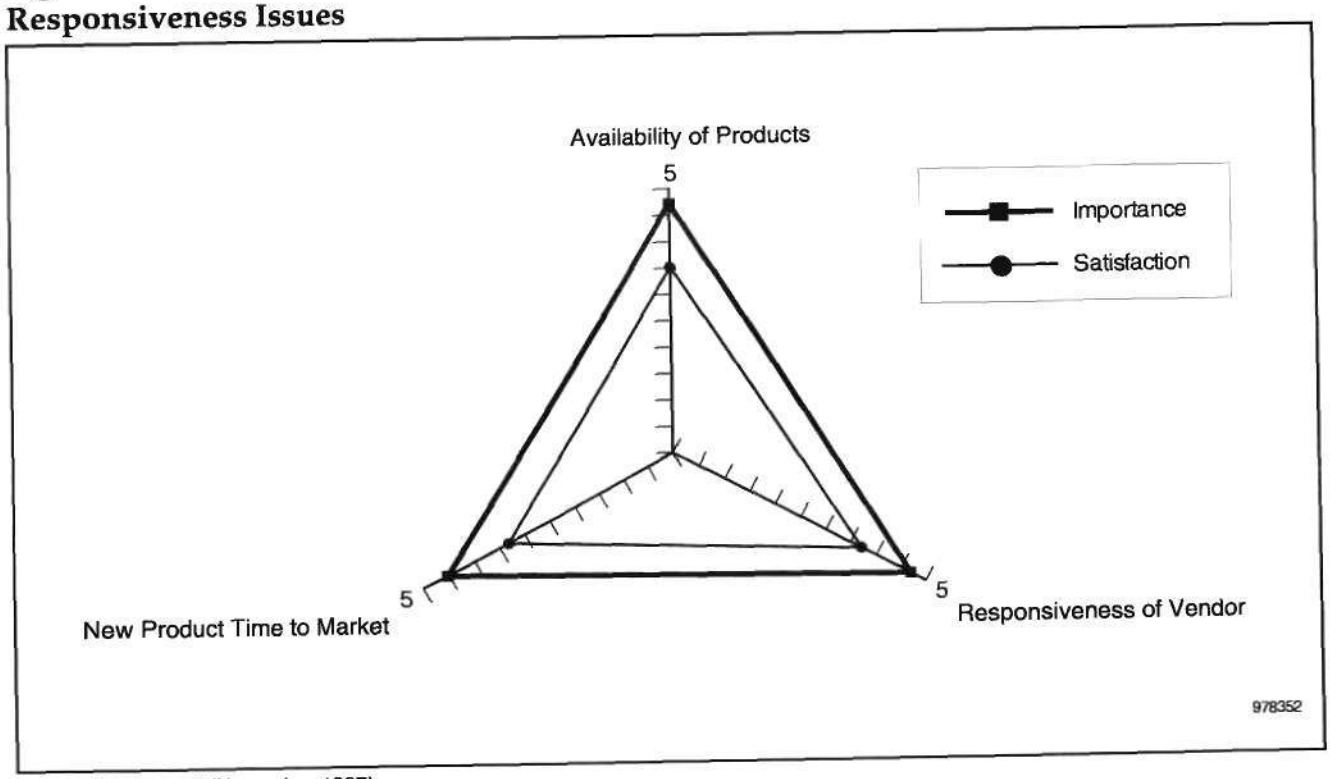
This subsection covers three issues: product availability, vendor responsiveness, and the speed with which new products are brought to market. The mean scores are shown in Figure 8-3. All received very high importance ratings—4.72, 4.69, and 4.53 for availability, responsiveness, and new product speed to market, respectively.

## Figure 8-2
## Quality Issues




Source: Dataquest (November 1997)

## Figure 8-3
## Responsiveness Issues




Source: Dataquest (November 1997)


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However, for each of the three criteria, buyers' mean scores for satisfaction were lower than the mean scores for importance. For both product availability and speed of new product introduction, the difference between importance and satisfaction was 1.2. For vendor responsiveness, the difference was 0.98.

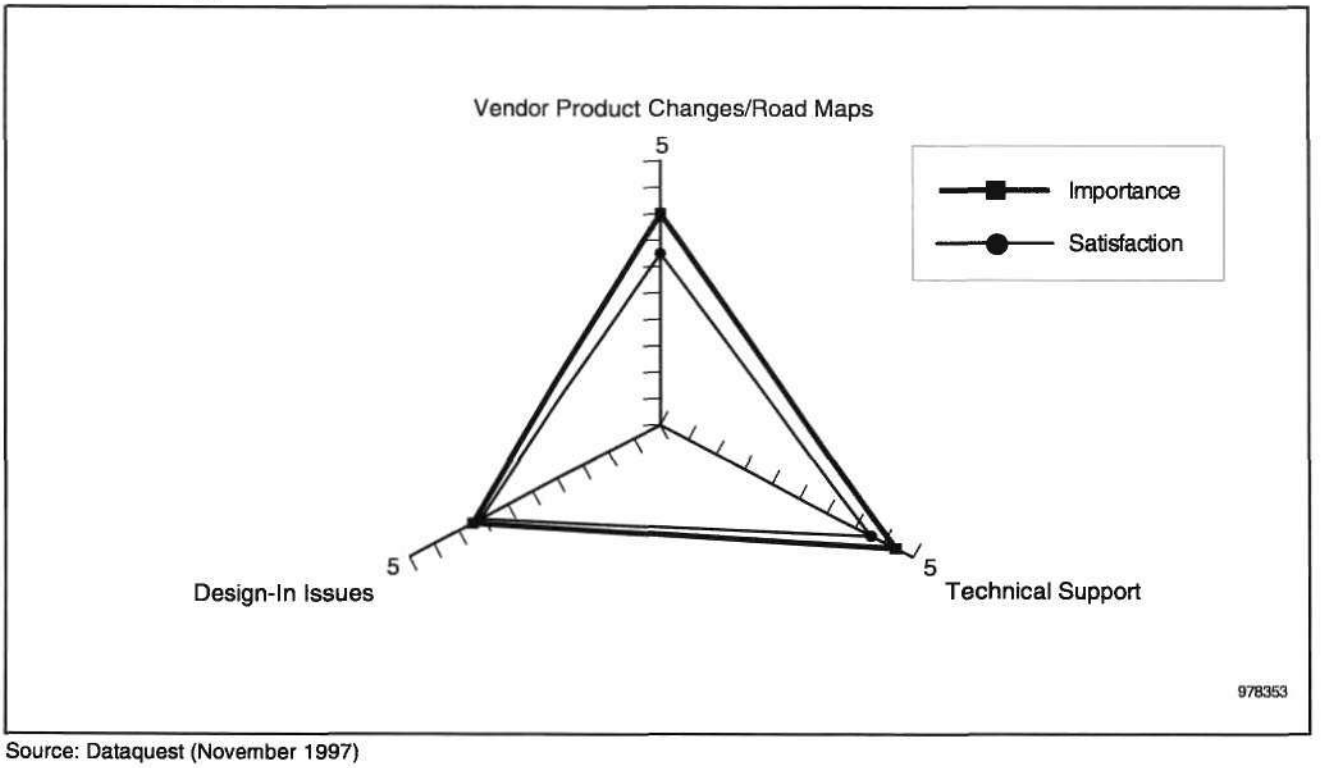
Vendors: There is definite room for improvement in this arena!

## Technical Support Issues

Technical support comprises three parts: vendor product changes or road maps, technical support, and design-in issues. The mean scores have been plotted in Figure 8-4. Design-in issues were the least important (a score of 3.72), while actual technical support (at 4.2) was the most important of the three. However, once again, satisfaction levels are lower than importance levels for all three.

For design-in issues, the difference between importance and satisfaction is a mere 0.16. Clearly, buyers believe that, once a device has been approved by engineering (designed in), this becomes a less important technical issue in the buyer/supplier relationship. The difference for the other two criteria is large enough to warrant greater focus on them by vendors.

**Figure 8-4**
**Technical Support Issues**




Source: Dataquest (November 1997)

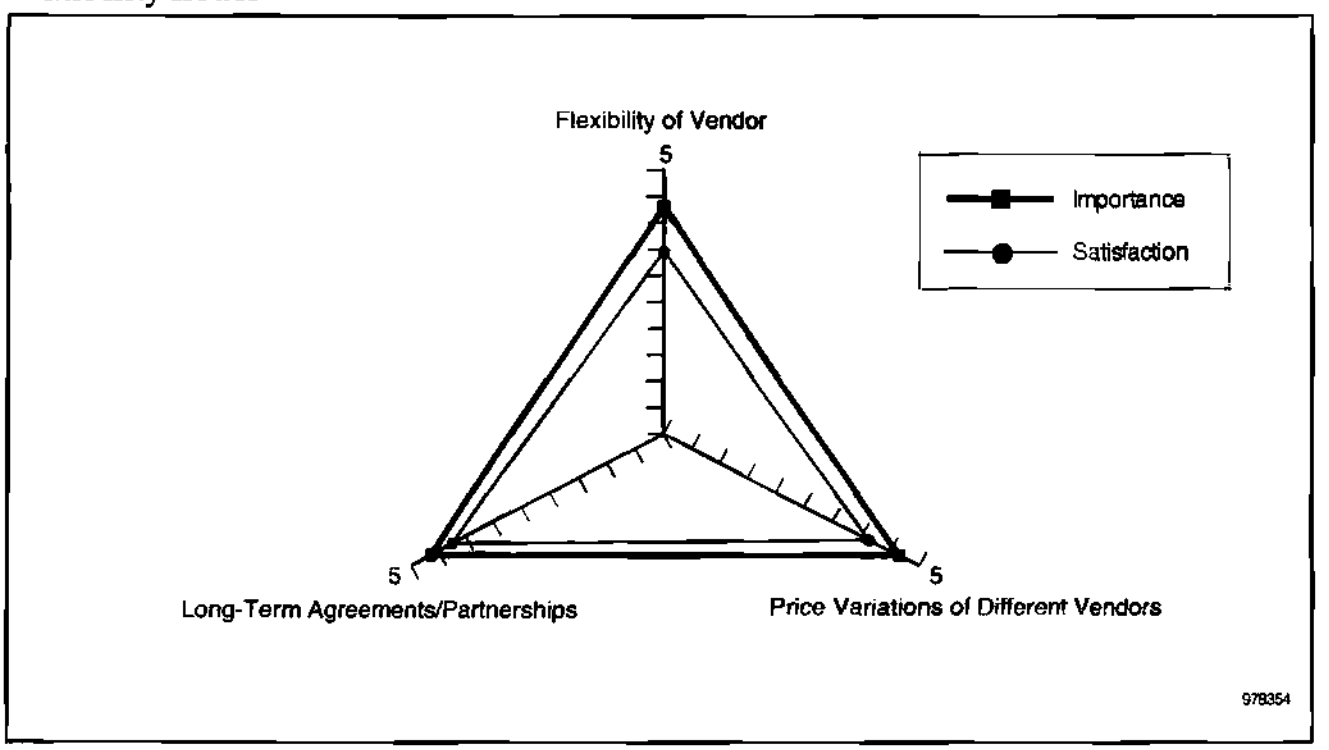
## Flexibility Issues

Dataquest asked about three criteria: vendor flexibility, managing the price variation between different vendors, and long-term agreements and partnerships. The mean scores for importance and satisfaction are plotted in Figure 8-5.

Of the three criteria measured, vendor flexibility received the highest importance score but the lowest satisfaction score. The mean satisfaction score trailed the mean importance score by 0.84. The other two criteria received almost the same importance mean score—4.15 and 4.13 for price variations and long-term agreements, respectively. However, in both cases, satisfaction lags behind importance.

This is a difficult area for vendors. Aside from the criterion of vendor flexibility, many suppliers feel that it is hard for them to improve on the other flexibility issues. For a criterion such as price variations between different vendors, obviously a buyer would like vendors to match the lowest price offered. Often a vendor feels powerless, because manufacturing costs and pricing strategies vary from company to company. However, if a buyer believes that a vendor has too high a margin and if the buyer can buy the same product for less from another vendor, then chances are high that the buyer will! Buyers do not expect price parity between vendors, but they do expect a vendor to follow market trends and to react to changing market dynamics.

**Figure 8-5**
**Flexibility Issues**




Source: Dataquest (November 1997)

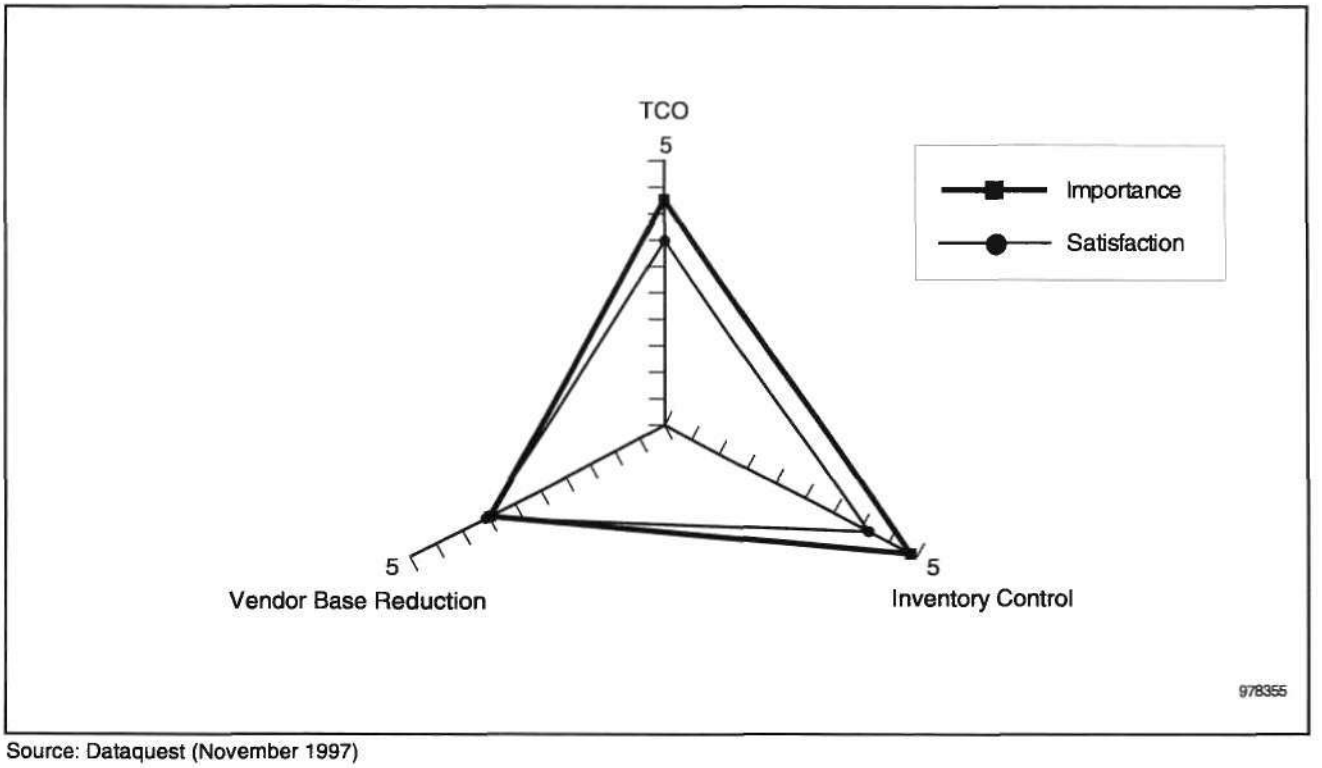
For long-term agreements, it is true that often it is the buyers' company that sets the framework, but a vendor can negotiate—a buyer and seller then come up with an agreement that works for both of them. A buyer has to feel that the vendor's company is making compromises for the greater commercial good of both parties and is truly committed to the future of the partnership. The words must be backed by actual deeds for credibility to exist. The mean scores in Figure 8-5 show that the surveyed buyers are satisfied with their vendors' performance to date.

## Total Cost of Ownership Issues

Dataquest asked about three different criteria—total cost of ownership, inventory control, and vendor base reduction. The mean scores for importance and satisfaction are shown in Figure 8-6.

Inventory control was clearly the most important of the three criteria measured, with a mean score of 4.39. And the vendors seem to be responding, because the satisfaction mean score was highest for inventory control. However, it still trails behind the importance score, so vendors definitely need to keep working on this one.

**Figure 8-6**
**Total Cost of Ownership Issues**




Source: Dataquest (November 1997)

TCO came in as the second most important of the three criteria, receiving a mean score of 4.27. However, its satisfaction mean score was the lowest of the three. The buyers have spoken—they are not satisfied with their vendors' efforts to reduce TCO. In fairness to vendors, though, TCO is probably the hardest of the three to pin down. It is subject to so many variations in itself, and the way it is tracked by buyers seems to be in a state of flux (according to the vendors). However, any means to reduce the TCO on the side of the vendors is appreciated by buyers, and the buyers certainly believe that the vendors can and need to do more.

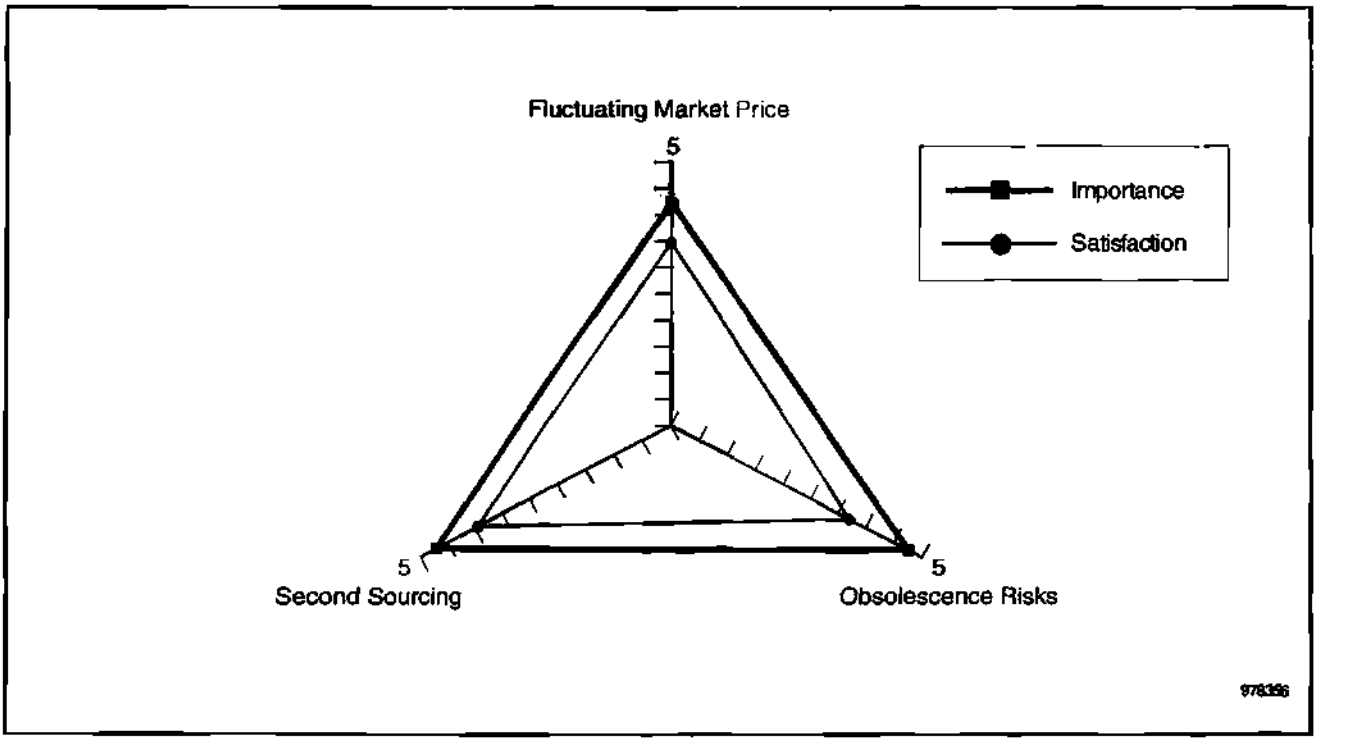
For vendor base reduction, the mean scores speak for themselves. Buyers do not rate it as important as the other total cost of ownership issues but are more than satisfied with their vendors on this front.

## Price Issues

The last of the areas covered is price, and Dataquest asked about three issues—fluctuating market price, obsolescence risk, and second sourcing. Of the three, obsolescence risk was the most important but scores the lowest on satisfaction (see Figure 8-7). Clearly, buyers think that vendors are not doing as much as they could to minimize their obsolescence risks or to share the cost pain. Again, this is something that needs more focus from vendors.

Fluctuating market price and second sourcing scored almost the same for both mean importance (4.22 and 4.21, respectively) and mean satisfaction (3.47 and 3.45, respectively). Both are important to buyers, and vendors have room for growth.

**Figure 8-7**
**Pricing Issues**




Source: Dataquest (November 1997)

## Summary

The buyers have spoken and their words are true.

Vendors are doing a reasonably good job of satisfying the buyers but still fall short of their customers' expectations. Some vendors would argue that the buyers' standards are too high and that a vendor cannot please every buyer all of the time. However, it must be remembered that the buyer is forking out the money and has a right to expect certain standards.


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## Chapter 9
# Truth or Token? Supplier and Buyer Trust

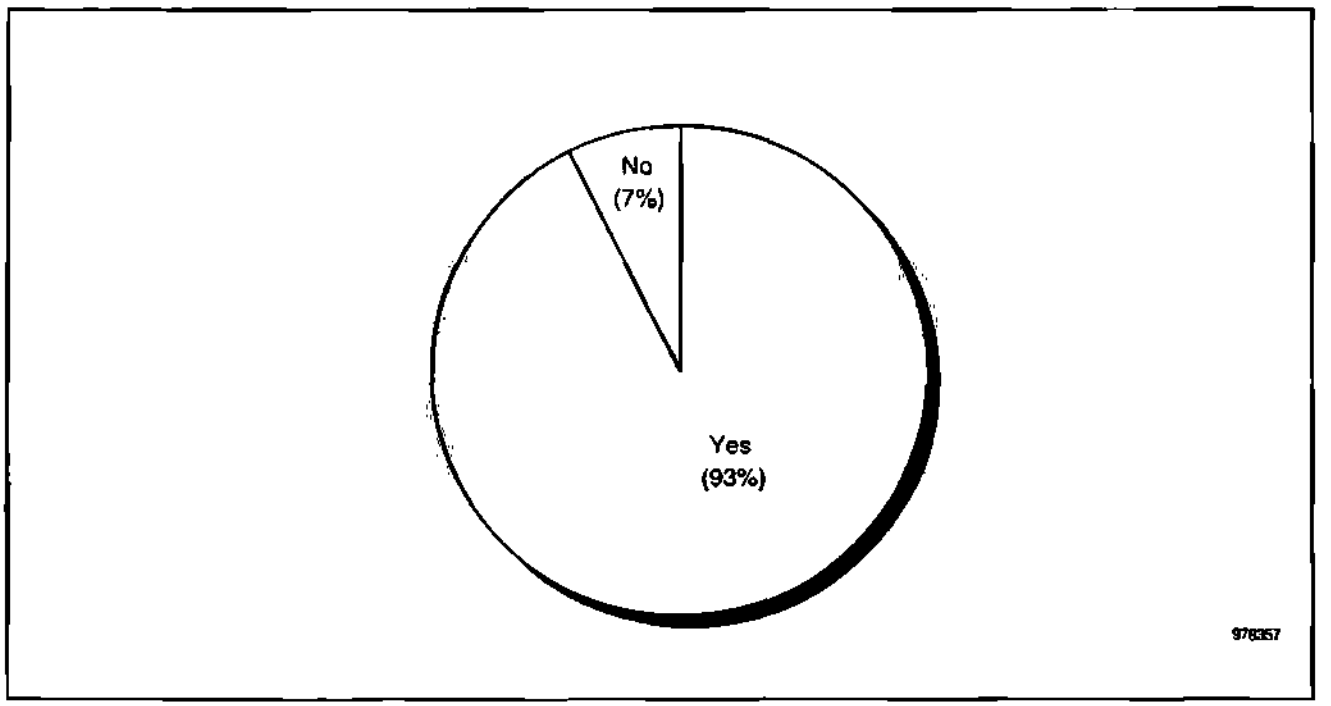
Over the years, supplier-buyer relations have run the gamut from the equivalent to warring camps, with each side out to beat their "opponent," to submission to "lovefests," with each company bearing in mind that suppliers have feelings, too, and should not be seen as the enemy. As the supplier/buyer pendulum continues to swing, it now appears that the most pragmatic approach to lowering overall costs and providing adequate revenue to suppliers correlates directly to the level of trust between the two parties involved. The bottom line is this: The more trust, the better the business relationship. Total costs are lower, and revenue streams are more consistent.

Critical in gaining and keeping trust between buyer and seller is the level of information exchange. Vendor-of-choice programs are regularly used by Dataquest's sample of semiconductor users. A linchpin of trust retention involves user feedback about VoC findings to the supplier, with a program of scheduled improvement where warranted.

## Vendor of Choice Feedback to Suppliers

Dataquest asked the buyers surveyed whether they give VoC feedback to their vendors. As shown in Figure 9-1, a strong majority of more than 90 percent of the sample involved with VoC programs share their findings with their suppliers. This was expected, because the main focus of VoC is the goal of improving performance through agreed-upon metrics. What was interesting is the 7 percent of VoC participants that keep the information to themselves. This appears to contradict the purpose of the VoC concept, but the practice of sharing once-confidential information can be an incremental process for some companies.

**Figure 9-1**
**VoC Feedback to Vendors**



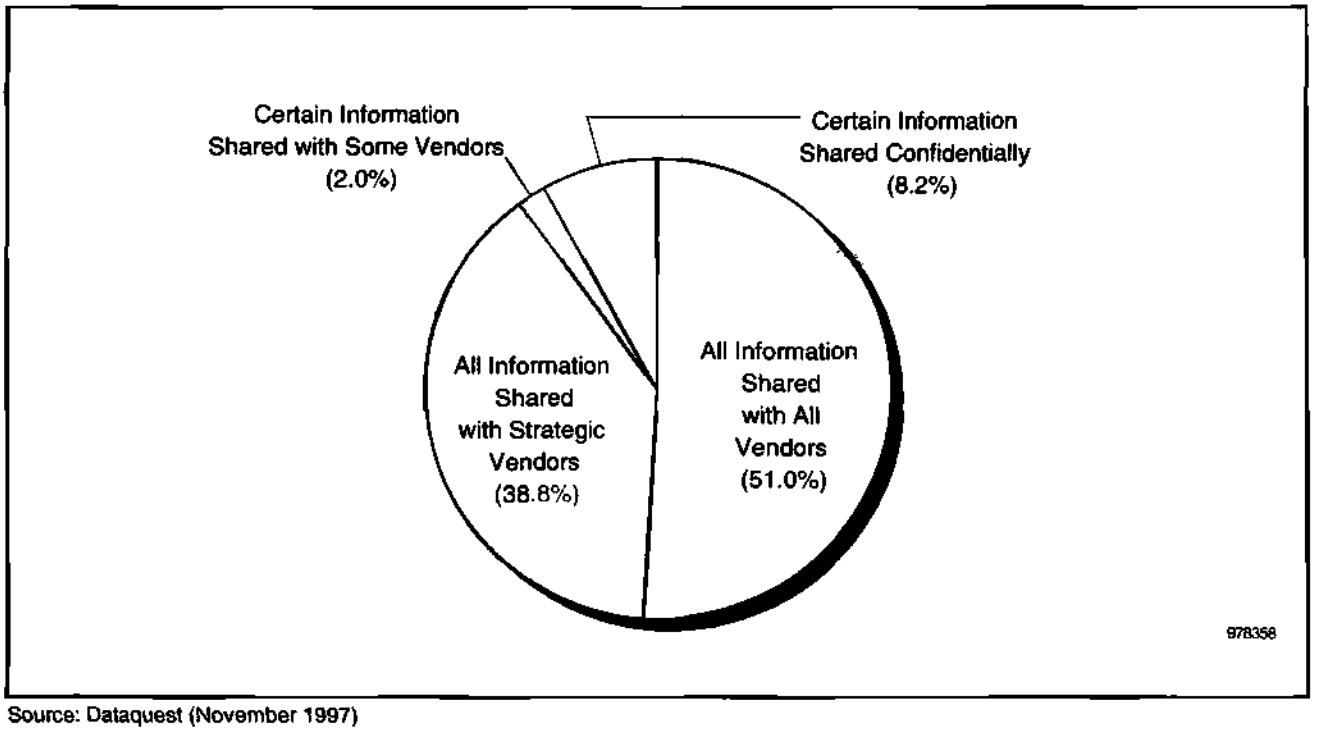

Source: Dataquest (November 1997)


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## How Is Information Shared?

How VoC information is shared often involves the type of information and with whom it is shared. Over half (51 percent) of the respondents with VoC programs share all the information gathered with all suppliers, as shown in Figure 9-2, while close to 40 percent (38.8 percent) of the respondents share information only with their strategic suppliers. A much smaller percentage shares limited information with selected suppliers. Close to 10 percent (8.2 percent) share certain information confidentially with vendors on a need-to-know basis only, while 2 percent of the respondents share select information with only some suppliers. Again, it appears that old habits are hard to break in the sharing of information, with some users reluctant to share all with their supply base. This should change toward sharing all information as the process becomes more comfortable.

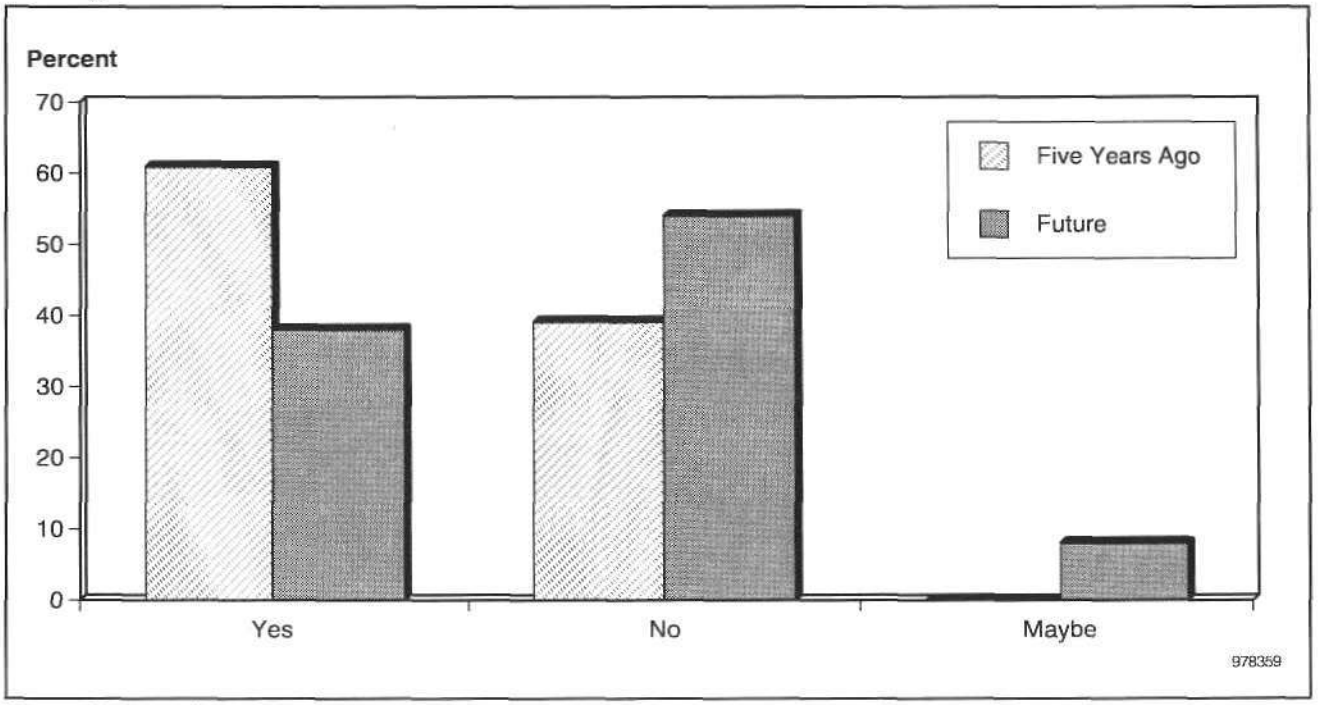
**Figure 9-2**
**Level of VoC Feedback to Vendors**




Source: Dataquest (November 1997)

Along these lines, Dataquest asked the sample to note how the practice of sharing information has changed and whether the respondents thought it would change in the future. Figure 9-3 shows that close to two-thirds (60.9 percent) of the study had changed the information shared over the past five years and that almost the balance (38.0 percent) plan on changing practices down the road. It was somewhat interesting that 8 percent were on the fence about whether to change practices in the future. This could be either a move toward or away from increased sharing of information with suppliers. One would hope the direction is toward the former rather than the latter.

**Figure 9-3**
**Changes in VoC Feedback to Vendors**

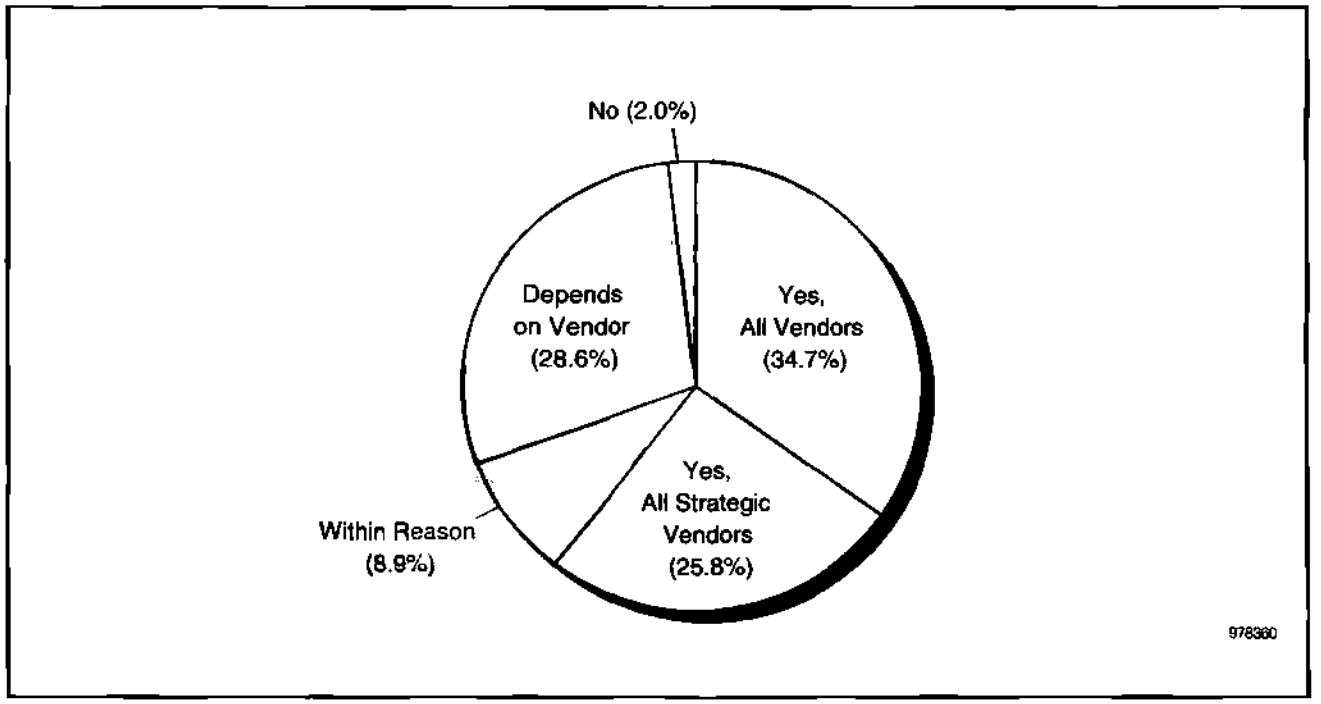



Source: Dataquest (November 1997)

## Buyer and Vendor Trust

A prerequisite for the overall practice of VoC is a level of trust between supplier and buyer. When users were asked about the level of their trust in their vendors, most of the responses were cautious, as shown Figure 9-4. Although more than one-third (34.7 percent) of the sample said they trusted all of their vendors, one-quarter of them trusted only their strategic vendors. Over one-fourth (28.6 percent) of the respondents trusted their suppliers "within reason." The concept of trust appears to be an area in which suppliers, in general, have room to improve, because only 2 percent of the users sampled absolutely did not trust their suppliers. This leaves room for suppliers to improve relations with those customers still somewhat receptive to opening lines of communication.

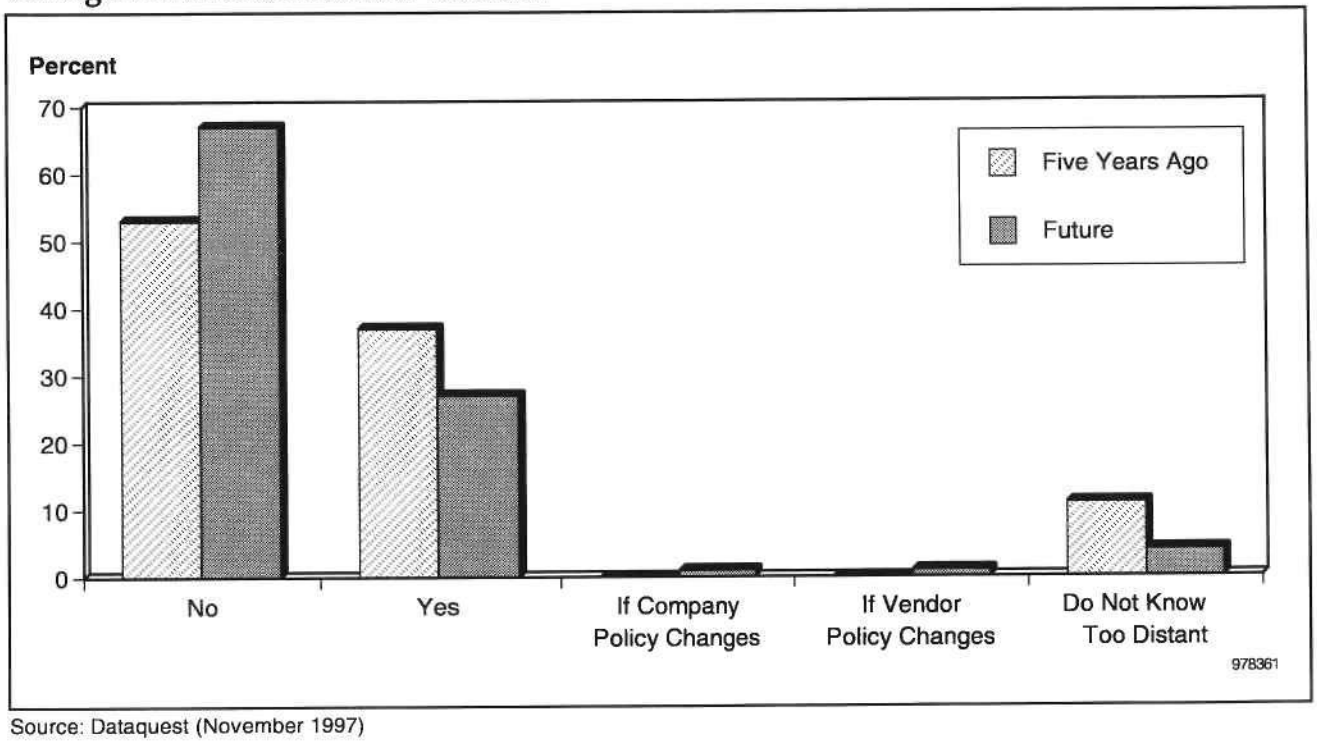
**Figure 9-4**
**Level of Trust in Vendors**




Source: Dataquest (November 1997)

As shown in Figure 9-5, when polled on whether their levels of trust had changed over the past five years, over half (52.9 percent) of the respondents said "no," while over one-third (36.5 percent) had seen their level of trust change. It was another confirmation to note that over one-quarter (26.9 percent) of the sample were planning to change the levels of trust they now had with their suppliers. As in the other responses, improved levels of trust and information sharing are now being planned by at least this sample of semiconductor users.

**Figure 9-5**
**Change in Level of Trust in Vendors**



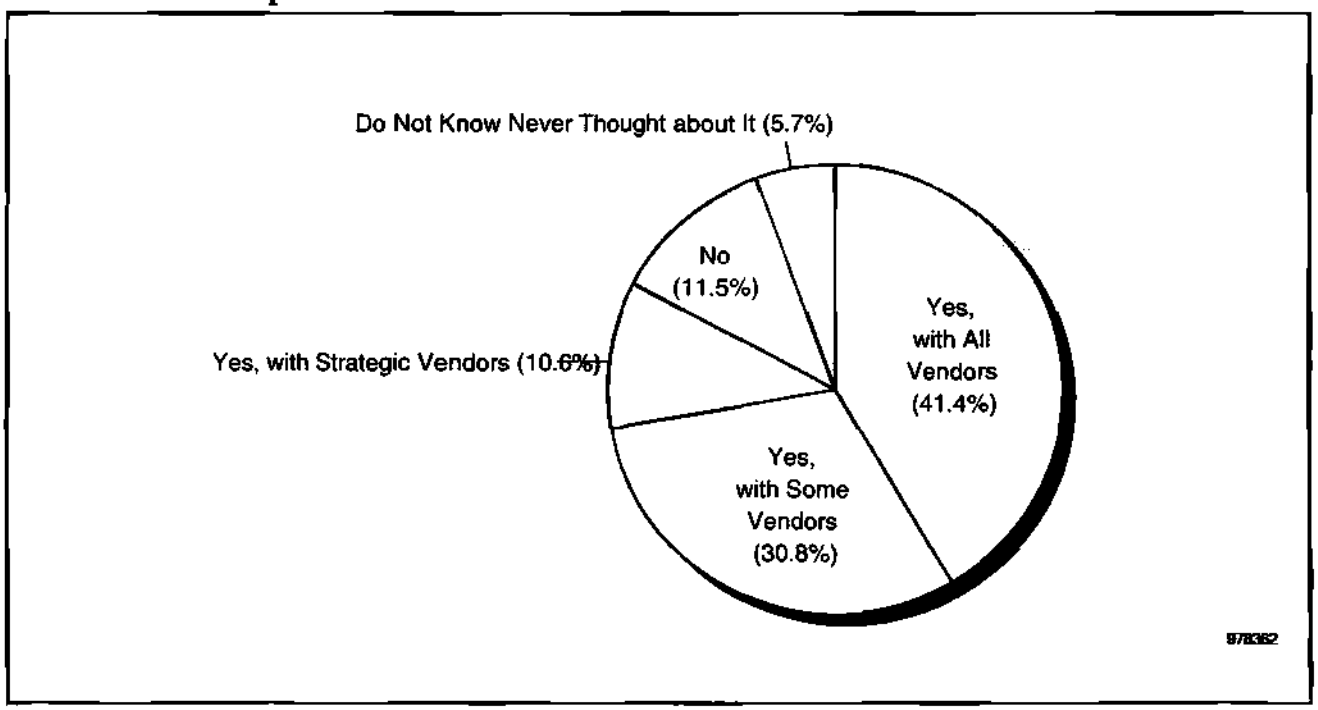

Source: Dataquest (November 1997)


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## Value and Goal Sharing

In order for a VoC program to provide benefit to both the user and supplier, both parties must generally share the same goals. Close to half (41.4 percent) of the respondents felt that all their vendors shared the same goals, while close to one-third (30.8 percent) noted that some did (see Figure 9-6). Interestingly, the percentage of respondents who noted that only their strategic suppliers (10.6 percent) shared the same market goals was nearly the same as those who noted that their suppliers did not share similar goals (11.5 percent). Although a strong majority of the sample seems to share similar market goals, as with improvement in planned sharing of information and trust, companies for which the VoC process is still evolving may also increase their levels of shared goals.

**Figure 9-6**
**Vendors' and Respondents' Shared Goals**




Source: Dataquest (November 1997)

# Chapter 10
# Teamwork: Supplier and Buyer Joint Approval

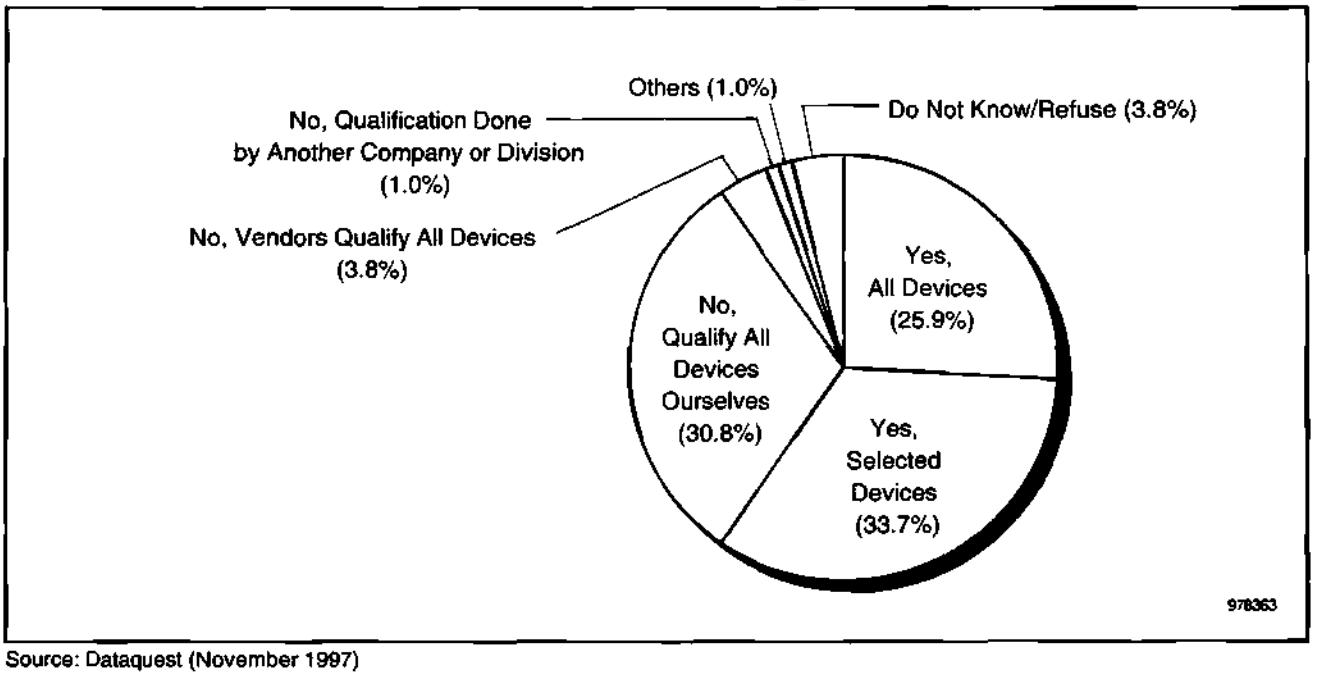
The concept of having buyer and seller on the same side with similar goals and benchmarks may strike many as odd at best or collusive at worst. When both semiconductor customer and vendor know each other's technology road maps and planned market focus, many of the problems involving new product development, phasing products in or out, and competitive pricing are solved proactively rather than reactively. This can provide the semiconductor user with a time-to-market or technology edge over the competition.

## Joint Qualification: Yes or No

A key part of semiconductor suppliers and users working as a team is the joint qualification of devices used. Dataquest asked the sample whether they jointly qualified or approved semiconductors with their vendors. Figure 10-1 shows that more than half (59.6 percent) of the respondents either jointly qualified all devices (25.9 percent) or at least jointly qualified critical, selected devices (33.7 percent). At one end of the spectrum, close to one-third (30.8 percent) of the respondents qualified all devices used internally, while at the other end, a small fraction (3.8 percent) had their suppliers qualify all products. The relatively high percentage of jointly qualified parts (especially for the selected parts) highlights the importance of this practice to the respondents. Companies that internally qualify all their parts are (with a few exceptions) generally smaller and may not have the resources yet in place to complete joint qualification procedures.

Some semiconductor devices are more likely to be jointly qualified than others, because of the level of customization required, such as special testing.

Figure 10-1
Semiconductor Joint Qualification—Vendors and Respondents



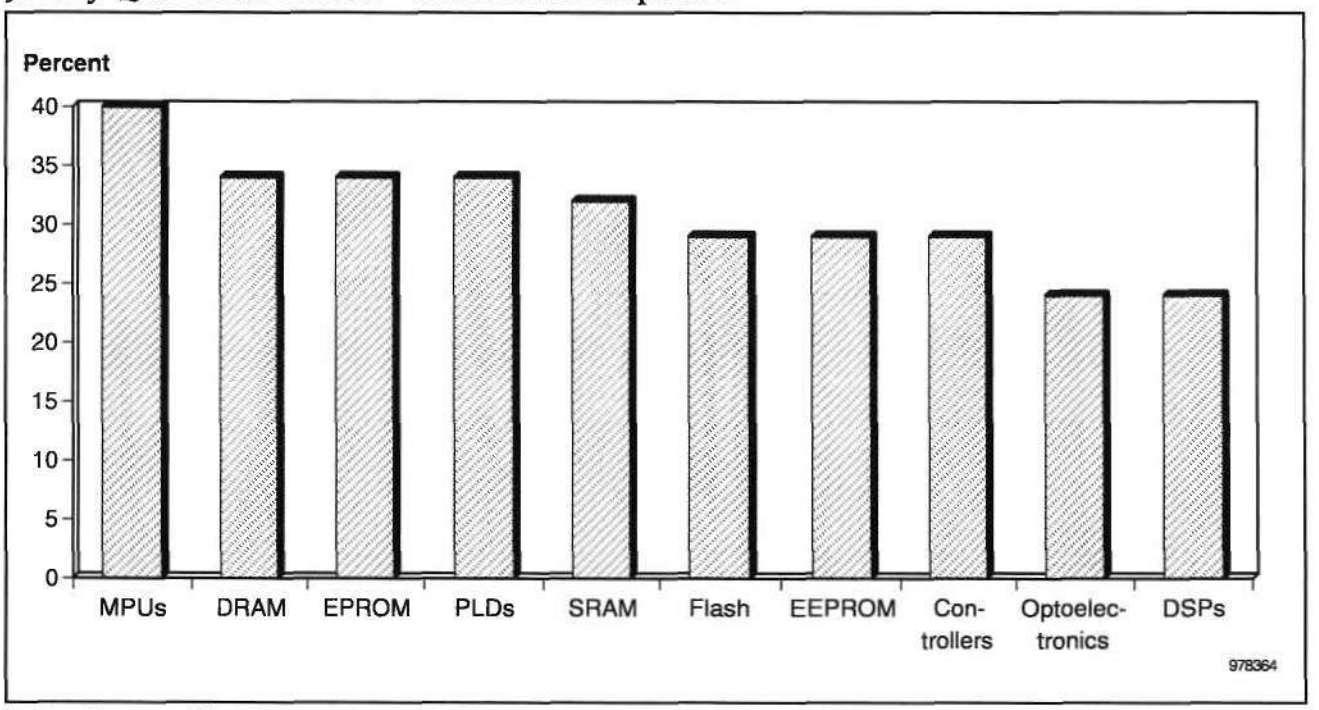

Source: Dataquest (November 1997)


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## Which Device Families

Dataquest asked those that did jointly qualify parts which parts families were included in the process. As shown in Figure 10-2, the averages by product family ranged from a low of 23.7 percent for optoelectronic devices and DSPs to a high of 39.5 percent for compute microprocessors (that is, Pentiums, K6s, and PowerPCs, among others). The devices that have the higher (31 percent and up) rates of joint qualification are parts that, with the exception of flash memory, require some level of supplier assistance because of the customized nature of the product (such as microprocessors or specialized speeds and configurations of memory). It is interesting to note that, traditionally, customized microcontrollers and digital signal processing (DSP) chips are not ranked higher in the joint qualification process. The commodity optoelectronic devices and programmable memory parts (flash and EEPROM) are usually jointly qualified as new generations are developed and released.

**Figure 10-2**
**Jointly Qualified Devices—Level of Participation**

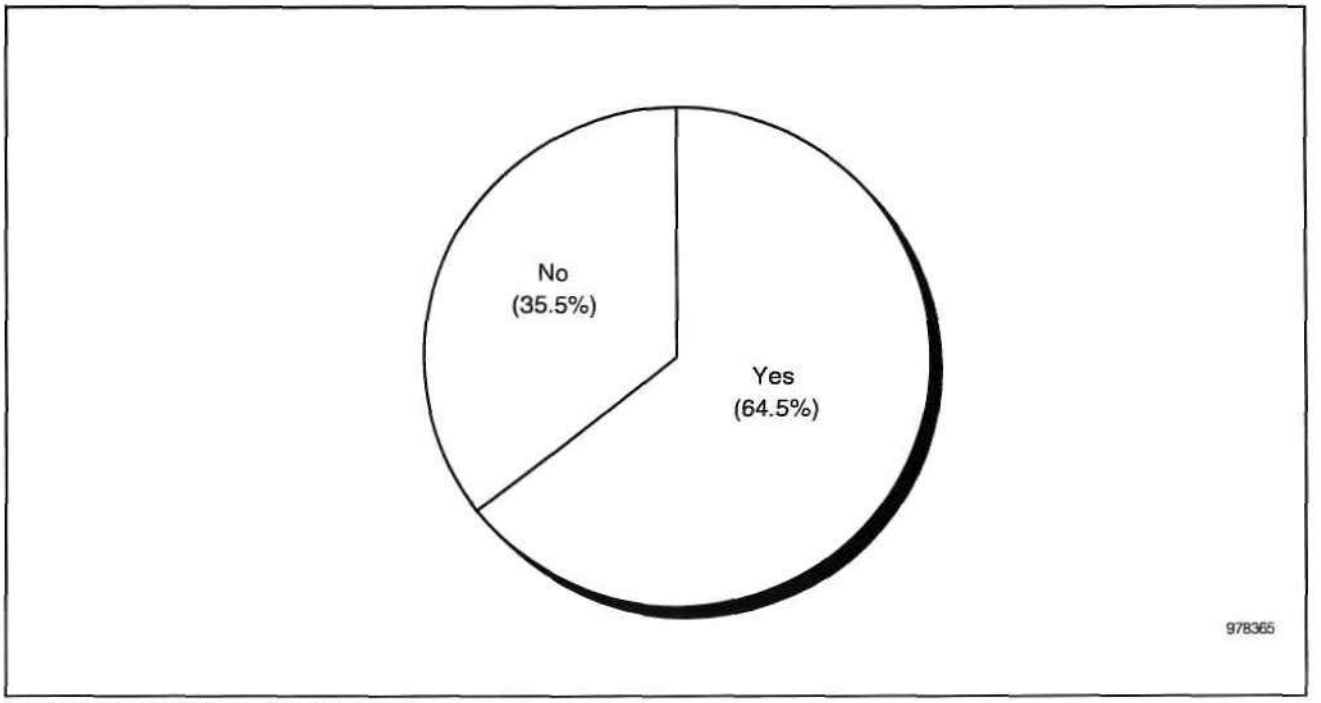



Source: Dataquest (November 1997)

## If Not Now, What about the Future?

Dataquest asked the respondents that currently do not jointly qualify semiconductors whether they were planning on doing so within the next year. Figure 10-3 shows that close to two-thirds (64.5 percent) of those not jointly qualifying will begin the process during 1998. The majority of the companies expecting to begin the joint qualification process are the larger companies with semiconductor purchase levels of over $10 million. The rest of the companies, which expect to continue to qualify parts on their own, appear to be in niche markets where customer-specific requirements at the hardware level are not critical.

**Figure 10-3**
**Plans for Joint Qualification**




Source: Dataquest (November 1997)

# Chapter 11
# Roundup: Conclusions and Comparisons

The buyers surveyed account for about 15 percent of total North American semiconductor spending, based on Dataquest's revenue results for 1996. The companies surveyed ranged from small companies to huge organizations, and they were split among data processing (50 percent), communications (25 percent), and others (25 percent). This split more or less aligned the survey respondents with Dataquest's consumption by application area. Thus, the findings of the report are fairly representative of the views and feelings of the North American buying community.

It was found that few buyers maintain actual inventory levels lower than their targets. The vast majority of buyers were running with inventory levels either at or above their target. So, clearly, any help that vendors can give to users on this front would be much appreciated!

Importance versus satisfaction ratings always unearth interesting findings, and the users in this survey certainly were not shy. Although most vendors did not exceed expectations, the buyers all ranked their vendors above 3 on a scale of 5. However, there is plenty of work to be done; the users have high standards and do not like to be disappointed. Also, given the current excess of semiconductor capacity, the vendors that perform best will be kept. Those who do not will be discarded like yesterday's newspapers.

Much is said about total cost of ownership. Although buyers clearly want the best overall deal for their companies, only half of those surveyed admitted that they actually measure TCO formally. However, the importance and satisfaction section showed that this was an area in which buyers wanted more from their vendors.

Likewise, questions about distribution and spot market channels as sources of supply yielded some interesting results. Charting the range of procurement spending through distribution showed that the results formed an inverse bell curve, with one-quarter of participants using it for 0 to 10 percent of total spending and another quarter using it for 90 to 100 percent of their requirements. Only 53 percent admitted to using the spot market to obtain product. The most popular device bought in the spot market was PLDs, with DRAM coming close behind. Only 3 percent of all respondents used the spot market as a channel when it was less expensive than contract pricing. This probably explains why a DRAM surplus remains in the spot market.

The survey revealed some interesting information on the current vendor base size and how it has evolved from 1996 and is planned to change in 1998. Even more interesting, it was impressive that 96 percent of respondents had some strategic vendors or had only strategic vendors. This would indicate a high level of professionalism and sophistication in the buyers surveyed.

Vendor-of-choice programs or other forms of vendor measurement were used by well over half of the respondents. Of those who use them, half measured all vendors, and half measured only strategic vendors. Measurement was usually conducted monthly, quarterly, or semiannually.

Dataquest discovered that 90 percent of those who conduct VoC programs share the findings with their vendors. However, only half shared findings openly with all suppliers, with 40 percent sharing them only with strategic suppliers.

Questions about trust between users and vendors showed that only one-third of the sample trusted all their vendors, one-quarter trusted only strategic vendors, and another one-quarter had boundaries for trust. Keep those communication channels open, vendors! It was also discovered that about 60 percent of the respondents jointly qualify all or some semiconductors with their vendors—an example of practical trust.

**For More Information...**

Evelyn Cronin, Senior Industry Analyst..... (408) 468-8075
Internet address..... evelyn.cronin@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive..... http://www.dataquest.com

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## DATAQUEST WORLDWIDE OFFICES


**NORTH AMERICA**

**Worldwide Headquarters**
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: 1-408-468-8000
Facsimile: 1-408-954-1780

**East Coast Research Center**
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6262

**Dataquest Global Events**
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

**EUROPE**

**European Headquarters**
Tamesis, The Glanty
Egham, Surrey TW20 9AW
United Kingdom
Phone: +44 1784 431 611
Facsimile: +44 1784 488 980

**Dataquest France**
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: +33 1 41 35 13 00
Facsimile: +33 1 41 35 13 13

**Dataquest Germany**
Martin-Kollar-Strasse 15
D-81829 München
Germany
Phone: +49 89 42 70 4-0
Facsimile: +49 89 42 70 4-270

**JAPAN**

**Japan Headquarters**
Aobadai Hills 4-7-7
Aobadai
Meguro-ku, Tokyo 153
Japan
Phone: 81-3-3481-3670
Facsimile: 81-3-3481-3644

**ASIA/PACIFIC**

**Asia/Pacific Headquarters**
Suite 5904-7, Central Plaza
18 Harbour Road, Wanchai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

**Dataquest Korea**
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

**Dataquest Taiwan**
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

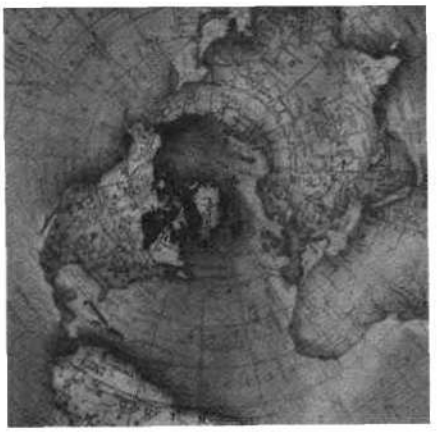
**Dataquest Singapore**
105 Cecil Street
#06-01/02 The Octagon
Singapore 069534
Phone: 65-227-1213
Facsimile: 65-227-4607

**Dataquest Thailand**
12/F, Vanissa Building
29 Soi Chidlom
Ploenchit Road
Patumwan, Bangkok 10330
Thailand
Phone: 662-655-0577
Facsimile: 662-655-0576

**Dataquest Australia**
80 Alfred Street
Milsons Point NSW 2061
Australia
Phone: 61-2-9941-4860
Facsimile: 61-2-9941-4868


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# PCB Market Trends: Shrinks Continue to Affect Market



Focus Report

**Program:** Semiconductor Supply and Pricing Worldwide
**Product Code:** SSPS-WW-FR-9704
**Publication Date:** August 4, 1997
**Filing:** Reports

# PCB Market Trends: Shrinks Continue to Affect Market



Focus Report

# Table of Contents


Page

1. Executive Summary ..... 1
2. Introduction ..... 3
   - Market Size ..... 3
   - Statement of Research Methodology ..... 4
3. PCB Market Overview ..... 7
   - Top Public PCB Suppliers ..... 7
   - PCB Survey Mix versus Overall Market ..... 7
   - PCB Suppliers Used ..... 8
   - PCB Market Drivers ..... 11
4. PCB Supply Choice Factors ..... 13
   - Forecasting PCB Needs ..... 13
   - Critical PCB User Issues ..... 15
5. PCB Supply Base Issues ..... 17
6. Prices per PCB Layer ..... 21
   - Methodology ..... 21
   - Buyers' Average PCB Costs ..... 21
   - Buyers' Mean Price per PCB Layer ..... 24
   - Suppliers' Average PCB Prices ..... 25
   - Suppliers' Mean Price per Layer ..... 29
   - Comparison of Buyers' and Suppliers' Mean Prices ..... 29
7. Lead Time Results ..... 31
   - Buyers' Average Lead Times ..... 31
   - Buyers' Mean Lead Times per PCB Layer ..... 34
   - Suppliers' Average Lead Times ..... 34
   - Suppliers' Mean Lead Times per PCB Layer ..... 38
   - Comparison of Buyers' and Suppliers' Mean Lead Times ..... 38
8. Premiums for Faster Lead Times and Effect on Mean Price per Layer ..... 41
   - Buyers ..... 41
   - Suppliers ..... 43
   - Comparison ..... 43
9. Summary and Conclusions ..... 47

Appendix A—PCB Suppliers Noted by User Sample ..... 49



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# List of Figures


| Figure | | Page |
|---|---|---|
| 2-1 | Worldwide Regional PCB Production, 1996 | 3 |
| 2-2 | Worldwide PCB Market Forecast, 1996 to 2000 | 4 |
| 2-3 | Survey Demographics—End-Product Application (N = 82) | 5 |
| 2-4 | Regional Location of PCB User Sites | 6 |
| 3-1 | Survey Demographics: User and Supplier Spending and Sales, 1997 (N = 79) | 8 |
| 3-2 | PCB Supplier Use: Prototype Supplier | 9 |
| 3-3 | PCB Supplier Use: Large OEM's Internal Supply (N = 82) | 9 |
| 3-4 | PCB Supplier Use: Contract Manufacturer | 10 |
| 3-5 | PCB External Design Use | 11 |
| 4-1 | Long-Term Forecasting of PCB Demand | 14 |
| 4-2 | Long-Term PCB Forecast Windows | 14 |
| 4-3 | PCB User Issues: Importance of Issue and User Satisfaction (N = 82) | 15 |
| 5-1 | PCB Supply Base (N = 78) | 18 |
| 5-2 | PCB Supplier Performance Measurement (N = 82) | 18 |
| 5-3 | Frequency of Measuring PCB Supplier Performance (N = 74) | 19 |
| 5-4 | PCB Supplier Review Impact (N = 75) | 19 |
| 6-1 | Buyers' Average PCB Price for Two-Layer PCBs | 22 |
| 6-2 | Buyers' Average PCB Price for Four-Layer PCBs | 22 |
| 6-3 | Buyers' Average PCB Price for Six-Layer PCBs | 23 |
| 6-4 | Buyers' Average PCB Price for Eight-Layer PCBs | 23 |
| 6-5 | Buyers' Mean Price per Layer | 24 |
| 6-6 | Suppliers' Average PCB Price for Two-Layer PCBs | 25 |
| 6-7 | Suppliers' Average PCB Price for Four-Layer PCBs | 26 |
| 6-8 | Suppliers' Average PCB Price for Six-Layer PCBs | 26 |
| 6-9 | Suppliers' Average PCB Price for Eight-Layer PCBs | 27 |
| 6-10 | Suppliers' Average PCB Price for 10-Layer PCBs | 27 |
| 6-11 | Suppliers' Mean Price per Layer | 28 |
| 7-1 | Buyers' Average Lead Times for Two-Layer PCBs | 32 |
| 7-2 | Buyers' Average Lead Times for Four-Layer PCBs | 32 |
| 7-3 | Buyers' Average Lead Times for Six-Layer PCBs | 33 |
| 7-4 | Buyers' Average Lead Times for Eight-Layer PCBs | 33 |
| 7-5 | Buyers' Mean Lead Time per PCB Layer | 35 |
| 7-6 | Suppliers' Average Lead Times for Two-Layer PCBs | 35 |
| 7-7 | Suppliers' Average Lead Times for Four-Layer PCBs | 36 |
| 7-8 | Suppliers' Average Lead Times for Six-Layer PCBs | 36 |
| 7-9 | Suppliers' Average Lead Times for Eight-Layer PCBs | 37 |
| 7-10 | Suppliers' Average Lead Times for 10-Layer PCBs | 37 |
| 7-11 | Suppliers' Average Lead Times for 12-Layer PCBs | 38 |
| 7-12 | Suppliers' Mean Lead Times per PCB Layer | 39 |
| 8-1 | Willingness of Buyers to Pay Extra for a Quicker Order Turnaround | 42 |
| 8-2 | Average Premiums for Faster Turnaround Buyers Would Pay | 42 |
| 8-3 | Suppliers Whose Customers Willingly Pay Extra for a Quicker Turnaround | 44 |
| 8-4 | Average Premiums for Faster Turnaround That Suppliers' Customers (Buyers) Pay | 44 |



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# List of Tables


| Table | | Page |
|---|---|---|
| 3-1 | Top Eight Public PCB Companies | 7 |
| 6-1 | Comparison of Mean Price per Layer for Buyers and Suppliers | 30 |
| 7-1 | Comparison of the Mean PCB Lead Times from Buyers and Suppliers | 39 |
| 8-1 | Buyers' Mean Price per Layer for Mean Lead Times and Premium Required for Quick Turnaround Orders | 43 |
| 8-2 | Suppliers' Mean Price per Layer for Mean Lead Times and Premium Required for Quick-Turnaround Orders | 45 |



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# Chapter 1
# Executive Summary

The printed circuit board (PCB) market remains in flux after a dramatic consolidation period from the late 1980s to 1996. The recent turmoil in the semiconductor industry pales in comparison with the fallout rate in the PCB industry. The continued impact of increasing capital costs, environmental regulations, and worldwide competition has forced improved efficiencies that still shape the survivors of the recent market shakeout. Citing industry data from the Institute for Interconnecting and Packaging Electronic Circuits (IPC), this report gives a brief overview of the PCB market and reviews PCB user issues. Based on Dataquest's latest survey of over 1,000 calls to more than 400 PCB suppliers and users, this report goes into detail regarding critical user issues and their satisfaction levels, supplier choice criteria, forecast trends, costs, and lead time issues. It can be used in PCB benchmarking programs by both users and suppliers toward the goal of a better-served market. An example of the top three criteria used by users in choosing a PCB supplier are:

- Facility
- Cost savings
- Equipment

Some of the other key findings of the report involving quality levels and supplier flexibility buck current thinking and should serve notice to suppliers of what their customers are now demanding. Tactical benchmark data and analysis regarding PCB costs, average lead times for production and quick turn jobs, as well as prototype price premiums combine with the strategic analysis to form a solid guidebook on what is of current concern in the PCB world. An appendix of commendable PCB suppliers noted by the user respondents rounds out this report.

*Project Analysts: This report was prepared by Director and Principal Analyst Mark Giudici and Senior Industry Analyst Evelyn Cronin (both of Semiconductor Supply and Pricing Worldwide). The survey was developed and programmed by Mei Ye (Research Operations).*


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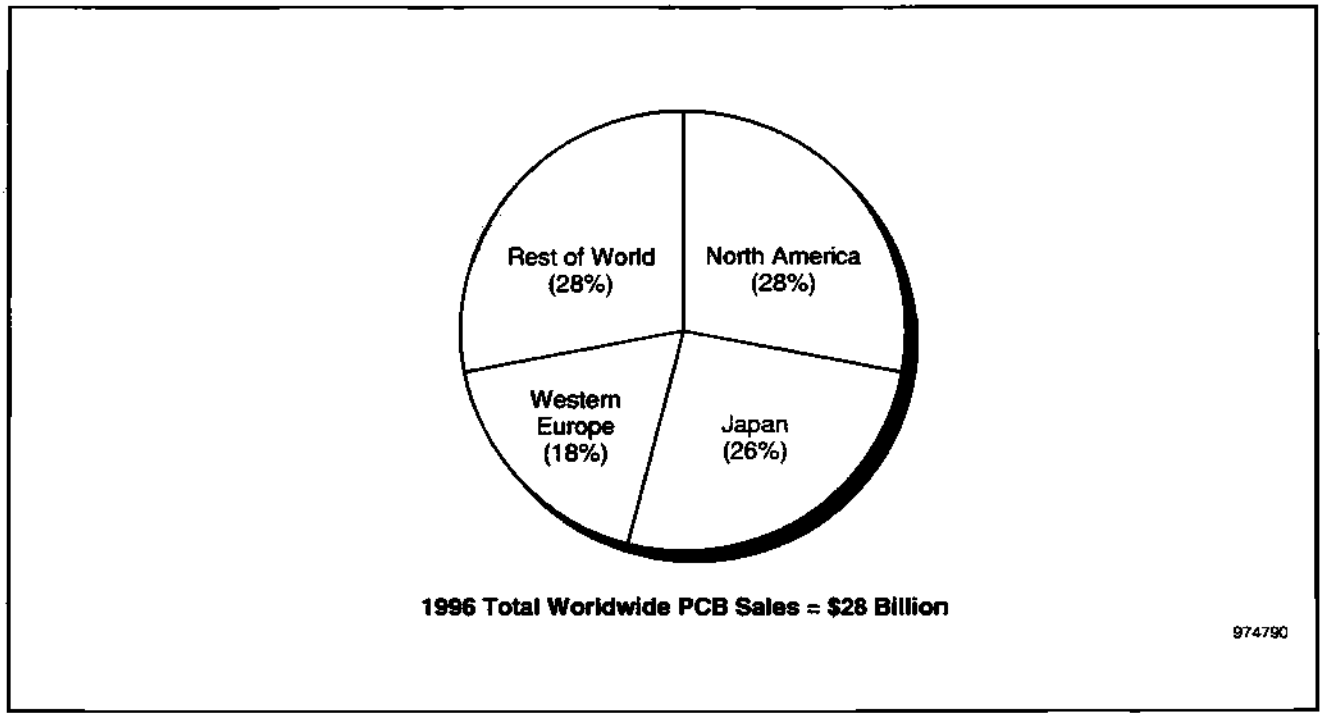
# Chapter 2
# Introduction

The printed circuit board market remains in flux. Many of the issues brought out in Dataquest's survey of 103 PCB users and suppliers emphasize how the consolidation over the past five years or more has altered many of the parameters that go into sourcing PCB technology and suppliers.

## Market Size

As shown in Figure 2-1, the worldwide PCB market in 1996 was $28 billion. North America has taken over as the largest single-region producer of PCBs (28 percent), followed closely by Japan (26 percent), then Western Europe (18 percent). The relatively large percentage of PCBs coming from the rest of the world (28 percent) includes Eastern Europe, Russia, Korea, Taiwan, China, and the rest of Asia. Figure 2-2 shows the estimated growth of this market. Although it will grow at an average 7.6 percent over the next four years (1996 to 2000), the emergence of the budding (but volatile) Asian supply base may well alter the current top suppliers in the future.

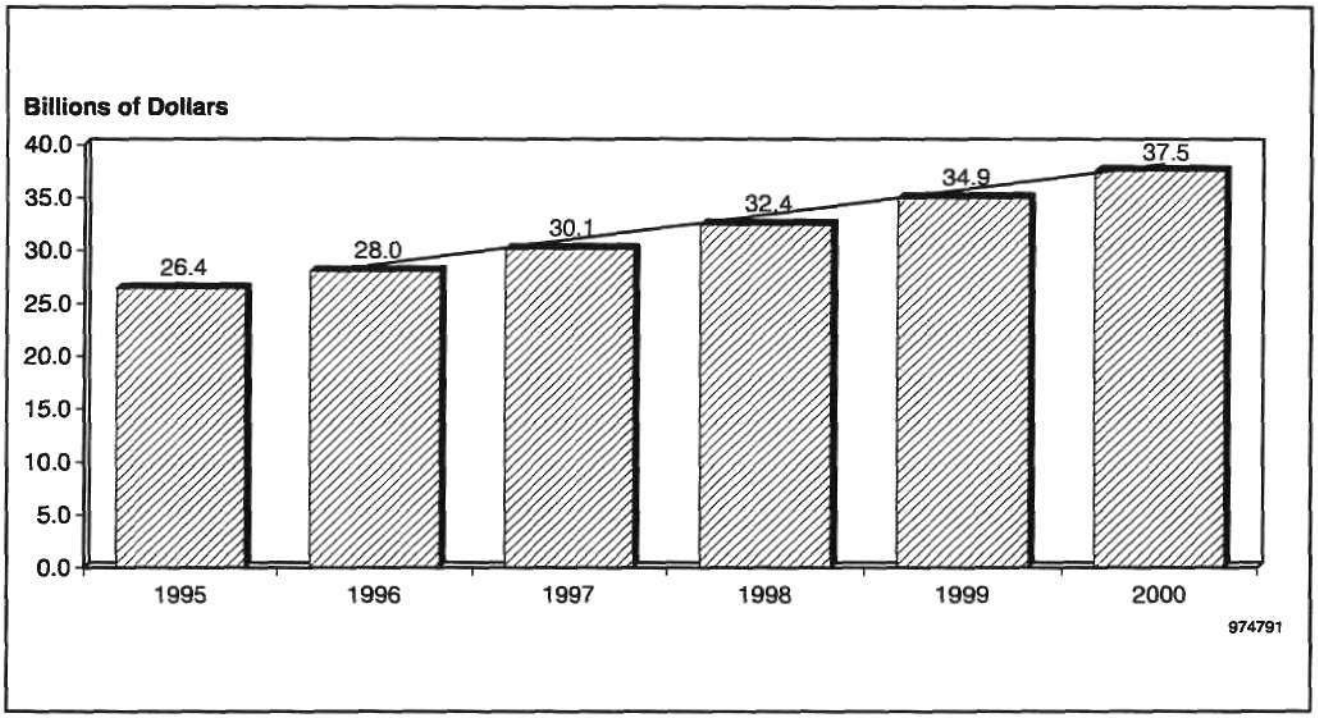
**Figure 2-1**
**Worldwide Regional PCB Production, 1996**




Source: IPC


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**Figure 2-2**
**Worldwide PCB Market Forecast Growth = 7.6 Percent, 1996 to 2000**




Source: IPC

## Statement of Research Methodology

Dataquest's 1997 PCB study contains the results of a telephone survey conducted by Dataquest's Research Operations group. The survey questionnaire was developed by analysts from Dataquest's Semiconductor Supply and Pricing Worldwide program (SSPS) and comprising 110 questions. On average, a respondent was asked to answer about 55 questions because not all questions applied to each respondent. Trained interviewers conducted the survey using a computer-aided telephone interviewing (CATI) system. Research Operations analysts tabulated the survey results using the Survey Systems software package.

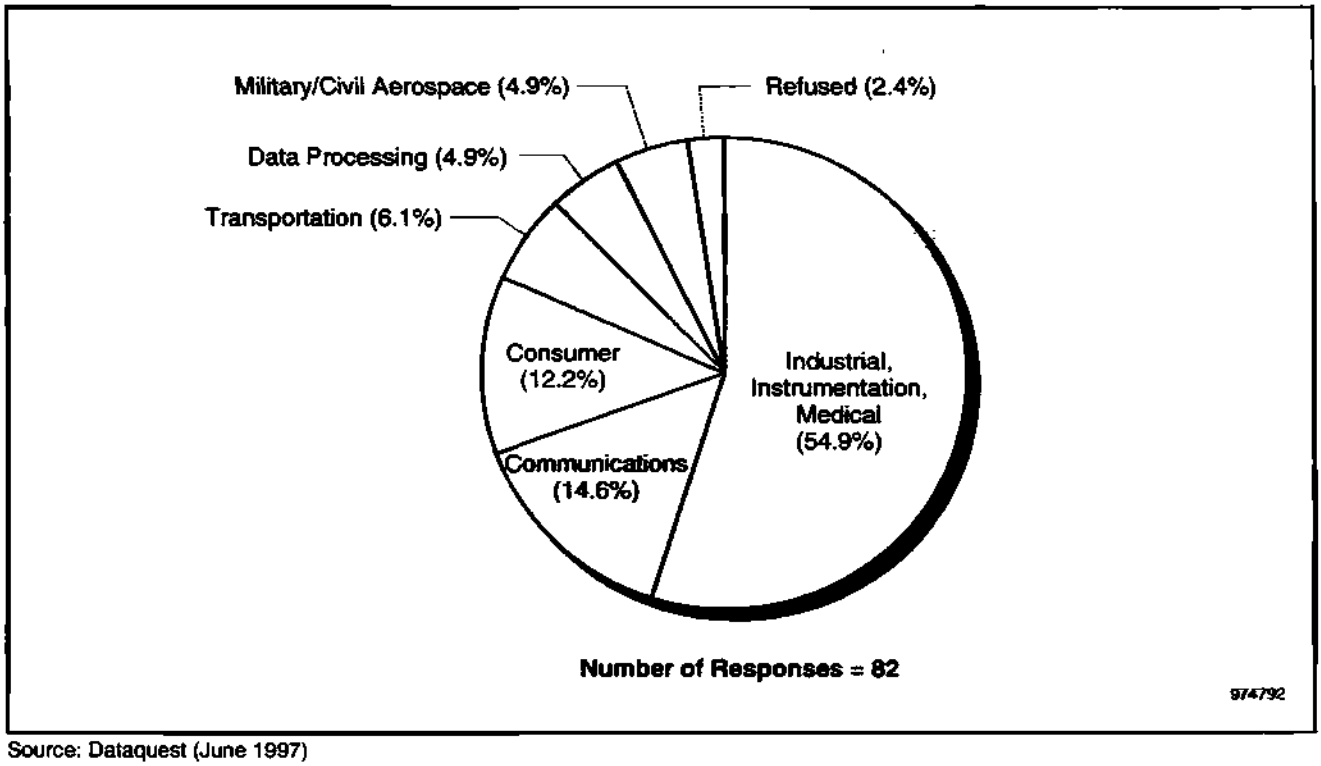
Dataquest conducted the study during May 1997. We contacted respondents based on a list of PCB buyers published by the research company Printed Circuit Directories and PCB vendors from the IPC listing of PCB assembly suppliers. The ninth edition of *Who Buys Printed Circuit Boards in High Volume* (February 1997) contains contact information on 364 companies in 22 states with major electronics manufacturing. The IPC database lists all IPC members that manufacture PCB boards.

Dataquest placed a total of 1,037 calls to about 455 names from the two lists. The sample disposition is as follows:

- 103 completed interviews
- 208 unable to contact respondents, left message, or others
- 289 refused interview/wrong telephone number/did not qualify to participate in study

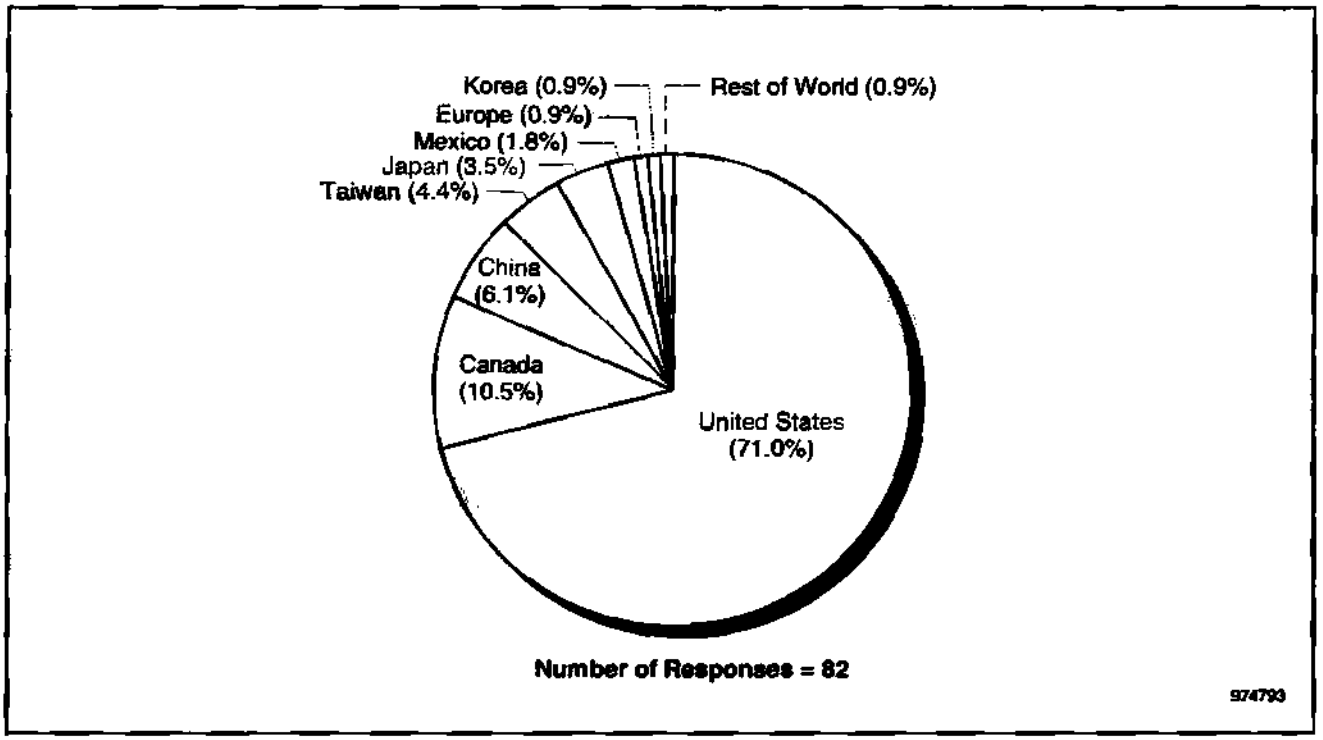
The application markets that the user respondents represent is slightly skewed to the industrial/instrumentation/medical segment at the expense of the computer and communications segments. Issues involving quality, flexibility, and total cost of ownership, however, cut across application boundaries (see Figure 2-3). Figure 2-4 shows the regional makeup of the responding users, highlighting the continued vitality of the domestic market along with selected offshore plants. It is interesting to note that the third-ranked region in this sample is China.

**Figure 2-3**
**Survey Demographics—End-Product Application (N = 82)**




Source: Dataquest (June 1997)

**Figure 2-4**
**Regional Location of PCB User Sites**




Source: Dataquest (June 1997)


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## Chapter 3
# PCB Market Overview

The PCB supply base has continued to contract since Dataquest did its last survey of this market. In 1994, there were fewer than 900 worldwide PCB suppliers. According to IPC estimates, there are slightly more than 670 PCB companies, of which fewer than 15 have sales of greater than $100 million and more than 550 have sales of less than $10 million. As an indication of the ongoing consolidation of this market, it is now estimated that the top eight merchant suppliers produce over 20 percent of North American PCBs. (In 1994, the top 10 made over 20 percent of this market.)

## Top Public PCB Suppliers

Table 3-1 shows the top publicly traded PCB suppliers with their 1996 revenue. As can be seen in this list, the market consolidation trend impacted both the largest and smallest, and both ends of the spectrum made acquisitions last year.

**Table 3-1**
**Top Eight Public PCB Companies**

| Company | 1996 Revenue ($M) | North American Market (%) |
|---|---|---|
| Hadco (with Zycon) | 594 | 7.6 |
| Sanmina | 302 | 3.9 |
| Merix | 171 | 2.2 |
| Altron | 165 | 2.1 |
| Elexys | 135 | 1.7 |
| Praegitzer | 119 | 1.5 |
| Continental Circuits | 107 | 1.4 |
| Tyco (with ElectroStar) | 71 | 0.9 |
| Subtotal | 1,664 | 21.3 |
| Others | 6,134 | 78.7 |
| **Total** | **7,800** | **100.0** |

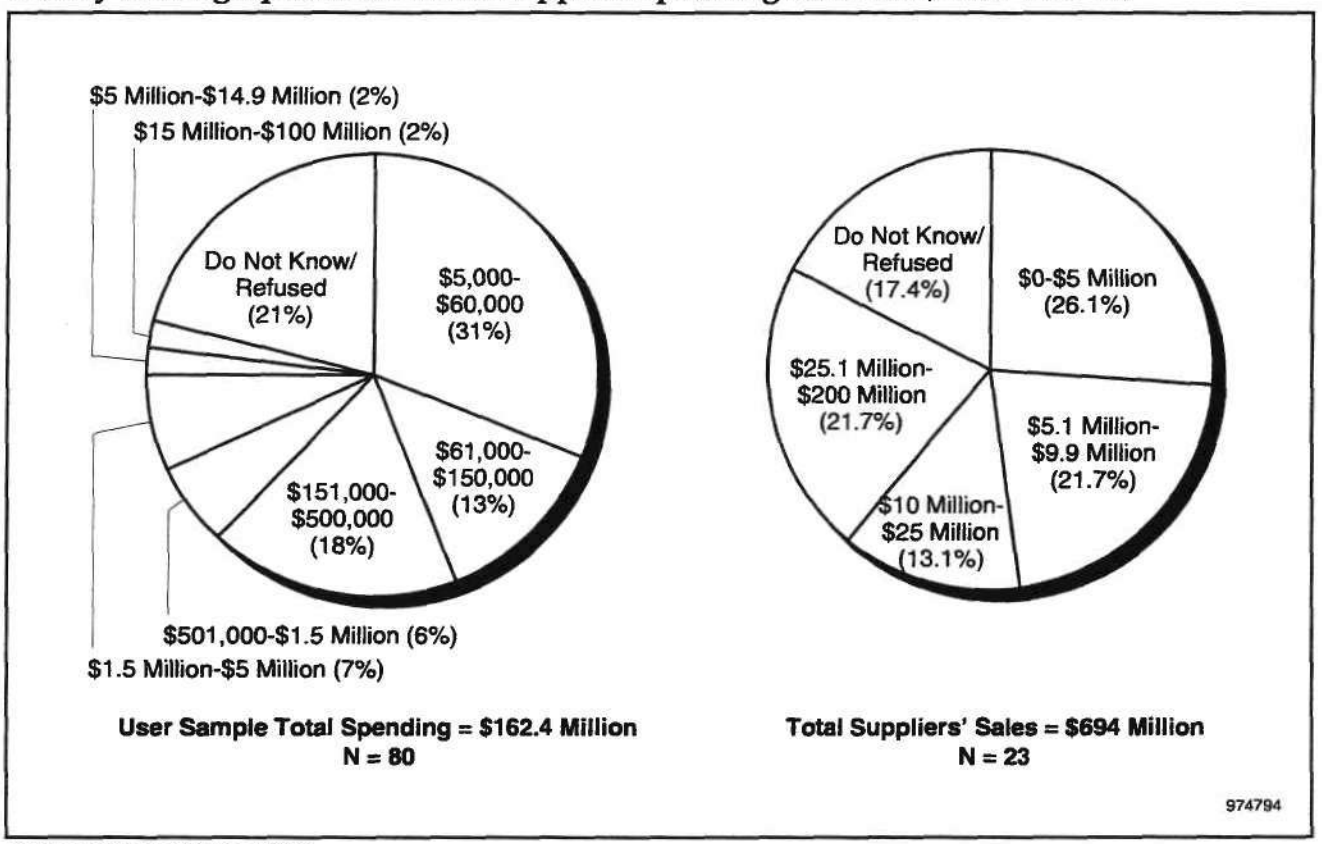
Source: Dataquest (June 1997)

## PCB Survey Mix versus Overall Market

The types of PCB suppliers noted as supporting the users in our survey compare well with the specialty boards required by the industrial segment. Figure 3-1 shows the broad makeup of the survey respondents, with a mix of smaller and large users and a like mix of small, medium-size, and large suppliers. This sample represents many of the companies that have survived consolidation and, although smaller, still highlight the needs and offerings of a vital segment of the industry.


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**Figure 3-1**
**Survey Demographics: User and Supplier Spending and Sales, 1997 (N = 79)**




Source: Dataquest (June 1997)

Although some of the larger suppliers were noted, the majority of PCB vendors used would fall into the "less than $10 million" category that makes up the majority of the PCB supply base. Appendix A lists the PCB suppliers that were noted by the user respondents for excellence in flexibility, quality, price, lead time, engineering support, and total cost of ownership.

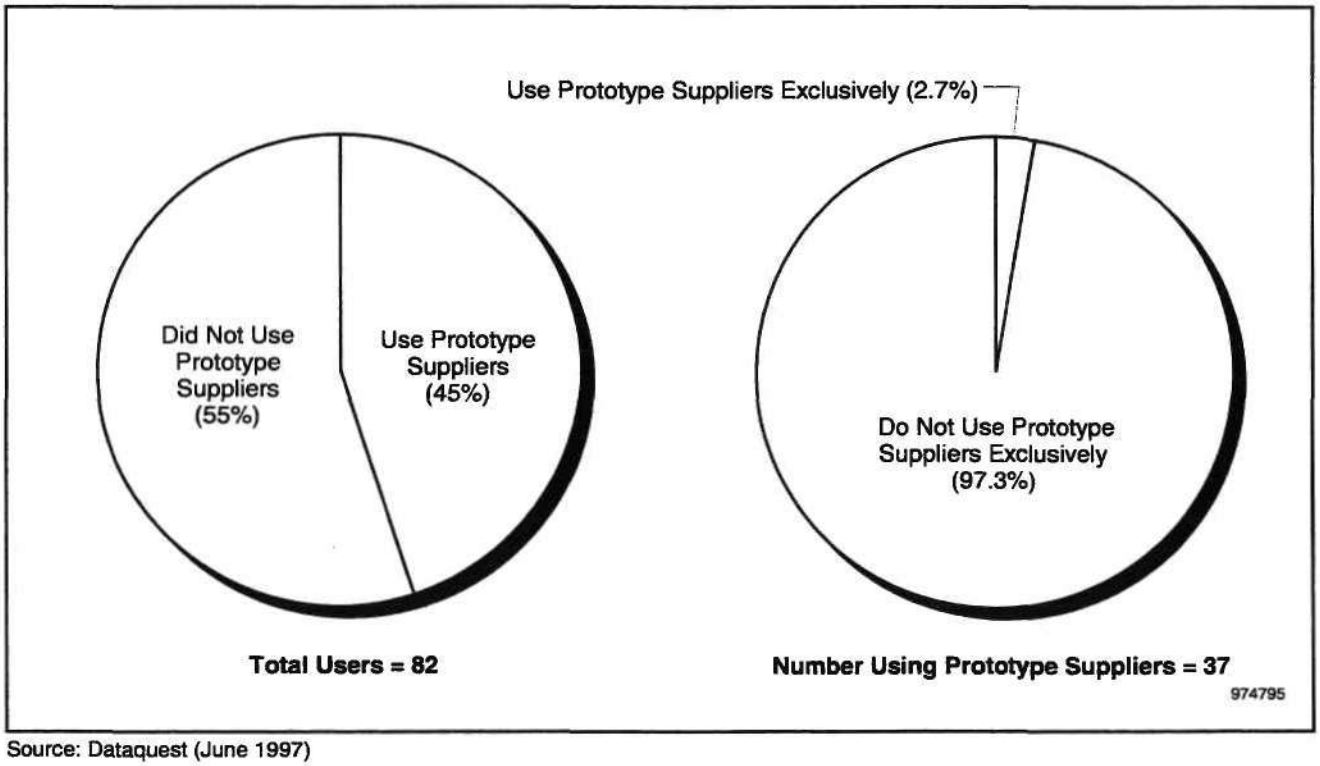
## PCB Suppliers Used

There are three main types of PCB suppliers:

- Prototype suppliers
- Suppliers within large system OEM companies
- Contract manufacturers of PCBs

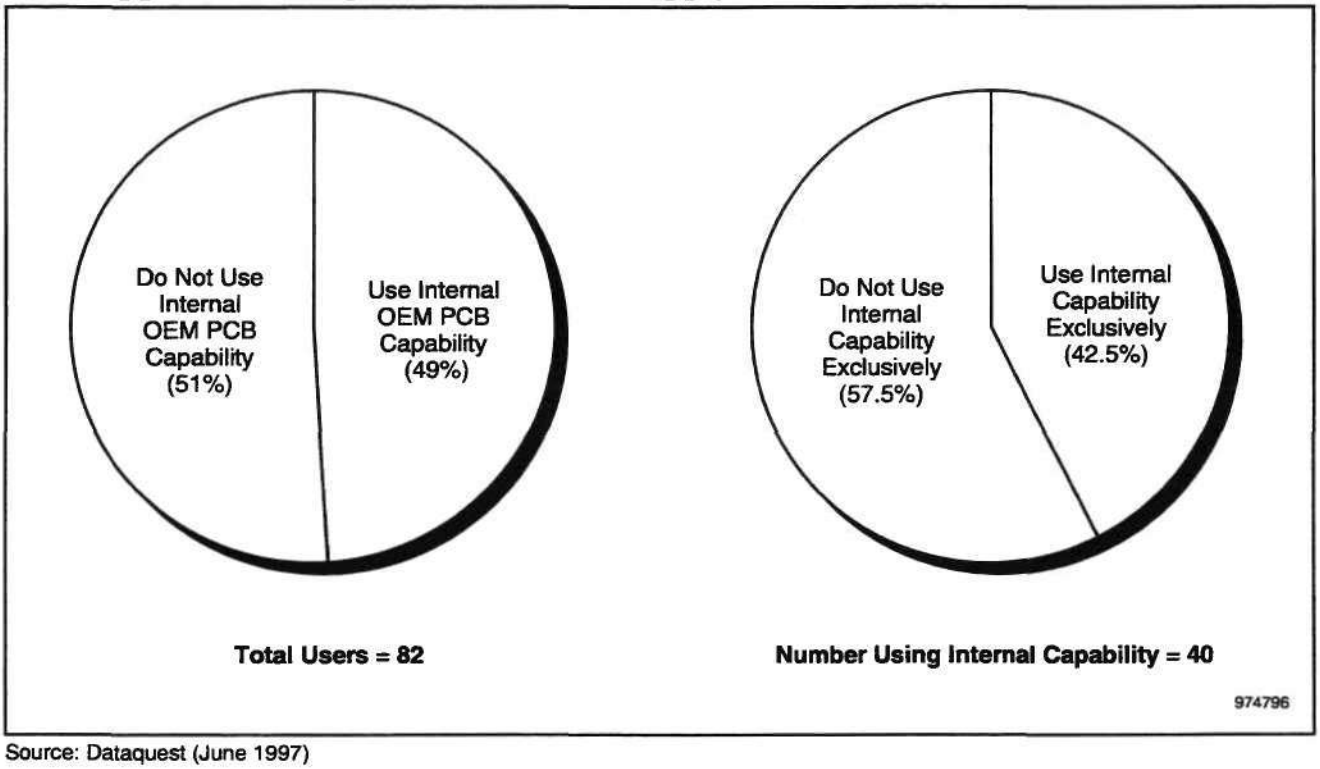
Figures 3-2, 3-3, and 3-4 show how survey respondents use these three types of suppliers and show what proportion use this type of supplier exclusively. Figure 3-2 shows that close to half (45 percent) of the user sample uses quick-turn prototype PCB suppliers, yet only one respondent uses prototype suppliers as an exclusive source of PCBs. Slightly less than half the sample (49 percent) has internal PCB manufacturing capability, as shown in Figure 3-3. Of these 40 companies, only 42.5 percent use their capacity to the exclusion of outside suppliers. Figure 3-4 shows that over half (51 percent) of the sample uses external PCB supplier s or contract manufacturers, and close to half of that half (47.6 percent) uses external suppliers exclusively.

## Figure 3-2
## PCB Supplier Use: Prototype Supplier



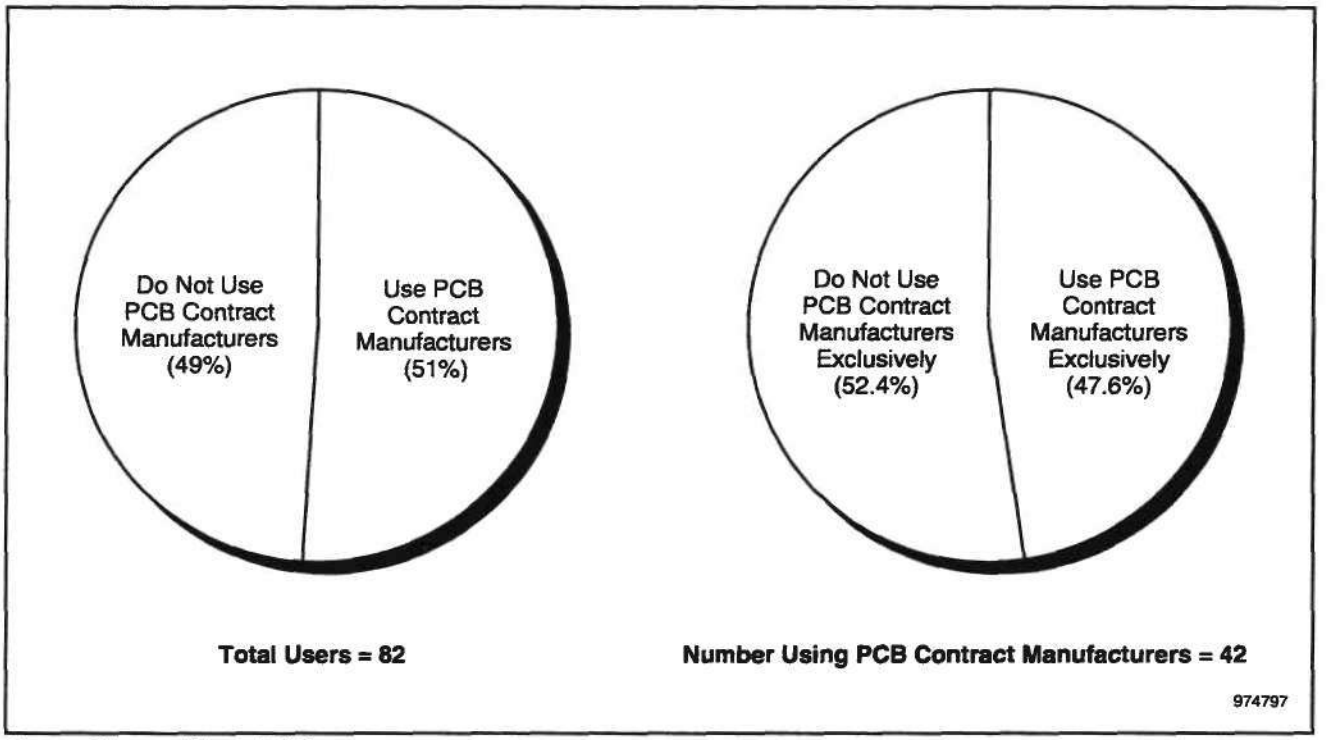

Source: Dataquest (June 1997)

## Figure 3-3
## PCB Supplier Use: Large OEM's Internal Supply (N = 82)




Source: Dataquest (June 1997)

**Figure 3-4**
**PCB Supplier Use: Contract Manufacturer**

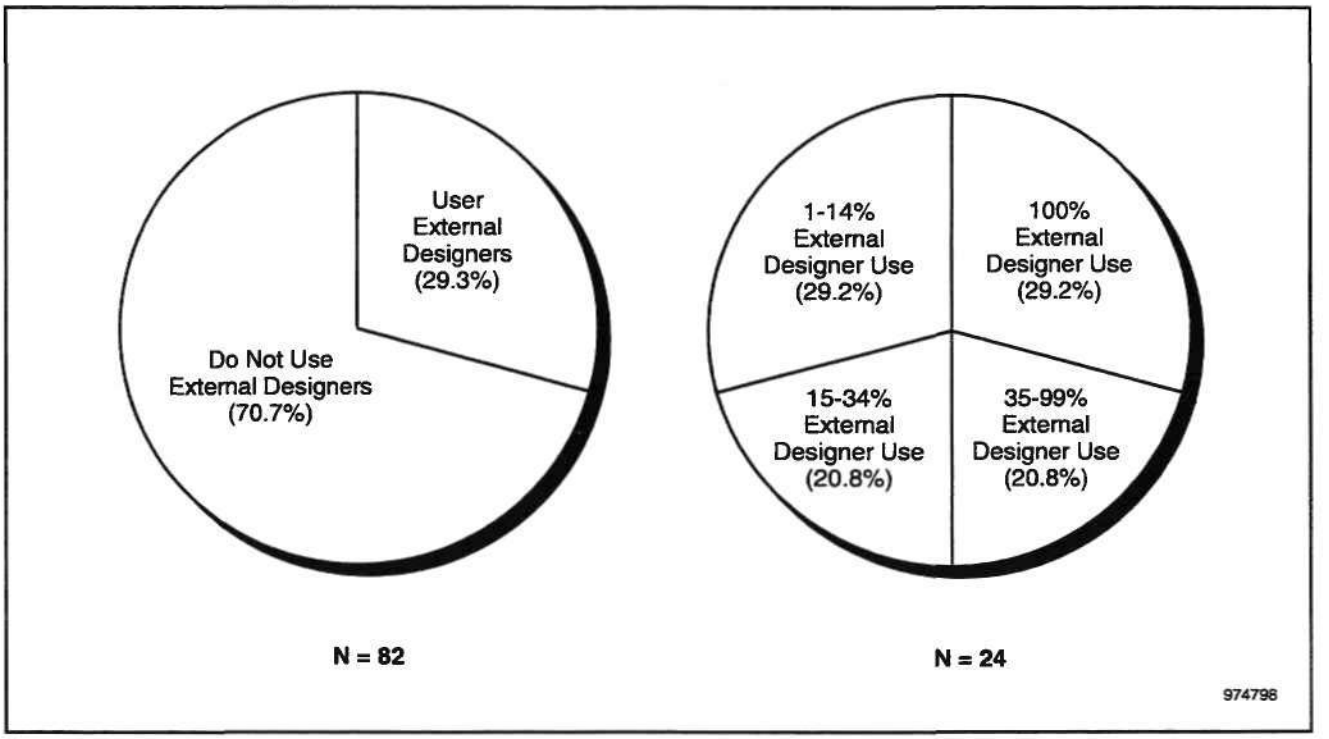



Source: Dataquest (June 1997)

Quick-turn prototype PCB suppliers often are used by companies with internal capability because of the flexibility and turnaround times that these suppliers provide. Of companies that have internal PCB manufacturing, those that also use external suppliers often take advantage of newer equipment outside or use external suppliers to maintain older PCB designs that underutilize internal equipment. The large number of users that use outside suppliers only fits the trend of outsourcing manufacturing because of high capital equipment costs and shrinking system life cycles. Because many companies in the user sample are small to medium-size, the outlay needed for PCB manufacturing equipment generally can be used more efficiently in other critical areas.

The outsourcing of PCB design was also investigated. Figure 3-5 shows that close to a third (29.3 percent) use outside designers, and of those, 29 percent use outside designers exclusively. Although use of external designers often allows flexibility and access to state-of-the-art technology, continued extensive use has the potential of diluting the viability of the outsourced company.

**Figure 3-5**
**PCB External Design Use**




Source: Dataquest (June 1997)

## PCB Market Drivers

The North American electronics market was about $302 billion (35.5 percent) of the $850 billion 1996 worldwide electronics market. North America's predominant equipment markets are computers, telecommunications equipment (wired and wireless), and data storage devices. All of these markets are driven by the currently strong industrial economy. Steady and sustainable growth in the United States and other regions of the world should keep this area of demand strong. The second-largest area of demand is for automotive and digital consumer electronics, which is a potentially large market driven by the volatile mix of consumer confidence and interest rates. The slowest-growth area of electronics is the military/aerospace market. This market continues to slowly shrink or remain static as high-technology defense budgets around the world stabilize or decline in the absence of the Cold War.

Because the U.S. market is heavily weighted toward computer and communications markets, where multilayer PCBs predominate, this segment of the market will continue to show steady increases in demand while higher-volume, single- or double-layer PCBs from Asia that go into consumer products will remain somewhat dependent on the fickle taste of consumers and on the interest rates that influence disposable income levels.

## Chapter 4
# PCB Supply Choice Factors

In choosing an external PCB supplier, many factors are taken into account by potential customers. The rank order of PCB supplier choice criteria for the 38 users of external suppliers (90 percent) that responded is as follows:

- Facility
- Cost savings
- Equipment
- Volume
- Quality
- Prototype
- ogistics management/lead time
- Design tools/geographic location
- Others

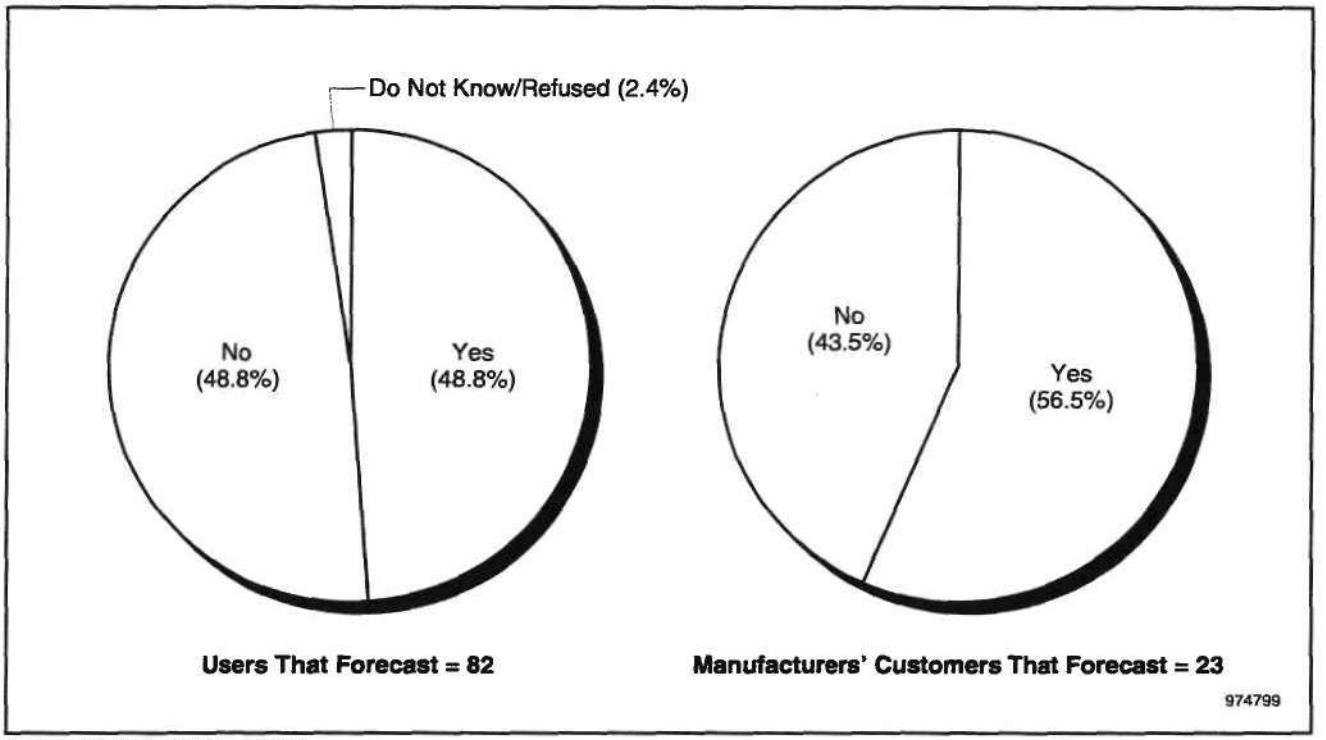
These findings reinforce the notion that PCB users need facilities that are cost-effective and have equipment that provides technological advantages over in-house capacity. Although they are listed, the issues of quality, prototype turnaround, and logistics support and supplier location are secondary to having access to affordable, state-of-the-art facilities.

## Forecasting PCB Needs

Forecasting for a critical component such as PCBs would seem automatic, but as seen in Figure 4-1, the user sample was evenly split between those that do formally forecast and those that do not. It is possible that the 49 percent that do not forecast may be the same 40 companies that have internal PCB manufacturing capability, so that sales may forecast system, and therefore PCB, demand of the factory. The level of forecast activity correlates well with the size of the respondent company (that is, the larger the company, the higher the likelihood of forecasting activity). When the same question was asked of the manufacturers in the survey, they reported that a solid 56.5 percent of their customers did forecast. What is of concern is the relatively high percentage (43.5 percent) of customers and the potential number of users that do not forecast their demand levels.

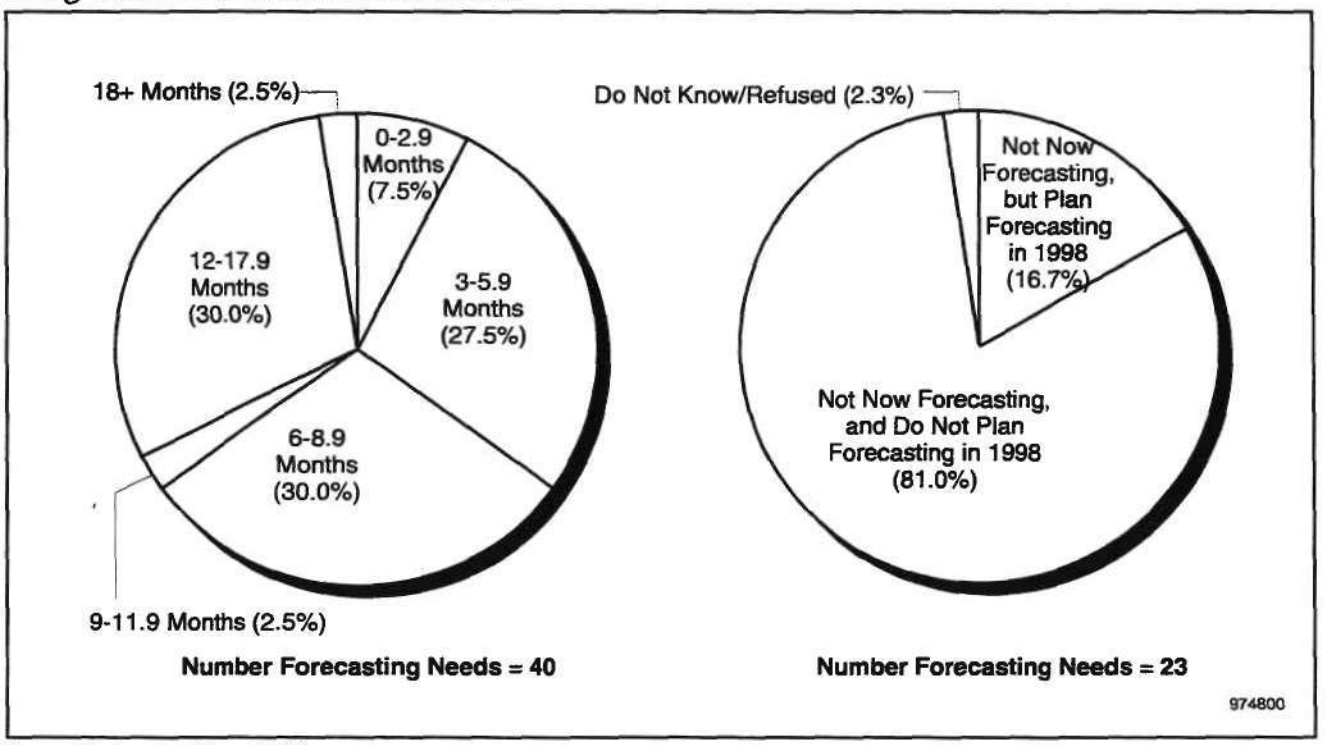
For users that do forecast their needs, the forecast window ranges from one to over 18 months, as seen in Figure 4-2, with an average forecast window of 3.3 months. PCB manufacturers noted a forecast window range between one and six months, with an average of 3.5 months, similar to the user response. Of the users not currently forecasting their needs, Figure 4-2 shows that only 17 percent plan on forecasting in 1998. The remaining 34 companies that will not forecast may well be those companies with internal PCB capacity that have other departments forecasting PCB needs.

## Figure 4-1
## Long-Term Forecasting of PCB Demand




Source: Dataquest (June 1997)

## Figure 4-2
## Long-Term PCB Forecast Windows

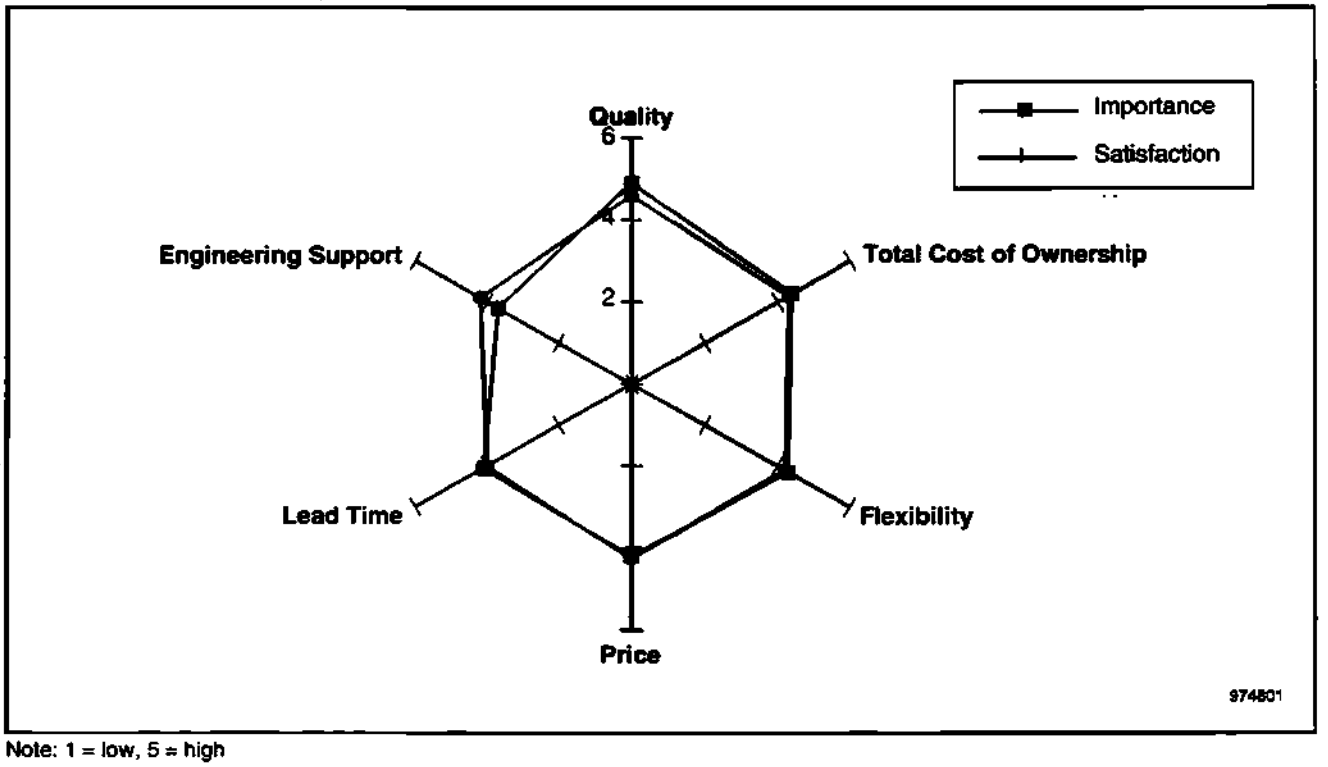



Source: Dataquest (June 1997)

## Critical PCB User Issues

Figure 4-3 is a satisfaction gap analysis of the most critical issues facing customers of PCB suppliers and how well their suppliers are meeting these ranked issues. Dataquest asked users on a scale of one (low) to five (high) what they deemed important and, on the same scale, how happy they were with their suppliers on that issue. The graph lists the highest-ranked issue (quality) and goes in a clockwise direction to the next-highest-ranked issue (total cost of ownership), and so on. Once ranked in order of importance, these criteria were then scrutinized for how well suppliers met these needs. The four top issues (quality = 4.9, total cost of ownership = 4.4, flexibility = 4.3, and price = 4.2) show very small gaps between level of importance and how well suppliers meet their customers' needs. The last two ranked issues, lead time = 4.0 and engineering support = 3.7, actually have levels of satisfaction higher than the deemed level of importance.

**Figure 4-3**
**PCB User Issues: Importance of Issue and User Satisfaction (N = 82)**




Note: 1 = low, 5 = high
Source: Dataquest (June 1997)

Users still deem quality to be the top issue, yet improvement still needs to be made (importance = 4.9, satisfaction = 4.6). The issue of total cost of ownership actually includes all of the issues listed is ranked second and also has some way to go (importance = 4.4, satisfaction = 4.3) to fully meet customer needs. The ranked issues of flexibility, price, and lead time all have a "satisfaction gap" of one or less, indicating that suppliers are doing a good job in meeting customer needs, with only small improvements needed, if any. The last-ranked issue, engineering support (importance = 3.7), has a satisfaction rating of 4.2, indicating that suppliers are far exceeding customer needs and could possibly scale back in this area and put more emphasis on quality or total cost of ownership. It appears that, while there is some room for improvement, most users in this study are relatively satisfied with their PCB supply base.


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## Chapter 5
# PCB Supply Base Issues

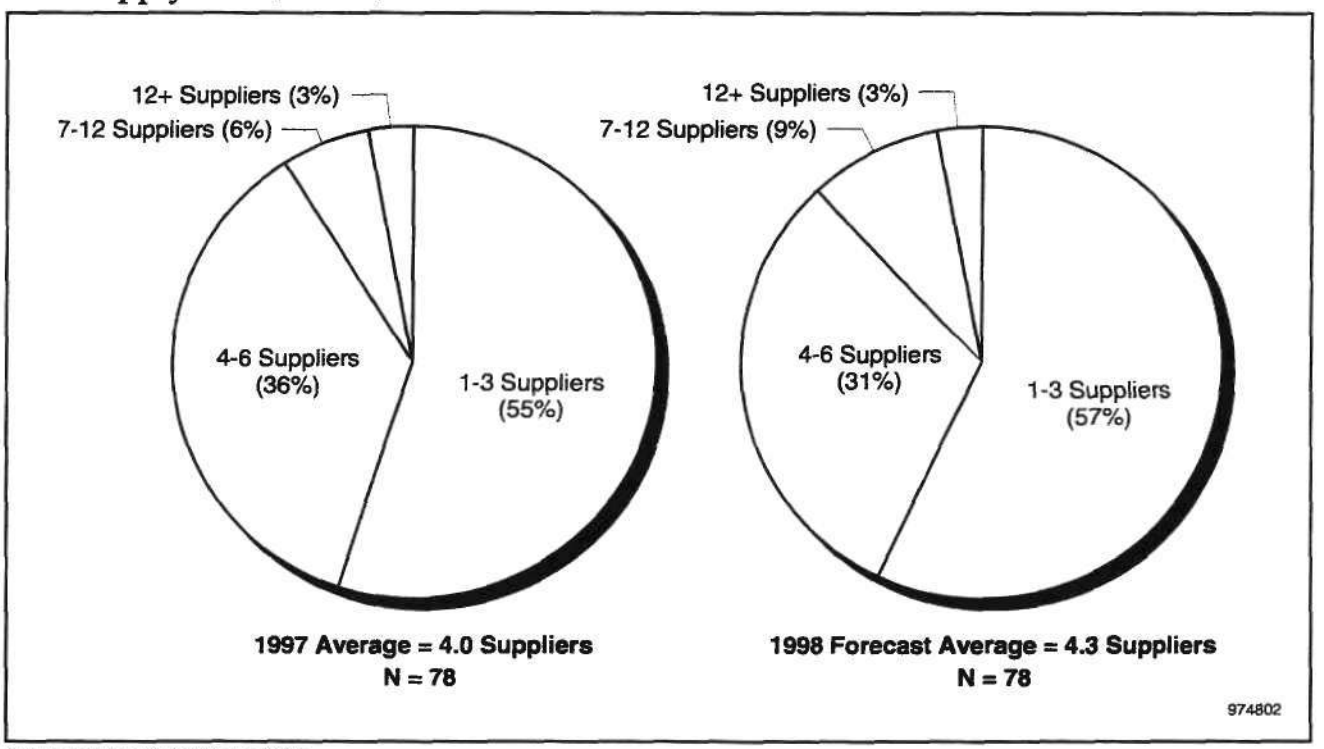
The number of suppliers of a given product often affects the level of quality, cost, and support involved with that product. The number of PCB suppliers that respondents in this study have ranges from one to 12 suppliers. Figure 5-1 highlights that the majority of the sample have under six suppliers and in 1997 averaged 4.0 suppliers. The outlook for next year notes a slight increase in the number of suppliers, with an average of 4.3. The users that currently have four to six suppliers will expand their supply base of PCB suppliers. Supplier reduction programs have passed through most companies and reduced costs and simplified sourcing logistics, but some users with an above-average number of suppliers plan on increasing their supply base, possibly in an effort to improve quality or lower total cost of ownership. For those using under the average number of suppliers, all but one will leave their supply base unchanged. This indicates that the majority of users has made the dramatic supplier reductions that contributed the contraction of the market. Although this is a small sample, we may now be seeing the beginning of a stabilization in the number of PCB companies.

Periodic review of a supply base to ensure how well the supplier meets customer needs has become more and more common. Figure 5-2 shows that over 80 percent of Dataquest's survey respondents perform regular PCB supplier reviews. Of those that currently do not, close to half plan on implementing a program next year. In line with the supply base management noted, a regular review of suppliers ensures that a customer's requirements and a supplier's offerings match. How often companies perform reviews generally tracks with the products the PCBs go into. Products with short life cycles have more frequent review cycles, and products with longer life cycles may have longer periods between review. Figure 5-3 shows that over half of the users either have monthly or quarterly supplier reviews. The 23 percent with review periods different from monthly, quarterly, or annually report review periods ranging from biweekly to 18 months.

The reason most companies perform supplier reviews is to influence their supply base to meet their needs better. Figure 5-4 shows that the vast majority (84 percent) of respondents said that supplier review affects current business levels; that is, if needs are met, the business relationship is maintained. Only 15 percent note that levels of business are not affected by supplier reviews. A like percentage of users (86 percent) notes that future levels of business are affected by supplier review programs. For example, customers generally will change suppliers after a period of supplier review if improvements identified as needed have not been made.

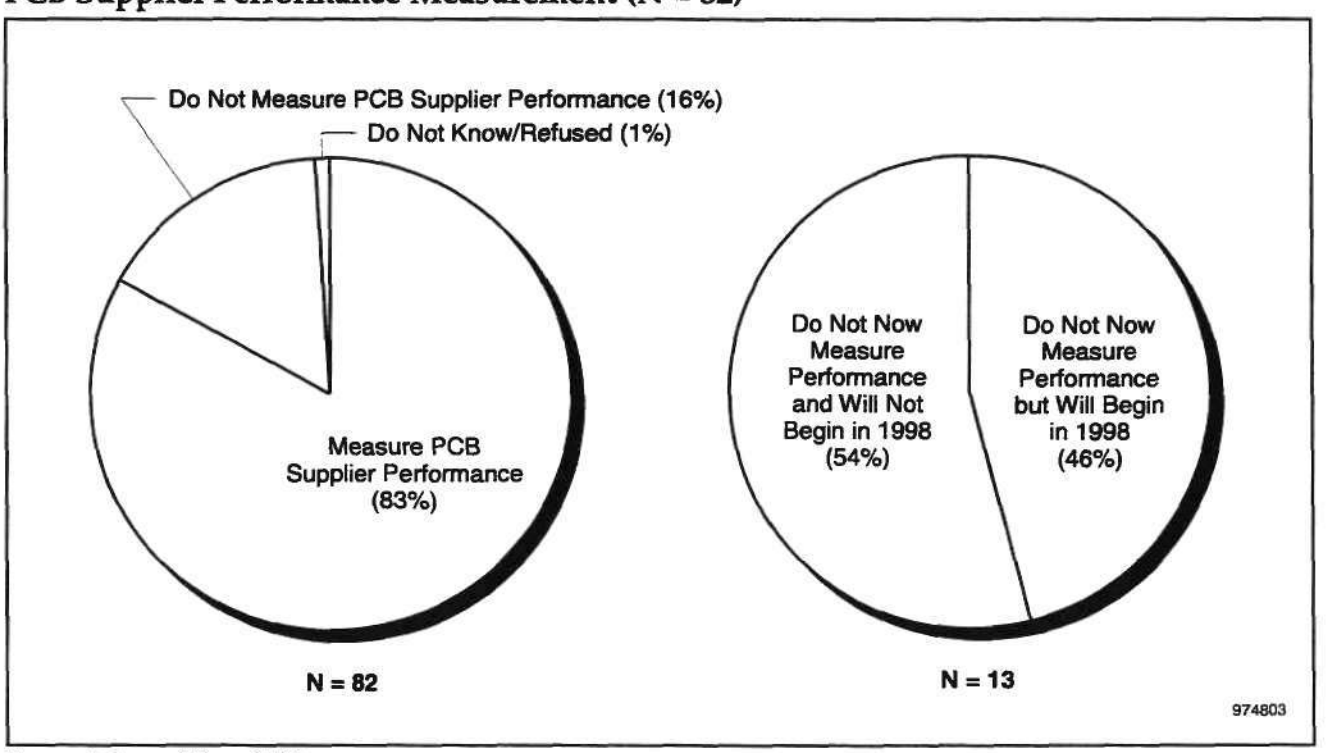
Although the number of PCB suppliers appears to be stabilizing for this sample, the overall PCB market will remain in the throes of worldwide competition. As noted earlier, geographic location was not a top priority when determining a PCB supplier. If offshore suppliers can successfully meet customer needs for quality, total cost of ownership, and flexibility, there may be further change in the number of PCB suppliers and in their level of regional support.

## Figure 5-1
## PCB Supply Base (N = 78)



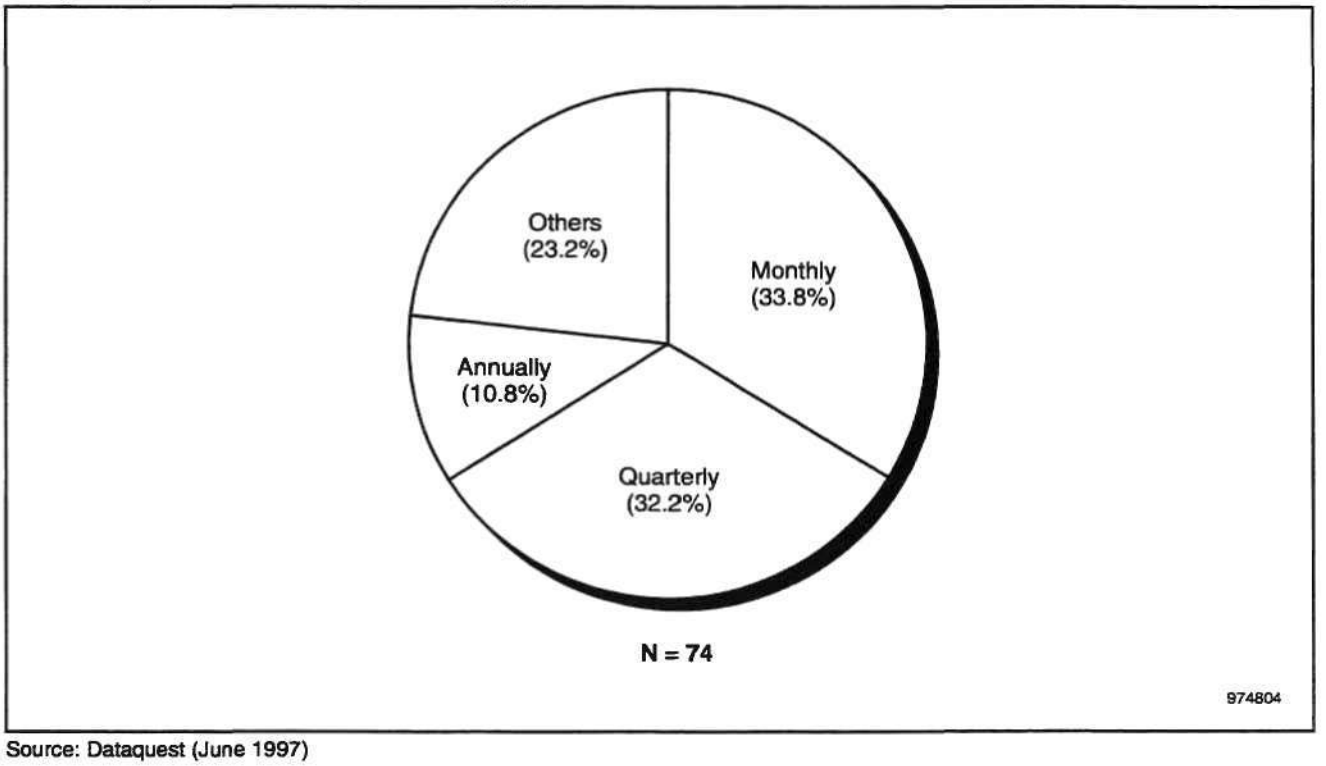

Source: Dataquest (June 1997)

## Figure 5-2
## PCB Supplier Performance Measurement (N = 82)



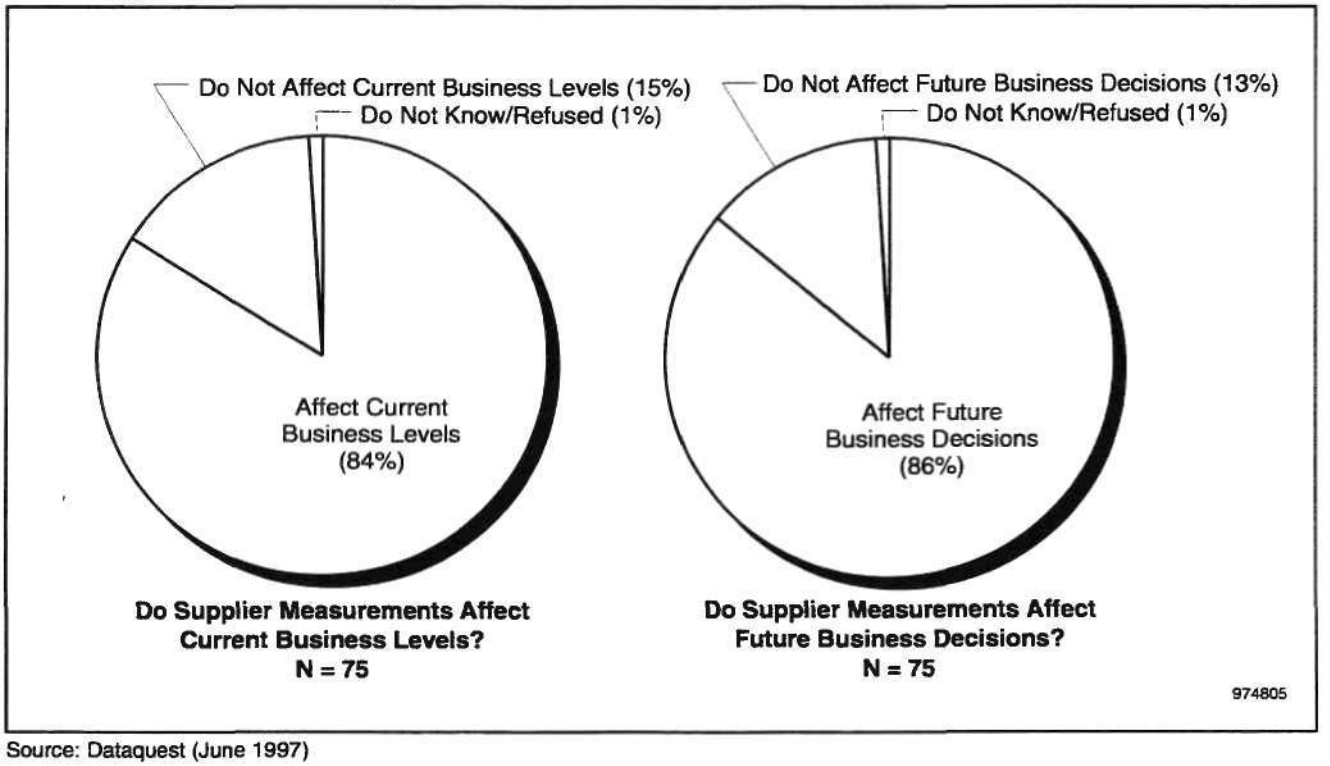

Source: Dataquest (June 1997)

**Figure 5-3**
**Frequency of Measuring PCB Supplier Performance (N = 74)**




Source: Dataquest (June 1997)

**Figure 5-4**
**PCB Supplier Review Impact (N = 75)**




Source: Dataquest (June 1997)

## Chapter 6
# Prices per PCB Layer

This chapter looks at the average prices or costs per layer of PCBs as disclosed by the survey participants. As both the users (buyers) and manufacturers (suppliers) were both asked the same question, this chapter has been split into three sections:

- Buyers' PCB prices
- Suppliers' PCB prices
- Comparison of buyers' and suppliers' PCB prices

Dataquest obtained information on the average costs per layers from each group and then calculated the mean cost per layer for both buyers and suppliers.

## Methodology

The survey mix was largely composed of industrial and military applications. However, for the purpose of the data on average cost per layer, Dataquest looked only at nonmilitary applications participants.

Also, because many companies view pricing as a key component in the success of their organization, many were reluctant to release this information to Dataquest. Thus, in some cases, the sample size may be too small, and Dataquest will not have a value for it. This is true mainly for the higher-layer boards.

Dataquest asked survey participants to estimate the average price or cost of the different layers of PCB in square inches. This was done because the PCBs procured or manufactured were not a standard size. It would make no sense to compare average board prices—some boards could be 1 inch x 4 inches, with others 144 inches x 144 inches and still be four-layer boards!

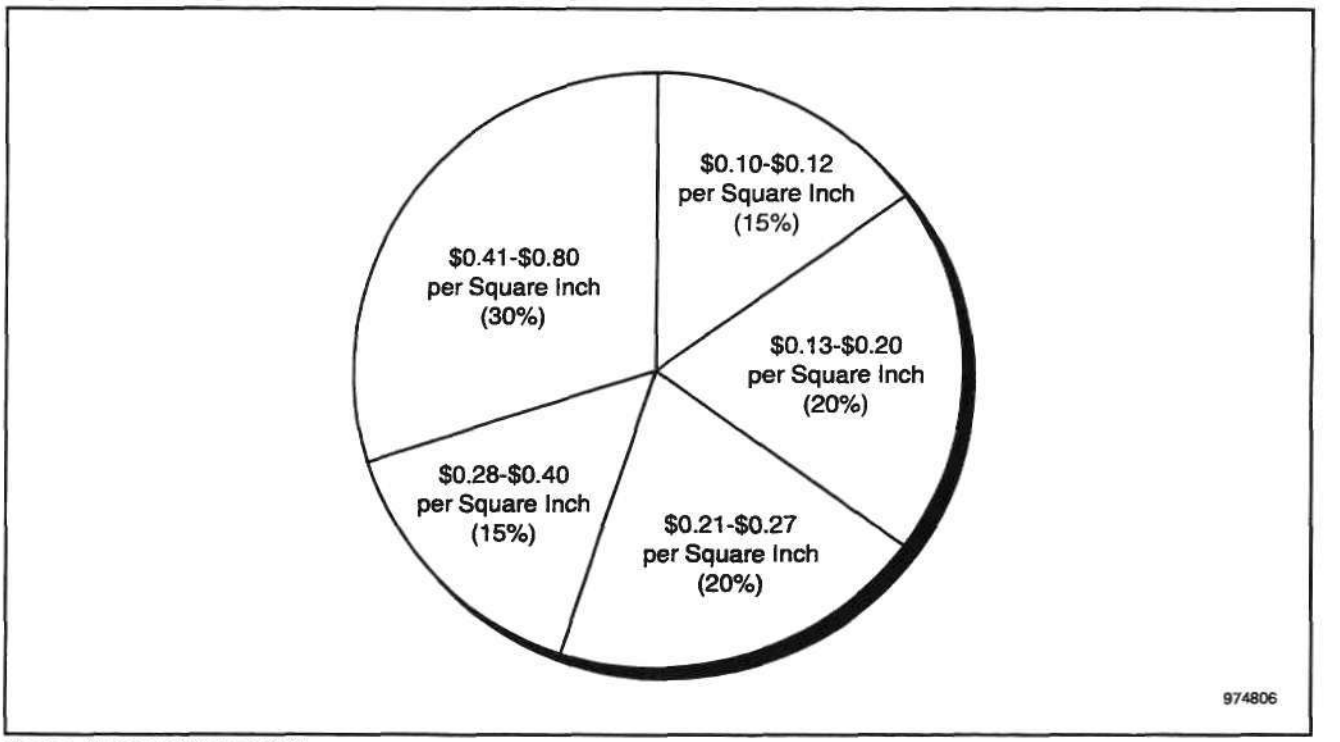
Board complexity could not be factored. Each application has its own design requirements and PCB functionality and complexity requirements. This factor explains why the range of average cost per PCB layer varies greatly from participant to participant.

## Buyers' Average PCB Costs

Dataquest asked the PCB buyers to estimate their average cost per square inch per PCB layer. Cost is defined as the buyer's price from the supplier or internal division. It does not refer to the total cost of ownership of the PCB.

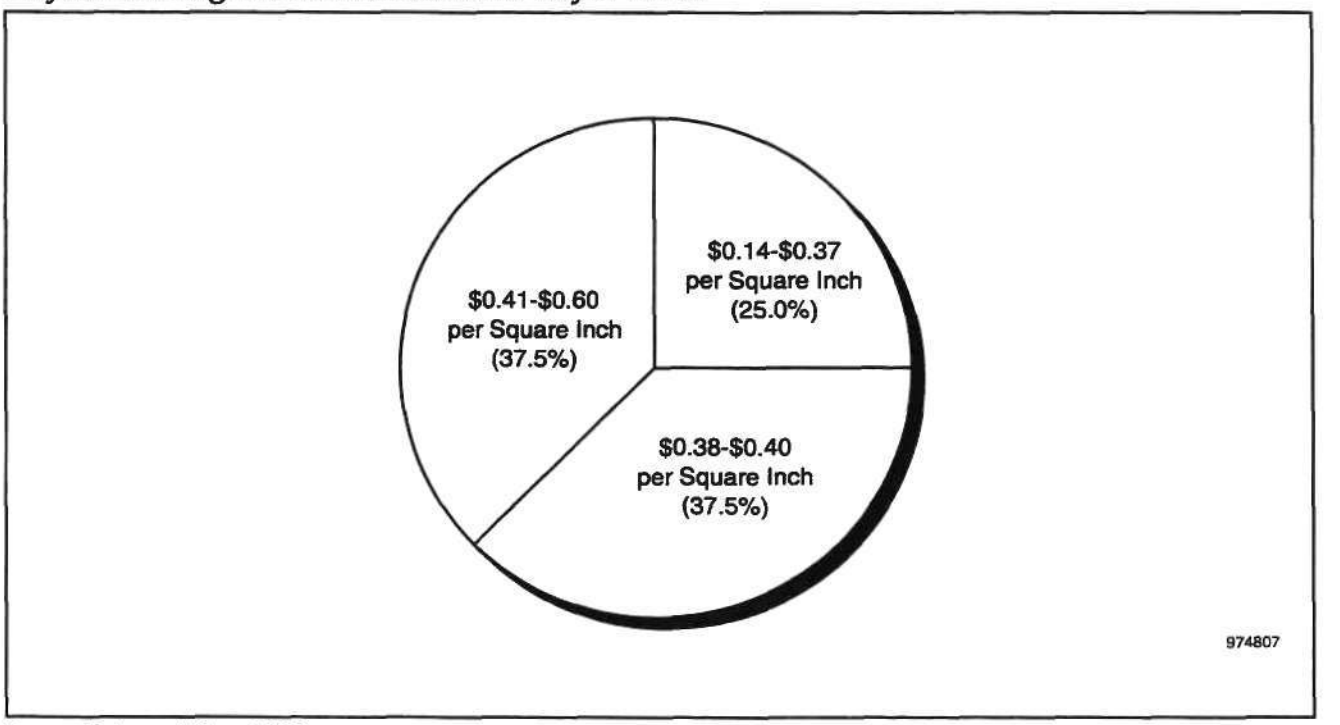
Figures 6-1 to 6-4 have classified the actual price given by the participating buyers into ranges. Please note that the buyers gave their own numeric value for their average price per layer. The range is used only to show how these average prices are clustered. These ranges were then graphed. However, to calculate the overall mean price per layer, Dataquest used the actual average price given by each supplier.

**Figure 6-1**
**Buyers' Average PCB Price for Two-Layer PCBs**



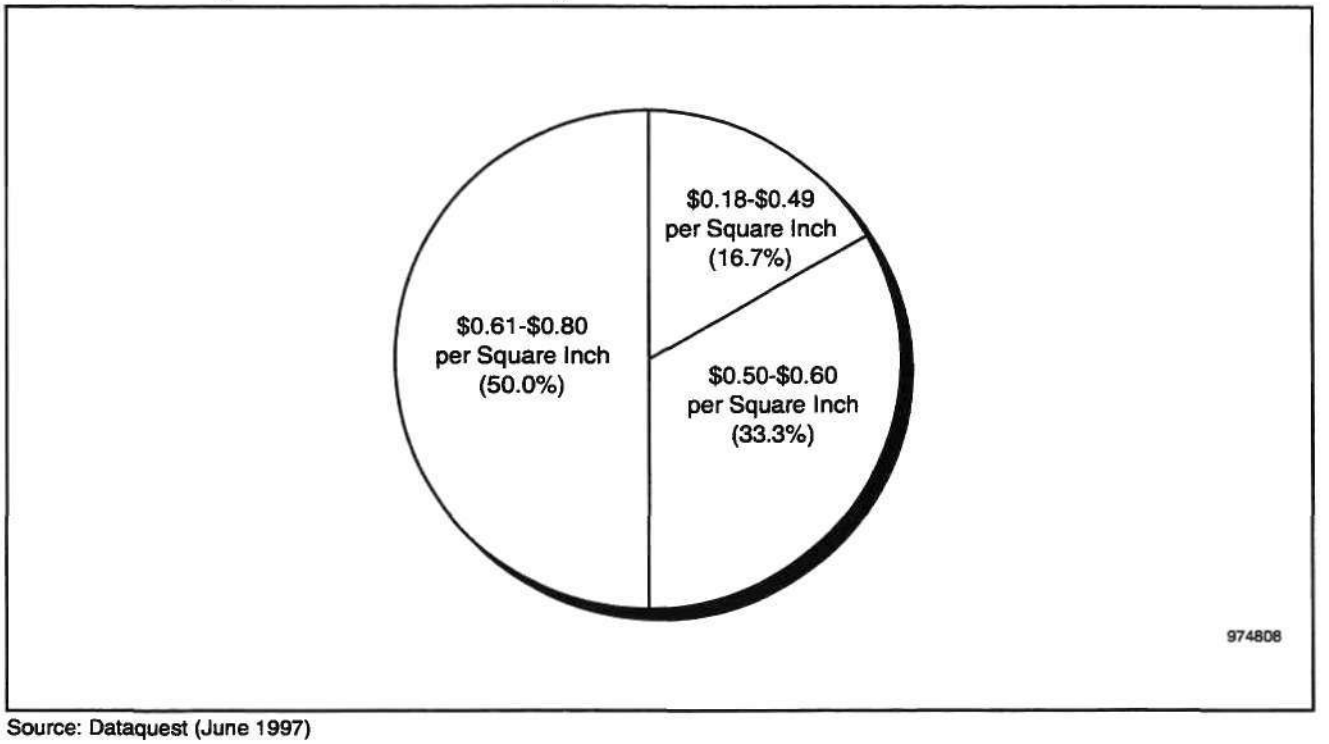

Source: Dataquest (June 1997)

**Figure 6-2**
**Buyers' Average PCB Price for Four-Layer PCBs**



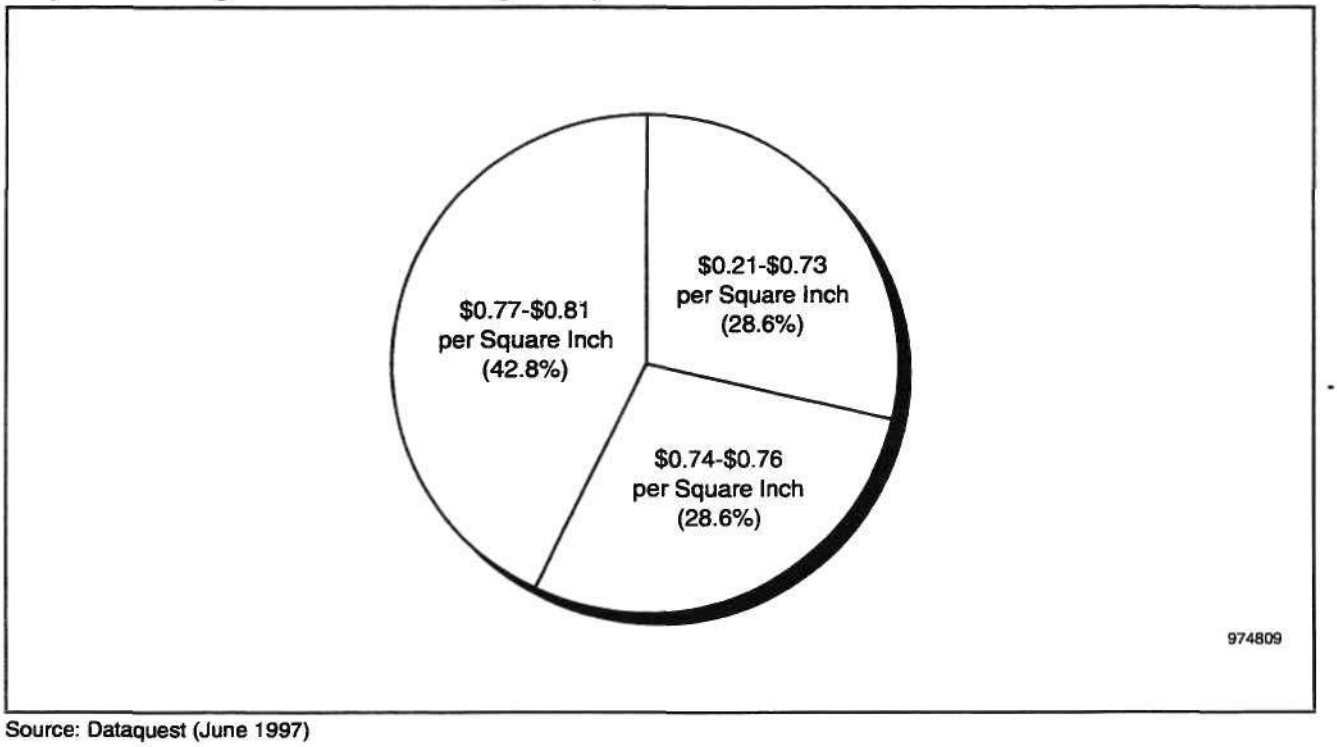

Source: Dataquest (June 1997)

**Figure 6-3**
**Buyers' Average PCB Price for Six-Layer PCBs**




Source: Dataquest (June 1997)

**Figure 6-4**
**Buyers' Average PCB Price for Eight-Layer PCBs**




Source: Dataquest (June 1997)

Figure 6-1 shows the average price per layer for each respondent in the buyers group for two-layer PCBs. The average cost per square inch ranged from $0.10 to $0.80. This range is extremely large and would indicate that a sizable number use very highly integrated and complex two-layer boards.

Figure 6-2 shows the range of average prices per square inch for four-layer boards among the participating buyers. It can be seen that this price range is from $0.14 to $0.60 per square inch.

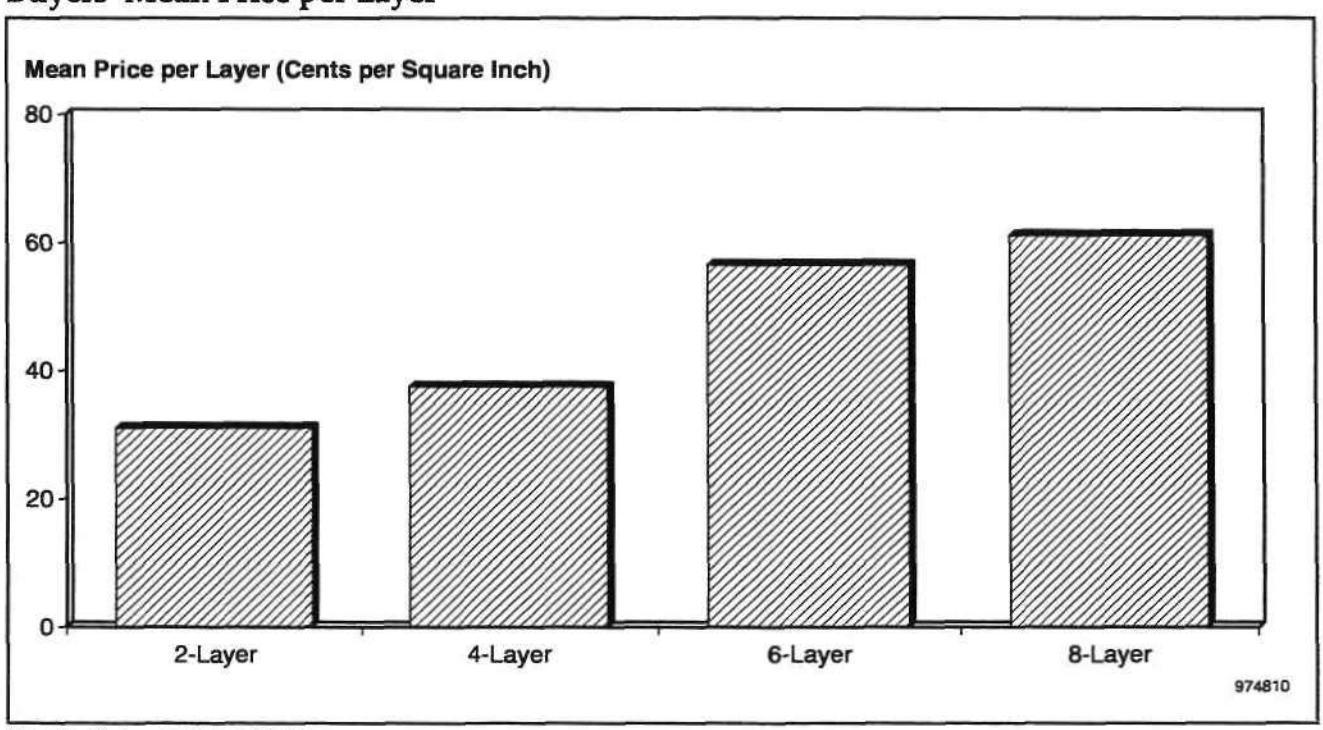
The range of average prices among the buyers who responded was from $0.18 to $0.80 per square inch (see Figure 6-3). At six layers, this range is accounted for largely by the volume and complexity differences within the sample.

The range of average prices shown in Figure 6-4 was from $0.21 to $0.81 per square inch. This is a very large price range and reflects the varied complexities and volumes procured at eight-layer board densities. Eight-layer boards were not bought in large quantities by the majority of survey participants.

## Buyers' Mean Price per PCB Layer

The mean of the results for the buyer group was calculated. Figure 6-5 shows the mean prices by PCB layer number for the buyers.

**Figure 6-5**
**Buyers' Mean Price per Layer**




Source: Dataquest (June 1997)

The sample size was insufficient to calculate a mean value for boards of greater than eight layers among the buyers' sample. From Figure 6-5, it can be seen that the average cost per square inch increases as the number of PCB layers increases. This is to be expected.

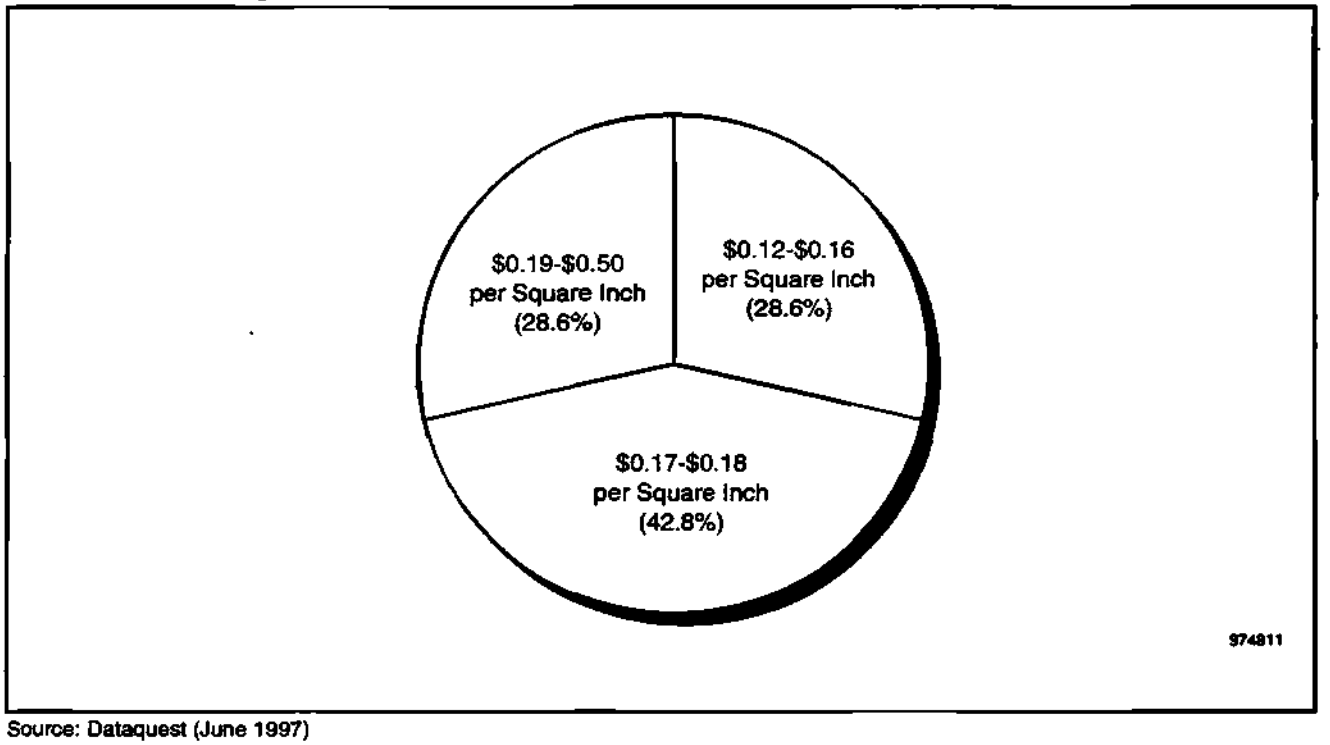
The two- and four-layer boards have mean costs in the same ballpark. For two-layer boards, the mean cost for buyers is $0.311 per square inch, while for four-layer PCBs, the mean came out as $0.375 per square inch. The mean costs were $0.565 and $0.611 for the six- and eight-layer boards, respectively, from the buyer sample.

## Suppliers' Average PCB Prices

The supplier or manufacturing category also gave their average cost. Here, the average cost or price refers to average sales price of the board to the supplier's customers in cents per square inch. It does not refer to the cost to manufacture the PCBs.

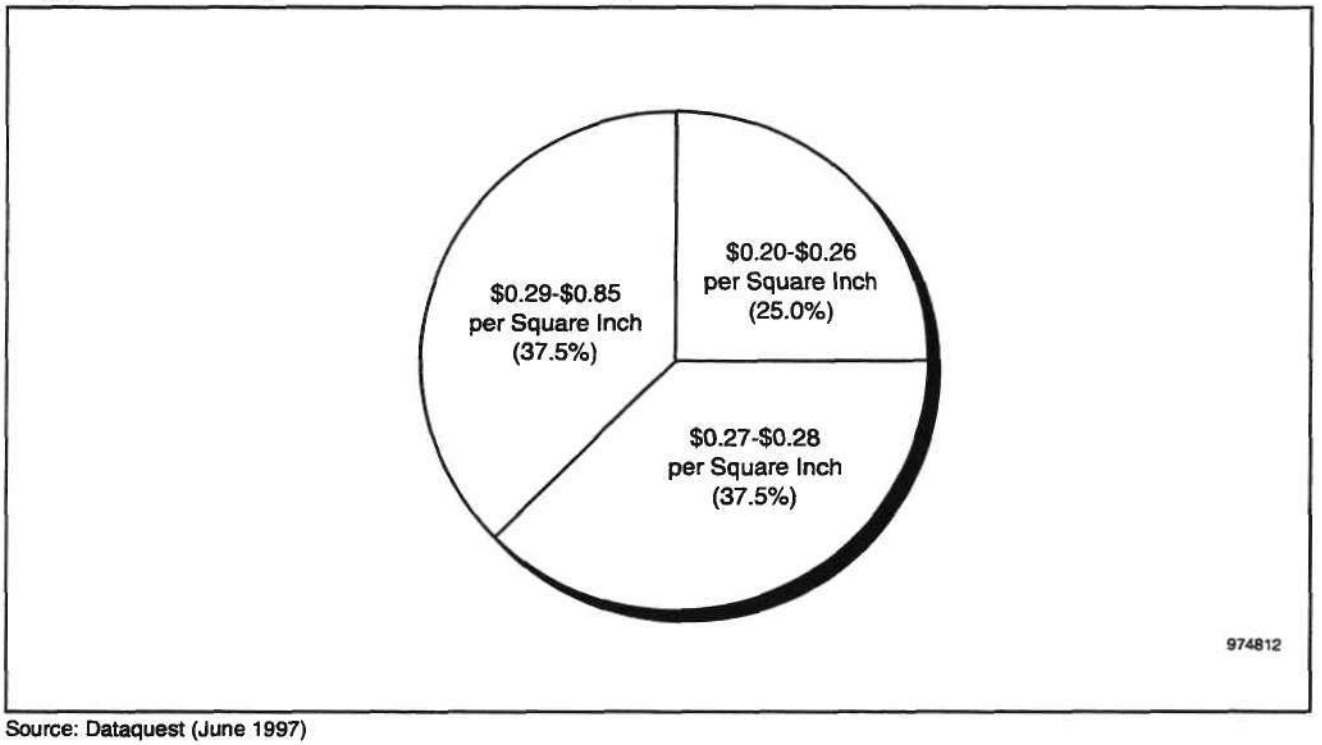
Figures 6-6 through 6-11 have classified the actual price given by the participants into ranges. Please note that participants gave their own numeric value for their average price per layer. The range is used only to show how these average prices are clustered. These ranges were then graphed. However, to calculate the overall mean price per layer, Dataquest used the actual average price given by each supplier.

**Figure 6-6**
**Suppliers' Average PCB Price for Two-Layer PCBs**



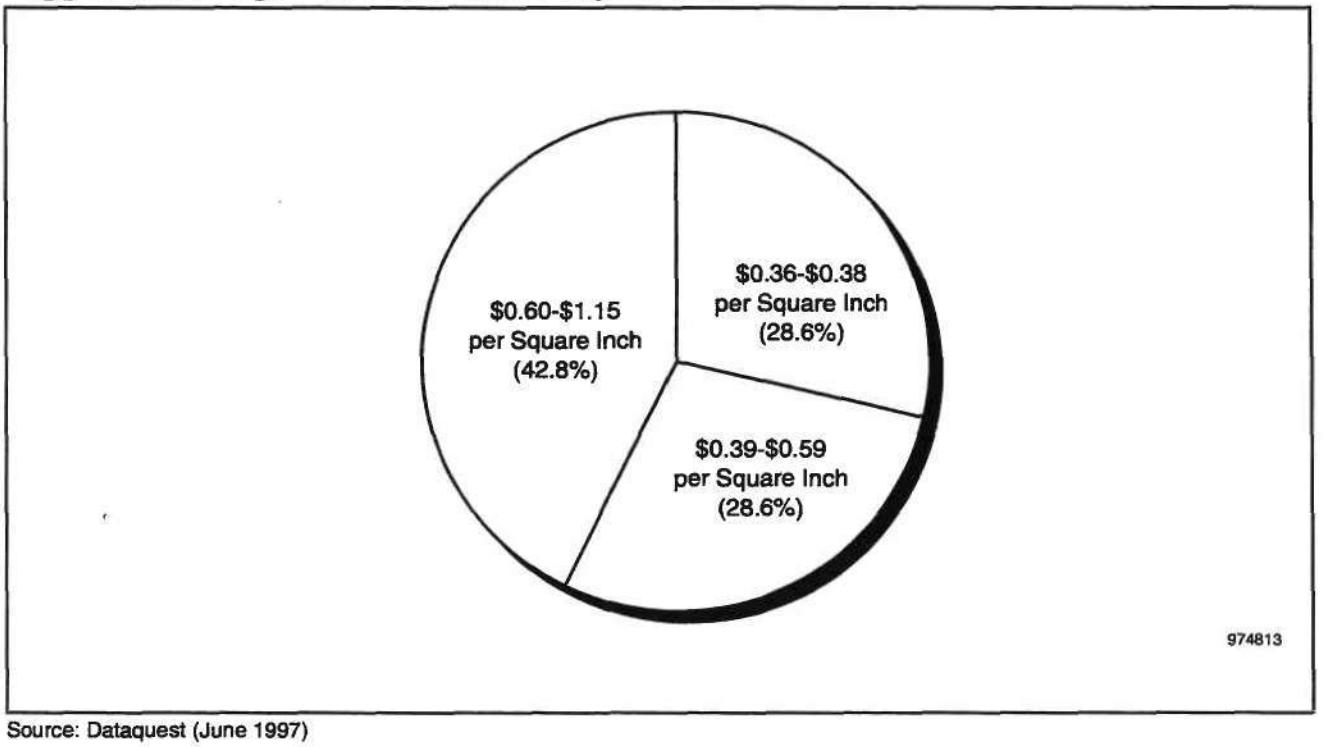

Source: Dataquest (June 1997)

**Figure 6-7**
**Suppliers' Average PCB Price for Four-Layer PCBs**




Source: Dataquest (June 1997)

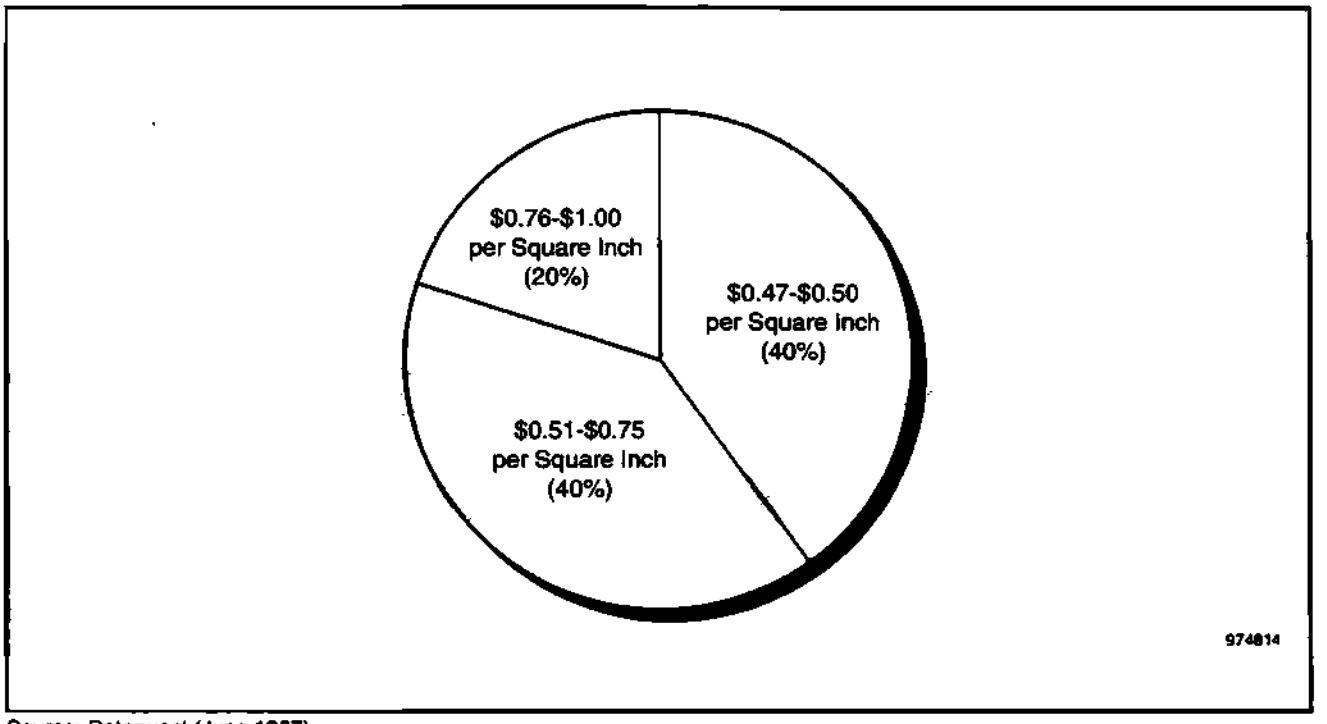
**Figure 6-8**
**Suppliers' Average PCB Price for Six-Layer PCBs**




Source: Dataquest (June 1997)

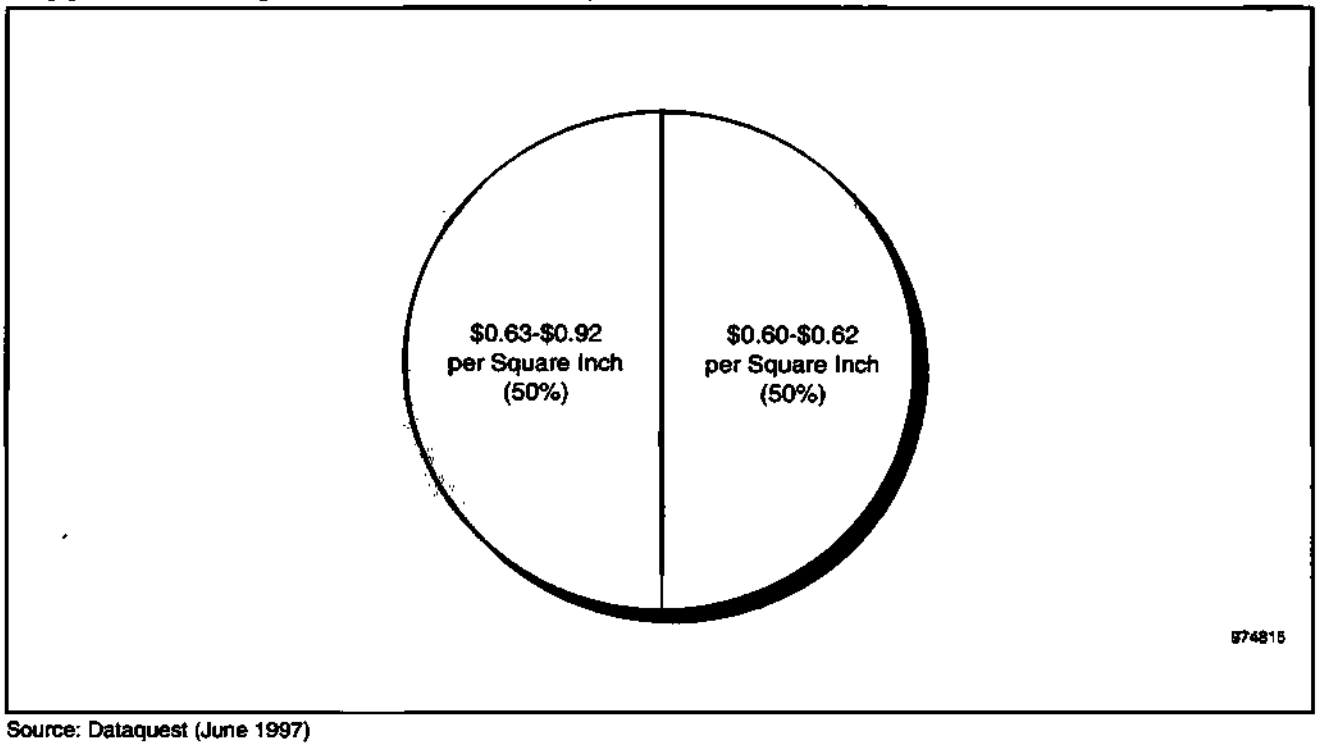

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**Figure 6-9**
**Suppliers' Average PCB Price for Eight-Layer PCBs**



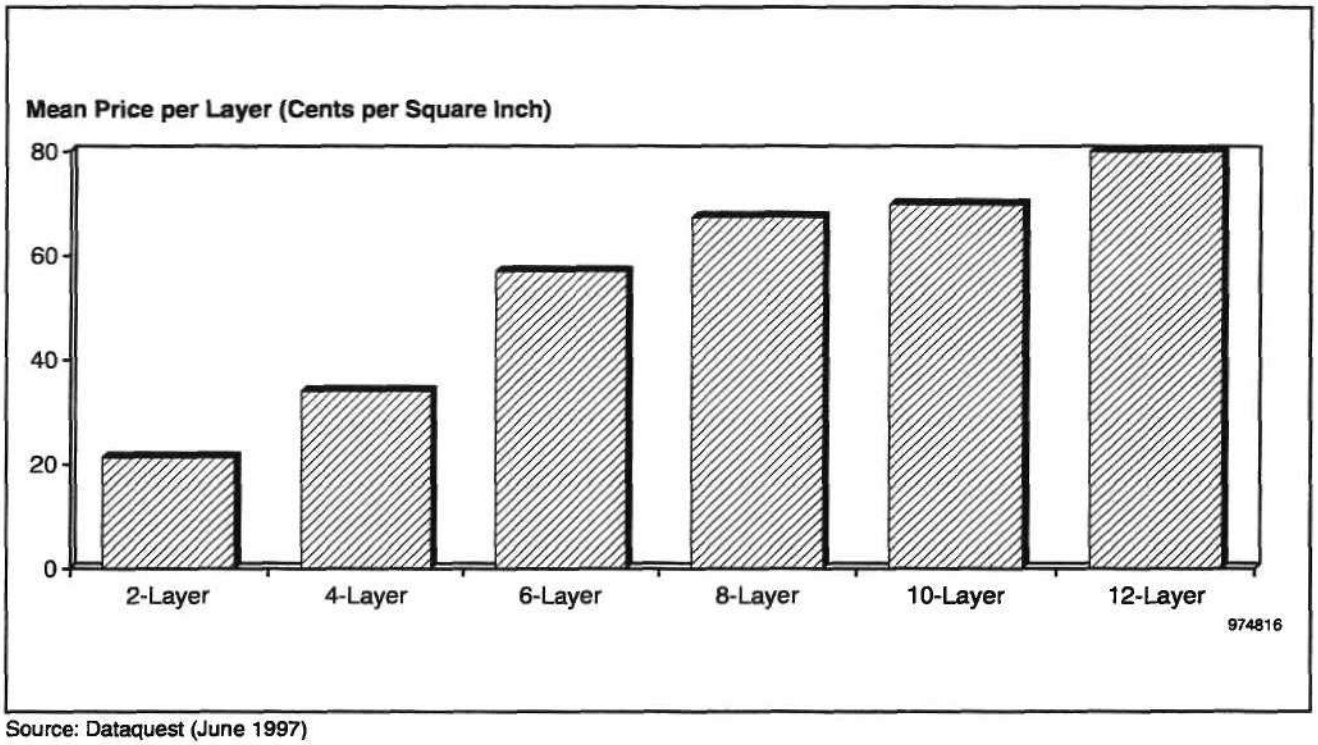

Source: Dataquest (June 1997)

**Figure 6-10**
**Suppliers' Average PCB Price for 10-Layer PCBs**




Source: Dataquest (June 1997)

**Figure 6-11**
**Suppliers' Mean Price per Layer**




Source: Dataquest (June 1997)

From Figure 6-6, it can be seen that the average sales price in cents per square inch for two-layer PCBs ranges from $0.12 to $0.50 per square inch. This is based on the data received by Dataquest from the suppliers.

Figure 6-7 shows the range of average sales price from suppliers to customers for four-layer PCBs. The average price ranged from $0.20 to $0.85 per square inch, based on the suppliers' inputs.

Figure 6-8 shows that there was quite a range of average prices reported by the suppliers sampled. These average prices ranged from $0.36 to $1.15 per square inch for six-layer boards.

The average prices for eight-layer boards as reported by the suppliers sampled is shown in Figure 6-9. The average sales prices ranged from $0.47 to $1.00 per square inch.

Figure 6-10 shows the range of average prices for 10-layer boards. From the data it can be seen that the range of averages was $0.60 to $0.92 per square inch.

The highest density reported by survey participants was 12-layer PCBs. Here, 100 percent of the respondents reported an average sales price of $0.80 per square inch.

## Suppliers' Mean Price per Layer

Dataquest calculated the mean price per layer based on the inputs from the supplier sample (see Figure 6-11).

There is a significant different between the two- and four-layer mean prices per square inch. This is no doubt a reflection of the customer base or of demand seen by the manufacturers. The mean price for six-layer boards was $0.57 per square inch. Mean prices for the eight- and 10-layer boards were both in the same range—$0.674 and $0.698 per square inch, respectively. Twelve-layer boards had a mean price of $0.80 per square inch.

## Comparison of Buyers' and Suppliers' Mean Prices

Table 6-1 compares the mean prices per layer for the buyers and suppliers surveyed. The data in the table is based on the mean price per layer for buyers and suppliers graphed in Figures 6-5 and 6-11. The table also shows the difference between the results of the buyers and suppliers for each layer's mean price.

As the number of layers increases, there is usually greater functionality incorporated into the overall PCB. The required greater detail and the additional layers of plastic and metal mean that costs will be higher as the number of layers increases. Thus it would be expected that the price per square inch would increase as the number of PCB layers increases. This is clearly the result seen from both buyers' and suppliers' responses.

It can be seen that the biggest difference between the mean prices of buyers and suppliers was at two-layer PCBs. The mean cost reported by buyers was nearly $0.10 per square inch more than that reported by suppliers. This is because buyers reported a range of cost per square for two-layer boards inch from $0.10 to $0.80. However, for suppliers, the range was $0.12 to $0.50 per square inch. These responses explain why the buyers had a higher mean price than the suppliers surveyed.

For four-layer boards, the mean prices were $0.375 and $0.34 per square inch for buyers and suppliers, respectively. This gives a difference of $0.035 per square inch, which is very little. The six-layer mean costs were almost identical—$0.565 and $0.57 per square inch for buyers and suppliers, respectively, giving a difference of 0.5. Also, the results for eight-layer PCBs were quite close ($0.611 per square inch for buyers and $0.674 for suppliers), with the difference being a mere $0.063.

Because there was insufficient data from buyers to calculate the mean price per square inch for densities above eight layers, it is not possible to directly compare the buyer and supplier data. It has to be taken at face value. The mean prices per square inch given for 10- and 12-layer PCBs were $0.698 and $0.80 per square inch.

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**Table 6-1**
**Comparison of Mean Price per Layer for Buyers and Suppliers (Cents per Square Inch)**

| | Buyers' Mean Price per Layer | Suppliers' Mean Price per Layer | Difference |
|---|---|---|---|
| Two-Layer PCB | 31.1 | 21.3 | 9.8 |
| Four-Layer PCB | 37.5 | 34.0 | 3.5 |
| Six-Layer PCB | 56.5 | 57.0 | 0.5 |
| Eight-Layer PCB | 61.1 | 67.4 | 6.3 |
| 10-Layer PCB | NA | 69.8 | NA |
| 12-Layer PCB | NA | 80.0 | NA |

NA = Not available
Source: Dataquest (June 1997)


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# Chapter 7
# Lead Time Results

This chapter looks at the average lead times experienced by the survey participants for different PCB layers. The survey participants were classified as suppliers or buyers (if both, the respondents were asked both the supplier and buyer questions), and the lead time questions were asked of both categories of respondents.

Thus, this chapter is broken into three sections for ease of analysis:

- Buyers' average lead times
- Suppliers' average lead times
- Comparison of buyers' and suppliers' average lead times

Please note that suppliers were asked to give the average lead time they quote to their customers at each of the layers they produce. Buyers were asked to give the average lead time they receive from their internal or external PCB suppliers.

## Buyers' Average Lead Times

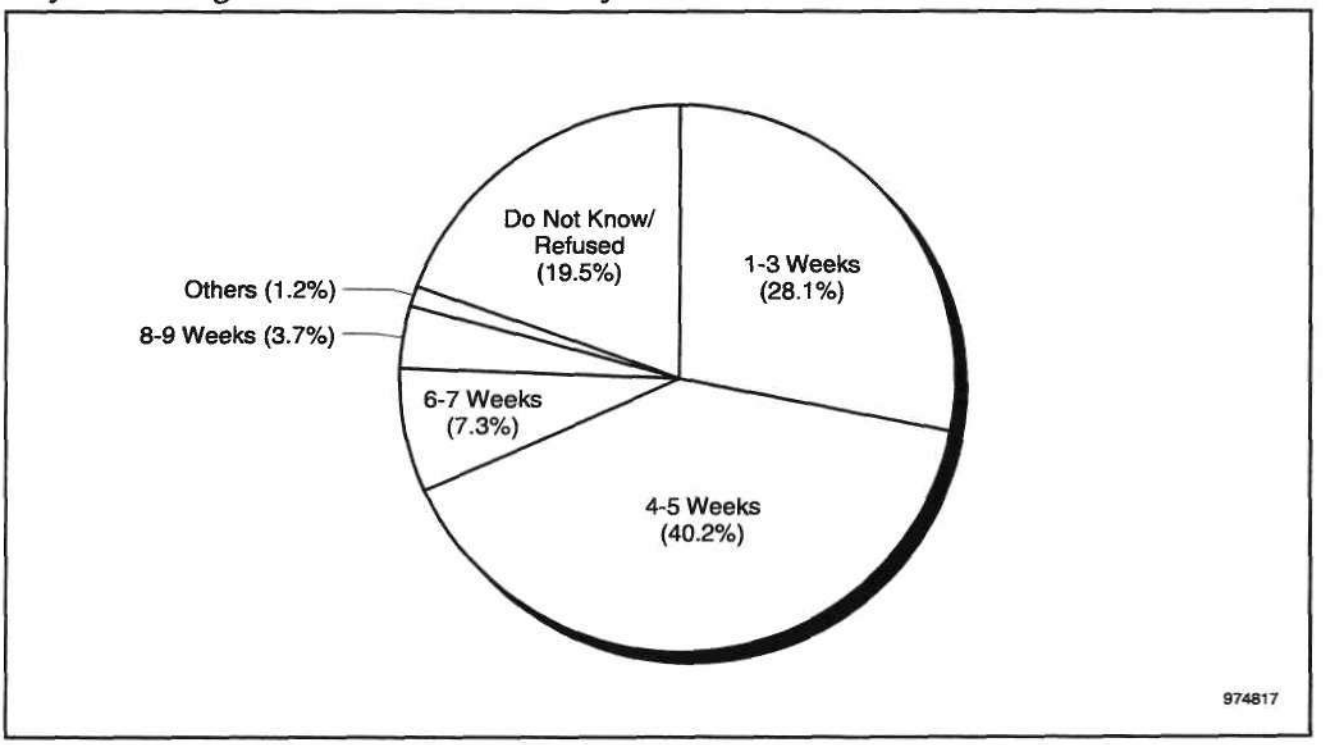
Figure 7-1 shows the range of average lead times experienced by buyers of two-layer boards. Here, the lower lead times were reported by nearly 70 percent of the sample—one to three weeks and four to five weeks by 28.1 percent and 40.2 percent, respectively. Over 7 percent of respondents had average lead times of six to seven weeks, and just under 4 percent had eight- to nine-week average lead times for two-layer boards. The remaining respondents either did not know or refused to answer (19.5 percent) or had other lead times (1.2 percent).

The average lead times for four-layer boards given by the buyer sample are shown in Figure 7-2. Although 12.5 percent had average lead times of one to three weeks, about 44 percent had average lead times of four to five weeks for four-layer boards. Higher lead time ranges of six to seven weeks and eight to nine weeks were reported by 14.6 percent and 6.2 percent of participants, respectively. Lead times outside the ranges shown were reported by 2.1 percent, and just under 21 percent either refused to answer or did not know their lead times at four layers.

Figure 7-3 shows the range of average lead times for six-layer boards reported by the participating buyers. Just under 9 percent had average lead times in the range of one to three weeks and eight to nine weeks. Nearly 38 percent of respondents had four-to-five-week average lead time ranges, while one-fifth had six-to-seven-week average lead times. Just under a quarter of respondents either refused or did not know the average lead time for six-layer boards.

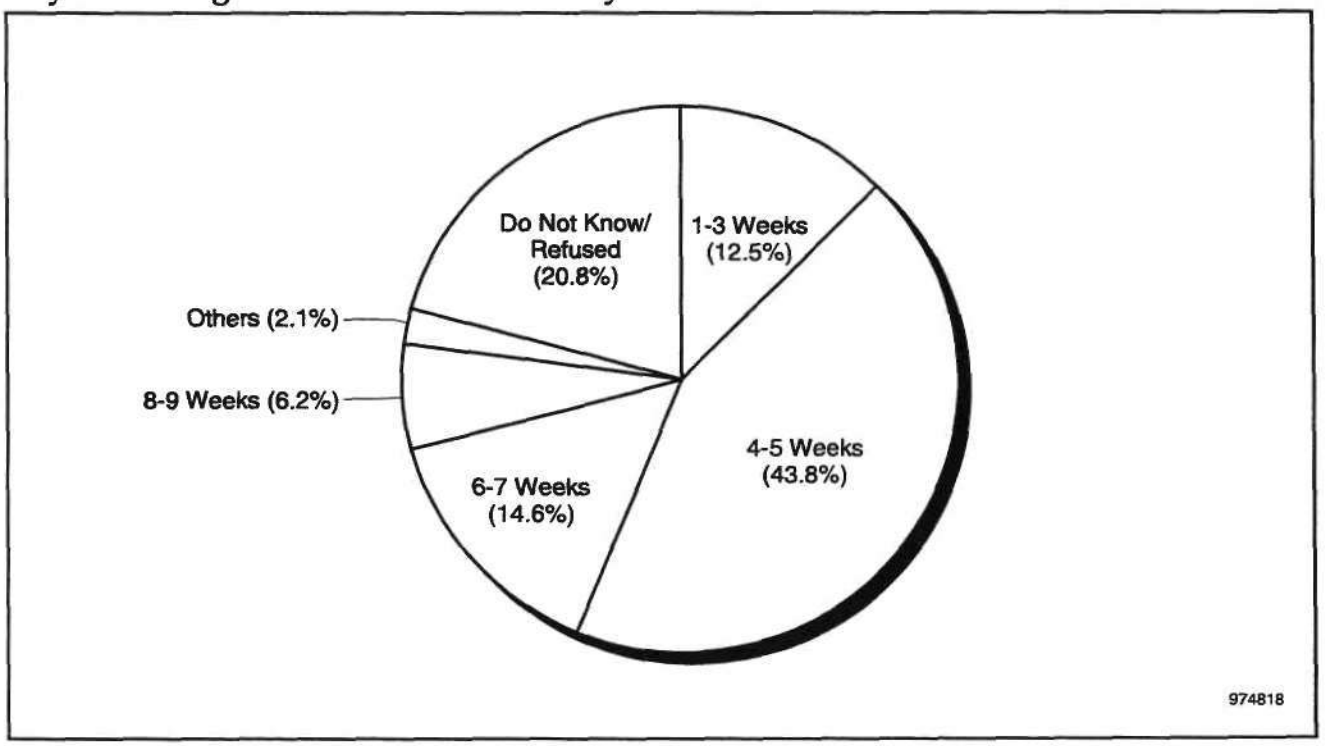
Figure 7-4 shows that over 37.5 percent of the sample either refused or did not know the lead time for eight-layer boards. For 22.5 percent of respondents, average lead time were four to five weeks, while a quarter of all participants reported six to seven weeks. The remaining respondents fell into two categories—10 percent had average lead times of eight to nine weeks and 5 percent had one-to-three-week average lead times.

**Figure 7-1**
**Buyers' Average Lead Times for Two-Layer PCBs**



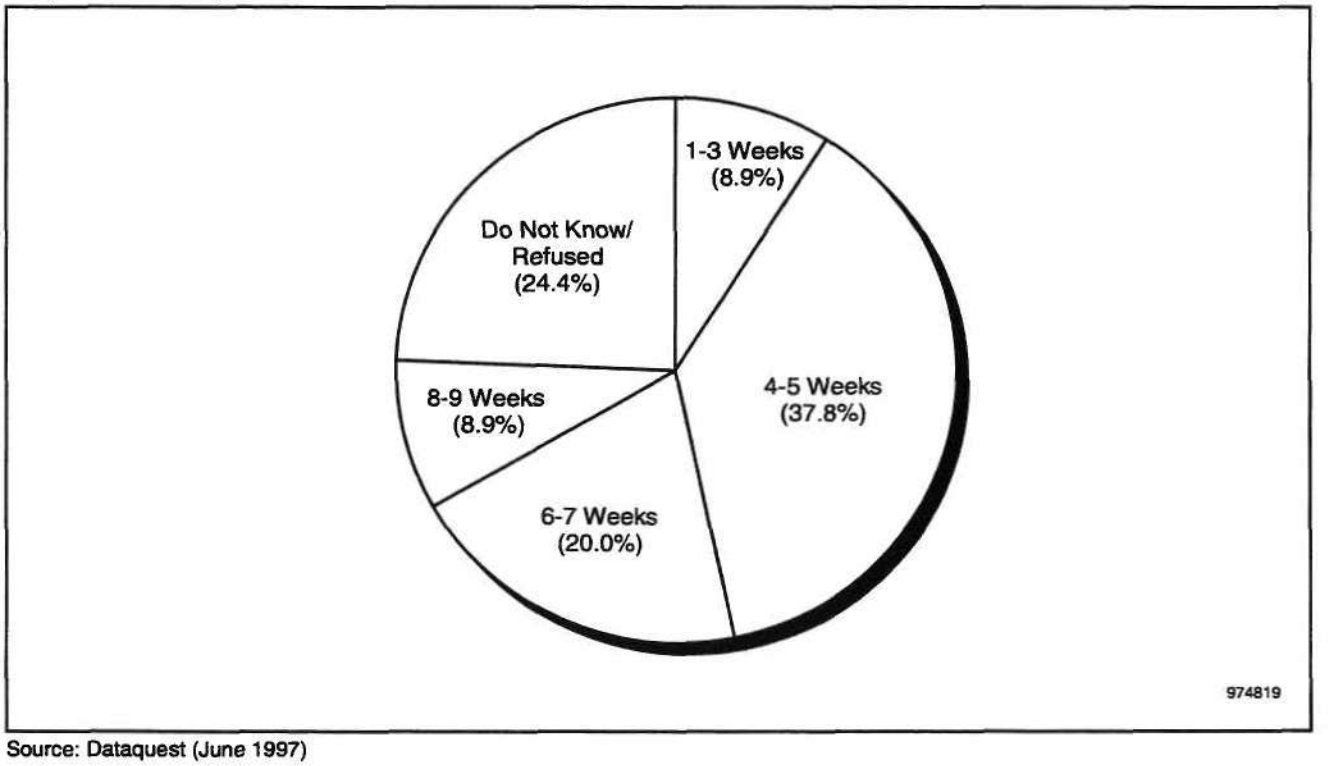

Source: Dataquest (June 1997)

**Figure 7-2**
**Buyers' Average Lead Times for Four-Layer PCBs**



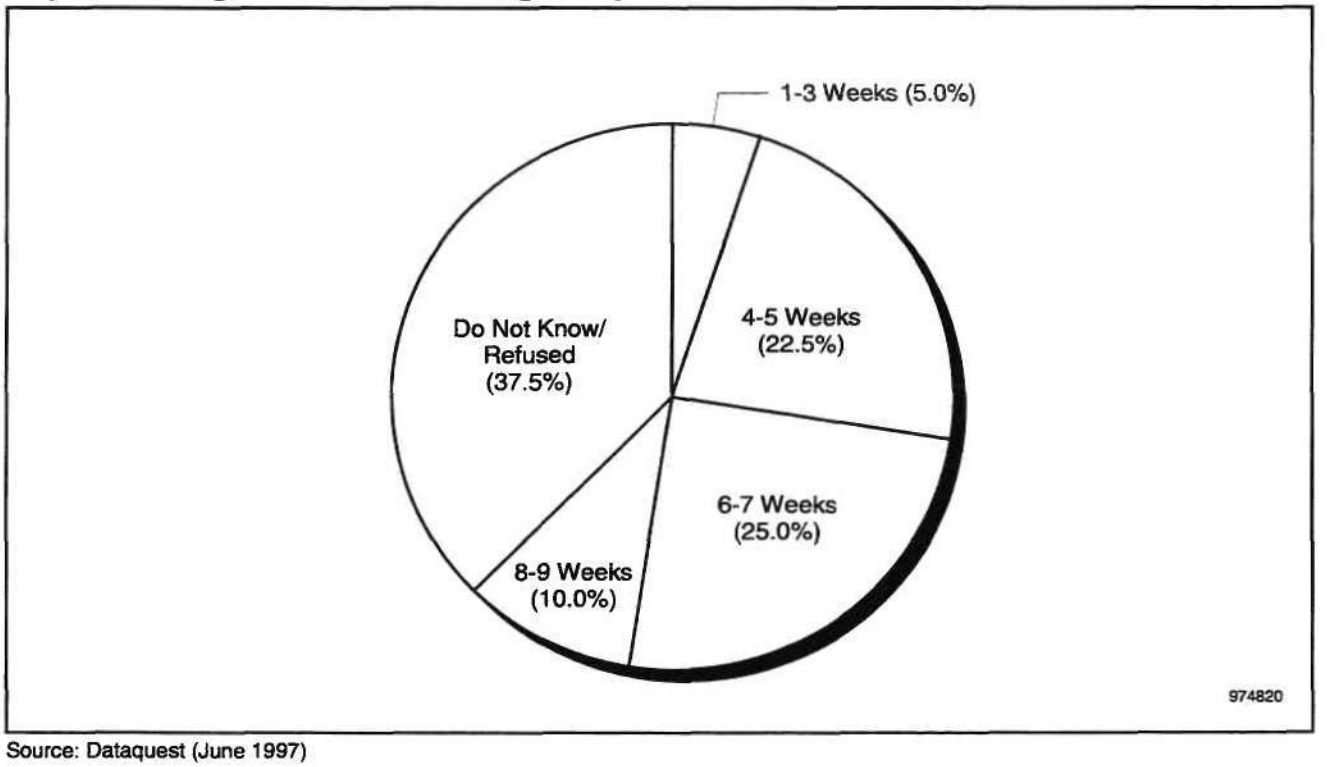

Source: Dataquest (June 1997)

**Figure 7-3**
**Buyers' Average Lead Times for Six-Layer PCBs**




Source: Dataquest (June 1997)

**Figure 7-4**
**Buyers' Average Lead Times for Eight-Layer PCBs**




Source: Dataquest (June 1997)

## Buyers' Mean Lead Times per PCB Layer

Figure 7-5 shows the mean lead times per layer for the buyer sample surveyed. In calculating the mean lead times, only participants who gave a lead time range were used; those who "did not know/refused" were not included.

The buyers' mean lead time increased as the number of PCB layers increased. The mean lead time for two-layer boards was just under four weeks, while that of four-layer boards was 4.8 weeks. For six-layer boards, the mean lead time was 5.21 weeks, and for eight-layer boards, it came to 5.74 weeks.

## Suppliers' Average Lead Times

For two-layer PCBs, the average lead time ranges given by the sample of surveyed suppliers is shown in Figure 7-6. Just under 5 percent reported an average lead time of less than a week. However, the vast majority gave a higher lead time range: 47.6 percent reported average lead times of between one and three weeks, just over 38 percent said that average lead times were four to five weeks for two-layer boards, and 9.6 percent of participants either refused to answer or did not know the average lead time.

Figure 7-7 shows the results of suppliers' average lead times for four-layer boards. Nearly 48 percent reported average lead times of four to five weeks, with 38.1 percent saying that average lead times were one to three weeks. Just under 5 percent reported six-to-seven-week lead times, and 9.5 percent either did not know or refused to give lead time information.

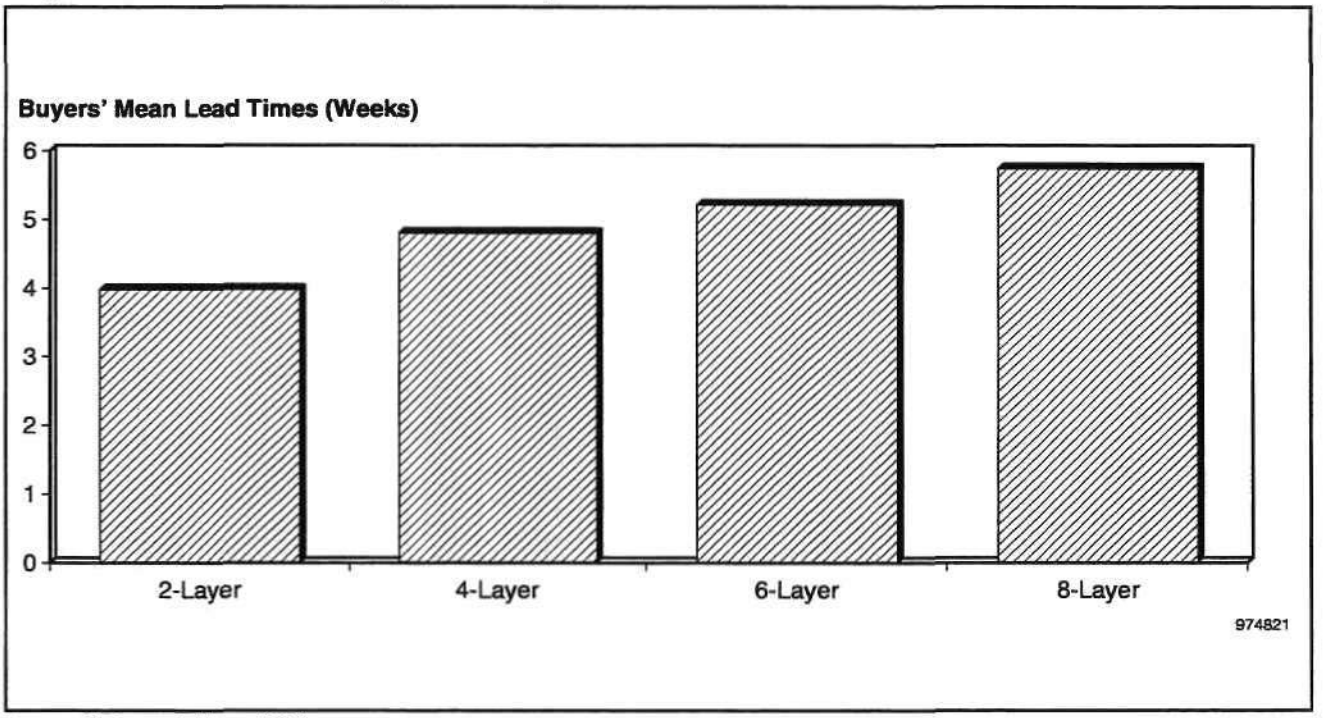
The average lead time information for six-layer boards from suppliers is shown in Figure 7-8. About 43 percent reported average lead times of one to three weeks, another third reported four to five weeks, 9.5 percent gave six to seven weeks as the average lead time, and the remainder did not comment.

For eight-layer boards, over 38 percent of participants reported average lead times between one and three weeks, while about 24 percent claimed average lead times of four to five weeks. Average lead time was six to seven weeks for 4.8 percent. A third of all respondents either did not know or refused to give average lead times for their eight-layer boards (see Figure 7-9).

Figure 7-10 shows that most respondents reported average lead times of one to three weeks (over 38 percent of those sampled). Next came the four-to-five-week average lead times, chosen by just under 24 percent of participants. About 5 percent reported six to seven weeks, and a third of respondents either refused to give or did not know their average lead time for 10-layer boards.

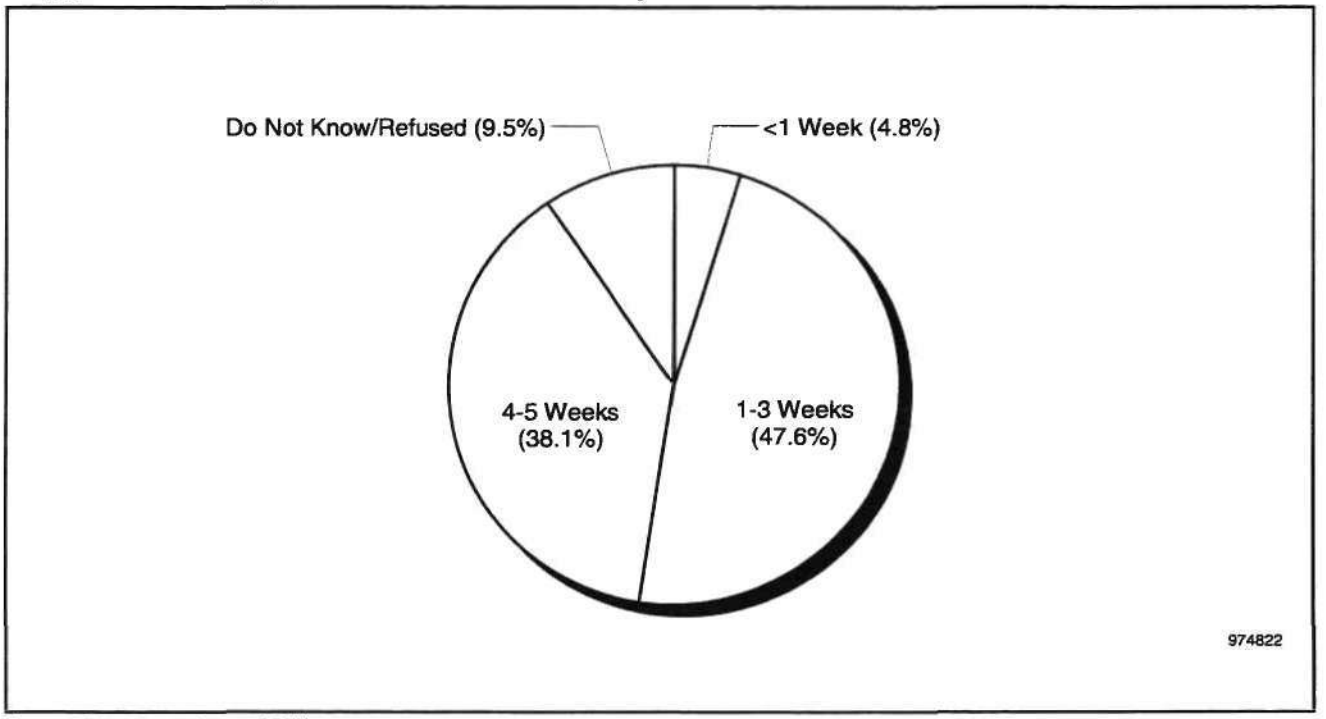
Figure 7-11 shows the average lead times for 12-layer boards from the suppliers sampled. Nearly half refused to give or did not know their average lead time for 12-layer PCBs. However, about 24 percent reported one to three weeks as the average lead time, and just under 29 percent reported four-to-five-week average lead times.

## Figure 7-5
## Buyers' Mean Lead Time per PCB Layer




Source: Dataquest (June 1997)

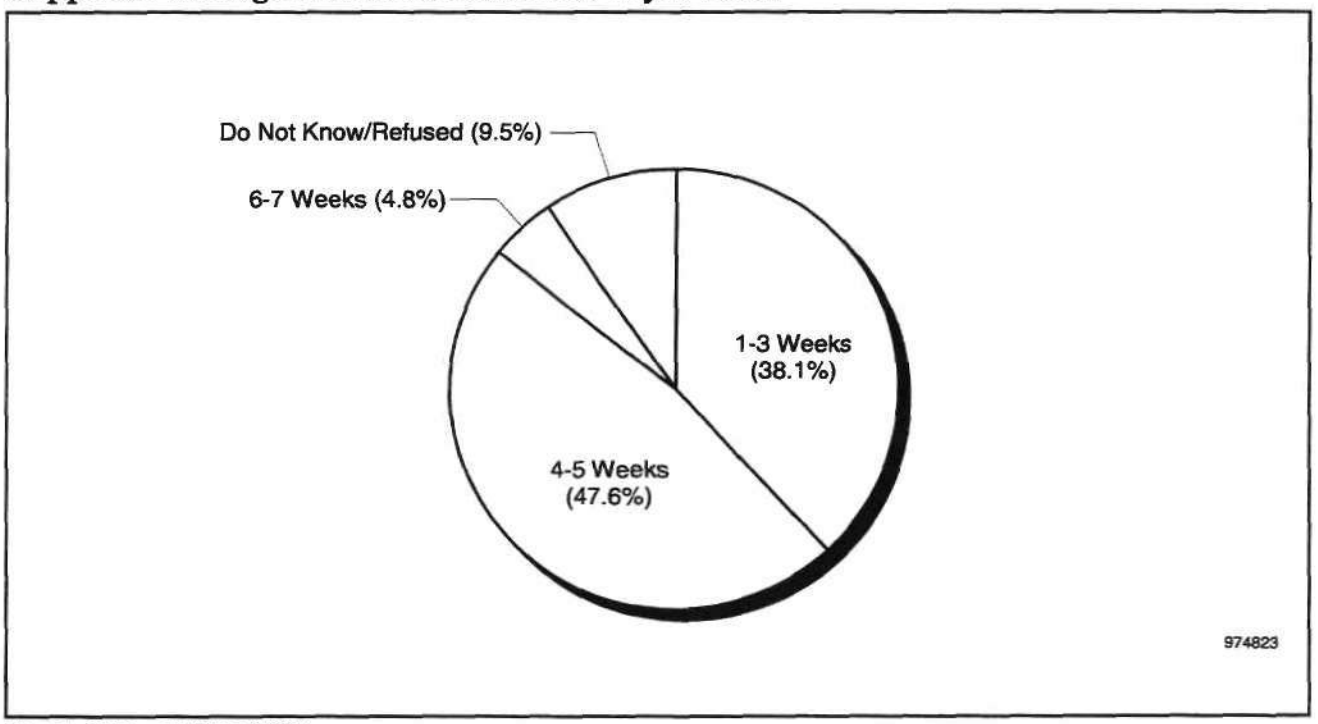
## Figure 7-6
## Suppliers' Average Lead Times for Two-Layer PCBs




Source: Dataquest (June 1997)

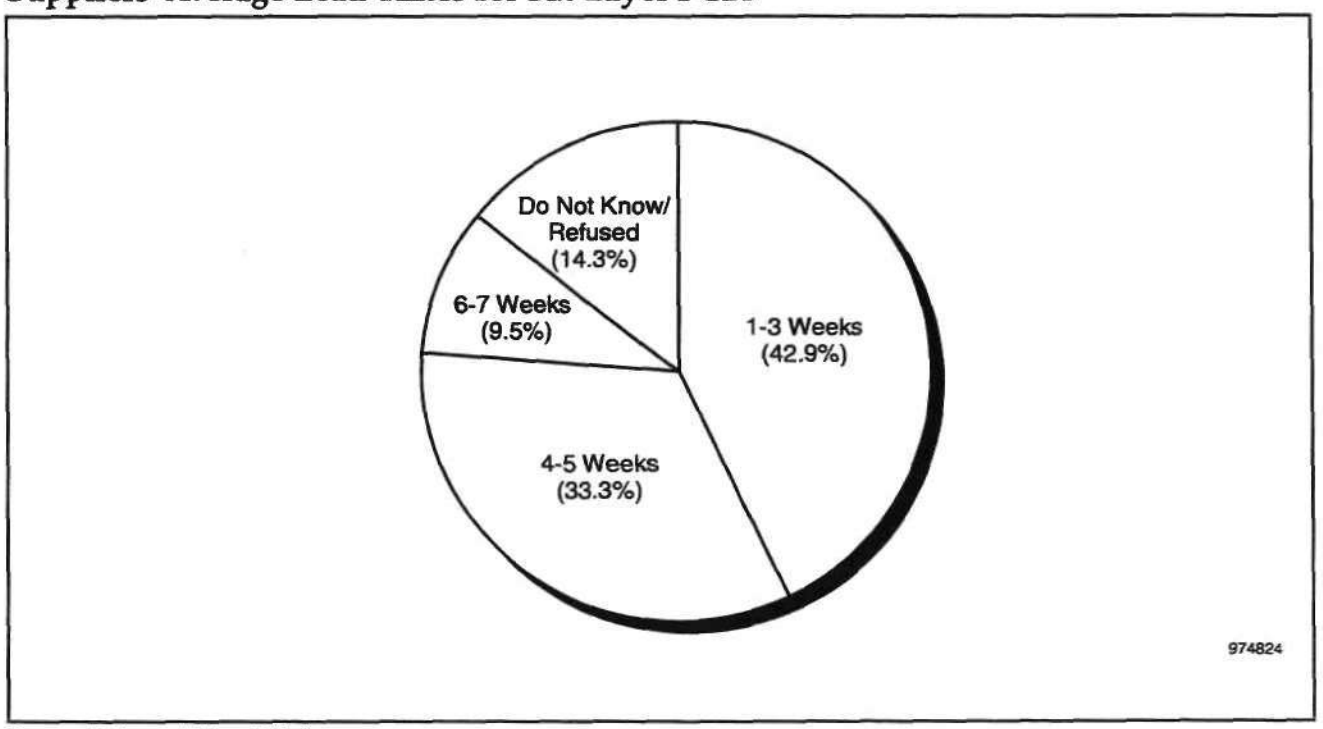

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**Figure 7-7**
**Suppliers' Average Lead Times for Four-Layer PCBs**




Source: Dataquest (June 1997)

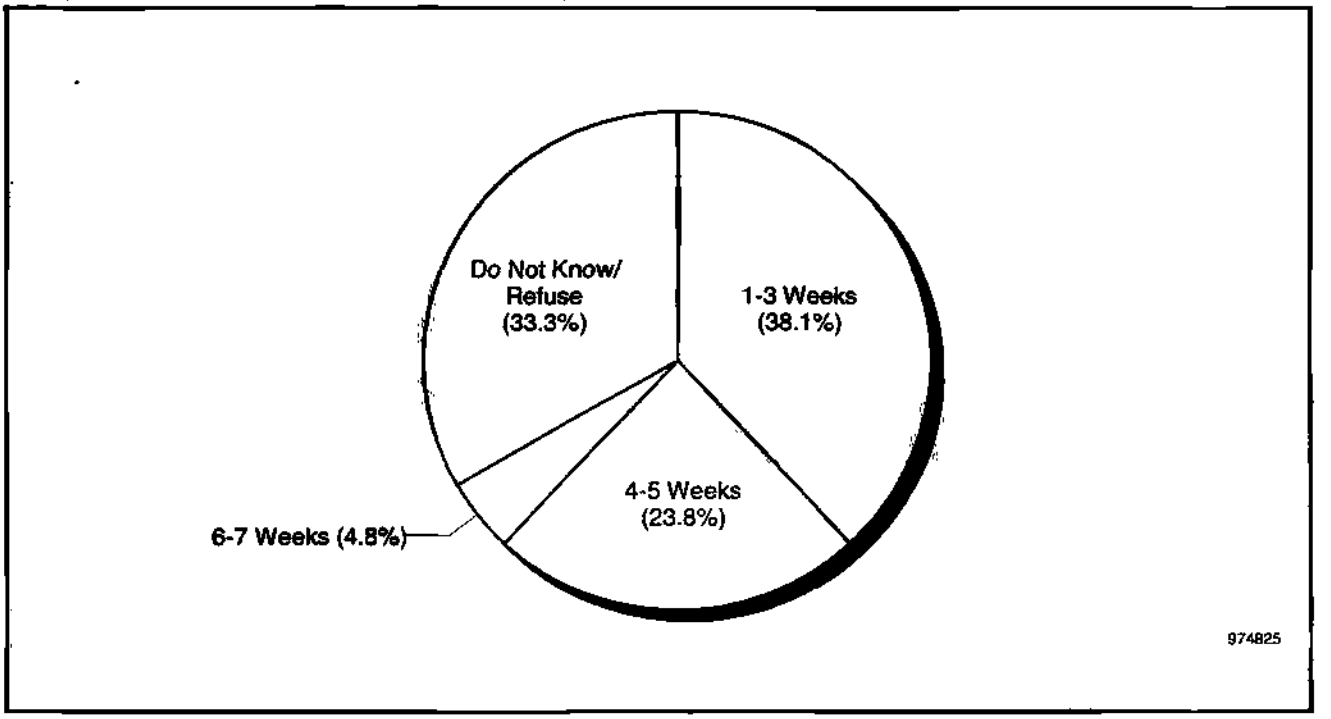
**Figure 7-8**
**Suppliers' Average Lead Times for Six-Layer PCBs**




Source: Dataquest (June 1997)

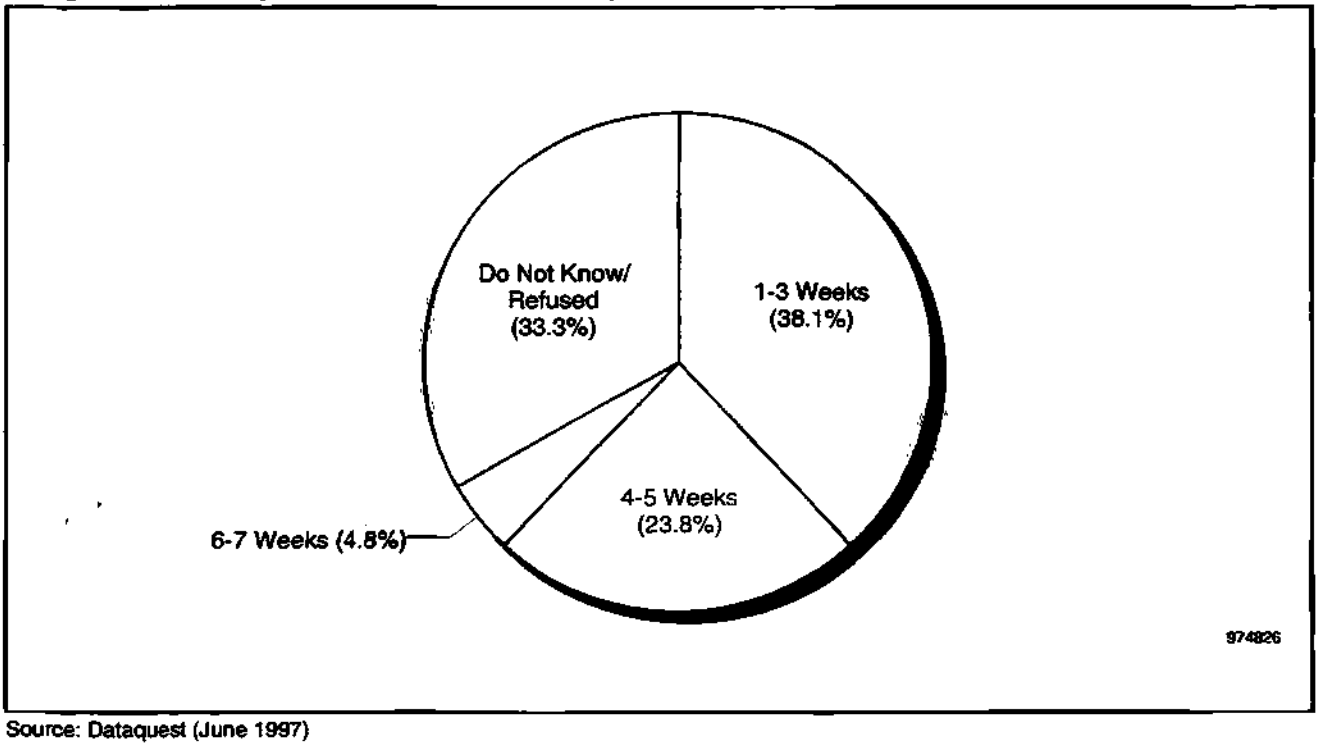

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**Figure 7-9**
**Suppliers' Average Lead Times for Eight-Layer PCBs**



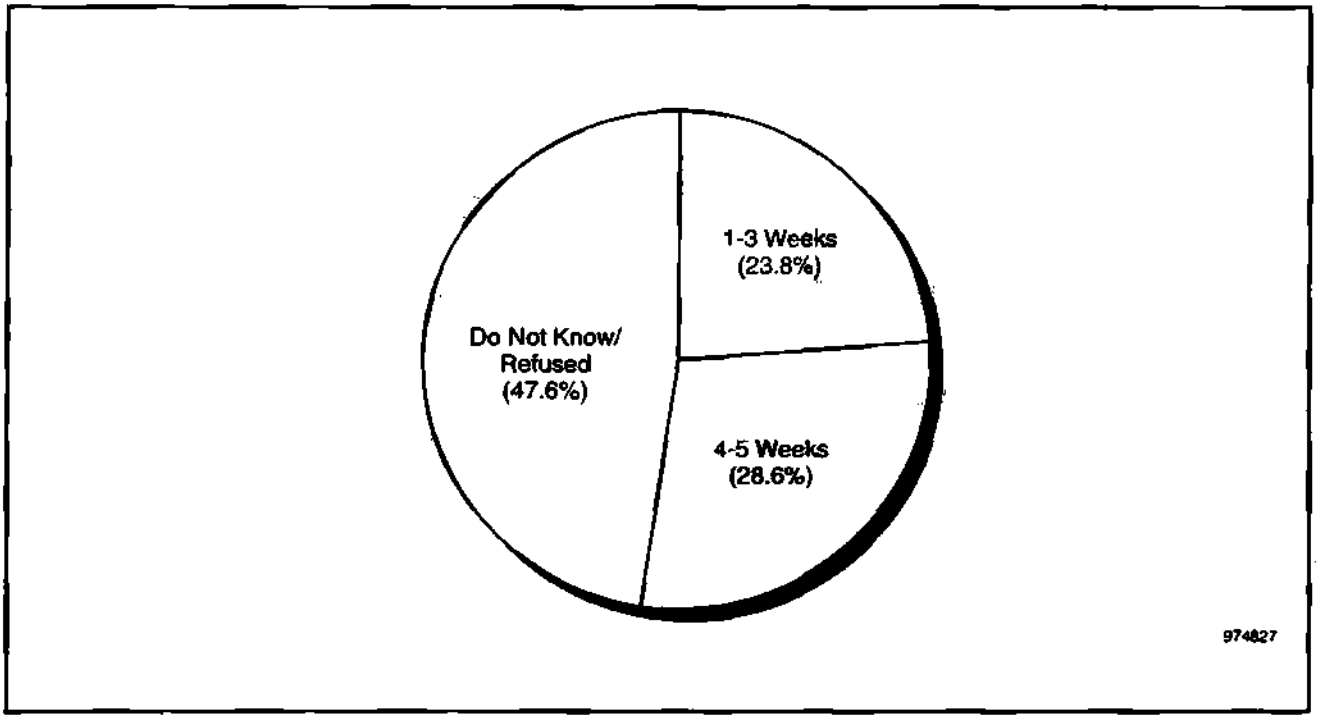

Source: Dataquest (June 1997)

**Figure 7-10**
**Suppliers' Average Lead Times for 10-Layer PCBs**




Source: Dataquest (June 1997)

**Figure 7-11**
**Suppliers' Average Lead Times for 12-Layer PCBs**




Source: Dataquest (June 1997)

## Suppliers' Mean Lead Times per PCB Layer

Figure 7-12 above shows the mean lead time per layer for the supplier group sampled, The mean lead times are calculated from the average lead times per layer (shown in Figures 7-6 to 7-11). To calculate the mean lead time, only those specifying a lead time range were included. Thus, responses of "did not know" and refusals were excluded.

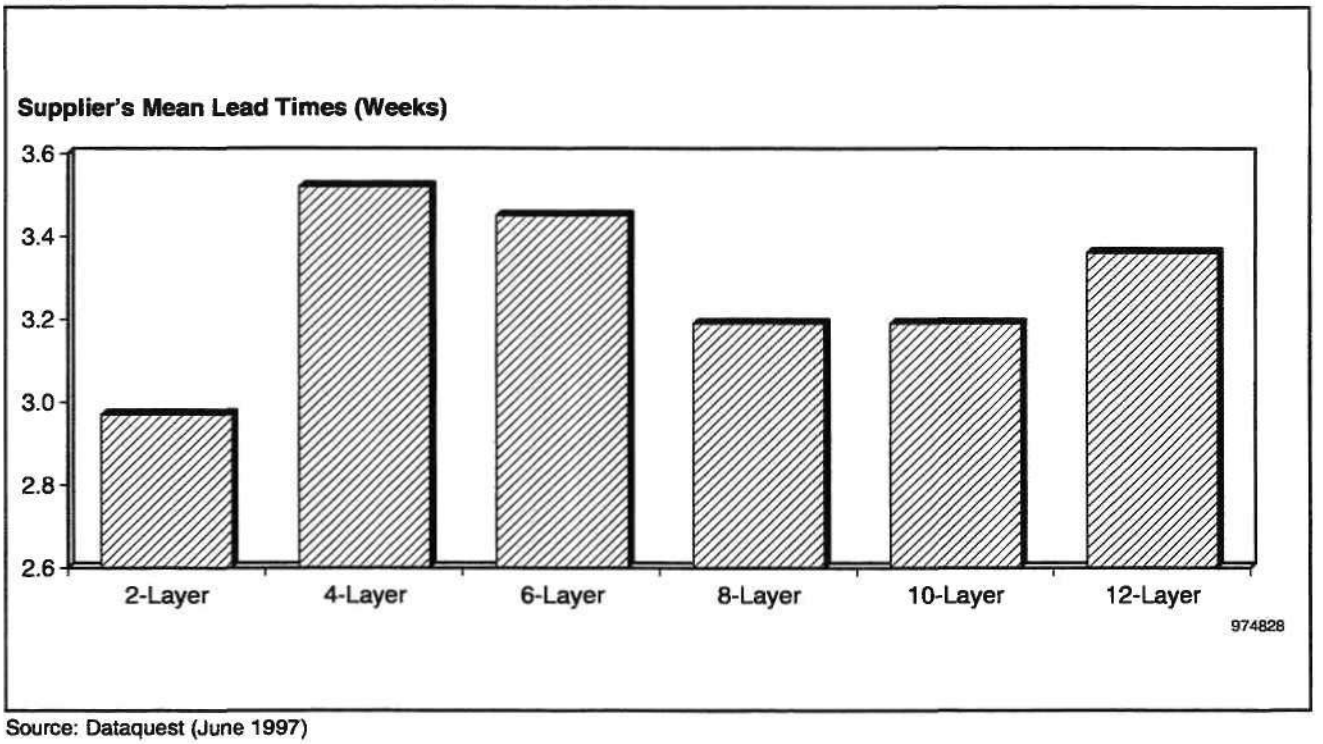
The mean lead times range from 2.97 weeks for two-layer boards to 3.52 weeks for four-layer boards. Both eight- and 10-layer boards have the same mean lead time—3.19 weeks. Twelve-layer boards have a mean lead time of 3.36 weeks, and six-layer boards have a mean lead time of 3.45 weeks.

## Comparison of Buyers' and Suppliers' Mean Lead Times

Table 7-1 shows the mean lead times for PCBs from the buyers and suppliers surveyed. This data is calculated from the average lead time per layer results for both groups. In calculating the mean lead times, the category "do not know/refused" was removed; only those respondents who gave actual lead time ranges were used.

Table 7-1 also shows the difference between the mean lead times of buyers and suppliers per layer. Please note that there was insufficient data to calculate the mean lead times for the buyers' sample for more than eight PCB layers. Thus, it was not possible to compute the difference in these cases.

## Figure 7-12
## Suppliers' Mean Lead Times per PCB Layer




Source: Dataquest (June 1997)

## Table 7-1
## Comparison of the Mean PCB Lead Times from Buyers and Suppliers (Weeks)

| | Buyers' Mean Lead Time | Suppliers' Mean Lead Time | Difference |
|---|---|---|---|
| Two-Layer PCB | 3.98 | 2.97 | 1.01 |
| Four-Layer PCB | 4.80 | 3.52 | 1.28 |
| Six-Layer PCB | 5.21 | 3.45 | 1.76 |
| Eight-Layer PCB | 5.74 | 3.19 | 2.55 |
| 10-Layer PCB | NA | 3.19 | NA |
| 12-Layer PCB | NA | 3.36 | NA |

NA = Not available
Source: Dataquest (June 1997)

The buyers' mean lead times increase as the number of PCB layers increase. The suppliers' mean lead times do not increase as the number of layers increase. Neither is right or wrong—they are just different observations from two different groups.

On the whole, the mean lead times from the supplier community are lower than those from the buyer community. For example, the highest mean lead time in the supplier group (3.52 weeks at four layers) is less than the lowest mean lead time from the buyer group (3.98 weeks for two-layer boards).

# Chapter 8
# Premiums for Faster Lead Times and Effect on Mean Price per Layer

Dataquest wanted to determine whether a premium would be charged for faster turnaround of board orders and, if charged, whether buyers would pay it. Buyers in this survey were asked if they would be willing to pay extra for a faster than usual order turnaround.

This chapter examines the effect on the mean price per layer for both buyers and suppliers and is split into three sections:

- Buyers
- Suppliers
- Conclusions

## Buyers

Dataquest asked buyers whether they would willingly pay a premium for faster turnaround from their suppliers. Figure 8-1 shows the results.

Figure 8-1 clearly shows that the vast majority of buyers surveyed would willingly pay a premium for the faster-than-normal order turnaround—that is to say, most buyers will pay more money to get the PCBs more quickly—nearly 70 percent expressed a willingness to pay extra.

To see how much extra the buyers would spend for faster order turnaround, Dataquest asked the buyer sample what extra percentage (or premium) they would willingly pay for turnaround times of three days, one week, and two weeks. Figure 8-2 shows the results.

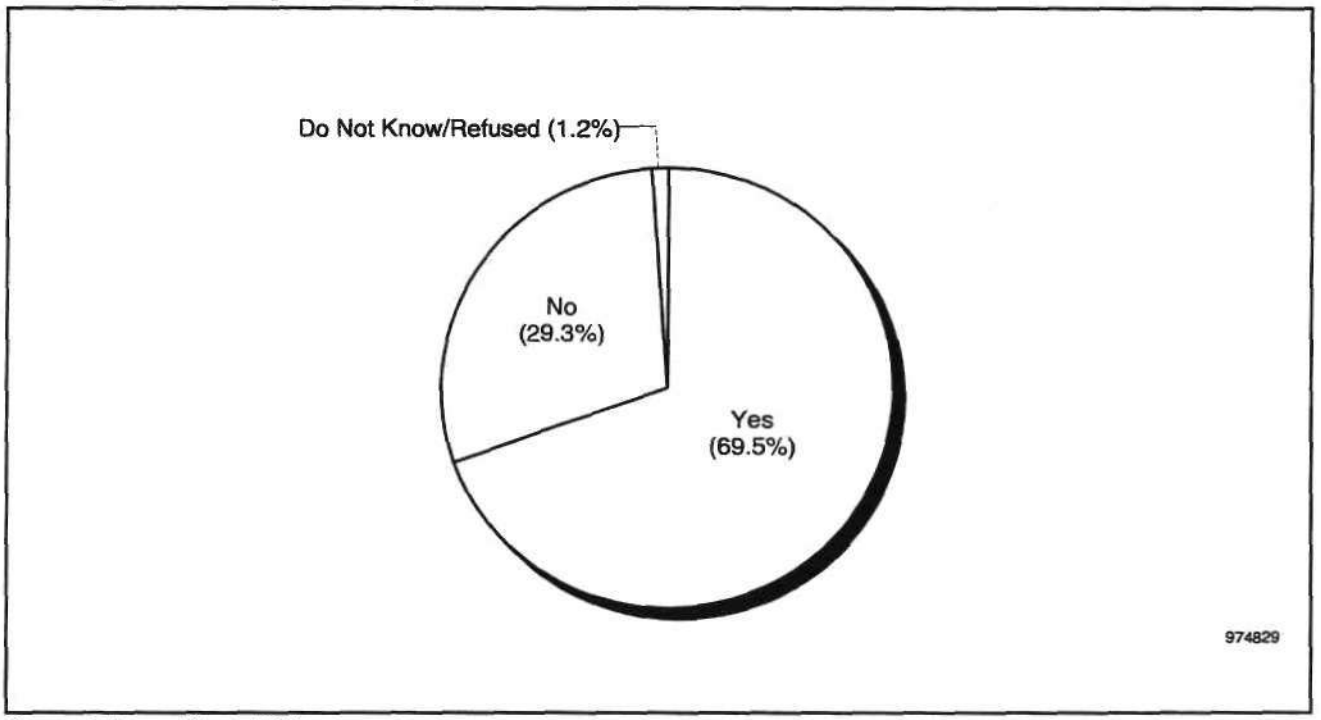
Figure 8-2 shows clearly that buyers will pay the most for the fastest turnaround. Among those surveyed, the mean extra percentage that buyers would pay for three-day turnaround is nearly 105 percent on top of the usual board price.

For one-week lead times, buyers would spend about 85 percent extra, and for a two-week lead time, the mean extra that buyers would willingly spend is 50.6 percent.

What effect does the data in Figure 8-2 have on the mean price per layer determined in Chapter 6? This outcome is shown in Table 8-1.

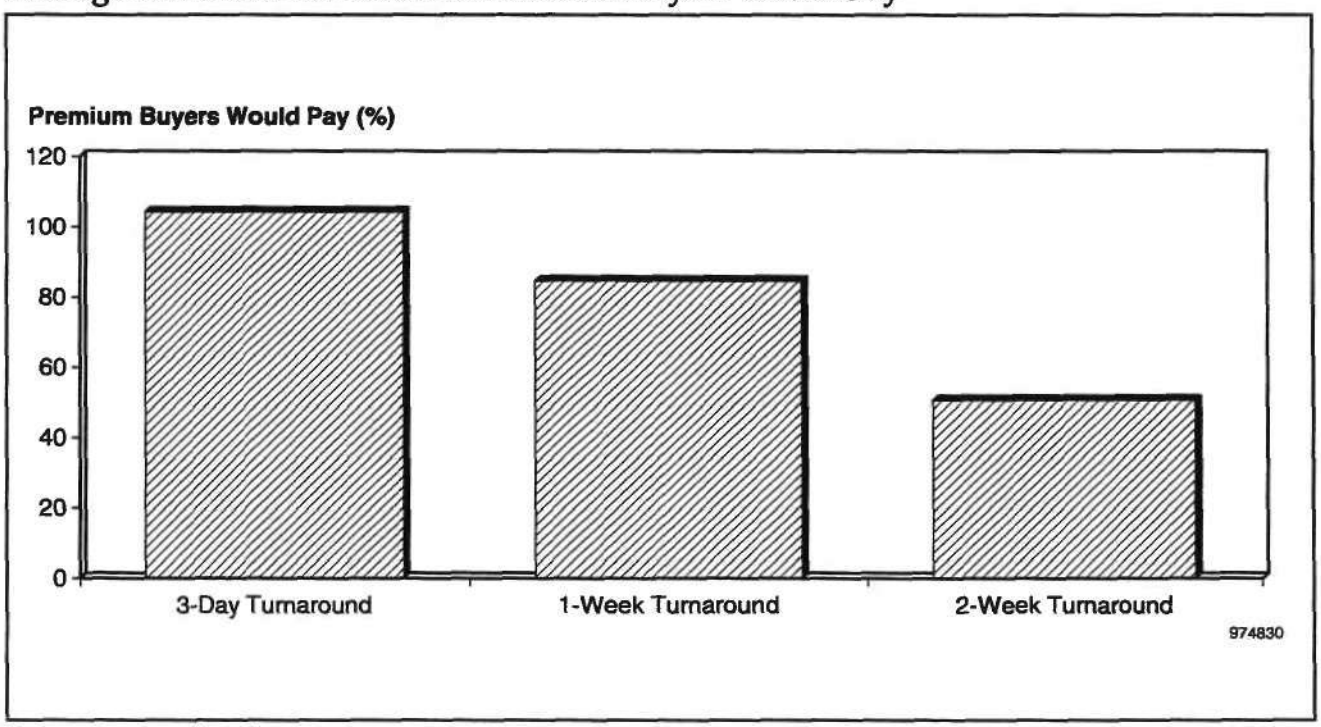
Table 8-1 shows the mean lead time (from Chapter 7) and mean buying price (from Chapter 6) per layer for buyers. Based on the data in Figure 8-2, Table 8-1 also shows the mean price per layer for the three faster-than-usual order turnaround times. Thus, it is clear that buyers will sacrifice lower purchasing price for emergency orders.

**Figure 8-1**
**Willingness of Buyers to Pay Extra for a Quicker Order Turnaround**




Source: Dataquest (June 1997)

**Figure 8-2**
**Average Premiums for Faster Turnaround Buyers Would Pay**




Source: Dataquest (June 1997)


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**Table 8-1**
**Buyers' Mean Price per Layer for Mean Lead Times and Premium Required for Quick Turnaround Orders (Cents per Square Inch)**

| | Buyers' Mean Lead Time (Weeks) | Buyers' Mean Price per Layer | Three-Day Turnaround Mean Price | One-Week Turnaround Mean Price | Two-Week Turnaround Mean Price |
|---|---|---|---|---|---|
| Two-Layer PCB | 3.98 | 31.1 | 63.5 | 57.4 | 46.8 |
| Four-Layer PCB | 4.80 | 37.5 | 76.6 | 67.2 | 56.5 |
| Six-Layer PCB | 5.21 | 56.5 | 115.4 | 104.2 | 85.1 |
| Eight-Layer PCB | 5.74 | 61.1 | 124.8 | 112.7 | 92.0 |

Source: Dataquest (June 1997)

## Suppliers

Dataquest also asked suppliers whether they charge their customers a premium for faster order turnaround that their customers willing pay. Figure 8-3 shows the results.

The vast majority of suppliers surveyed stated that they do charge their customers extra for faster-than-normal order turnaround and their customers will pay more than usual to get the PCBs more quickly. Over 95 percent said that they charge extra and that their customers pay it.

Dataquest also wanted to know how much extra suppliers charge, and receive, for faster order turnaround. Dataquest asked the supplier sample to specify the extra percentage (or premium) they would charge for lead times or turnaround times of three days, one week, and two weeks (see Figure 8-4).

Once again, the results show that suppliers charge more for the fastest turnaround, three days. Among those surveyed, the mean extra percentage suppliers charge is a staggering 142 percent for three-day turnaround, 60 percent extra for a week, and 53 percent extra for two weeks.

Dataquest sought to discover the effect of the faster order turnaround premiums on the suppliers' mean price per layer (see Table 8-2).

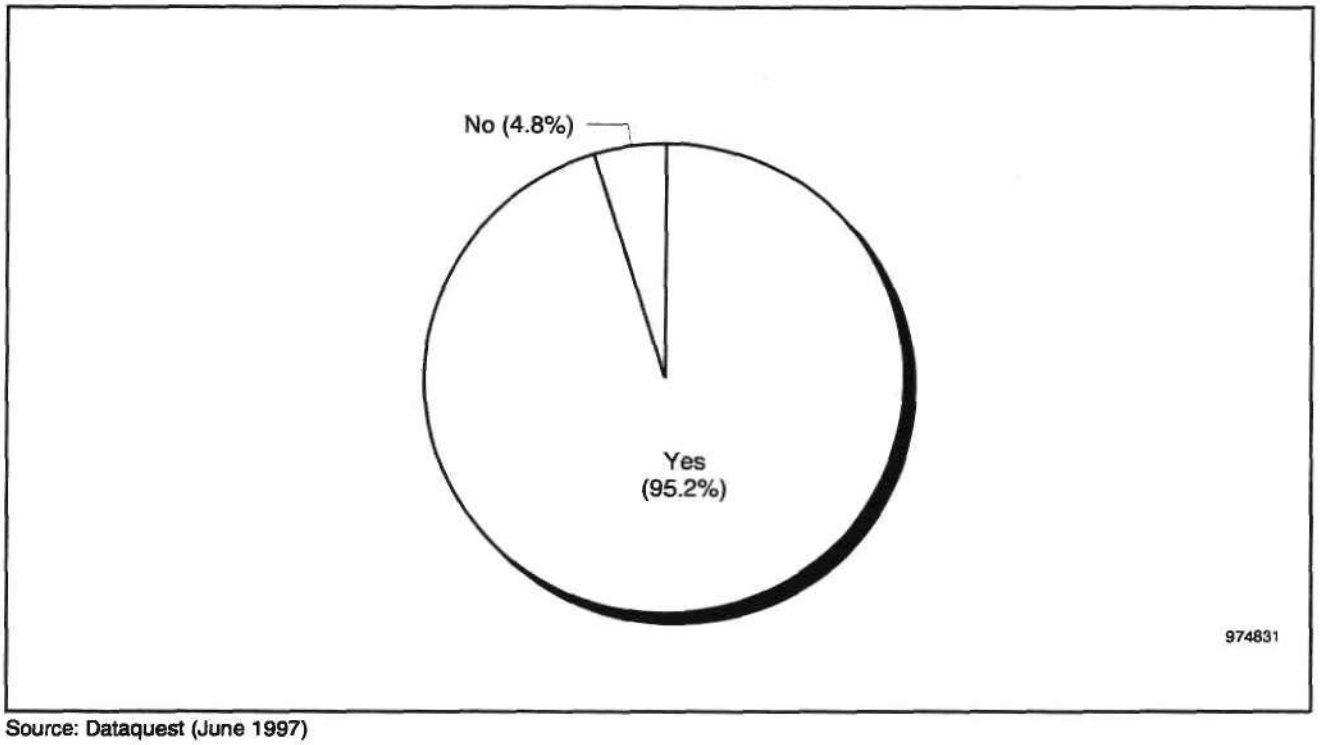
The effect of the price premium on the new mean prices per layer is quite incredible. For three-day turnaround, the mean price per layer increased by nearly one and a half times, pushing prices way up.

## Comparison

Tables 8-1 and 8-2 show that the overall effect of price premiums on mean prices is staggering. However, buyers are willing to pay extra for emergencies—clearly affirmed by the results in Figures 8-1 and 8-3. Although buyers do pay extra for certain orders, it probably is not something they like doing. However, desperate situations often call for desperate measures. And suppliers seem only too willing to charge!

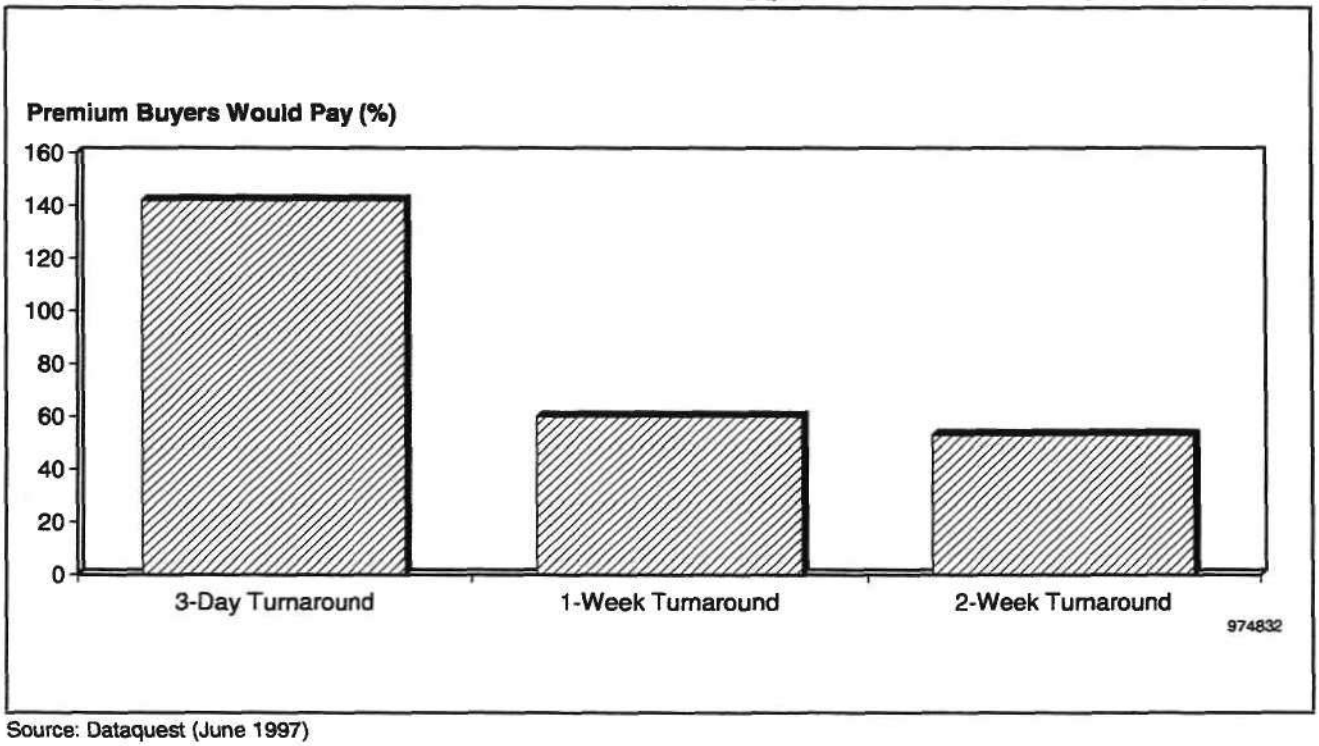

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**Figure 8-3**
**Suppliers Whose Customers Willingly Pay Extra for a Quicker Turnaround**




Source: Dataquest (June 1997)

**Figure 8-4**
**Average Premiums for Faster Turnaround That Suppliers' Customers (Buyers) Pay**




Source: Dataquest (June 1997)


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**Table 8-2**
**Suppliers' Mean Price per Layer for Mean Lead Times and Premium Required for Quick-Turnaround Orders (Cents per Square Inch)**

| | Suppliers' Mean Lead Time (Weeks) | Suppliers' Mean Price per Layer | Three-Day Turnaround Mean Price | One-Week Turnaround Mean Price | Two-Week Turnaround Mean Price |
|---|---|---|---|---|---|
| Two-Layer PCB | 2.97 | 21.3 | 51.5 | 34.1 | 32.6 |
| Four-Layer PCB | 3.52 | 34.0 | 82.3 | 54.4 | 52.0 |
| Six-Layer PCB | 3.45 | 57.0 | 137.9 | 91.2 | 87.2 |
| Eight-Layer PCB | 3.19 | 67.4 | 163.1 | 107.8 | 103.1 |
| 10-Layer PCB | 3.19 | 69.8 | 168.9 | 111.7 | 106.8 |
| 12-Layer PCB | 3.36 | 80.0 | 193.6 | 128.0 | 122.4 |

Source: Dataquest (June 1997)

Both groups also had a sliding scale of charges for faster-than-usual lead times. The faster the goods were required, the higher the premium charged. However, there was a difference in the percentage reported by the two groups for the different lead times.

It is worth remembering that the mean lead times per PCB layer are different for the buyers and the suppliers. The suppliers report consistently lower lead times than the buyers surveyed. This has an impact on the flexibility suppliers offer. Suppliers probably feel that they are "pulling out the stops" to give their customers low standard lead times, so the suppliers felt justified in charging extra for faster turnaround.

Both groups reported the highest charges for three-day turnaround, and both groups reported that the extra premium was over 100 percent. However, the suppliers said they charged 142 percent, while the buyers said that they would pay 104.2 percent, on average. Thus there was deviation between the two groups, but the expectations of both were in similar ranges.

For one-week turnaround, the buyers stated a willingness to pay 84.5 percent extra. However, the suppliers stated that they charge 60 percent extra for this turnaround. This seems like a big difference, but both results are close when compared to their three-day turnaround premiums: 84.5 divided by 142 equals 0.59, and 60 divided by 104.2 equals 0.58. Thus, both state the same relative price premium for one week versus three days.

For two-week turnaround, the buyers and suppliers reported very similar raw percentage results. The buyers were willing to pay about 50.6 percent extra for 14-day turnaround, while the suppliers claimed to charge about 53 percent extra.

Thus, the one-week lead time is nearly the same from both groups relative to both groups' premiums for three-day lead times. However, the expectations for the premium for two-week lead times from both groups fell into the same real percentage terms.

# Chapter 9
# Summary and Conclusions

The PCB market continues to change in response to economic forces in the electronics market. As the overall supply base of PCB manufacturers continues to consolidate, customers of these companies are also refining their level of sophistication regarding forecast frequency, critical issue and problem resolution, and supplier choice criteria. This study polled the overall North American market and received responses that mirrored the size of companies in the market, if not the exact application match. The user issues noted as critical cut across application boundaries and should be used by suppliers as guidelines for improvement and to enable survival in the continuing competitive arena.

The satisfaction gap analysis highlighted that, although respondents were mostly satisfied with the current supply base, improvements still need to be made in quality and in the overall cost situation of PCBs. Total costs do not have to equate to pricing alone, but involve the entire spectrum of logistical support, engineering support and communications, and delivery flexibility and inventory handling, among other issues. Suppliers that can improve in these areas will stand out even if pricing is left alone.

When it comes to lead times, both buyers and manufacturers reported that the mean price per layer increased as the number of board layers increased. The participating buyers reported higher mean costs across the board, compared with the sellers. This difference ranged from as low as 0.5 percent for six-layer boards to as high as 9.8 percent for two-layer boards. However, that said, both groups did report similar trends. The differences in the data results is to be expected.

By contrast, lead times did not increase or decrease in a linear fashion as the number of layers increased or decreased. For price per layer, an increase is to be expected because more work is involved as the number of layers increases. However, for lead times, this is not a given. Factors such as supply base for buyers and customer base for sellers are the biggest influences on board lead times and determine who buyers use and who suppliers target. Clearly, both groups negotiate lead times for the boards based on buying volumes, manufacturer's production capacity, and so on.

The results of whether buyers would pay a premium for faster-than-usual order turnaround are interesting. Over 70 percent of buyers said that they would pay extra for accelerated turnaround, while about 95 percent of suppliers said that they charge extra (and customers pay extra) for accelerated order turnaround. The actual percentage extra was also noted, and then an analysis was done to determine the ramifications to the mean price per layer for both groups. The bottom line: Getting product fast is more important than price, in some cases.

## Appendix A

# PCB Suppliers Noted by User Sample

The PCB suppliers listed in this appendix were noted by Dataquest's user sample for their excellence in quality, total cost of ownership, flexibility, price, lead time, and engineering support.

- ABC
- Advanced Electronics
- Allphase
- Altron
- Amatron
- American Circuits
- ASAP Circuit
- Automata
- Bay State Circuits
- Brand Express
- Calyer Circuits
- Central Florida Circuits
- Champion Circuits
- Circuit Automation
- Circuits Brand
- Circuit Graphics
- Circuit Partners
- Circuit Plus
- Circuit Services
- Circuit Technology
- Circuit Wise
- Circuit World
- Computer Circuitry
- Concepts
- Connect
- CORE
- Cuplex Inc.
- Custom Design
- Davilla
- Delta Precision
- D&R Services


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- DCI
- ECD
- EE International
- Electro Pac
- Electro Plate Circuitry
- ElectroStar
- Electronic Interconnect
- Electrotech
- Elexas
- Etma
- Excell Circuit Concepts
- Express
- Futura Circuit
- Gammon
- Grande
- Graphic Production
- Hadco
- Herco
- H&L
- HR Industries
- Imagineering
- ITO
- Janco
- Kalmus
- Laser Technology
- Masse Circuit
- Merix
- Multilayer
- Multiplex
- Multi Tec
- NTDU Electronics
- Nassau Circuit
- Network Circuit
- North Texas Circuits
- Pacific
- PC Design and Drafting


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- Photo Circuit
- PNE
- Pope
- Praegitzer
- Printed Circuits
- Prototron
- QFAB
- QMS
- Quality Printed Circuits
- Radicon
- SAE Circuits
- Strategic Alliance Services Circuits
- Senstitive Electronics
- Speedy Circuit
- South Bay Circuits
- Strategic Alliance Services
- Surface Mount Depot
- Sytek
- Technet
- Tektronix NTI
- Texas Circuit
- Tri Star
- Tyco
- United Electronics
- Universal Circuits
- Waytech
- Westech
- Win-Onyx
- Wizards Parks


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**For More Information...**

Mark Giudici, Director and Principal Analyst ..... (408) 468-8258
Internet address ..... mark.giudici@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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## DATAQUEST WORLDWIDE OFFICES


**NORTH AMERICA**

**Worldwide Headquarters**
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: 1-408-468-8000
Facsimile: 1-408-954-1780

**East Coast Headquarters**
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6262

**Dataquest Global Events**
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

Sales Offices:
Washington, DC (Federal)
New York, NY (Financial)
Dallas, TX

**LATIN AMERICA**
Research Affiliates and Sales Offices:
Buenos Aires, Argentina
Sao Paulo, Brazil
Santiago, Chile
Mexico City, Mexico

**EUROPE**

**European Headquarters**
Tamesis, The Glanty
Egham, Surrey TW20 9AW
United Kingdom
Phone: +44 1784 431 611
Facsimile: +44 1784 488 980

**Dataquest France**
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: +33 1 41 35 13 00
Facsimile: +33 1 41 35 13 13

**Dataquest Germany**
Kronstadter Strasse 9
81677 München
Germany
Phone: +49 89 93 09 09 0
Facsimile: +49 89 93 03 27 7

Sales Offices:
Brussels, Belgium
Kfar Saba, Israel
Milan, Italy
Randburg, South Africa
Madrid, Spain

**JAPAN**

**Japan Headquarters**
Aobadai Hills 4-7-7
Aobadai
Meguro-ku, Tokyo 153
Japan
Phone: 81-3-3481-3670
Facsimile: 81-3-3481-3644

**ASIA/PACIFIC**

**Asia/Pacific Headquarters**
Suite 5904-7, Central Plaza
18 Harbour Road, Wanchai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

**Dataquest Korea**
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

**Dataquest Taiwan**
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

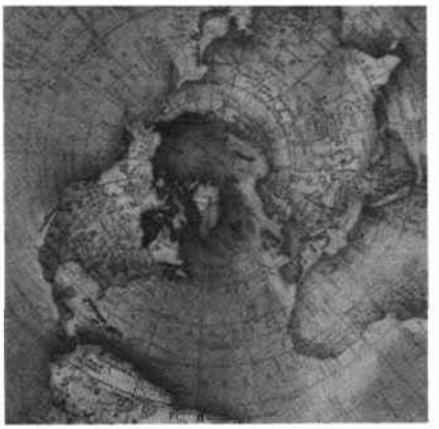
**Dataquest Singapore**
105 Cecil Street
#06-01/02 The Octagon
Singapore 069534
Phone: 65-227-1213
Facsimile: 65-227-4607

**Dataquest Thailand**
12/F, Vanissa Building
29 Soi Chidlom
Ploenchit Road
Patumwan, Bangkok 10330
Thailand
Phone: 662-655-0577
Facsimile: 662-655-0576

Research Affiliates and Sales Offices:
Melbourne, Australia
Beijing, China


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# The Semiconductor Applications Market—An Overview



Focus Report

**Program:** Semiconductor Supply and Pricing Worldwide
**Product Code:** SSPS-WW-FR-9703
**Publication Date:** April 14, 1997
**Filing:** Reports

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# Table of Contents

Page

1. Executive Summary ..... 1
2. Introduction ..... 3
3. Top Level Semiconductor Forecast ..... 5
4. Personal Computer Application Markets ..... 7
   - Summary ..... 7
   - Market and Production Trends ..... 7
     - Personal Computers ..... 7
   - Midrange to Supercomputer Markets ..... 10
     - Summary ..... 10
     - Market Trends ..... 10
   - Data Storage Markets ..... 11
     - Summary ..... 11
     - Storage Market Trends ..... 11
   - Printer Markets ..... 15
     - Summary ..... 15
     - Printer Market Trends ..... 16
   - Selected Input/Output and Dedicated Systems ..... 17
     - Summary ..... 17
     - Key Trends ..... 17
5. Communications Applications ..... 21
   - Local Area Networks: Market Drivers and Technology Directions ..... 21
     - Market Drivers ..... 21
     - Technology Directions ..... 21
   - Modems: Recent Market Developments ..... 25
     - Market and Technology Directions ..... 25
   - Fax Machines: Market and Technology Directions ..... 28
   - Digital Wide Area Network Applications: Recent Market Developments ..... 28
     - Market and Technology Directions ..... 29
   - Videoconferencing Applications: Market and Technology Directions ..... 30
   - Premise Switching and Call Processing Applications: Market and Technology Directions ..... 31
   - Public Switching and Transmission Applications ..... 32
     - Background Trends ..... 32
     - Market and Technology Directions ..... 33
     - Fiber Optics-Based Local Loop Technology ..... 33
     - Digital Modem Local Loop Technology ..... 35
     - Wireless Local Loop and Distribution ..... 35
     - ATM ..... 36

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# Table of Contents (Continued)

Page

6. The Consumer Applications Market ..... 37
   - Digital Satellite and Cable Set-Top Boxes ..... 37
   - DVD Video Players ..... 37
   - Video CD Players ..... 38
   - Next-Generation Video Game Consoles ..... 38
   - HDTV/ATV/SDTV ..... 39
   - Digital Still Cameras ..... 39
   - Other Next-Generation Consumer Electronics Products ..... 39
7. Automotive Applications Market ..... 41
   - Navigation, Communication, and Smart Highways ..... 42
8. Summary and Conclusions ..... 45
   - Conclusions ..... 45

# List of Figures


| Figure | | Page |
|---|---|---|
| 5-1 | LAN Technology Trends | 22 |
| 5-2 | Alternative Network Technologies | 22 |
| 5-3 | Worldwide NIC and Hub/Switch Node Shipments by Standard | 23 |
| 5-4 | Fast Packet Switching | 29 |
| 7-1 | Electronic Module and System Content | 42 |


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# List of Tables


| Table | | Page |
|---|---|---|
| 3-1 | Revenue from Total Semiconductors Shipped Worldwide for Use in Each Electronic Equipment Group, 1995-2000 | 5 |
| 4-1 | The Evolving PC | 9 |
| 5-1 | Broadband Local Loop Alternatives | 34 |

# Chapter 1
# Executive Summary

The aim of this Focus Report is to look briefly at future trends in the various semiconductor application segments that Dataquest tracks. It will offer top-level opinions from Dataquest on what the principal directions in the tracked application will be in the near term. This report will also look at the top-level semiconductor applications forecast from Dataquest.

For more in-depth analysis of semiconductor applications, Dataquest has a number of programs that cover the various segments in more detail. Semiconductor Application Markets programs exist both on a worldwide and regional basis. There are also separate worldwide services focusing specifically on one application segment. These segments are:

- Consumer
- Automotive
- Communications
- PCs and multimedia


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# Chapter 2
# Introduction

Man as a species is constantly evolving. It is our inquiring minds and hunger for knowledge that has helped differentiate us from other life forms on planet earth. Our quest for redefinition and reinvention has translated itself into almost every facet of our lives, from the way we obtain food and prepare it to what we do in our spare time for entertainment and how we go about our daily business.

Most homes buy frozen food for convenience that can be microwaved before eating. Likewise, many families spend time together either relaxing in front of the TV, listening to music from a stereo, or playing against each other on computer games. Last year, more mail was sent via the Internet than via the U.S. Postal Service. Medical breakthroughs have made it possible for premature babies weighing less than a bag of sugar to survive. During the terrible weather in the midwest United States this winter, there were numerous stories of people being saved from almost sure death in blizzard conditions through use of their cellular phones. These things we take for granted would have been unimaginable less than fifty years ago.

Nowadays it seems that the difference between madcap inventors with harebrained ideas and technology messiahs with lifestyle-enabling brain waves are the commercial applications for their work. Although few people know the names of the inventors of most process technologies or designs, most will at least testify to how the quality of their lives has improved through the use of technology. True, many talk of the lost art of storytelling and the hectic, stressed pace of life most live in the developed world, but the benefits for most have been enormous. Few would be willing to give up the technology we take for granted to return to the lifestyle of yesteryear.

When adults marvel at the changes that have taken place during their lifetimes, most children conclude that their parents grew up in the dark ages. "Get with the program, Mom—this is the 1990s, not the 1890s" is the children's common response to parental awestruck moments of pondering.

Semiconductor applications have really taken off. However, what will our children and our grandchildren take for granted in a number of years that at present seems like a flight of fancy or a "hot new app," in Silicon Valley small talk?


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# Chapter 3
# Top Level Semiconductor Forecast

This chapter is based on the *Worldwide Semiconductor Consumption by Application Market* forecast (SAMM-WW-MS-9603) published by Dataquest in June 1996. This data is produced by the Semiconductor Application Markets Worldwide program.

Table 3-1 shows the revenue from total semiconductors shipped worldwide for use by each electronic equipment group or application area. All data is expressed in millions of U.S. dollars. The data for 1995 is based on actual revenue, while data for 1996 to the year 2000 is based on forecast revenue.

**Table 3-1**
**Revenue from Total Semiconductors Shipped Worldwide for Use in Each Electronic Equipment Group, 1995-2000 (Millions of U.S. Dollars)**

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|
| Total Semiconductor | 151,272 | 136,977 | 154,605 | 188,922 | 234,916 | 290,219 |
| Data Processing | 74,132 | 62,074 | 68,880 | 85,541 | 110,707 | 142,966 |
| Computers | 49,095 | 41,116 | 45,763 | 56,814 | 75,058 | 100,128 |
| Data Storage | 8,169 | 7,647 | 8,224 | 10,362 | 12,967 | 15,530 |
| Input/Output | 10,020 | 7,996 | 8,999 | 11,036 | 13,593 | 16,161 |
| Dedicated Systems | 4,064 | 3,198 | 3,504 | 4,423 | 5,644 | 7,145 |
| Other Data Processing | 2,784 | 2,116 | 2,390 | 2,906 | 3,444 | 4,001 |
| Communications | 25,934 | 26,982 | 32,395 | 39,752 | 47,565 | 55,800 |
| Premise Telecom | 10,183 | 9,540 | 10,760 | 12,931 | 15,273 | 18,024 |
| Public Telecom | 4,586 | 4,408 | 4,744 | 5,453 | 6,507 | 7,168 |
| Mobile Communications | 8,073 | 9,980 | 13,349 | 16,962 | 20,346 | 23,930 |
| Broadcast and Studio | 918 | 850 | 1,028 | 1,279 | 1,543 | 1,853 |
| Other Communications | 2,174 | 2,204 | 2,514 | 3,127 | 3,897 | 4,825 |
| Industrial | 15,087 | 14,006 | 15,693 | 19,484 | 24,369 | 29,680 |
| Security and Energy Management | 1,475 | 1,399 | 1,620 | 1,998 | 2,493 | 3,066 |
| Manufacturing Systems/Instruments | 9,389 | 8,695 | 9,644 | 12,058 | 15,043 | 18,324 |
| Medical Equipment | 1,728 | 1,697 | 1,938 | 2,419 | 3,064 | 3,786 |
| Other Industrial | 2,495 | 2,214 | 2,491 | 3,009 | 3,769 | 4,504 |
| Consumer | 26,071 | 24,185 | 27,015 | 31,881 | 38,185 | 45,746 |
| Audio | 4,790 | 4,269 | 4,710 | 5,551 | 6,420 | 7,676 |
| Video | 11,156 | 10,281 | 11,623 | 13,496 | 16,129 | 19,398 |
| Personal Electronics | 4,768 | 4,640 | 5,107 | 6,484 | 8,055 | 10,096 |
| Appliances | 3,750 | 3,597 | 3,980 | 4,472 | 5,424 | 5,991 |
| Other Consumer | 1,607 | 1,399 | 1,595 | 1,879 | 2,157 | 2,584 |
| Military/Civil Aerospace | 2,874 | 2,706 | 2,779 | 2,983 | 3,273 | 3,529 |
| Transportation | 7,174 | 7,024 | 7,842 | 9,281 | 10,818 | 12,498 |

Source Dataquest (April 1997)


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Clearly, 1996's declines represent a contraction experienced worldwide that year. This resulted in an overall revenue decline from 1995 to 1996. However, within the communications application segment, there was a net increase in revenue shipped to this segment.

Based on the semiconductor revenue forecast, Dataquest is showing a compound annual growth rate (CAGR) of 13.9 percent from 1995 to the year 2000. This translates into a forecast revenue increase from $151.3 billion in 1995 to $290.2 billion in the year 2000.

Semiconductors shipped into each individual application segment are growing at positive rates. However, the shipment rates to each application segment vary greatly. The CAGRs of semiconductors shipped into the application segments from 1995 to 2000 are:

- Data processing: 14.0 percent
- Communications: 16.6 percent
- Industrial: 14.5 percent
- Consumer: 11.9 percent
- Military/civil aerospace: 4.2 percent
- Transportation: 11.7 percent

Looking at the forecast CAGR of semiconductors shipped into each segment and comparing it to overall semiconductor growth rates, it can be seen that three segments have CAGRs above the overall and three below.

Clearly, these do not reflect the actual growth rates of each application—these figures show only the semiconductor content revenue growth in the segments.

Within the semiconductor application categories, there are some specific applications that are growing at faster rates. These are the "hot" applications from a semiconductor shipment perspective. These areas include mobile communications, medical equipment, other communications (including intercom equipment and electrical amplifiers, among others), personal electronics, and security and energy management.

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# Chapter 4
# Personal Computer Application Markets

## Summary

The PC market and semiconductor markets are inherently linked by the simple fact that PCs consume more semiconductors than any other single application. The growth of the semiconductor market depends on a robust PC market just as the PC market depends on new semiconductor devices to differentiate the latest models from older designs. This relationship is symbiotic—profits from the semiconductor industry are funneled back into product and process development, driving more features and more performance into microprocessors, graphics chips, memory devices, and all the other semiconductor devices in PCs.

The PC market, including motherboards and handheld PCs, is forecast to grow at a cumulative annual growth rate of 16.3 percent on a revenue basis from 1995 to the year 2000, with Japan and Asia/Pacific exhibiting higher growth than other regions. The semiconductor content of that total PC market, including motherboards and handheld PCs, is forecast to grow at a 16.1 percent cumulative annual growth rate for the same period. So the semiconductor content of the typical PC will remain steady as a percentage of factory selling price.

## Market and Production Trends

### Personal Computers

Market and production trends in PCs and workstations are as follows:

- Although notebook and subnotebook computers have enjoyed strong growth, desktop systems will continue to dominate the computing platform because of their lower manufacturing costs, their ability to handle robust configurations with large amounts of storage, and their role in offering the fastest and latest computing technologies.
- Notebooks have enjoyed solid unit growth and even higher revenue growth because of their ability to replicate desktop environments. Larger LCDs, bigger hard disks, and integrated CD-ROM drives continue to narrow the performance gap between desktop and notebook PCs.
- Ultraportable and notepad shipments continue to grow but may be surpassed by handheld PCs as the second-largest mobile category, behind notebooks.
- Shipments of laptops and transportable units declined again for 1995 but are forecast to remain steady in terms of unit volume through the forecast period.


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- In the world of mobile computing, handheld devices continue to promise function and mobility but face size, weight, and cost issues. Dataquest has defined two categories for these handheld devices, but only the handheld computer category is covered in this document.
  - Expandable organizers: These are computers that typically measure 3.0 x 6.0 x 0.75 inches and weigh less than a pound. They are distinguished by their ability to allow the user to add applications and memory and by the fact that expansion is proprietary to a particular device or family. The operating systems typically are proprietary. The market for these devices is expected to peak at more than 0.5 million unit shipments in 1995 and then slowly shrink to fewer than 0.4 million by 1999.
  - Handheld computers: These devices typically measure 4.0 x 7.0 x 1.0 inches and weigh about one pound. They are distinguished from expandable organizers by their adherence to hardware and software compatibility standards. The operating systems are open and licensed, and application development and memory expansion are open to third-party developers and may be distributed in a standard format (such as PCMCIA). Personal digital assistants (PDAs) fall into this category.
- Strong growth in the worldwide home PC market will continue across all regions of the world except for the U.S. home market, which shows early signs of saturation. Price elasticity is a key issue in reaching lower-income homes in all regions of the world.
- Microsoft's Windows 95 operating system was launched in the second half of 1995 with actual product sales beginning on August 24. Its most significant impact on hardware is the need to upgrade to 16MB of main memory.
- Emerging markets and regions will account for a sharply increased proportion of shipments by 1998.
- The multimedia PC market continued its torrid growth in 1995. Shipments of complete multimedia systems doubled from 1994 to 1995, reaching 20.9 million shipments.
- Major PC manufacturers will continue to place a strong emphasis on the branding of PCs.
- Manufacturing strategies are dictated by economies of scale, with strong influence from free trade zones, the availability of components, and the quality and price of labor. For desktop PCs, the trend is toward assembling units close to the end market or at least having the final configuration (including CPU and main memory installation) executed on demand close to the end market. For mobile PCs, production is largely focused in Japan and other Asian countries. A rising tide of OEM notebooks from Taiwanese vendors will maintain Asia/Pacific's growing influence on the mobile PC market.
- Motherboard production will depend more heavily on the Asia/Pacific region as suppliers regain some of the market share they lost because of Intel's rapid growth in the motherboard business in 1994 and 1995.

Table 4-1 shows the evolving PC.

**Table 4-1**
**The Evolving PC**

| | 1994 | 1996 | 1998 | Trend |
|---|---|---|---|---|
| Main Memory | 8MB to 10MB FPM DRAM | 14MB to 16MB EDO DRAM | 32MB to 40MB SDRAM | Toward synchronous types of DRAM |
| CPU | 486 DX2/DX4 | Pentium 100 MHz to 133 MHz | Pentium 180 MHz/ Pentium Pro 150 MHz to 200 MHz; all with MMX | Rapid adoption of MMX; shift from Pentium to Pentium Pro; K6? |
| Cache (Factory-Configured) | 128KB | 0KB/256KB | 256KB/512KB | Cacheless Pentium Pro systems are unlikely; minimum increases to 256KB |
| Peripheral Buses | VL/ISA | PCI/ISA | PCI/AGP | Rise of AGP for graphics; systems will have some support for legacy ISA peripherals |
| Graphics and Video | 32-bit, 2-D acceleration, 1MB buffer | 64-bit, 2-D and video acceleration, 2MB buffer | 64-bit, 2-D, 3-D and video acceleration, 2.5MB dedicated, sharing of main memory via AGP | Rapid growth of 3-D as graphics vendors strive to continue to add value |
| Storage | EIDE (5MB/sec)/SCSI | EIDE (13MB/sec)/SCSI-2 | EIDE (20MB/sec)/SCSI-2/ 3/1394 | EIDE likely to remain in-box interface; rise of 1394 |
| Local I/O | RS-232/422 | RS-232/422, beginning of shift to USB | USB, RS-232/422 | USB will become primary interface; RS-232/422 for legacy items |

Source: Dataquest (April 1997)


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# Midrange to Supercomputer Markets

## Summary

Supercomputers and mainframes are expected to decline in growth as networked midrange-based systems and LAN-based clusters of PCs and workstations continue to displace the large machines in certain applications. Likewise, midrange system growth is being clipped by PC LAN clusters. As Microsoft's Windows NT Advanced Server grows in popularity in the low-end commercial and PC server markets, UNIX vendors are moving upscale, using symmetrical multiprocessing (SMP) and clustering techniques for midrange computers and the massive parallel processing (MPP) approach for supercomputers.

Across all performance categories, server versions oriented toward providing resources to LAN clusters (storage, computing, and printing, among others) are growing rapidly.

## Market Trends

The principal market trends in this high-power arena are as follows:

- There is a continuing trend toward the decentralized client/server model of computing using distributed machines optimized for networking, efficient mass storage, and on-demand number crunching. Mainframes and supercomputers are reinventing themselves as high-I/O-capacity, high-performance servers.
- Intel's Pentium Pro-based motherboards are growing in popularity. Among others, Tiva Microcomputer Corporation (TMC) announced its Mercury-IQ, the industry's first dual-Pentium Pro processor-based server motherboard to incorporate $I^2O$ (Intelligent I/O) subsystems using the Intel i960 RP and redundant arrays of independent disks (RAID) hardware. The on-board RAID provides higher performance and reliability, and compatibility with the $I^2O$ specifications enables future technology expandability by providing a standard interface for drivers and a message-passing protocol between multiple independent I/O subsystems.
- With Microsoft's Windows NT Advanced Server growing in popularity in the low-end commercial, PC server, and workstation markets, UNIX vendors are moving upscale. Vendors introducing systems that run Windows NT on Pentium Pro processors are confident that they can, in the long term, win over technical users who have traditionally used low-end UNIX workstations for CAD or 3-D applications. Alternatively, UNIX-RISC system supporters are introducing CMOS/BiCMOS, microprocessor-based, scalable multiprocessor architectures that can take an OEM's line from workstation to supercomputer. Dataquest believes that UNIX will keep the high-end server market to itself at least through 1998. Midrange systems are turning to symmetrical multiprocessing architectures, and supercomputer systems are using a massive parallel processing approach.
- From the reseller perspective, vendors seem to be a bit too product-based and seem to have some problems in ease of doing business. All vendors could benefit from re-evaluation of the business relationship with server resellers. This may be attributable in part to the significant

amount of two-tier business that takes place in the server market. Although this is necessary, the vendor must redouble its efforts to maintain strong communications links with its resellers. Technical support is another problem area for most vendors, and, given the mission-critical nature of servers, this area is well worth any attention paid to it.

- There is a trend toward increased use of the Internet over pricey private lines (for example, T1 leased lines) for electronic communications and commerce (that is, allowing remote offices, traveling staffers, business partners, and customers to reach company networks). Companies can significantly reduce costs and simplify communications by eliminating 800 lines, modem pools, and long distance charges as well as transferring the maintenance of the WAN-to-WAN connection to an Internet service provider (ISP). These so-called Virtual Private Networks (VPNs) are using tunneling technology. Microsoft has promised to incorporate the Point-to-Point Tunneling Protocol (PPTP) in its version 4.0 of Windows NT for access of the company's Windows NT servers from remote individual PCs. Digital Equipment Corporation has already released its Internet Tunnel software. Unlike PPTP, Digital's setup does not require ISPs to use special gear. Also unlike PPTP, Digital's software uses LAN-to-LAN tunneling as well as individual-to-LAN approaches. The current version runs on Alpha-based systems running Digital UNIX. IBM is upgrading its Internet Connecting Secured Network Gateway. This product is for customers that want to create VPNs between offices using RS/6000 servers. Hewlett-Packard formed a new division called the Internet Solutions Operation to develop Internet and intranet systems that allow users of corporate computer networks to perform common tasks from a standard World Wide Web browser.

# Data Storage Markets

## Summary

As rigid disk drive single-platter capacities grow and their cost declines, a floor is imposed on the available capacity that can be marketed at a profit. The 540MB single-platter disk drive is the lowest-cost, lowest-priced product available. Soon the smallest will be 850MB, and then 1GB. The point is that below that imaginary floor, there is a vast black hole in which there are no rotating magnetic storage products available. What can a PC user do to satisfy the requirement for storage capacities between the 1.44MB diskette and the mass of gigabit products available at the other end of the spectrum? These opportunities have been recognized by emerging new removable media, and the outcome can only but spur the success of the removable storage segment.

The future looks good for the industry. Captive manufacture of components will continue to be an advantage enjoyed by a few companies.

## Storage Market Trends

### Fixed Rigid Disk Drives

The new Dataquest rigid disk drive forecasts have been revised upward because of the strong upgrade market requirements. Sales of disk drives in 2000 should exceed 214 million units. Upgrades will continue to keep the distribution market healthy, and the eventual office upgrade to Microsoft

Windows 9x will cause explosive buying of computers and disk drives. A replacement market for the home will drive demand in late 1998 and 1999 to these high levels.

The year 1996 saw the introduction of two new rigid disk drive form factors that are disrupting the normal competitive environment—the JTS 3-inch drive and the Quantum 5.25-inch Bigfoot. Each product is positioned in the market to take advantage of its larger recording area and its potentially lower cost per megabyte. However, it is likely that the 5.25-inch drives will find technological barriers as the demand for higher-capacity products forces them into magneto-resistive (MR) heads and higher data rates. The 5.25-inch disk drives will likely lose their advantage by 1998.

RDD market trends are as follows:

- Helped by personal computer industry growth of 25.6 percent in 1995, the rigid disk drive industry exploded with a 30 percent increase in unit sales. This strong showing was enabled by the unending thirst for low-cost storage in the installed base of PC users. As a result, disk drive upgrade sales to consumers were 23 percent higher than shipments to computer makers, VARs, and integrators, thus reducing inventories.
- 5.25-inch disk drives may have limited success. The increased capacity available on a single platter meets today's demand for 1GB disks using low-cost inductive head technology. But this economical advantage will erode in 1998 when the transition to MR heads is required, and the capacity-limiting read channel data rate is likely to erase this advantage in 1999.
- 3.5-inch RDDs will continue to dominate the PC market, reinforcing their credibility in large and medium-scale RAID storage subsystems. In 1995, total sales were 79.5 million units, including 51.5 million units to computer makers, 11.8 million to the upgrade market, and 16.1 million units to the workstation and server market, with Seagate and IBM holding the majority market shares in the latter segment. Server storage products continue to be on allocation, and prices seem to be falling at tolerable rates.
- Smaller disks (2.5-inch and below) found a home in the mobile computer market because they help minimize power consumption and weight. However, they offer less capacity at a higher price than the 3.5-inch or the newly introduced 3-inch drives. Manufacturers of 2.5-inch disk drive may want to drop their prices to meet the new competition coming from 3-inch disks.
- JTS Corporation's 3-inch disk drives offer the promise of 70 percent greater capacity on a single platter at a substantial savings in cost when compared with 2.5-inch products. The drive is manufactured from widely available parts and will not reach data rate limitations. The 3-inch products will continue to have an advantage at higher capacities because they will not be forced into using expensive MR heads as quickly as the 2.5-inch drives. They can also be expected to be offered as removable modules for the home user, further increasing their potential market size.

- More than half the RDDs shipped in 1996 will have densities exceeding 1GB. In 1997, these drives will represent 80 percent of the RDDs. The move to more memory-intensive software based on Windows 95 is raising user storage needs considerably in PC applications. The need for larger storage space for multimedia (audio and video) data and rasterized images is also a significant factor contributing to growth.
- RDD product life cycles are running about one year.

**Removable Storage Product Drives**

The year 1996 has proved to be an interesting time to observe the removable disk drive market, and today the future looks much better than it did last summer. The black hole of capacity between 100MB and 1GB is nourishing innovation, and manufacturers are hurrying to find a way to offer a product that can be purchased easily from discretionary funds by as many consumers as possible. The success of the flexible diskette is undeniable, primarily because it has exceeded the PC criteria for removable storage devices. However, these criteria have evolved, and the end users are now demanding high-capacity, fast-backup capabilities as well as removable storage that can provide high-performance multimedia output.

As cost and reliability are still key, 3.5-inch, 1.44MB floppies are still a good deal, but their performance and capacity are far behind the times. The battle to find a replacement is just commencing. It is too early to predict which device(s) will be the long-term winner in this search to replace the 3.5-inch, 1.44MB diskette.

Dataquest will now examine the main market trends in removable drivers, breaking them into three principal categories, namely, optical disc drives (ODD), flexible drives, and tape drives.

Optical disc drive market trends are as follows:

- ODDs, especially CD-ROM drives, continue surging in sales. The standardized software distribution data format used on all platforms today is the CD-ROM because the size of software has far exceeded the capability and convenience of a 1.44MB diskette. The CD-ROM drive (a possible candidate to replace 3.5-inch floppies) is starting to come down in price but is still closer to $800 than the $200 price point.
- CD-ROM demand comes from a burgeoning multimedia market where drives are being incorporated into the system or added via upgrades (by kit or as standalone devices). Home and corporate users are using CD-ROM drives for reference (for example, encyclopedias, publications, and manuals), education, and games. CD-ROM drives are finding their home on many servers and workstations as a software distribution medium. The use of DVDs will obviate the need for CD products toward the end of the decade.
- Rewritable optical drives, comprising principally magneto-optical (MO) technology, are showing signs of getting competitive and meeting most PC criteria, but the costs related to rewritable optical disc products continue to exceed those of magnetic products. Higher capacities in the RDD market are also hurting this market's development. The most popular versions will be 3.5 inches.

- DVDs are poised to boost opportunities for many semiconductor components. With higher storage capacity, faster data transfer rates, interactive capabilities, and, most important, applications across computer and consumer electronics markets, DVD has moved the capabilities of optical storage forward by an order of magnitude. Recent agreement on a common format standard should enable the launch of DVD-ROM and DVD-Video products by end of 1996. DVD-WORM and DVD-RAM standards will be established over the next one or two years. The combined market shipments of all DVD reading/playing products would drive factory revenue over $10 billion by the year 2000. The DVD optical drive market itself should generate $4.3 billion by the end of the decade.
- An in-depth report on DVD, *DVD: The Hot New Digital Video Destination for Semiconductors* (MSAM-WW-FR-9602, July 8, 1996), has been published by Dataquest's Consumer Multimedia Semiconductor Application Markets program. This report provides detailed analysis and forecasts of the semiconductor opportunity in DVD products.

Flexible drive market trends are as follows:

- Last year's forecast showed a decline in both FDD unit shipments and factory revenue. To the dismay of many, the latest data displays a revival of a 4.3 percent CAGR for 1995 through 2000. Total worldwide flexible drive sales in 1995 were 81.2 million units, while total computer sales were about 62 million units, and FDD sales are expected to grow 13.5 percent in 1996.
- For the lack of a widely industry-supported alternative, the 3.5-inch, 1.44MB FDD technology is expected to remain the predominant standard, whereas 5.25-inch versions are in rapid decline (down 39 percent from 1994, to 6 million units in 1995, with a projected 67 percent decline in 1996 over 1995). Those 2.88-inch versions are expected to disappear soon from shelves because of the OEM price that turned out to double the price of the disk as well as the capacity.
- Iomega's Zip drive is offered at 100MB for $199 and meets the previously mentioned end-user needs. Several OEM contracts have been announced, including Unisys, Bandai Digital Equipment, Power Computing, Micron Electronics, Hewlett-Packard, Acer, Packard Bell, IBM, NEC, and Escom. Dataquest believes that the OEM configuration of the Zip drive can be cost-reduced and supplied at less than $100 in large quantities. Although it is still an inexact science to estimate where this product and its market may be headed, the success of the Zip drive is probably limited by production capacity.
- SyQuest has attempted to compete with the Zip drive with its EZ-135 product and has suffered severe losses. SyQuest appears to be moving back to its solid installed base of 2 million users to market a new 230MB rigid drive called the EZ Flyer. SyQuest is also competing against Iomega's 1GB Jaz drive with its 1.2GB Sylet.
- The latest permutation of floptical technology is the LS-120 product from Matsushita Kotobuki Electronics (MKE), Panasonic, Compaq, and Imation (3M's spin-off). OR and Mitsubishi have also announced that they will manufacture their own version, and Maxell will produce floptical media at the market price of $19.95 per diskette. Although this optical tracking technology is solid and well-proven, the additional cost

of this servo mechanism brings the product to between $115 and $120 in large OEM quantities. The high cost and the lack of a single point of control over the sales strategy make the LS-120 an unlikely candidate for standard use as an OEM product.

- Another 120MB, 3.5-inch pretender has been announced by Mitsumi. This multigap read-write head technology product provides high-density recording as well as backward compatibility. Although this product is still more expensive than the LS-120, it has the chance of having its cost reduced quickly if the volumes warrant. Legal battling over the license to the technology (with Swan Instruments and Antek as other participants in the ownership discussions) has clouded its immediate prospects.

Tape drive market trends are as follows:

- Tape has always had the lowest cost per megabyte for the storage industry, but its sequential performance characteristics and price have relegated tape to the backup and archive business.
- Emerging applications are focused on new functionality such as hierarchical storage management, near-line storage, large file transport, and direct recording and playback of audio, video, and multimedia files.
- With heavy use as PC server and workstation backup devices, 1/4-inch cartridge tape will remain the dominant tape drive device throughout the forecast period (about 70 percent of the total tape drive market). The DC-2000 1/4-inch version, which fits into 3.5-inch bays, will grow to be the dominant version.
- Helical scan technology based on either digital audio tape (DAT) at 4mm, camcorder technology at 8mm, or VHS-type technology will show average growth.

## Printer Markets

### Summary

Printers are definitely not getting dumber. Host-based printing solutions can be applied successfully to certain environments (mainframes and networks with only one printer).

Because the price curve of RAM has slowed dramatically, data compression is becoming increasingly important. This is especially true given the increasing demand for higher resolutions and color, both of which require more data to move around. Even with compression, high-end printers are still memory hogs, which is good news for RAM suppliers.

Color also demands more advanced logic components for matching, alignment, and halftone generation. PostScript Level 2 code is big, which is good news for ROM suppliers. Color laser printers use up to 8MB of ROM. Color and PostScript Level 2 will be growing applications for ROM.

RISC is alive and well in laser and thermal transfer printers. Lots of opportunities still exist for differentiating logic products based on performance, features, and level of integration.

## Printer Market Trends

In the following overview, the terms "serial printer" and "page printer" are historical and are quickly losing their relevance. A serial printer is defined as printing one character at a time. A page printer stores the entire page image in a buffer before printing it out in one uninterruptable pass. Historically, serial printers meant ink jet and some dot matrix printers and page printers meant laser and thermal transfer printers. However, there has been significant crossover between these two historical categories.

Printer market trends are as follows:

- The small office/home office market continues to drive much of the low-end printer market growth for economical ink jet and laser versions.
- Dot matrix technology is quickly being replaced by ink jet. However, there is still a large market for dot matrix and thermal printers embedded into cash registers, calculators, automatic teller machines, and gas pumps.
- The logic functions of printers are now being integrated or even eliminated altogether, with the rasterization being done in the host computer's processor. Host rasterization, or host-based printing, is very attractive because it eliminates redundancies between the printer and the computer. In particular, it dramatically reduces memory requirements.
- The 300-dots-per-inch (dpi) laser/LED technology page printers are being replaced by true 600-dpi laser/LED and higher-quality 300-dpi ink jet technology; 1,200-dpi technology is deployed into the high end of laser printer market.
- Following is a list of the new features that printer manufacturers are implementing:
  - Higher quality: Printers are moving to 600 dpi from 300 dpi.
  - Enhanced image: Variable dot sizes and advanced halftone generators are two techniques that can boost the image quality beyond the printer engine's rated maximum.
  - Color: Colored ink, ribbons, or toner
  - New form factors: Portable with multiple paper trays and handling options
  - Multifunction: Systems combining fax, copier, scanner, and phone are beginning to see market ramp-up. Multifunction machines now have their own industry association, the Multifunction Peripheral Association (MFPA).
  - Faster speed: Usually a trade-off for quality
  - Power conservation: Low power consumption during idle and sleep mode is a feature. Page printers using less than 30W to 45W when idle can qualify for the coveted U.S.-based Energy Star label. About 90 percent of laser printers and 60 percent of thermal transfer printers are now compliant with this specification.

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- Multiple connections: Supporting different network interfaces, built-in Ethernet, and automatic emulation switching

- Most ink jet and laser printers support HP's Printer Control Language (PCL). However, Adobe's PostScript is the de facto standard language for complex graphics. PostScript Level 1 is for black and white; PostScript Level 2 supports color. PostScript is primarily implemented in laser and thermal transfer printers. Both PostScript Level 2 and HP's PCL 5 font technology are becoming more prevalent in midrange and low-end page printers.

Color page printers remain expensive (about three times more than serial printers). It should be some time before they become economical and mainstream. Color-capable and full-color ink jets rapidly are becoming the majority in that market.

## Selected Input/Output and Dedicated Systems

### Summary

With the advent of multimedia and digital video/audio features, the need for a universal and faster I/O bus is growing. The Universal Serial Bus was designed as a low-cost connection for multiple, simultaneous use of I/O devices and provides a new opportunity for semiconductor manufacturers in terms of digital/analog converter functions, in particular.

### Key Trends

Dataquest has split this group into a number of categories that are examined individually. These areas are sound boards, graphics boards, digital video boards, monitors, copiers, scanners, and keyboards.

#### Sound Boards

Key trends in sound boards are as follows:

- The sound board market faces increasing competition from integrated designs with sound chips on the motherboard or on custom daughtercard modules. Integrated sound chips are primarily used for mobile and consumer PCs, although a few business desktops have integrated sound capability.
- Microsoft has adopted DSP Group's TrueSpeech technology as a compression standard. Several vendors already support adaptive differential pulse code modulation (ADPCM) for compression.
- Movement to 16-bit technology is nearly complete. Wave-table synthesis is gaining market share.
- Key chip functions include FM and wave-table synthesis (512KB to 4MB ROM-based), ASSPs/ASICs (mixed-signal and digital CMOS), audio amplifiers, and mixers. SCSI host adapters have declined in popularity compared with EIDE or proprietary variants of EIDE.

### Graphics Boards

Key trends in graphics boards are as follows:

- These may receive a boost from the 3-D graphics market until mid-1997, when several new graphics controllers make 3-D hardware more attractive for motherboard implementations.
- Boards are moving to greater than 1000 x 1000-pixel resolutions, accelerated BitBLT-based, 64-bit data paths, and RAMDAC technology moving from 85 MHz to 135 MHz. Also, digital video, 3-D, and sound capability are appearing in the high-end boards.
- Extended data out (EDO) DRAM will be the dominant memory for 1996 but will be replaced with SDRAM/SGRAM in 1997. Minimal buffers start at 1MB and move to 4MB with optional single in-line memory modules (SIMMs). Most high-end add-in boards have separate RAMDAC, and digital video functions are being integrated into virtually every design.

### Digital Video Boards

Key trends in digital video boards are as follows:

- There will be continued penetration into the multimedia content creator market (software title development, market communications, and training). Playback board growth will be limited to full-screen 15-fps-to-30-fps acceleration. Other opportunities exist for TV tuner, capture passthrough, and integrated audio and graphics boards.
- MPEG-1 hardware shifted partly to the motherboard in 1995 but has already reverted to add-in cards, creating greater opportunities for video board OEMs.
- Key semiconductor opportunities include compression decoders for MPEG-1 and JPEG, among others (and encoders for real-time algorithms), decoders and encoders among various video standards such as PAL, NTSC and CCIR, ASICs (CMOS), digital video processors (scaling, among other functions), and DRAM/VRAM pixels buffers.

Leading digital video board OEMs worldwide are ATI, Creative Technologies, Diamond Multimedia, FutureTel, IBM, Intel, Matrox, Media Vision, Optibase, Optivision, Orchid, Sigma Designs, SuperMac, and Video Logic.

### Monitors

Key trends in monitors are as follows:

- Color will grow to 98 percent of the market in 1999.
- The predominant tube size in 1996 will be 15 inches; 17-inch tubes will predominate in 1997.
- Chip content will be about $5 for primarily video amplifier controls (moving to 135 MHz) and CRT controls.

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### Copiers

Key trends in copiers are as follows:

- Dataquest believes that the worldwide total copier market will decline by the year 2000, largely because of a decline in placements of low-volume personal copiers (up to 30 copies per minute). However, the high-end copier market will continue to grow, and digital and color copier are emerging quickly.

Digital and color copiers (combining printing and scanning, among other functions) are emerging. In 1995, a mere fraction (1 percent) were digital in nature, including standalone and connected units. Even by the year 2000, less than 10 percent will be digital. However, it is clear that digital will be more important in the high-end segment of this market. Digital will represent 3 percent of low-volume copiers, 13 percent of midvolume copiers, and 29 percent of high-volume copiers.

- The low-volume copier market will continue to grow for one more year but will decline each year thereafter. Although personal copiers are undeniably inexpensive, reliable, and easy to use, their popularity will decline as users start to respond more heavily on alternate reproduction methods: printer/faxes, fax/printers, scanners, and multifunctional devices that, at last, are hitting the right price/performance points to attract buyers. When Dataquest refers to the low end (tabletop; up to 30 cpm) of the copier market, we are talking about the Personal Copier (PC) Segments 1 and 2. Obviously, these economically priced units represent the lion's share of the copier market: 77 percent of the total market in 1995. However, in terms of revenue, they only represent 27 percent of the total. All vendors, besides Kodak and Océ, are represented in this market.
- The midvolume part of the market (31 cpm to 69 cpm, tabletop or console) refers to Segments 3 and 4. This has been referred to as the heartland of the market, in particular as it pertains to Xerox, which is still a market leader in this area. However, the midvolume segment is also the part of the market that Japanese vendors have aspired to and where they now excel. In terms of units, Segments 3 and 4 represent 20 percent of the market, but in terms of revenue, they represent 44 percent of the market, hence their attraction. Depending on the size of the end-user company, a midvolume unit may be the production copier or a walk-up copier. In either case, they are speedy, nicely featured, and productive. The midvolume has also been targeted by the Japanese vendors for multifunctional units. Introduction of digital and color copiers may enable the "copier company" to win the battle against multifunction printers.

The high-volume part of the market refers to Segments 5 and 6 (console; over 70 cpm). Traditionally, this part of the market has belonged to U.S. high-end players Xerox and Kodak. Although this is still largely true in Segment 6, Segment 5, like the midvolume segment, is home to all Japanese vendors as well. Although in terms of units the high end is a small part of the market (3 percent), in terms of revenue it represents 30 percent. Clearly, the attraction for the Japanese vendors has been this revenue potential. The continuing growth of high-volume products is fueled by end users' desire for speedy units and the increased popularity of digital units. This part of the market should not be threatened by multifunction

machines. It is much less convenient to print out multiple sets on a slow printer or use a scanner/printer combination. Also, copiers have finishing, a feature still lacking on printers. This also makes them very productive. When a printer is used for a job, the sets would neither be sorted nor stapled, which means that the printer user would have to separate and staple the sets. In the meantime, the copier user would be walking away from the copier with finished sets. Copiers still have many advantages that people would be loath to give up.

Leading copier OEM players are Canon, Kodak, Konica, Lanier, Minolta, Mita, Océ, Panasonic, Pitney Bowes, Ricoh, Sharp, Toshiba, and Xerox.

### Scanners

Key trends in scanners are as follows:

- Scanners are an expanding desktop/digital document tool.
- The bulk of the market is at 300 dpi today, moving to 600 dpi; color will move from 35 percent to 60 percent of the market by 1999.
- Handheld scanners are projected to be 35 percent of the market by 1999.
- The semiconductor content includes linear CCD arrays, 8-bit MCUs, ASICs, and DRAM.

Leading scanner OEMs worldwide are HP, Apple, Canon, Mustek, Fujitsu, Microtech, and Logitech.

### Keyboards

The trend in keyboards is commodity items moving toward ergonomic and wireless versions.

Leading keyboard OEMs worldwide are Keytronic, Silitek, and Maxi-Switch.

# Chapter 5
# Communications Applications

## Local Area Networks: Market Drivers and Technology Directions

### Market Drivers

- Large-size and medium-size office LAN desktop connectivity will continue to rise, reaching nearly 100 percent saturation in the United States and Europe by the end of the decade. The majority of new connectivity growth will come from businesses in Japan and the rest of world and small office/home office (SOHO) hookups everywhere.
- LAN bandwidth demands will be driven by a variety of trends, including increased use of application servers, networking, faxing, groupware (such as Lotus Notes), and, ultimately, multimedia-rich file transfer messaging (store and forward or conferencing).

IS managers are under pressure to upgrade as they consider a variety of speed-enhancing technologies for desktop connectivity and the backbone. These include:

- Full duplex Ethernet (20 Mbps)
- Iso-Ethernet (16 Mbps)
- Switched Ethernet (10 Mbps)
- Switched token ring (16 Mbps)
- Fast Ethernet (100 Mbps; shared media and switched)
- 100VG-AnyLAN (100 Mbps; shared media and switched)
- Fiber-distributed data interface/copper-distributed data interface (FDDI/CDDI; 100 Mbps)
- ATM (25 Mbps to 622 Mbps)
- Gigabit Ethernet (1,000 Mbps)

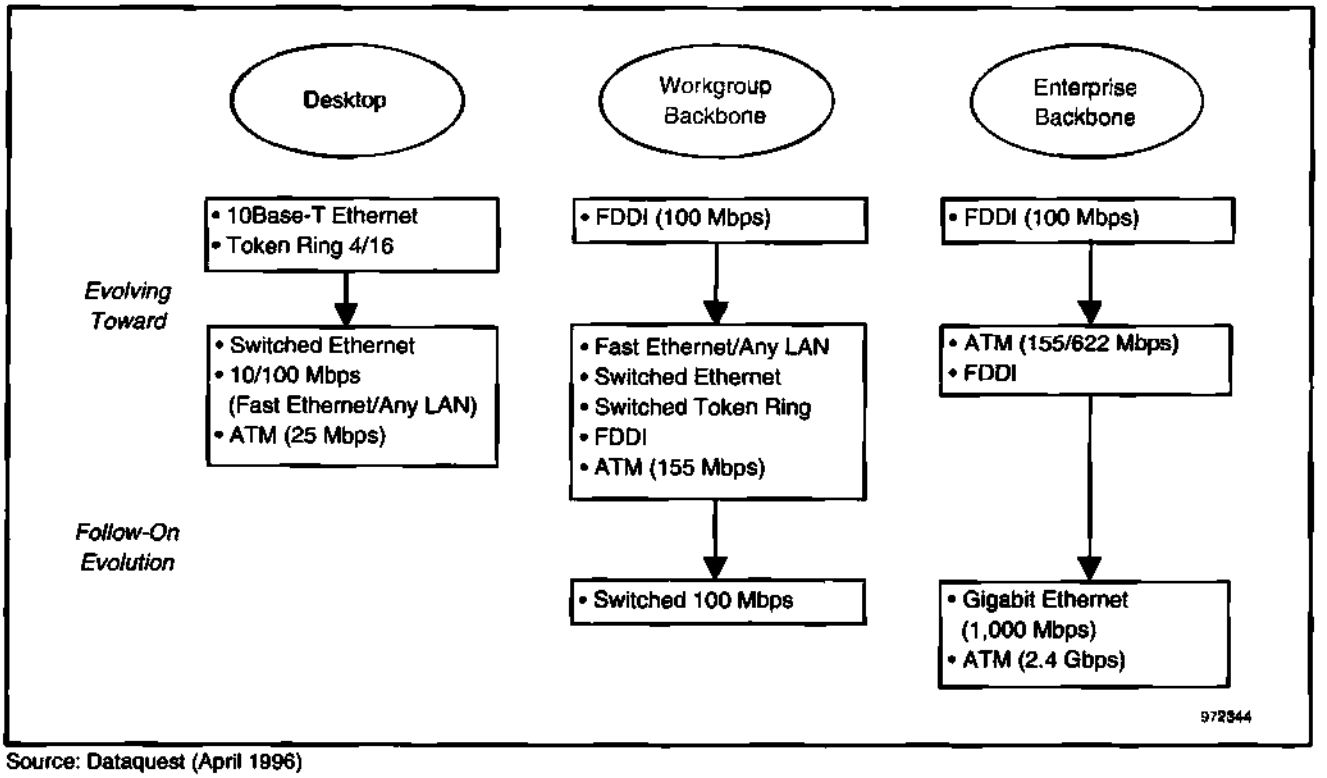
Figure 5-1 illustrates the various LAN technology trends by segment. Figure 5-2 shows alternative network technologies, and Figure 5-3 shows network interface card and hub/switch node shipments.

### Technology Directions

The LAN area is one with many different technologies at the moment. Dataquest has included some strategically significant new direcitons below:

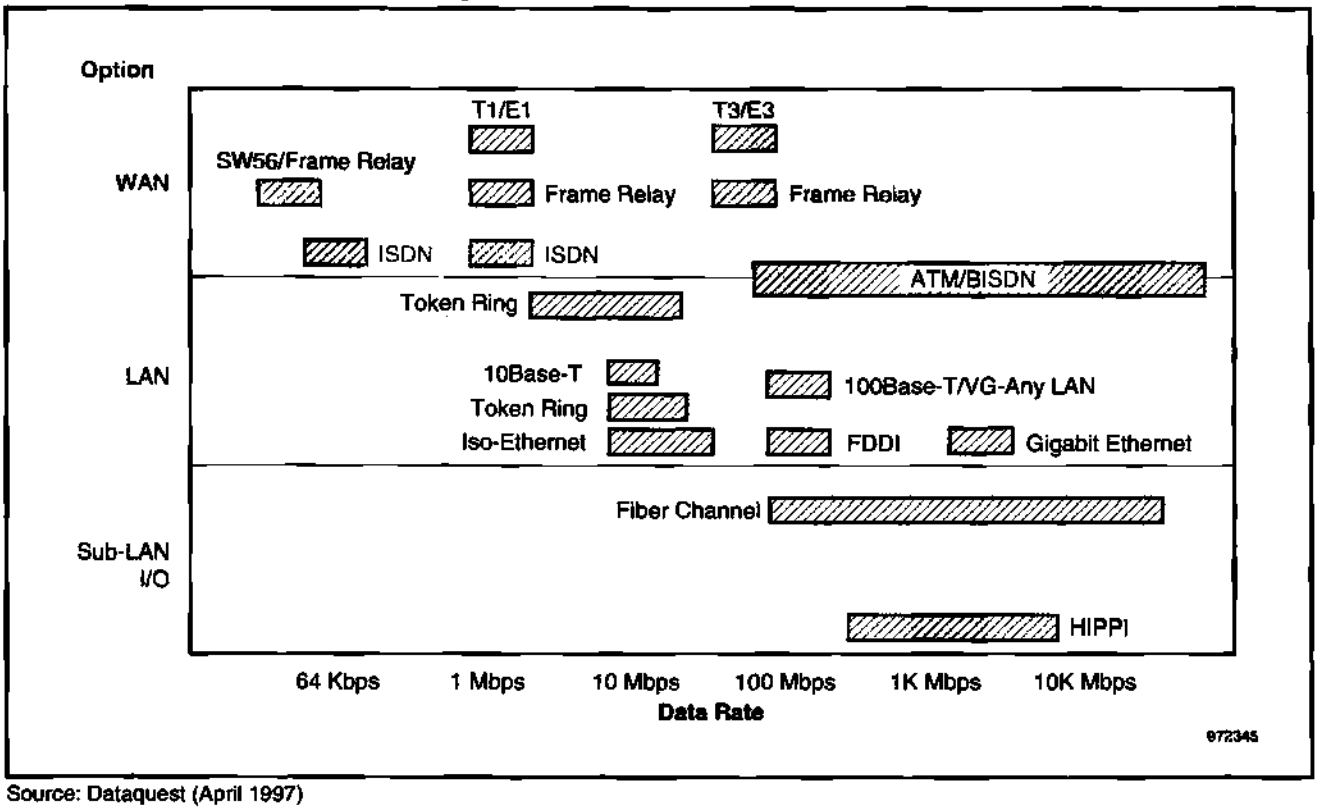
- High speed
  - New high-speed technologies like 100-Mbps Fast Ethernet, 100VG-AnyLAN, and asynchronous transfer mode (ATM) are being employed in desktop NICs and network backbones. Increasingly, 10-Mbps Ethernet and token ring will be displaced by these faster technologies for desktop connections. The market is moving rapidly to technology known as 10/100, which uses networking systems capable of both 10 Mbps and 100 Mbps.

**Figure 5-1**
**LAN Technology Trends**



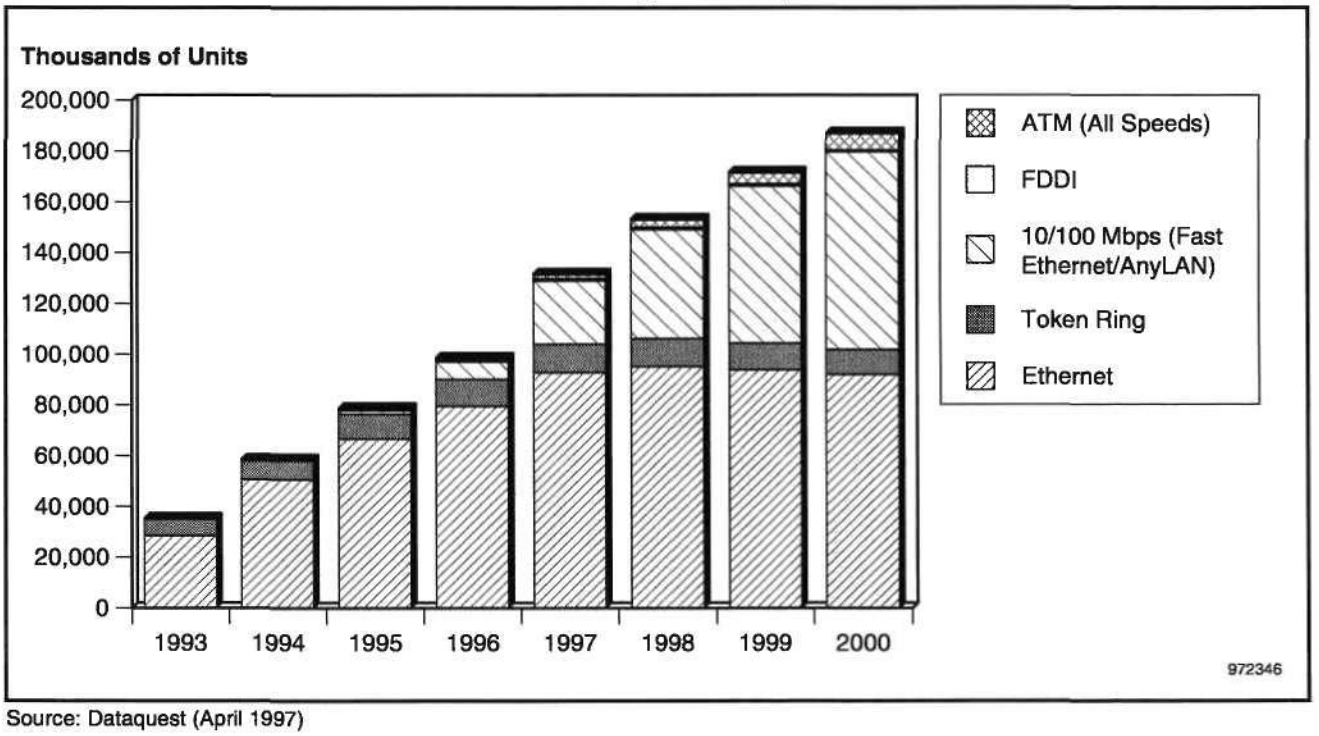

Source: Dataquest (April 1996)

**Figure 5-2**
**Alternative Network Technologies**




Source: Dataquest (April 1997)

**Figure 5-3**
**Worldwide NIC and Hub/Switch Node Shipments by Standard**




Source: Dataquest (April 1997)

- Network Interface Cards
  - NICs capable of 10-Mbps and 100-Mbps speeds are penetrating the market rapidly. The price premium for these dual-capable boards has dropped to under 50 percent, and MIS managers interested in investment protection are buying them in lieu of slower-speed-only boards. In three years, the majority of boards sold will be dual speed.
  - Fast Ethernet is becoming the dominant next-generation desktop and workgroup backbone technology, and VG-AnyLAN and 25-Mbps ATM will play niche roles.
  - PCI bus NICs are entering the mainstream, displacing the ISA bus versions.
  - The trend is toward installing category 5 twisted pair or fiber in most upgrades and new installations. Category 3 twisted-pair wire is the most common currently.
  - PCMCIA card (or PC Card) versions are enabling notebook computer connectivity and are expected to continue to grow rapidly.
  - Key value-add features include remote monitoring (RMON), which allows remote management of campuswide LANs and wide area networks (WANs), and power-up/down modes such as Advanced Micro Devices' Magic Packet technology.
  - PCs targeted at large businesses, like most workstations today, will have embedded LAN controllers designed onto the motherboard at an increasing rate.

- Hubs, switches, and routers
  - Intelligent shared media (also known as repeater) hubs are being replaced by LAN switches capable of dedicating full bandwidth (such as 10, 16, or 100 Mbps) to the desktop. Most hubs/switches today have as minimum eight to 16 ports with one or more high-speed uplinks to a server or other hub/switch. Modular and stackable hubs are gaining strong market acceptance because of their flexibility. Key value-added directions for hubs and switches are toward better manageability and robustness in the form of reliability and uptime. Support of full duplex transmission is increasing as well.
  - Routers are used to direct network traffic from one LAN segment to another and come in local and remote forms. For the most part, routers have displaced bridges as a more flexible alternative. Many routers can now be added as modules to hub bays. Some have speculated that switch-based networks that implement virtual LAN (VLAN) techniques would make routers obsolete. It will take a few years before full-featured switches that support VLANs and a full suite of management functions hit the market.
  - The remote LAN access server (with built-in routers, modems, integrated services digital network, or ISDN, adapters, and so on) is also proving to be very popular. Access to files at work, e-mail, and remote offices are the drivers. Remote LAN access servers typically incorporate a LAN interface, a number of modem ports (now V.34 or ISDN or T/E carrier), and some sort of CPU-based protocol mapping engine.
- ATM
  - ATM technology employs 53-byte, fixed-length cells that can operate from speeds as low as 25 Mbps to 155 Mbps and up to 2.4 Gbps in backbone and public transmission applications. Adopted initially by the hub/switch vendors, adapter cards for workstations and servers are also hitting the market. The main standards body is the ATM Forum, which works with interested players to ensure that LAN, WAN, and public equipment will work with each other. ATM is viewed as the overarching technology that can link LAN and WAN. ATM's adoption in LANs has been slowed somewhat by Fast Ethernet's success, but key pockets of opportunity exist in enterprise and departmental backbone switches, "power user" 155-Mbps NICs, and 25 Mbps for upgrading token-ring desktops.
- Wireless LAN
  - Radio-frequency (RF) versions employing spread spectrum technology operating in the ISM bands are expected to be the most popular, although infrared (IR) will find many point-to-point uses. Worldwide, the 2.4-GHz band should become the most popular, with 900 MHz being the most popular band in existing vertical applications in the United States.
  - Early market build will come from the rollover of users from proprietary solutions in the handheld data terminal market. Work on the IEEE 802.11 standard, which would govern wireless LAN interoperability, would have a flexible media access control (MAC) layer (up to 20 Mbps) and three physical (PHY) layers, two spread spectrum

(frequency hopping and direct sequence), and IR. Ratification of IEEE 802.11 is expected this year.

- Key market acceptance issues revolve around costs (currently $500 to $600 for adapters and $1,000 to $2,000 for bridges) for data throughput (typically 0.5 Mbps to 2 Mbps currently). To appeal to more than a certain set of vertical markets, the prices must drop in half and performance must at least double, approaching seamless Ethernet connectivity at 10 Mbps.

## Modems: Recent Market Developments

In 1995, 1996, and beyond, some basic modem market trends will affect the nature of the opportunity for vendors selling to that industry:

- Near-term shipment growth is being driven heavily by the ongoing ramp-up in home modem use. The modem market (add-in cards, PC Card, standalone, and rack mount) grew over 50 percent in 1995 on a unit basis. The market is expected to grow another 30 percent in 1996.
- V.34 modems capable of speeds up to 33.6 Kbps are projected to be 60 percent of the market in 1996. Digital modem shipments, comprising ISDN adapters, asymmetrical digital subscriber line (ADSL), and cable modems are expected to exceed 1.5 million units in 1996.
- Nearly 100 percent of the PCs sold through the retail channel come bundled with modem cards or some built-in modem functionality. Usage is being stimulated by the rise of the home office, remote access for work-at-home use, and the rapid rise in popularity of online services such as the Internet, America Online, and CompuServe. In particular, access to the Internet's World Wide Web is the big attraction for home modem users.
- The Japanese and western European modem markets have experienced strong growth over the past year as the home multimedia PC market takes off in those countries as well. High growth rates are expected to continue for at least another year. Internet access is also a big driver of demand in these countries. Evolving privatization of the European PTT is helping expand modem ownership.
- Robotics/Megahertz was the largest modem supplier in the world in 1995, nearly doubling its business with effective retail and bundling strategies. GVC Corporation became the second-largest company by being a strong behind-the-scenes provider.
- U.S. Robotics was acquired by 3Com.

### Market and Technology Directions

#### Analog

- V.22bis (2,400-bps, two-wire, and full duplex) was the most popular analog standard worldwide in 1993. In 1994, it was surpassed by V.32bis modems (14.4-Kbps and lower, two-wire, and full duplex) as prices come down. V.32bis should remain the dominant standard until 1997, when V.34 (28.8-Kbps/33.36-Kbps) becomes dominant. V.34 was ratified as a standard and has become an International Telecommunications Union (ITU) standard.

- Most PC modems are now capable of data and fax transmission and reception and various degrees of "telephony" functionality, including answering machines, plain old telephone service (POTS), and speakerphone.
- PC Card (PCMCIA) versions continue gaining in popularity for notebook computer users desiring to gain access to e-mail while not in the office. Of the PC Card versions, a growing percentage are dual LAN NICs and modems.
- Most modems now support error correction (MNP 2-4 and V.42) as well as data compression (MNP 5 and V.42bis). There is also a strong trend to add plug-and-play functionality to PC modem cards so they can be installed without concern for the system configuration. Other evolving features include call discrimination, which can distinguish the types on incoming calls, caller ID support, answering machine emulation, business audio I/O, MNP 10 for more robust cellular communication, and universal "worldwide" standards support for call progress and handshaking, among others.
- A committee of the ITU has approved the V.70 digital simultaneous voice data (DSVD) standard. This standard allows collaborative computing to take place such that data can be shared while a voice conversation takes place. In this scheme, 8 Kbps of bandwidth is allocated to digitized voice, which uses the G.729 Annex A coder specification. The next generation of modems are expected to be equipped with DSVD capability.
- Many modems are now being combined with sound card functions (Sound Blaster compatibility, for example). These are generally the two add-in cards found in multimedia PCs, and some PC OEMS have seen benefit in combining them and saving costs.
- Another feature that companies are working on is to allow power-down modem reception. This capability would power parts of the PC when an incoming transmission is detected.
- Some computers, most notably IBM with its Mwave technology, have moved to using a general-purpose, digital signal processor-based (DSP-based) processor for handling modem, telephony, and sound I/O.
- The trend is toward most modems supporting V.17 faxing (14.4-Kbps) in addition to V.29 (9.6-Kbps) and other fax speeds. There also is a trend toward supporting the EIA/TIA-578 Class 1 standard, which extends the "AT" command set, allowing the PC application software control over advanced fax functions.
- Telephony (data and fax modem) functions are becoming more standardized as the Microsoft Windows Telephony Application Program Interface (TAPI) feature becomes standard in Windows 95. This is not only supporting the plug-and-play rollout but is also simplifying application developers' jobs by creating a standard software interface capable of using a multitude of modem features.
- The traditional modem market is being threatened with displacement on two fronts: high-speed digital alternatives and host-based "soft modems." With soft modems, an increasing amount of the functionality is run on the host CPU (x86 or PowerPC). Ultimately, only an analog front end interface would be required as separate hardware. The approach salutes the increasing amount of mips available with the latest

MPUs. Intel's Multimedia Extensions (MMX) MPU instruction extensions, which accelerate DSP-type functions, are expected to enhance the Pentium and Pentium Pro processors, making them suitable for "voice band" processing for audio and modem I/O. The rate of conversion to this approach is being accelerated as chip vendors start to provide controllerless versions of modem chipsets, allowing the host software to take over that function.

- 56 Kbps is staving off digital competition for PC applications in the short term. However, the prestandard 56 Kbps is split into two camps:
  - Rockwell/Lucent (No. 1 and No. 2 in modem chipsets)
  - U.S. Robotics (No. 1 in finished modems)/TI/Cirrus

As mentioned earlier, U.S. Robotics has been acquired by 3Com. U.S. Robotics, according to Dataquest, is both a technology and modem supplier. Its success is bolstering TI's market position.

### Digital

Several digital technologies can offer a speed advantage over V.34 (33.6 Kbps). As access requirements spiral upward, these digital alternatives are becoming more available and are dropping in price. Key digital alternatives include ISDN, asymmetric digital subscriber loop (ADSL), and cable modem. By the year 2000, digital modems are expected to account for about 20 percent of the market.

- ISDN basic rate interface (BRI), capable of 128-Kbps transfer rates, continues to roll out with over 4 million lines in service worldwide. ISDN is being aggressively rolled out in many areas around the world. The highest penetration is in Germany spurred on by historically low service charges. After a slow start, several U.S. regional carriers now have low residential tariffs and are improving installation services. Average monthly charges have dropped below $50, with ISDN PC terminal adapters with a U interface (also known as NT1) costing $300 or less. The number of ISDN lines installed is expected to grow to over 10 million worldwide by 1999.
- Cable modems are emerging as a viable high-speed digital modem technology that can push data to speeds exceeding 10 Mbps. Cable modem technology works over cable TV (CATV) coaxial lines via service provided by the cable TV company. Expect small scale trails and deployment to continue for 1996 and most of 1997. Once infrastructure systems are in place to manage traffic routing and customer service, the cable multiservice operators (MSOs) are expected to accelerate deployment as they try to capture the Internet access business. Key hardware providers include General Instrument, Hewlett-Packard, LANCity, Motorola, and Scientific-Atlanta.
- Asymmetrical digital subscriber loop (ADSL) employs a DSP-based line-conditioning technology to make standard twisted-pair phone lines capable of more than 6-Mbps data transfer, fast enough to carry MPEG-2 compressed videos. As the telephone companies do battle with the cable companies and others, they are expected to place more emphasis on ADSL. The United Kingdom, United States, Australia, and Israel lead a group of countries with ADSL trials. Current estimates place the number of ADSL lines to be installed by the year 2000 at 10 million. An extended version of ADSL known as VDSL (very high-speed DSL) capable of 52 Mbps over 3,000-feet local loops is also being considered.

Key ADSL equipment vendors include Westell, Amati, Aware, Alcatel, ECI Telecom, and AT&T Paradyne. Of the two primary algorithms used in ADSL, one known as discrete multitone (DMT) is expected to become the most widely implemented.

## Fax Machines: Market and Technology Directions

Key trends with the fax machine market and technology include:

- Unit growth is slowing in the professional segment as market saturation nears in most of the developed countries. Developing countries and home use in countries such as the United States are the main growth opportunities for fax machines.
- The trend toward plain paper machines continues as they decrease in price relative to direct thermal transfer. Plain paper machines are expected to be the majority of shipments by the end of 1996.
- Laser/LED marking engines for plain paper machines are ramping quickly as a percentage of the market. The combination of good printing performance and cost-effectiveness will propel the ink jet technology promoted by Hewlett-Packard, and Canon should become the volume leader by 1998.
- Network faxing is becoming a reality, with client/server fax software that allows users to send and receive documents directly from their PCs as an adjunct to e-mail or perhaps in its absence. The same is true with home PCs. These latter trends are serving to limit the growth of standalone machines capable of scanning.
- Numerous efforts are under way to push integrated faxing, printing, scanning, and copying technology. Several integrated systems are on the market, targeted at small office/home office users.
- Group 4-based or ISDN-based faxing continues to be relegated to a small fraction of the market as line availability, cost, and lack of user interest limit demand. Color fax remains a very small consideration.

## Digital Wide Area Network Applications: Recent Market Developments

Before looking at market and technology directions for digital WANs, let us first look at some basic WAN market trends that will affect the nature of the opportunity for vendors selling to that industry.

- Digital WAN systems market revenue grew nearly 25 percent in 1996 and at an average growth rate of 17 percent through the end of the decade. Like other areas of the IT industry, the Internet and Web are stimulants of demand. Frame relay, for example, has become one the most popular ways for corporations to hook their Web servers up to the network.
- The WAN systems market is also benefiting from the consolidation of the concept of corporate intranets. Although there is technically nothing new about an intranet, the use of groupware (such as Lotus Notes), distributed data bases, and remote access (from home or small branch offices) is clearly on the rise, stimulating demand for more and faster WAN equipment.
- The availability of cost-effective WAN services from the public carriers is crucial for the expansion of the market. The liberalization efforts in

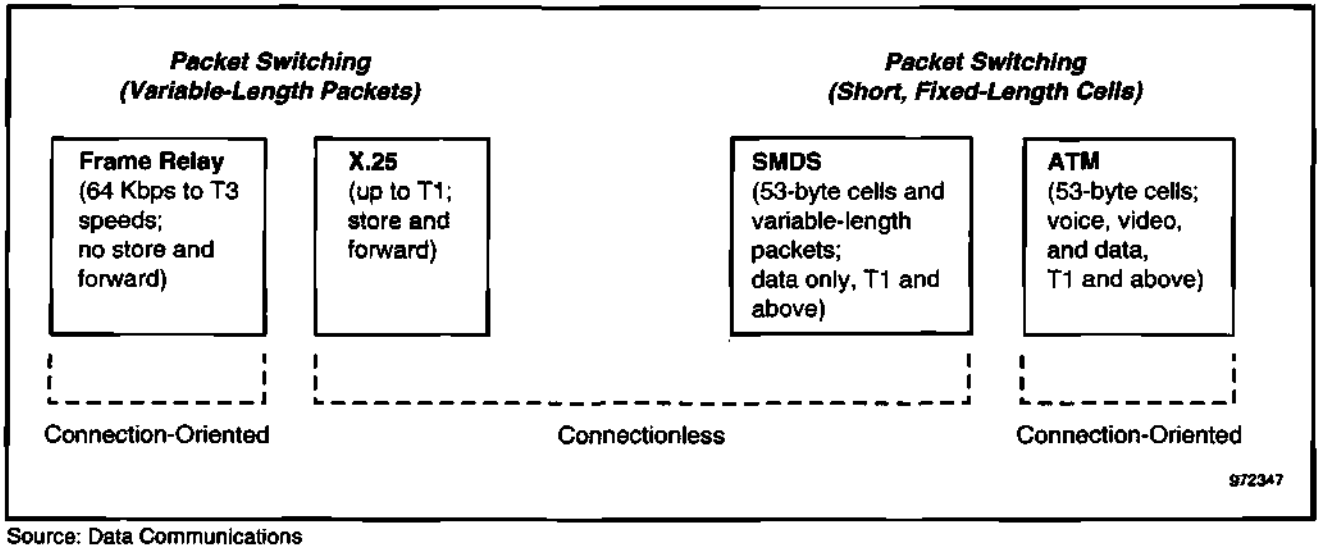
Europe and passage of the telecommunications reform act in the United States should help set the stage for healthy competition with new services and dropping prices on existing services.

## Market and Technology Directions

The following highlights some of the market and technology trends in WAN equipment:

- Digital WAN equipment is increasingly being used to extend campus LANs across wide geographic areas. Newer WAN technology can support server and real-time video traffic in addition to voice and data. New technologies include a group of fast packet switching approaches including frame relay, switched multimega digital services (SMDS), and ATM. Figure 5-4 details some of the differences among these technologies.
- Key digital WAN equipment includes T/E-1 and 3 carrier multiplexers, fractional and sub-T1 multiplexers, inverse multiplexers, cell switches (ATM and proprietary), ATM concentrators, frame relay switches and access devices (the later known as FRADs), and X.25 packet assembler/disassemblers (PADs) and switches.
- Frame relay is rapidly becoming a dominant WAN service in the United States and Europe as prices drop and it becomes more available. Europe, however, remains a large user of X.25 services. Frame relay is a layer 2 protocol technique and therefore can employ various physical layer approaches, from 56/64 Kbps to T/E 1 and 3. An estimated 80 percent of frame relay links are 128 Kbps or less today. This is predicted to drop to less than 70 percent by 2000. The two key pieces of equipment used in frame relay include a frame relay assembler/disassembler (FRAD), which converts LAN packets to and from frame relay frames. The other system is a switch that is capable of directing frame relay traffic to different destinations. The switches can be located either on the customer premises or with the carrier. Many of these switches are capable of multiple services, including frame relay, SMDS (IEEE 802.6 MAN), and ATM.

**Figure 5-4**
**Fast Packet Switching**




Source: Data Communications

- ATM is gaining momentum as the WAN service and technology for ultimate migration. Its flexibility at providing a variety of services, including voice, data, and multimedia, puts it high in consideration by corporate MIS departments. ATM-capable, multiservice switches are already being shipped into carrier points of presence (POPs) and customer premises alike in the form of so-called edge and enterprise switches, respectively. Initially, most ATM traffic is being mapped over T/E carrier WAN lines, but 155 Mbps (OC-3) is available as well. The faster OC-12 (622 Mbps) and OC-48 (2.4 Gbps) rates are used in carrier core switches or enterprise (premise) backbones.
- Inverse multiplexers are becoming very popular because they are used to map LAN traffic onto multiple T1/E1 lines, thus avoiding the tariffs of the higher-speed T3/E3.
- In general, data service units (DSUs) and channel service units (CSUs) are being incorporated into multiplexers, remote routers, and other access equipment.

## Videoconferencing Applications: Market and Technology Directions

Under videoconferencing, Dataquest includes systems that facilitate real-time audio/video and data communications. These systems can be fixed in place, roll about on movable carts, or be desktop-based as a PC or workstation enhancement with add-in cards and a camera/microphone input. Video telephones are primarily consumer-targeted items in standalone form with a built-in LCD screen, and they can use the family camcorder for input and the TV for display. The following comprise some of the principal market and product feature trends:

- In general, this market continues to gain notoriety as efficient, downsized companies turn to videoconferencing as a means of improving internal productivity and customer communications. This technology is finding great use in vertical markets such as telemedicine, teletraining, and tele-education, where limited professional personnel can be used more effectively.
- Room systems have served much of the need until recently, when rollabout systems became popular. In general, these systems are integrated with these main elements: video/audio compression/decompression (codec), displays, cameras, speakers, microphones, computer interfaces (for presentation, graphics, and scanned images), remote control units, and multipoint control units for three-way or more conferences. Perhaps the clearest defining element is the software, which manages the user interface, the computer interface, and the telephone network.
- Room/rollabout systems are feature-rich and typically allow 640 x 480-pixel resolutions at 30 frames per second (depending upon the type of line leased). Most of the recent entries from the established videoconferencing players support the International Telecommunications Union (ITU) H.320 standard, which is an open standard specifying various protocol, formatting, and compression features. The established videoconferencing vendors continue to sell proprietary approaches while also supporting the interoperable H.320 standard. H.320 uses the H.261

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real-time compression standard. A new standard known as H.324 enables the use of regular analog phone lines.

- Most high-performance videoconferencing setups use a T1/E1 (1.5-Mbps to 2-Mbps) or fractional T1 (384-Kbps) link to transfer the video, audio, and support data and control signals. Because these lines are expensive to lease, lower-performance conferencing systems operate over switched 56-Kbps or ISDN basic rate lines (128-Kbps).
- The latest incarnation of videoconferencing is the enhancement of the PC or workstation into a personal conferencing system. This system today generally requires one or two add-in boards (including an ISDN or modem connection), a camera, a speaker, and a microphone. Systems capable of 320 x 240-pixel video at 15 frames per second can cost $2,500. Prices should drop to less than $1,000 per seat as volumes develop (or vice versa).
- Desktop videoconferencing should be aided by an initiative established by Intel and Microsoft that brings a standard telecommunications applications interface to Windows 95/NT, known as TAPI. This, along with the display control interface (DCI) capability that supports multiple software and hardware codecs, should aid in software development and interoperability. H.320, which typically uses ISDN lines, is now being joined by H.324, which uses traditional analog lines and analog modems (now V.34), as a lower-cost/performance alternative. Another ITU standard known as T.120 has been devised to support the sharing of data between conferencing desktops. As MPU power increases with Pentium Pro and accompanying MMX technology, expect the desktop videoconferencing solution to improve in quality and for the price per seat to drop. The latter has to do with an increasing number of features being accomplished as software running on the host.
- Video telephones continue to offer the consumer marginal frame rate performance relative to the price. This market has also suffered from a lack of interoperable, multivendor solutions until recently, when H.320 and H.324 have been appearing. Newer versions that employ the TV as an output device and the camcorder (or low-cost bundled camera) as an input device are now hitting the market at under $1,000. The H.324 versions that use 33.6-Kbps transfer rate will continue to struggle with performance levels acceptable to most. The spread of availability ISDN, cable modem, and other types of digital home connectivity is the ultimate stimulant to this market.

## Premise Switching and Call Processing Applications: Market and Technology Directions

There are numerous market and technology drivers in the areas of premise switching and call processing. Principal trends with voice communications equipment such as PBXs, key telephone systems (KTS), voice messaging (VM) systems, interactive voice response (IVR), and automatic call distribution (ACD) systems include:

- PBXs and KTS will remain the central premise equipment in nonresidential voice communications. The other voice systems are typically used as adjuncts to PBXs. The main market attraction of these systems is for productivity, and thus they are very sensitive to capital spending cycles. They are enjoying a general upswing in the developed countries

and new penetration in places such as eastern Europe, Latin America, and Asia.

- KTS phone systems are principally used by smaller companies with two or more lines. They typically do not require an access code, as PBXs do, but do provide various features such as holding (plus music) and intercom. In general, KTS users are turning to digital processing as new models emerge. There are about as many KTS lines shipped as PBX lines. This market is very mature and is expected to remain flat over the forecast period.
- PBXs continue to add value by incorporating many new features, including:
  - Wireless options, with offerings emerging from many, including Ericsson (CT-3), Spectralink, and Northern Telecom. Digital European Cordless Telecommunications (DECT) wireless technology is mentioned often as a solution for wireless offices.
  - Computer telephony integration (CTI) describes a general trend toward PBXs being modified to support LAN and WAN environments. Today many PBXs can connect to servers or intelligent hubs, with Novell's NetWare being the most popular network operating system. Microsoft and Intel are evangelizing the TAPI technology as a means of standardizing the software interface to telecom premise equipment.
  - Most PBXs can now offer T1/E1 and ISDN primary and basic rate trunk line interfaces. In the future, other WAN features such as ATM, T3, routers, and modems are not out of the question as the PBX vendors attempt to do battle with the networking vendors.
  - PBXs will also tend to offer support for fax and audio/video store-and-forward as well as real-time support for videoconferencing.
- Robust unit growth in voice message systems will continue into small businesses that do not yet have these systems but can afford them. These systems continue to offer more features, including larger message capacity, thanks to lower disk drive prices. Some of the market continues to be absorbed by PBX systems integrating this functionality.
- IVR, as a newer technology, continues to emerge as it moves away from the United States into other markets. These systems continue to find good interest from almost any organization (such as banks and pension funds) with customer or public support requirements for information that can easily be accessed with key telephone button strokes. Improvements planned include speech recognition.
- ACDs distribute phone calls to waiting agents (such as airlines agents). They will continue to push into smaller operations willing to stay competitive. This function is also being absorbed by PBXs equipped with ACD software, but separate functionality remains a robust market.

## Public Switching and Transmission Applications

### Background Trends

Key equipment involved in the public switching and transmission markets are central office switches and fiber-optic and nonfiber-optic transmission systems consisting of primarily digital cross-connects, digital

access transceivers, multiplexers, repeaters, optical, wireless transceivers, power systems, and optical network units. Transmission systems comprise the local telephone line (local loop), the trunk lines (conduits between switches), and the long distance lines. In the United States, there are separate, privately owned local (regional Bell operating companies—RBOCs—or Baby Bells) and long distance telephone service companies (AT&T and MCI, among others) that invest in this equipment. In most of the rest of the world, there is generally a single state-controlled PTT of telephone and data transmission services. There is a trend toward privatizing many of these, however, and Japan (NTT), the United Kingdom (British Telecom), Germany, (Deutsche Telekom), and Mexico (Telephonos de Mexico) have sold majority stakes of their PTTs to investor interests.

The following describes key trends in the public switching and transmission markets:

- Principal new access line shipments will occur in eastern Europe, China and the rest of Asia, and Latin America. Line shipments in the United States, western Europe, and Japan are flat to slightly down during the forecast period because the conversion to digital is nearly completed and replacement economics is taking over.
- With liberalization in Europe, Japan, and Latin America and the passage of telecom deregulation legislation in the United States, many new service providers will be getting into the market. These new competitors are primarily other phone companies and cable TV companies. The other phone companies are, for the most part, initially, reselling capacity provided by the incumbent phone company. These companies are expected to invest in equipment eventually as they endeavor to differentiate themselves. The cable MSOs have been investing in some regions by updating trunks with SONET/SDH rings and two-way voice- and data-capable transmission and switching.
- Internet access has swept in as the major market driver for broadband local loop upgrade, augmenting video-on-demand (VOD) and video dial tone. Internet and World Wide Web access are becoming increasingly multimedia-intensive as Web pages are loaded with bit-mapped pictures, 3-D animation, video clips, and sounds. Voice communications and videoconferencing via the Internet are also being developed.

## Market and Technology Directions

Aside from deploying and upgrading basic POTS, the most important system market to discuss from a growth standpoint is the installation of broadband local loops. Broadband local loop systems will be provided to telephone companies and their new competitors (cable MSOs, among others). They will need upgraded capability to provide multimedia-intensive Internet access and seamless home or remote access to office LANs and server systems. Table 5-1 presents a comparison of the local loop alternatives and their current status and backers.

## Fiber Optics-Based Local Loop Technology

This includes a whole host of technologies including hybrid fiber coax (HFC), switched digital video (SDV), fiber-in the-loop (FITL), and fiber-to-the-curb (FTTC). These techniques all involve a mixture of fiber

**Table 5-1**
**Broadband Local Loop Alternatives**

| Technologies | Speed | Major Patrons | Status | Advantages | Disadvantages |
|---|---|---|---|---|---|
| ISDN (BRI/PRI) | 128 Kbps/1.5 Mbps | Telcos | Full rollout in Europe/Japan; getting untracked in United States | Infrastructure provisioning | Modem cost<br>Possibly too slow compared with alternatives |
| Cable Modem | >10 Mbps | Cable MSOs | Trails/limited deployment | Bandwidth | Lack of infrastructure |
| ADSL/VDSL | >6 Mbps one way | British Telecom, Bell Atlantic | Trails | Leverage installed lines | Cost of modems |
| HDSL | 384 Kbps | To be determined (possibly telcos) | Just introduced | 3x ISDN performance at same price | Possibly too late to get noticed |
| HFC/SDV/FITC/FITL | 155 Mbps to 2.4 Gbps | Telcos | Trail/early deployment | Best bandwidth | Most expensive |

Source: Dataquest (July 1996)



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optics-based transport out to a last few homes or up to the home directly. A solution like HFC, for example, involves taking fiber to an optical network unit (ONU) and then splitting copper-coaxial cables to pass the few tens or hundreds of homes that individually tap into the line. The fiber-based technologies provide the ultimate bandwidth option for the telephone companies as they compete with the cable TV companies for the right to provide high-speed services. The principal issue slowing deployment in the meantime remains the cost of these systems, which runs $1,000 per residence or more.

## Digital Modem Local Loop Technology

This technology involves extending the life of the existing copper twisted-pair wiring through the use of digital transmission techniques.

### ISDN

The telephone companies around the world are rolling out ISDN basic rate service (up to 128 Kbps). Over 4 million ISDN lines are in operation globally, and that number should rise to 14 million by the end of the decade. Germany's Deutsche Telekom is the leader in deployment, having dropped tariffs dramatically to appeal to a mass market. The same is happening in the United States and Japan. U.S. telephone companies still remain somewhat unfocused with regard to ISDN as they consider more permanent or higher-performance local alternatives.

### Cable Modems

This is under heavy trial in the United States and United Kingdom. Cable MSO-backed service providers are conducting trials in several sites. Key issues regarding infrastructure development and end-to-end connectivity will keep large-scale deployment at bay for at least a year.

### ADSL/HDSL

This technology, undergoing trial in the United Kingdom, United States, Australia and other areas, can be both a video distribution technology as well as an Internet access technology. It should be adapted by some carriers as a near-term combatant to cable modems. ADSL will cost at least $1,000 per line initially with a modem at each end. This technology can take advantage of existing switching and billing systems, among others. VDSL capable of over 50 Mbps over shorter distances is being discussed as a complement to ADSL in certain situations or loops.

HDSL as a T1 upgrade technology is being proposed as way of obtaining 384-Kbps performance at ISDN prices. This technology holds promise for moving the price/performance in the right direction but seems to lack market clout at this point.

## Wireless Local Loop and Distribution

### MMDS/LMDS (Multipoint/Local Multichannel Distribution System)

Multipoint/local multichannel distribution system (MMDS/LMDS) is a wireless cable TV distribution system that uses distributed transmission points for wireless delivery of TV signals to house-mounted dishes and accompanying set-top decoder box boxes. The video signals can be fed to the transmitter sites by land line or satellite downlink. MMDS systems employ analog transmission techniques and operate primarily in the

frequencies around 2.5 GHz. The main difference between MMDS and LMDS is that LMDS operates the microwave range at 25 GHz to 28 GHz and is generally being positioned as a two-way technology capable of supporting interactivity and Internet access. Cellular Vision is one company making a system that works in the microwave band. Current subscribership for wireless cable is estimated at 1 million homes in the United States and 2 million total worldwide.

Once the province of smaller cable companies trying hard to reach rural areas, MMDS is being targeted by at least one group of telephone companies as a way of deploying TV services quickly and relatively cheaply. Perhaps the most visible force in MMDS is the TeleTV group, comprising the U.S. telcos Pacific Telesis, Bell Atlantic, and NYNEX. This group has placed orders with Thomson Consumer Electronics for 3 million set-top boxes. The set-top box is essentially the same as the company's Digital Satellite System version but sports a radio frequency front end tuned for a different broadcast type. TeleTV's platform would employ digital transmission techniques with MPEG-2 compression.

### Wireless Local Loop

This technology entails the use of telco-owned wireless base station transceivers to communicate with transceivers mounted on buildings and homes. The attraction of this approach to deploying new phone lines is fast deployment. The disadvantage is cost; wireless can cost over $2,000 per subscriber to deploy, which is about double the cost of wireline.

There are two leading competing technologies for addressing wireless solution: Digital European Cordless Telephone (DECT) and code division multiple access (CDMA). DECT would employ a time division multiple access (TDMA) technique with a picocell architecture. CDMA would employ spectrum CDMA access with a technology developed initially for full-capability cellular services. The great potential for these technologies is to provide quick infrastructure for regions of the world that are receiving their first phone service. Preliminary estimates are for 5 million wireless local loop lines to be in service by 2000, up from 1 million today.

## ATM

Nearly every telco in the world has some form of ATM service in trial or early deployment. Positioned as both a WAN service and a transport technology, ATM appears ready for a slow but steadily increasing takeoff. In the meantime, frame relay and, to some degree, switched multimegabit data service (SMDS) is where the opportunity is for telephone services and the equipment they buy. ATM services are ramping up an end-of-the-decade replacement. ATMs scalablity and support for various service classes (data, voice, and multimedia) should prove irresistible by then as service prices come down. In the meantime, edge and core ATM switches and access multiplexers are being installed, as well as WAN multiservice switches that employ ATM backbone technology.

# Chapter 6
# The Consumer Applications Market

## Digital Satellite and Cable Set-Top Boxes

Digital set-top boxes represent a fast-growing market for video and audio compression and processing devices. They also are significant consumers of memory, mainly DRAM, although SRAM and flash also are used in such systems. The primary type of video compression used in both cable and satellite systems is MPEG-2. For audio, both the MPEG-1 and MPEG-2 standards are used, although some systems are beginning to adopt Dolby's AC-3 compression technology. In addition to decompression, digital set-top boxes perform a variety of different types of video and audio processing, including demultiplexing, graphics control and acceleration, and NTSC/PAL encoding.

In a quest for cost reduction, the market as a whole is transitioning away from a mix of ASICs and standard parts and toward highly integrated ASSPs. Analog, digital, and mixed-signal ASSPs all are playing an increasingly important role in new and future set-top boxes and will account for an ever-larger percentage of value in those systems. The cost of memory used in digital set-top boxes significantly decreased in 1996 as DRAM prices plunged. DRAM costs will continue to decline as more use is made of integrated video processing ASSPs that employ unified memory architectures (UMAs).

Because of a price war in the digital satellite set-top box market, makers of those systems are aggressively cutting costs through integration. Because so far they have not been a large-volume product, digital cable set-top boxes are lagging behind their satellite counterparts on the integration front. Digital cable boxes also tend to possess a larger amount of differentiation, more microprocessing horsepower, and a higher level of audio/visual processing than satellite systems. Near the end of the century, some new cable boxes will include audio and video compression capabilities to support two-way communication and data storage applications.

## DVD Video Players

After a long delay that has created high anticipation among consumer electronics retailers, manufacturers, and consumers, DVD video players began shipping to the market in Japan and Korea on November 1, 1996. Shipments in the United States and other countries started in early 1997. These video players are based on MPEG-2 and AC-3 compression technology and use shorter-wavelength diodes to allow playback of full-length movies from one CD-ROM-size disc. Although early video players will employ a variety of ASICs and ASSPs in a low-integration solution, there will be a shift to second-generation products quickly that employ highly integrated ASSP and ASIC solutions. Many chip companies are targeting this opportunity with competitive digital and mixed-signal ASSP solutions. The advanced optical storage technology employed in these products drives higher costs for the optical electronics and motor drivers. The channel and video processing requirements in these systems are 2.5MB of

DRAM. These initial video players are playback devices only and use decoder technology that combines MPEG-2 and AC-3 as mandatory standards with other optional compression standards.

Although the cost for MPEG-2 compression chipsets ranges in the thousands of dollars currently, Dataquest's forecast for this market anticipates the development of low-cost MPEG-2 encoding chipsets that would enable a mass market for recordable DVD video players. Full read/write-capable players that employ codecs are expected to reach the market by late 1998 or early 1999. There are also opportunities to create hybrid set-top box and DVD products because of the common compression technologies employed in these products. This forecast does not attempt to project the market for these hybrid products.

## Video CD Players

Although relatively unknown in the Americas and Europe, video CD players have achieved high-volume shipments in Japan and Asia/Pacific, approaching a production rate of 10 million units in 1996. With their application in karaoke products and the support of a large number of low-cost movie titles, these players are expected to continue on a strong growth path over the next three to four years even in the face of the DVD video player introduction. These players are based on MPEG-1 compression technology. C-Cube Microsystems Inc. has been a leader in enabling this market with its MPEG-1 chipsets. The combined drop in price of CD-ROM drives and MPEG-1 chips during the latter part of 1995 and 1996 led to a significant drop in the price for video CD players, which helped push market demand up significantly. The chips in these players are highly integrated, and even with the introduction of a new video CD standard, the technology is maturing and has the potential for further cost reductions. The channel/video processing in these players only requires 4Mb of memory, which could eventually be integrated with the other logic in the next level of integration.

## Next-Generation Video Game Consoles

With the introduction of the Nintendo 64, the industry has completed its shift from 16-bit hardware to an emphasis on shipments of next-generation 32- and 64-bit video game consoles by all three major players, Sega, Sony, and Nintendo. All of these systems employ ASICs extensively. However, the Nintendo 64 has achieved the highest level of integration in its design and the most efficient use of DRAM. The Nintendo 64 uses two Rambus RDRAM chips, while the Sega Saturn and Sony PlayStation use a variety of DRAM and VRAM. The high cost of memory in these systems was a major cost driver until the major DRAM price erosion in 1996. This drop in memory costs helped offset losses experienced by the manufacturers in selling these systems for $199 when introduced. One of the main differentiators between the Sony and Sega systems and the Nintendo system is their use of a CD-ROM instead of cartridges for software delivery. There is no compression technology employed in any of these systems today. There has been some discussion of eventual migration to DVD drives, but Dataquest does not expect this to happen until late 1998 at the earliest.

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## HDTV/ATV/SDTV

The market for next-generation television currently consists of analog high-definition TV (HDTV) receivers in Japan. However, by 1998, advanced television digital broadcast standards should be finalized in the United States and in Europe, paving the way for the sale of digital HDTV systems. In the intervening years, advanced television systems will use predominately analog components. After that, both digital HDTV and digital standard definition television (SDTV) platforms should begin to trickle into the market. Such systems will have a semiconductor content resembling some digital set-top boxes to a degree, with MPEG-2 video decompression, AC-3 or MPEG-2 audio decompression, and some DRAM for decompression buffering.

## Digital Still Cameras

Sales of digital cameras are expected to grow rapidly as prices decline. The year 1998 is expected to show the strongest unit growth through the end of the century as mainstream camera prices drop into the range of $200 or less. Although digital cameras can replace conventional film cameras, most consumers through the end of the century will use them exclusively to import images into PCs. Because of this, the available market for digital cameras is expected to be limited to PC owners and PC buyers through the end of the century. Graphics processing accounts for the majority of the value of the semiconductor content in a digital camera. The charge-coupled device (CCD) is the single most expensive component in most digital cameras, although learning curve reductions in CCD prices should help reduce digital camera average selling prices (ASPs) significantly in the future. To maximize memory efficiency, digital cameras also include compression engines that use JPEG or a proprietary algorithm. The compressed images are stored in flash memory. Flash memory cost reductions also should help to further drive down the price of digital cameras. Current digital cameras, which are in their first or second generation, make heavy use of standard digital products. However, as cameras evolve, they are expected to make increasing use of more cost-effective ASSPs.

## Other Next-Generation Consumer Electronics Products

Products included in the other category of this forecast include digital camcorders based on the digital videocassette (DVC) standard, DVD audio players, and other advanced consumer devices that may be introduced over the next five years. This forecast does not attempt to measure the size of the DVC compression chip market in digital camcorders. Because the specification for DVD audio is still under discussion, it is not possible to present a detailed forecast for this product.

# Chapter 7
# Automotive Applications Market

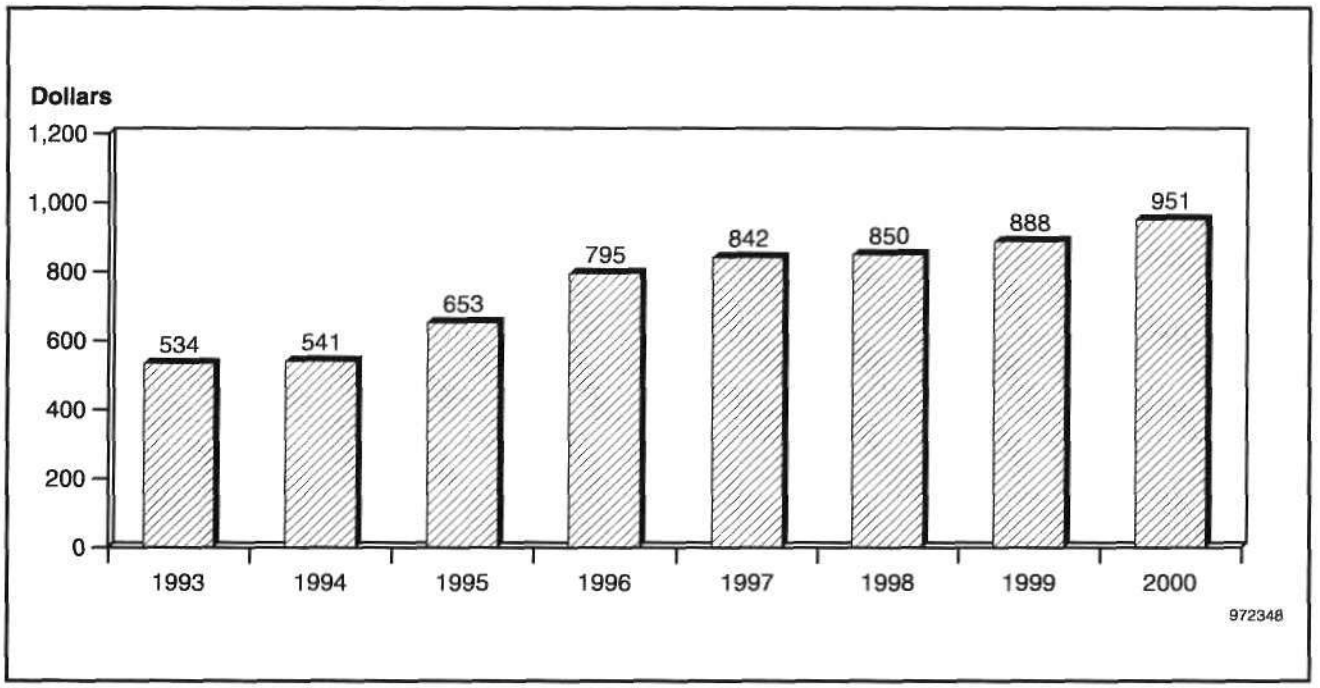
There is a continuing penetration of various electronic subsystems and controls into cars and trucks. Key factors driving the wave of electronics penetration continue to be public initiatives such as better fuel economy, lower levels of emissions, air bag safety, and a new one that standardizes the diagnostics/communications system. Consumer demand and product differentiation, as in most markets, contribute to the proliferation of options. Figure 7-1 shows that Dataquest estimates that the average vehicle today has about $653 of modules, systems, and electromechanical content. By 2000, the figure will be $951 per vehicle as more electronic-intensive features and controls are mixed into the vehicle's overall value. The average car has a dozen or more modules (circuit boards) today, typically located in the passenger or engine compartment.

Key trends are as follows:

- About 100 new or redesigned vehicles are introduced worldwide each year. An estimated 60 percent of these involve new electronics. Assuming six modules or subsystems per vehicle, there are 350 to 400 new design-win opportunities each year.
- A new class of controls for integrated engine and transmission management is emerging in the drive train area. A trend toward 32-bit MPU-based integrated modules is being stimulated by efficiencies needed for even higher corporate fuel economy requirements.
- Electronics-intensive antilock brakes and air bag controls continue their penetration of vehicle shipments. Antilock braking is emerging from its traditional use on trucks (two wheels) to be used on high-end cars (four wheels). Driver-side air bags are becoming standard equipment on almost every vehicle. Passenger-side air bag versions now are entering the market. Side air bags are emerging as an option.
- Electronic suspension and steering are beginning to appear on some models as the market and vendors evaluate the future of these systems.
- Head-up displays (HUDs) appear to be moving from just indicating speed to an entire list of dashboard, road information, and communications displays oriented toward keeping the driver's eyes on the road.
- Keyless and remote entry and light timers are proving to be popular options in a more security-conscious world.
- Personalization features such as memory seats, mirror, and radio settings are now popular on high-end modules.
- Entertainment systems are predominantly cassette-based today, with CD-based systems emerging at a modest rate. Intelligent/distributed speaker systems are becoming more common.


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**Figure 7-1**
**Electronic Module and System Content**




Source: Dataquest (April 1997)

- To satisfy the California Air Resources Board (CARB) requirement for a common diagnostics interface, SAE J1850 has been adopted in the United States. This interface is heading toward serving as the communications link between modules. Europe is rolling out a standard called ISO 9141 and two proprietary standards known as CAN and VAN.
- Electric vehicles are being developed by global manufacturers to satisfy California's requirement that 2 percent of all vehicles sold in that state by 1998 be electric (10 percent by 2003). Several manufacturers have chosen a minivan test platform. The most critical challenge is creating cost-effective battery technology. Nickel metal hydride seems to be the leader at the moment. Electric vehicles now cost about 50 percent more than gas engine versions. Battery life averages about three years; replacement costs the consumer $3,000. Hybrid approaches are being considered, including advanced flywheel technology. As of early 1996, CARB is relaxing its near-term zero emission requirement as manufacturers run behind in development. CARB appears to be sticking to its requirement of 10 percent by 2003, however. Several electric models are expected to be offered this year to buyers as manufacturers begin to test the market.

## Navigation, Communication, and Smart Highways

Market trend highlights in the navigation, communications, and smart highways areas are as follows:

- Navigation systems based on dead reckoning and the Global Positioning System (GPS) are becoming very popular in Japan and are appearing in the United States and Europe. General Motors has introduced a

$2,000 system that uses a PC Card for the map database and a Motorola-based 68EC020 processor for GPS and dead reckoning processing (made by Zexel and Rockwell). The rental car market has emerged as the first broad application of GPS navigation systems in the U.S. market.

- The Radio Data Broadcast System (RDBS) has been available in Europe for some time and now is rolling out in the United States. The system will alert the driver to traffic reports and will display radio station format and call letters.
- Intelligent vehicles that employ infrastructure-integrated navigation aids and collision avoidance systems and that communicate with the highway system to optimize traffic flow remain at least a decade away from broad use. Japan has embarked on its Vehicle Identification and Communication System (VICS), in which government and industry join to devise ways to route vehicles efficiently over Japan's crowded highways. Japan has spent more than $1 billion in the past decade researching intelligent traffic management methods. To date, Japan has progressed furthest in making navigational aides such as GPS receivers available.

The $800 million Prometheus Program in Europe is an effort to devise a common way for smart cars and smart infrastructure to communicate with each other. Drive I and Drive II are other pan-European programs. Drive II, which started this year, also covers other modes of transportation, such as trains. Other European efforts include one in Manchester, England, that involves the use of 500,000 wireless smart cards for automatic toll collection on roads.

The major program in the United States was dubbed the Intelligent Vehicle Highway System (IVHS) and is underwritten by $659 million in federal highway administration funding for several R&D contracts. Tests were completed in Orlando, Florida, of a GM system known as TravTek that informed the driver of area attractions, weather, and road conditions. It could give voice-synthesized instructions on where to turn. The goal of the IVHS program is to develop a standard technology for car-road navigation as well as vehicle control, such as intercar spacing and movement. A trade association known as IVHS America estimates that $200 billion could be spent on IVHS in the next 20 years in the United States alone.

# Chapter 8
# Summary and Conclusions

## Conclusions

It can be seen that the semiconductor application market offers tremendous growth opportunities for certain companies as overall semiconductor growth rates are set to remain high, with a CAGR forecast of 13.9 percent from 1995 through 2000. Chapters 4 through 7 were intended to provide insight into the future directions of the four segments covered by Dataquest. As mentioned in Chapter 1, more in-depth analysis of semiconductor applications areas is available from a number of Dataquest programs.

Suppliers' relationships to specific applications are like the chicken-and-egg relationship. Which comes first? Undoubtedly, some suppliers set their caps at specific application segments and then come up with a strategy to develop selected chips or technologies. They then need to try to get designed in with the "key players" in the segment—not necessarily a done deal for any supplier. On the other hand, other companies with specific design strengths often develop products with one segment in mind or as a sideline from another project, which can have a major sales impact in another application.

Likewise, key players in the market are not just going to wait for Mohammed to come to their mountain. Companies in many cases actively target certain semiconductor suppliers to start a sourcing relationship that they deem product compatible. It is often purchasing that drives this, either as a supply base diversification or to lay the foundation for future sourcing requirements.

Although the overall semiconductor application segment has a bright future, it should not be assumed that the rising tide will lift all boats. Far from it. The application segments can be cutthroat, and market share leaders often lead at a loss. Also, in some segments, a company is only as good as its current product—mind share is not a birthright, it's got to be earned.

The purchasing professionals play a pivotal role in the long-term strategies and survival of companies. Apart from the obvious ones of total cost of ownership reductions, strategic supplier selection and maintenance, and providing a real-time technology availability focus for companies, there are other ways in which procurement is vital.

In some applications, companies are often growing at mind-boggling rates through acquisitions and mergers. These other companies are usually snapped up to gain entry to a new growth market or to preempt a competitor's move. Purchasing can often act as a practical focus to help integrate the different management and corporate cultures. It is also vital to leverage new buying power for the greater good of the expanding company and provide a solid corporate image by issuing common messages to suppliers, as appropriate.

In more cost-sensitive applications, it is often purchasing facing crucial make-or-buy decisions on the manufacturing of existing and future products or modules. This is difficult work but is vital if companies are to remain economically viable.

Purchasing must also remember that, regardless of a company's size (in headcount and current revenue), if it is a leader in its segment, regardless of how specialized, it will command respect from suppliers focusing on it. Buyers should use this power to ensure the best deal is obtained for their companies. After all, if buyers can't sell their companies to suppliers, who can?

In short, semiconductor revenue will continue to grow at a CAGR of 15.4 percent in the next five years, and it will remain fraught with thrills and spills as pink elephants are sorted from future must-haves. It remains an area where a great product released at the right time can have a tremendous impact on the market. The lives of literally millions of people can be dramatically changed in a short time as new application areas take off.

The semiconductor application market—may it live long and prosper!


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**For More Information...**

Evelyn Cronin, Senior Industry Analyst ..... (408) 468-8075
Internet address ..... evelyn.cronin@dataquest.com
Via fax ..... (408) 954-1780
Dataquest Interactive ..... http://www.dataquest.com

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## DATAQUEST WORLDWIDE OFFICES


**NORTH AMERICA**

**Worldwide Headquarters**
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: 1-408-468-8000
Facsimile: 1-408-954-1780

**East Coast Headquarters**
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6262

**Dataquest Global Events**
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

Sales Offices:
Washington, DC (Federal)
New York, NY (Financial)
Dallas, TX

**LATIN AMERICA**
Research Affiliates and Sales Offices:
Buenos Aires, Argentina
Sao Paulo, Brazil
Santiago, Chile
Mexico City, Mexico

**EUROPE**

**European Headquarters**
Tamesis, The Glanty
Egham, Surrey TW20 9AW
United Kingdom
Phone: +44 1784 431 611
Facsimile: +44 1784 488 980

**Dataquest France**
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: +33 1 41 35 13 00
Facsimile: +33 1 41 35 13 13

**Dataquest Germany**
Kronstadter Strasse 9
81677 München
Germany
Phone: +49 89 93 09 09 0
Facsimile: +49 89 93 03 27 7

Sales Offices:
Brussels, Belgium
Kfar Saba, Israel
Milan, Italy
Randburg, South Africa
Madrid, Spain

**JAPAN**

**Japan Headquarters**
Aobadai Hills 4-7-7
Aobadai
Meguro-ku, Tokyo 153
Japan
Phone: 81-3-3481-3670
Facsimile: 81-3-3481-3644

**ASIA/PACIFIC**

**Asia/Pacific Headquarters**
Suite 5904-7, Central Plaza
18 Harbour Road, Wanchai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

**Dataquest Korea**
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

**Dataquest Taiwan**
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

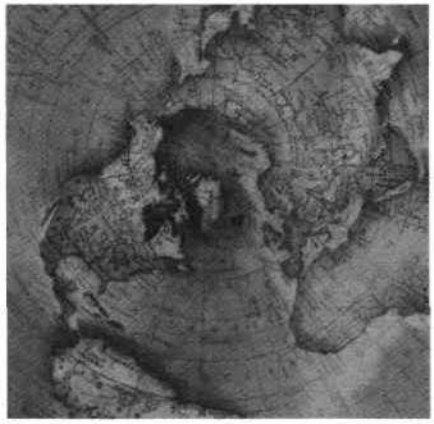
**Dataquest Singapore**
105 Cecil Street
#06-01/02 The Octagon
Singapore 069534
Phone: 65-227-1213
Facsimile: 65-227-4607

**Dataquest Thailand**
12/F, Vanissa Building
29 Soi Chidlom
Ploenchit Road
Patumwan, Bangkok 10330
Thailand
Phone: 662-655-0577
Facsimile: 662-655-0576

Research Affiliates and Sales Offices:
Melbourne, Australia
Beijing, China


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# 1997 Semiconductor Industry Capital Spending Overview

Focus Report

**Program:** Semiconductor Supply and Pricing Worldwide
**Product Code:** SSPS-WW-FR-9702
**Publication Date:** March 3, 1997
**Filing:** Reports

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# Table of Contents


Page

1. Executive Summary ..... 1
   - Capital Spending Overview ..... 1
   - Checkpoint: Looking Past 1997, Setting Up for Growth in 1998 ..... 1
   - What Happened? ..... 1
   - How Are Semiconductor Companies Responding? ..... 2
   - When and How Will the Recovery Occur? ..... 2
   - Highlights on the Wafer Fab Equipment Market ..... 3
   - Dataquest Perspective ..... 3
2. Semiconductor Capital Spending Forecast ..... 5
   - Chapter Highlights ..... 5
   - Capital Spending Tables ..... 6
   - And the Spending Binge Comes to an End ..... 6
   - How Long Will This Downturn Last? How Will Capacity Be Absorbed? ..... 10
   - Are Spending Levels Forecast Too High Relative to Semiconductors? ..... 12
     - Before 1985: An Immature Manufacturing Industry ..... 12
     - 1985 through 1992: Becoming Manufacturing-Smart ..... 13
     - 1993 through 2001 (?): Growth ..... 13
     - Beyond 2001: A Maturing Manufacturing Infrastructure ..... 14
   - The Americas Market Will Exhibit Strategic Strength Long Term 14
   - Japan: DRAM Capacity Additions Stop, Investment in Technology Under Way ..... 15
   - Europe Sustains Presence as a Growth Market ..... 16
   - Asia/Pacific Investing Focusing on Foundry as DRAM Falls ..... 17
   - Who's Investing Where? ..... 18
3. Capital Spending Analysis ..... 21



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# List of Figures

Figure Page
2-1 Capacity Trickle in the Semiconductor Industry Today ..... 11

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# List of Tables


| Table | | Page |
|---|---|---|
| 2-1 | Semiconductor Capital Spending—Top 20 Spenders, Comparison of 1995 and Projected 1996 Worldwide Capital Spending | 7 |
| 2-2 | Historical Worldwide Capital Spending by Region, Includes Merchant and Captive Semiconductor Companies | 8 |
| 2-3 | 1995-2001 Forecast of Worldwide Capital Spending by Region, Includes Merchant and Captive Semiconductor Companies | 8 |
| 2-4 | Regional Investment Patterns of Semiconductor Manufacturers in 1995 | 18 |
| 2-5 | Regional Investment Patterns of Semiconductor Manufacturers in 1996 | 19 |



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# Chapter 1
# Executive Summary

## Capital Spending Overview

Capital spending patterns of semiconductor suppliers (or potential suppliers) is a good gauge of how a company responds to market competition and what its future plans are. Semiconductor users utilize this information to compare their strategic plans with their supply base in order to make adjustments on long-term arrangements if divergent spending levels occur.

Analysis done by Dataquest's Semiconductor Equipment, Materials, and Manufacturing program here highlights the major trends of semiconductor company capital spending along with a capital spending forecast. Capital spending on semiconductor equipment directly relates to semiconductor unit supply. Knowledge of the industries' capital spending in comparison with aggregate end market demand trends can help in semiconductor price negotiations. For example, if a large level of capital spending is not offset by a like increase in unit demand, the potential for an over-supplied market exists. Early knowledge of the situation can benefit users during price or delivery negotiations.

## Checkpoint: Looking Past 1997, Setting Up for Growth in 1998

Overcapacity in the DRAM market, created by the massive spending from 1994 through the first part of 1996 and the normal DRAM product migration, finally took its toll, resulting in a faster-than-expected contraction in the wafer fab equipment market. We expect this contraction to be sharp and relatively deep but slightly shorter than historical norms, around 18 to 24 months. The key reason for the belief that the slowdown will be shorter than normal is the continued robust forecast for PC unit shipment growth through this decade.

## What Happened?

Although Dataquest has been forecasting since 1995 that a DRAM oversupply-driven capital spending slowdown would occur in 1997, the swift nature of its arrival still has shock value. We should point out why we were looking for a slowdown in capital spending.

The industry migration from 4Mb to 16Mb DRAMs would cause overcapacity even in the face of a high bit demand growth. Why? Die size relationships mean that the average 16Mb DRAM has two to three times more bits per square inch than the 4Mb generation. Because capacity in the industry is built in wafers, this event causes a step-function increase in bit capacity of the industry. This usually happens in a hurry and is triggered by the new generation hitting a critical yield level of about 65 percent, estimated to have been hit by the end of 1995.


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The complicating factor, and the reason for the severity of the downturn today, was the artificial demand created in 1995 by the anticipation of Windows 95, which, taken with the tight supply of memory last year, caused inventories to inflate to enormous levels. This corrected in the final quarter of last year, slightly in advance, but essentially on top, of the conversion timing, and now we have a double-barreled driver (demand and supply) for the DRAM price slide and capital spending downturn. These events together have increased the anticipated severity of the downturn.

## How Are Semiconductor Companies Responding?

It is very normal in this type of a downturn to get a pocket of companies that will stay and continue to invest in the infrastructure. These companies today are IBM, Texas Instruments, and, on a moderate level, the Korean companies. Japanese companies, which were the companies that held on in the last cycle for a year or more, have already shut off spending, and these companies as a group will spend slightly less in dollar terms in 1996 than in 1995. Except for Taiwan Semiconductor Manufacturing Co., Chartered Semiconductor, and Macronix, Asian companies are cutting back dramatically, starting in the last couple of months. As a group, the DRAM manufacturers are responding more rapidly to the situation, cutting spending faster than in previous cycles.

The industry must now rely on the continued growth in personal computer unit sales, with added growth in telecommunications and networking products to create a unit demand picture that will keep this slowdown short-lived from a historical perspective. The wafer fab capacity bubble has burst in all regions and for most semiconductor products, most notably DRAMs, mixed-signal devices, and analog devices. Whereas the 1995 spending growth was almost entirely driven by DRAM and microcomponent capacity purchases, 1996 was a year of transition, and 1997 will be a year of investment in technology.

## When and How Will the Recovery Occur?

Based on how capacity is migrating among device types, we believe the first areas of spending recovery will be in the advanced logic area, as early as mid-1997. Equipment companies positioned for these markets will have a more moderate slowdown and perhaps can grow through this time if they have advanced technology. The MCU, analog, mixed-signal, and telecom chip capacity will be next to recover, but probably not until the end of 1997 or early 1998. The DRAM segment, the root cause of the problem and the very last to recover, is not expected to resume robust spending until mid-to-late 1998. The next major and broad investment cycle will have momentum by 1999.

Dataquest believes that capital spending may be influenced in late 1997 through 1999 positively with the facility construction and purchase of equipment toward the world's first 300mm wafer fab. We have built this infrastructure investment into our model. However, our outlook for a significant 300mm equipment market will wait until well after 2000.


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## Highlights on the Wafer Fab Equipment Market

Wafer fab equipment spending is expected to grow 14 percent worldwide in 1996. The only reasons that 1996 remains a double-digit growth year are that there were strong backlogs coming out of 1995 and increased spending by some companies early in the year.

After three and a half strong expansion years from 1993 through 1996, equipment purchases in 1997 should decline markedly, followed by an essentially flat 1998. Investment in DRAM capacity will be curtailed as producers elect to convert their 4Mb DRAM capacity to 16Mb, which adds bit capacity through the instant increase in bits per square inch. Also, many Japanese DRAM facilities now running 150mm wafers will convert to 200mm wafers, further delaying the need for new equipment. DRAM-sensitive equipment technologies or capital-intensive segments will be affected more than logic-sensitive technologies. The next expansion should kick in by 1999, driven by 0.3-micron to 0.35-micron capacity expansion.

During the coming slowdown, there will be two kinds of purchasing behavior that equipment companies can take advantage of to buffer sales declines. The first behavior is tied to which types of capacity will be required early in the recovery cycle. If there is a heavier dependence on advanced logic or supply to the materials industry, these segments will fare better than DRAM or semiconductor capacity dependent segments. Included in this category are the segments of nontube CVD, sputtering, metal etch, silicon epitaxy, maskmaking lithography, process control systems in the materials business, and rapid thermal processing (RTP).

The second purchasing behavior that will be prevalent over the next 12 to 18 months will be new processes and equipment directed at solving issues for 0.35-micron and 0.25-micron manufacturing. These segments will be those related primarily to deep-ultraviolet (deep-UV) lithography and inspection and 0.25-micron multilevel metallization schemes.

## Dataquest Perspective

Our forecast for capital spending and wafer fab equipment sales during the next six years assumes the excessive growth in 1995, which carried over into the first half 1996, will be sharply corrected in 1997. Our outlook for the future includes moderated growth in equipment spending in 1998, accelerating into the start of another boom in 1999, likely lasting into early 2001.

Where the PC goes, so go semiconductors. This is true from the perspective of the business forecast as well as the production line. Europe and Asia/Pacific, with very large capital spending upticks over the last several years—and expected to continue that trend—will continue to gain share in world production over the next several years.

The shifts and currents in semiconductor production trends mean that equipment and material suppliers will absolutely need a global presence in every sense of the word to remain competitive in the market. Product supply can no longer depend on local trends, as all major semiconductor companies have made it clear they are investing on a worldwide basis.


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However, local service and support are required to maintain customer satisfaction.

Taiwan is clearly the new major production growth area. We would expect Malaysia and Thailand to be the next major growth countries in three to five years. Evidence of this includes recent joint-venture fab announcements by Texas Instruments and others. Silicon plants are now being strategically placed, such as Shin-Etsu Handotai's Malaysian plant and recently announced joint venture in Taiwan, Komatsu's joint venture with Formosa Plastics in Taiwan, and MEMC Electronic Materials' joint ventures in Korea (Posco-Hüls), Taiwan (Taisil), and Malaysia (MEMC-Kulim).

Further, the concept of contract manufacturing in semiconductors is clearly here to stay. Equipment and material suppliers could find themselves selling their technical products to an international team from several companies, including the manufacturer and the designer. However the emergence of the dedicated foundry company taking ownership of the process and manufacturing flow will tend to centralize this activity. Dataquest has started a research program—Semiconductor Contract Manufacturing Seervices Worldwide—to continue exploring the key trends in contract manufacturing and foundries, including technology trends and supply/demand balance through the decade.

*Contributing Analysts: Ron Dornseif, Clark Fuhs, Mark Giudici, and Yoshihiro Shimada*


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# Chapter 2
# Semiconductor Capital Spending Forecast

This chapter presents data on worldwide semiconductor capital spending by region. Capital spending in a region includes spending by all semiconductor producers with plants in that region. Components of capital spending are property, plant, and equipment expenditure for front-end and back-end semiconductor operations.

## Chapter Highlights

This chapter will discuss the following highlights:

- On the heels of booming growth of 74 percent in 1995, global semiconductor capital growth will slow to 18 percent in 1996 to $45.3 billion. With excess capacity clearly present in the industry for the next year or two, capital spending is expected to contract 10 percent in 1997 and modestly recover in 1998 before the next capacity cycle starts in late 1998 into 1999.
- Capital spending in the Americas region grew at an accelerated 69 percent in 1995, with most of the investment growth in 1995 coming from U.S. companies connected with ASIC and logic products. Capital spending is decelerating in 1996 into 1997, but we expect that investment in advanced technology, coupled with the earlier capacity upturn from the advanced logic segment, will stabilize the region's spending later in 1997 and will lead the market's recovery in 1998 and 1999 as it did in 1993. We expect the Americas region to be the second-fastest-growing market as foreign multinationals and foundry company invest in capacity in the United States.
- Japan's 49 percent increase in capital spending in 1995 is only 37 percent on a yen basis, as Japanese companies look to invest outside Japan to optimize buying power. Japanese spending has essentially stopped growing and will actually decline about 2 percent in 1996. Because of the early cutback in spending, 1997 remains a flat capital spending year as well, with only modest growth in 1998. Lagging investment patterns in Japan are expected to continue throughout the decade.
- Japanese companies, however, grew spending during 1995 about 58 percent worldwide, spending a total of $12.0 billion, second only to Americas company spending of $13.8 billion and well ahead of the Asia/Pacific companies' $9.1 billion level. In 1996, however, with the quick brakes the Japanese have put on spending, Asia/Pacific companies will surpass Japanese company spending.
- Although spending on capacity has essentially stopped in Japan, two other types of investments are likely to be important in Japan now through 1998. First, Japanese companies will invest in any new technology and equipment targeted at the 0.25-micron production arena. Second, the Japanese companies will build shells in 1996 and 1997, initially at very low run rates, as a preparation to ramp when the market turns up.

- We are looking for continued growth for Europe of 22 percent in 1996 as production continues to ramp from Siemens, SGS-Thomson, and eight new fabs, most notably by GEC-Plessey and TEMIC. However, in part because we do not believe Siemens can sustain its current spending, we are calling for a 12 percent decline in spending in Europe for 1997 and a flat-to-down 1998 as we expect multinationals will ramp domestic memory fabs before Europe. Longer term, we still see Europe as a significant growth region for spending through the decade.
- The often erratic but sustained semiconductor capital spending growth in the Asia/Pacific region continued at the explosive rate of 112 percent in 1995. We expect a "moderated" growth of about 30 percent in 1996 as several new fab projects are built and equipped. However, the tide has turned in the DRAM area, and we are forecasting the Asia/Pacific region to be hit the hardest in 1997, with a nearly 15 percent decline in capital spending. Longer term, we expect Asia/Pacific to exhibit one of the most aggressive growth rates in capital spending of any region.
- However, several Asia/Pacific companies continue with their planned projects in expansion of foundry capacity, and new entries continue to be announced, with more expected. The reason for the continued interest in spending capital in this area comes from the fact that the core business is dependent on logic and PC unit demand rather than DRAM. The foundry industry is now a *strategic* industry rather than simply a tactical one.

## Capital Spending Tables

A final list of the top 20 semiconductor capital spending companies in 1996 is presented in Table 2-1. Capital spending details by region are provided in two tables in this chapter. Table 2-2 shows historical semiconductor capital spending by region for the years 1988 through 1995. Table 2-3 shows the capital spending forecast by region for the years 1995 through 2001. Yearly exchange rate variations can have a significant effect on the interpretation of the data for 1988 through 1996.

## And the Spending Binge Comes to an End ...

After a 24 percent growth in semiconductor capital spending in 1993, accelerated growth of 54 percent followed in 1994, and growth has now peaked at 74 percent worldwide during 1995. Based on our most recent capital spending survey, 1996 will have markedly slower growth of nearly 14 percent. Nearly all of this growth has already occurred in the first half of this year, and we expect the spending contraction to begin in the second half of 1996, spilling into 1997.

The industry is now relying on the continued growth in PC unit sales, with added growth in telecommunications and networking products, to create a unit demand picture that will keep this slowdown short-lived from a historical perspective. The wafer fab capacity bubble has burst in all regions and for most semiconductor products, most notably DRAMs, mixed-signal devices, and analog devices. The 1995 spending growth was almost entirely driven by DRAM and microcomponent capacity purchases, 1996 is a year in transition, and 1997 will be a year of investment in technology.

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## Table 2-1
## Semiconductor Capital Spending—Top 20 Spenders, Comparison of 1995 and Projected 1996 Worldwide Capital Spending (Millions of Dollars)

| 1995 Rank | 1996 Rank | Company | 1995 | 1996 | Change (%) |
|---|---|---|---|---|---|
| 1 | 1 | Intel | 3,550.0 | 3,400.0 | -4.2 |
| 3 | 2 | LG Semicon | 2,258.1 | 2,747.5 | 21.7 |
| 12 | 3 | Texas Instruments | 1,079.3 | 2,300.0 | 113.1 |
| 5 | 4 | Samsung | 1,946.6 | 2,247.9 | 15.5 |
| 9 | 5 | Hyundai | 1,492.0 | 2,123.8 | 42.3 |
| 4 | 6 | NEC | 2,010.1 | 1,808.7 | -10.0 |
| 10 | 7 | IBM Microelectronics | 1,150.0 | 1,550.0 | 34.8 |
| 16 | 8 | Siemens AG | 850.0 | 1,450.0 | 70.6 |
| 6 | 9 | Toshiba | 1,624.1 | 1,437.7 | -11.5 |
| 14 | 10 | Micron Technology | 960.0 | 1,400.0 | 45.8 |
| 8 | 11 | Hitachi | 1,497.6 | 1,296.7 | -13.4 |
| 7 | 12 | Fujitsu | 1,592.1 | 1,275.4 | -19.9 |
| 2 | 13 | Motorola | 2,530.0 | 1,150.0 | -54.5 |
| 13 | 14 | SGS-Thomson | 1,001.0 | 1,000.0 | -0.1 |
| 17 | 15 | Matsushita | 846.6 | 962.8 | 13.7 |
| 11 | 16 | Mitsubishi | 1,118.2 | 927.6 | -17.0 |
| 22 | 17 | TSMC | 583.9 | 901.8 | 54.4 |
| 18 | 18 | Chartered Semiconductor | 786.7 | 872.3 | 10.9 |
| 15 | 19 | Philips | 959.0 | 841.0 | -12.3 |
| 44 | 20 | Winbond | 117.8 | 700.0 | 494.2 |
| | | Total Top 20 Companies | 27,953.0 | 30,393.2 | 8.7 |
| | | Total Worldwide Capital Spending | 38,410.8 | 43,707.1 | 13.8 |
| | | Top 20 Companies Percentage of Total | 72.8 | 69.5 | |

Note: Specific company information not available for Japanese companies. However, Dataquest estimates that as a group, Japanese companies will spend 12 to 15 percent less in 1997 versus 1996.
Source: Dataquest (March 1997)


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**Table 2-2**
**Historical Worldwide Capital Spending by Region, Includes Merchant and Captive Semiconductor Companies (Millions of Dollars)**

| | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | CAGR (%) 1989-1995 |
|---|---|---|---|---|---|---|---|---|
| North America | 3,833 | 4,320 | 3,895 | 4,135 | 4,943 | 7,194 | 12,170 | 18.8 |
| Percentage Growth | 15.5 | 12.7 | -9.8 | 6.2 | 19.5 | 45.5 | 69.2 | |
| Japan | 5,415 | 5,732 | 5,702 | 3,958 | 4,413 | 6,667 | 9,910 | 9.6 |
| Percentage Growth | 21.6 | 5.9 | -0.5 | -30.6 | 11.5 | 51.1 | 48.6 | |
| Japan (Billions of Yen) | 748 | 826 | 787 | 500 | 491 | 679 | 931 | 2.0 |
| Percentage Growth | 29.2 | 10.4 | -4.7 | -36.4 | -2.0 | 38.3 | 37.1 | |
| Europe | 1,198 | 1,598 | 1,248 | 1,188 | 1,738 | 2,504 | 4,137 | 17.2 |
| Percentage Growth | 26.0 | 33.4 | -21.9 | -4.8 | 46.3 | 44.0 | 65.2 | |
| Asia/Pacific-ROW | 1,884 | 1,580 | 2,300 | 2,318 | 3,238 | 5,720 | 12,194 | 40.6 |
| Percentage Growth | 84.1 | -16.2 | 45.6 | 0.8 | 39.7 | 76.6 | 113.2 | |
| Worldwide | 12,331 | 13,230 | 13,145 | 11,599 | 14,333 | 22,085 | 38,411 | 23.8 |
| Percentage Growth | 26.5 | 7.3 | -0.6 | -11.8 | 23.6 | 54.1 | 73.9 | |

Source: Dataquest (March 1997)

**Table 2-3**
**1995-2001 Forecast of Worldwide Capital Spending by Region, Includes Merchant and Captive Semiconductor Companies (Millions of Dollars)**

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | CAGR (%) 1995-2001 |
|---|---|---|---|---|---|---|---|---|
| North America | 12,170 | 14,185 | 13,910 | 15,427 | 18,729 | 23,442 | 27,470 | 14.5 |
| Percentage Growth | 69.2 | 16.6 | -1.9 | 10.9 | 21.4 | 25.2 | 17.2 | |
| Japan | 9,910 | 9,362 | 8,160 | 9,102 | 11,723 | 15,541 | 17,424 | 9.9 |
| Percentage Growth | 48.6 | -5.5 | -12.8 | 11.5 | 28.8 | 32.6 | 12.1 | |
| Japan (Billions of Yen) | 931 | 1,009 | 917 | 1,023 | 1,318 | 1,747 | 1,959 | 13.2 |
| Percentage Growth | 37.1 | 8.5 | -9.1 | 11.5 | 28.8 | 32.6 | 12.1 | |
| Europe | 4,137 | 4,756 | 4,228 | 4,209 | 5,563 | 7,195 | 8,308 | 12.3 |
| Percentage Growth | 65.2 | 15.0 | -11.1 | -0.4 | 32.2 | 29.3 | 15.5 | |
| Asia/Pacific-ROW | 12,194 | 15,405 | 11,205 | 11,035 | 14,599 | 23,312 | 31,627 | 0 |
| Percentage Growth | 113.2 | 26.3 | -27.3 | -1.5 | 32.3 | 59.7 | 35.7 | |
| Worldwide | 38,411 | 43,707 | 37,503 | 39,773 | 50,614 | 69,490 | 84,829 | 14.1 |
| Percentage Growth | 73.9 | 13.8 | -14.2 | 6.1 | 27.3 | 37.3 | 22.1 | |

Source: Dataquest (March 1997)


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The first companies to cut back were the U.S. companies, as they tend to be more driven by short-term cost issues. The most severe slowdown in capital spending that is occurring today is in Japan, as the overcapacity in DRAM has caused Japanese companies to quickly draw the purse strings in hope of avoiding a more serious price erosion. The spending plans have already started to be cut back within DRAM companies in Taiwan, and we would expect this spending cutback to extend into Korea in late 1996 into 1997.

But meanwhile, the big three Korean companies are increasing spending a more modest 27 percent to a combined $7.2 billion in 1996, which is still above the industry in terms of growth. This above-industry growth has meant that all three large Korean companies are in the top five for capital spending in 1996, as was shown in Table 2-1. As noted earlier, Japanese suppliers of memory cut back investment early in this cycle. Japanese companies as a group will actually spend 7 percent less in 1996 in dollar terms (6.5 percent growth in yen terms). As a result, only two Japanese companies appear in the top 10 capital spenders in 1996—NEC and Toshiba. Most of the other Japanese companies do appear in the second 10. Intel still heads the list for 1996, as the microprocessor giant demand continues to be strong on a unit basis. Intel's capital spending growth has slowed primarily because yield ramps on its new fabs have been better than expected, so Intel therefore needs less equipment to produce the same unit volume. Motorola, the long-time No. 2 spender, has dropped to No. 13 as the demand for telecom-related chips softened in conjunction with the overcapacity in this area.

A mostly new crowd of Taiwanese companies that entered the DRAM manufacturing business, spending over $1 billion collectively in 1995, increased spending feverishly in the first half of 1996 and has likely spent more than in all of 1995 already. However, the spending planned for the second half of the year has been predominantly delayed, mostly into 1997, likely later, and, in some cases, indefinitely (read late 1998 or 1999).

TSMC debuts on the top 20 list for 1996 with an estimated $901 million spent on capacity, as foundry capacity expansion has now evolved into a major trend. TSMC and Macronix, a company that we understand does some second-source work for TSMC, are the two major Taiwanese companies still maintaining the spending plans set early in the year for 1996. This industry has transformed into a dedicated bona fide business and is no longer a specialized way to use excess capacity. There are several companies that we understand will try to enter the foundry business as a result of today's overcapacity. Unless these companies commit to the foundry business in the long term, their success at entering the market will be limited. Gone are the days when the "temporary" foundry can exist. Customers of foundry are now requiring long-term relationships and contracts for winning their capacity business.

It is very normal in this type of a downturn to get a pocket of companies that will stay and continue to invest in the infrastructure or that have niches that maintain growth, thus supporting an increase in spending. These companies in 1996 include IBM (advanced 16Mb DRAM to support systems), Texas Instruments (primarily digital signal processors, or DSPs, and logic), TSMC (foundry), Siemens (advanced DRAM), and Chartered

Semiconductor (foundry). All of these companies have continued to increase investment during 1996. Micron Technology may be the surprise of 1996 to some, particularly because it has delayed the Lehi, Utah, fab. However, it has been spending aggressively in Boise, Idaho, upgrading the facilities for 200mm production and advanced technology for the 16Mb generation. We would expect Micron to return to 1995 levels at least in 1997.

With the cutback of the big Japanese players in the industry and with some smaller companies continuing to be aggressive in spending plans, the concentration of capital spending by the top 20 has decreased in 1996 by a few percentage points to 69.5 percent.

## How Long Will This Downturn Last? How Will Capacity Be Absorbed?

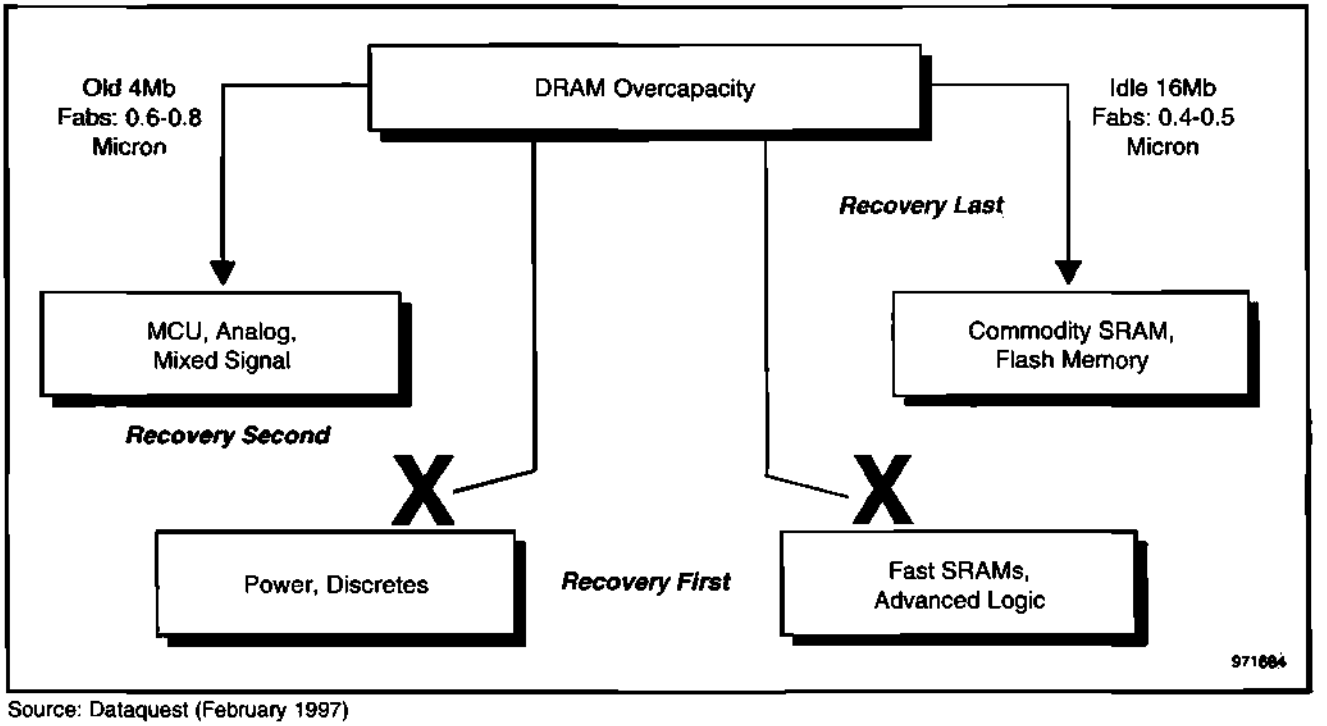
Our longer-term forecast projects that this contraction will be sharp and relatively deep, but slightly shorter than historical norms, about 18 to 24 months. The key reason for the belief that the slowdown will be shorter than normal is the continued robust forecast for PC unit shipment growth worldwide through this decade, driving the need for silicon. We also do not see a stoppage in advanced technology investment, indicating a belief in the customer base of a strong end-user market for semiconductors. Overall semiconductor product demand is expected to remain strong longer term, with sustained growth through 2001 with a compound annual growth rate (CAGR) of 15.5 percent.

How will the industry recover? What are the anticipated dynamics? Today, the industry is primarily experiencing a DRAM oversupply coupled with a product transition. In order to determine how capital spending may recover, it is important to understand how this excess capacity may migrate or trickle to other areas in semiconductor capacity.

There are two general blocks of capacity now available from today's conditions (see Figure 2-1). These two blocks are being redirected into other semiconductor product areas today. The first comprises old 4Mb DRAM fabs that cannot run 16Mb chips. These are limited to two-level metal and are 0.6-micron to 0.8-micron technology. Microcontrollers, telecommunications chips, mixed-signal ICs, and analog ICs are quite happy being processed in these fabs. It is likely that most of these fabs in Japan and some in Korea will migrate into this area. The power and discrete chips have specialized processes not found in old DRAM fabs, so these segments are relatively isolated from extraneous supply impacts because significant time and money is required to convert. We therefore expect capital spending patterns to be closely tied to demand in this specialty segment.

The second block of capacity comprises idle or underused advanced 16Mb capacity, which is limited today to two-level metal but at 0.4 micron to 0.5 micron. Because these fabs generally lack the process sequences of self-aligned silicide and three-level metal or more (which requires chemical mechanical polishing at 0.5 micron), they cannot be effectively redirected to advanced logic or fast SRAM. Therefore, they are limited to commodity SRAM, flash, other nonvolatile memory, or a limited span of logic products. We expect most of these plants to remain somewhat idle through the overcapacity period.

**Figure 2-1**
**Capacity Trickle in the Semiconductor Industry Today**




Source: Dataquest (February 1997)

Based on how this capacity is migrating, we believe that the first areas of spending recovery will be in the advanced logic area, as early as mid-1997. Equipment companies positioned for these markets will have a more moderate slowdown and perhaps can grow through this time if they have advanced technology. The MCU, analog, mixed-signal, and telecom chip capacity will be next to recover, but probably not until the end of 1997 or early 1998—Motorola will be a key company to watch. The DRAM segment, the root cause of the problem and the very last to recover, is not expected to resume robust spending until mid-to-late 1998. The next major and broad investment cycle will have momentum by 1999.

Our model does not include significantly more 16Mb DRAM capacity expansion until late 1998 into 1999. In the two "pause" years, we believe DRAM manufacturers will concentrate on converting capacity away from 4Mb toward 16Mb, which increases bits per square inch processed, then concentrate on shrinks to squeeze out value per square inch before a capital cycle starts again. Further, in Japan, we expect that many 4Mb/16Mb fabs now running 150mm wafers will convert to 200mm wafers, further gaining efficiency and productivity from the capital investment. Although this will increase the demand for silicon and 200mm wafers, it will likely delay the capital spending cycle by six to nine months.

Through 2001, we project a six-year worldwide capital spending CAGR of 16.7 percent, slightly ahead of the semiconductor consumption growth. We believe that capital spending may be influenced in late 1997 through 1999 positively with the facility construction and equipment purchases for the world's first 300mm wafer fab. We have built this infrastructure investment in our model.

A couple of years ago, Dataquest introduced a model that quantifies the overinvestment and underinvestment picture for wafer fab equipment and semiconductor capacity. Although the early 1990s created and sustained a net underinvestment, this picture was corrected to create about a 37 percent overinvestment by the end of 1995. Clearly this was in the danger zone, and we are seeing the results of this overinvestment today. By the end of 1998, should our forecasts for investment and semiconductor demand be on target, we would expect the industry to return to a 16 percent net underinvestment, setting the stage for a robust recovery starting in 1999.

## Are Spending Levels Forecast Too High Relative to Semiconductors?

As capital spending as a percentage of semiconductor revenue exceeds 27 percent in 1996, clearly high by historical standards and creating overcapacity, a question is being asked often. What spending level is dangerous? What spending level is normal?

The industry normally cycles through overcapacity and undercapacity, because there is an inherent lag time between capital investment decisions and productive capacity. This will never go away. But we are experiencing levels of spending today that we have not seen since 1984; should we return to the spending levels of the late 1980s, the current downturn will clearly last longer than we are forecasting.

We think the industry is structured differently today, and there is a valid reason why higher levels of investment as a percentage of revenue than in the late 1980s are justified today.

We would split the market into four periods: before 1985, 1985 to 1992, 1993 to 2001(?), and 2002 and after. We will describe the conditions and trends in the production market and manufacturing infrastructure during these periods.

### Before 1985: An Immature Manufacturing Industry

Characteristics of the period are:

- The semiconductor manufacturing infrastructure was fairly immature, characterized by large integrated systems companies, mostly in the United States.
- Manufacturing technology was favored over efficient use of capital, and device performance was favored over yield.
- Capital equipment manufacturers did not assume complete ownership of processes and system performance.
- These factors led to a capital spending ratio between 26 percent and 30 percent of revenue.

Two things happened to change the structure. First, the semiconductor downturn in 1985 ended up being extremely bloody, and, second, the emergence of the Japanese producer introduced a true manufacturing efficiency element into the infrastructure.

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## 1985 through 1992: Becoming Manufacturing-Smart

The Japanese manufacturing ethic and the losses incurred during the 1985 downturn introduced the need for the industry to become more efficient in its manufacturing infrastructure. Several things happened:

- A focus developed on manufacturing productivity and yield.
- SEMATECH was formed, in part as a result of the need to coordinate this effort in the United States.
- Equipment companies were expected to take, and accepted, the ownership of the process and system performance parameters.
- Equipment performance and productivity increased substantially.
- Fab factory automation migrated from robotics to computer-controlled systems, and statistical process control became commonplace.
- The emergence of the Korean manufacturing power provided momentum for this transition.

By 1992, manufacturers had increased yields, and fab productivity was up dramatically. During this period, it was natural for the industry not to be required to spend as much on capital equipment, because the return per dollar spent was very high. Capital spending decreased to an artificially low 18 percent of revenue, on average.

Once yields achieved high levels and system productivity approached the point at which it was impractical to continue for most equipment types (to do otherwise would mean decreased equipment utilization), the return from these activities were diminished. The industry then entered the next period.

## 1993 through 2001 (?): Growth

As the industry built an efficient manufacturing infrastructure, it was now ready for the emergence of the semiconductor as the enabling technology in many electronic systems, and the industry entered an era of prosperity. Semiconductors have become the productivity engine for the world's business, implementing communications systems and the power of the PC to improve worker efficiency. Characteristics we are now experiencing are:

- Unit growth in semiconductors has required manufacturers to invest in capacity for growth.
- Profitability has attracted new entrants with a concentration on manufacturing.
- Dedicated contract manufacturing has emerged as a new manufacturing model for the industry, enabled because of equipment efficiencies and the need to separate manufacturing from device innovation.

When the industry reached the point at which returns from yield and productivity from equipment had diminishing returns, the capital spending ratio could no longer be maintained at artificially low levels. We believe the current equilibrium level is about 22 percent of semiconductor revenue.


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Further, because of the growth in the device market, this boom has been unprecedented in the industry in terms of length and levels of growth in capital spending. This has been the result of the industry adjusting to a new, higher spending level and of the increased unit demand.

### Beyond 2001: A Maturing Manufacturing Infrastructure

With the emergence of dedicated contract manufacturing, Dataquest believes that the industry's manufacturing infrastructure will evolve so that the foundry becomes an integral part of the manufacturing environment, as been the case with electronic equipment in general (Solectron is an example).

The foundry business model requires high equipment utilization, and we expect that sometime in the next five years this will influence the capital efficiency and decrease the capital spending ratio to perhaps 20 percent of revenue. This will not become evident until contract manufacturing increases in scope, from the estimated 9 percent of semiconductor production in 1995 to levels that could approach 35 percent to 45 percent by the year 2010.

## The Americas Market Will Exhibit Strategic Strength Long Term

Capital spending in the Americas region grew at an accelerated 69 percent in 1995, with most of the investment growth in 1995 coming from U.S. companies connected with ASIC and logic products. Capital spending is decelerating in 1996 and into 1997, but Dataquest expects that investment in advanced technology, coupled with the earlier capacity upturn from the advanced logic segment, will stabilize the region's spending later in 1997 and will lead the market's recovery in 1998 to 1999 as it did in 1993. Dataquest is currently forecasting that the Americas region will be the second-fastest-growing region, at a 14.5 percent CAGR for 1995 through 2001, driven by the recent low cost of capital and the need for foreign multinational and foundry manufacturers to build fabs in the United States to be closer to their customers.

The relatively strong growth in capital spending had been driven by the ongoing growth in PCs, telecommunications, and networking. This key driver has not disappeared, as these products have seen increasing use as tools to increase workplace productivity. Electronic products with increased semiconductor content have created enormous demand for microprocessors, microcontrollers, SRAM, programmable logic and memory, standard logic, and peripheral controllers. The U.S. companies dominate many of these market segments. These segments combined are expected to maintain fairly stable growth rates over the next few years, with PC growth slowing (however, still maintaining a 17 percent CAGR) and networking and telecommunications expanding. The near-term market for PCs has remained robust worldwide, despite the slower growth and penetration into the U.S. home market.

New products and services, such as personal communicators, interactive television, and video on demand provide the potential for enormous growth in semiconductor sales longer term, especially for highly integrated complex logic and signal-processing chips that will be the core engines of future systems.

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Although the strategic strength of the core logic products enables a healthy and flourishing semiconductor production environment, it is also one that is less volatile in capital spending. In the boom years of 1994 and 1995, the Americas region grew at somewhat lower than the market rates. This trait will also enable the Americas market to grow in capital spending at faster than market rates (or remain more stable) in the slower years, such as 1997 and 1998. We believe companies will strategically invest in technologically advanced capacity to preserve competitive advantage.

Capital investment trends in the Americas region for 1996 have a definite split personality. While Intel is finishing up expansion of Fab 11.2 in New Mexico and ramping Fab 12 in Arizona, it has reduced spending from initial expectations because of increased yields. Micron Technology stopped investments in Lehi, Utah, but continues aggressive expansion and conversion to 200mm at all three fabs in Boise, Idaho. Memory-sensitive plant expansions such as Fujitsu's Gresham, Oregon, plant and Integrated Device Technology's Oregon fab have been delayed or have slower ramps, yet IBM has been very aggressive in its Burlington, Vermont, expansion of 16Mb DRAM production thus far. Logic investment has seen a slowdown as well, with LSI Logic's push out of its Oregon fab, the delay of Motorola's North Carolina PowerPC fab, and the slow ramp-up of Advanced Micro Devices' Fab 25 in Austin, Texas. Yet Cirrus Logic and Lucent Technologies have increased spending dramatically to ramp fabs in the eastern United States, with Atmel expanding aggressively in Colorado and Rockwell's emerging success creating opportunity for equipment companies in California. SGS-Thomson has remained aggressive in spending in the United States, placing finishing touches on its new Arizona facility, as well as starting up Fab 4 in Carrollton, Texas. Texas Instruments remains aggressive, spending in capacity expansion for DSP chip capacity. Although it is not likely that either Samsung or TSMC will place equipment into their new U.S. fabs in 1996, capital spending on the shells is progressing.

## Japan: DRAM Capacity Additions Stop, Investment in Technology Under Way

Japan's 49 percent increase in capital spending in 1995 is only 37 percent on a yen basis as Japanese companies look to invest outside Japan to optimize buying power. Japanese spending has essentially stopped growing and actually will decline about 5.5 percent in 1996. Because of the early cutback in spending, 1997 remains a negative capital spending year, as well, with only modest growth in 1998.

Some of the Japanese electronics giants that experienced good profit growth in 1995, driven by semiconductor operations, have seen those profits evaporate with the precipitous fall of DRAM prices. Although spending on capacity has essentially stopped, two other types of investment are likely to be important in Japan now through 1998.

First, Japanese companies will invest in any new technology and equipment targeted at the 0.25-micron production arena. This technology will not likely be in volume production until 1999, but the Japanese companies are expected to take advantage of this slowdown to understand and progress down the learning curve on these new process technologies. Second, the Japanese companies found that the shells built in 1990 and

1991 became an asset during the ramp in 1993 and 1994. By building a fab shell, equipped with a skeleton equipment set, they were positioned to more quickly ramp up production when the market turned up. We see that same pattern repeating, so we would expect several new fabs to be started in 1996 and 1997, although at very low run rates. Once these fabs are in place, the Japanese companies can continue to review the market every six months, making course corrections in April and October, as they have been doing through the last cycle ramp.

Although new facilities by Japanese companies will come on line outside Japan throughout the rest of this decade, DRAM investments inside Japan are really the only driving force today, although diversification has come to the forefront again in Japan. Japanese companies will continue to invest but will grow outside Japan faster than within Japan. We are therefore forecasting a below-average CAGR of 9.9 percent for the Japan region for 1995 through 2001.

One bright spot is that a PC boom could emerge in Japan over the next year or two, spawned by the networking infrastructure that is being built. This would breathe new life into the Japanese semiconductor market and our forecast would be brightened a bit. We do not think that even a PC boom, however, would create a forecast different from several percentage points below the world average. The fundamentals of Japanese production capacity are still too heavily concentrated in DRAMs, with no clear future direction emerging as yet, which keeps us from being more optimistic about capital activities in Japan.

## Europe Sustains Presence as a Growth Market

After a growth bubble of 46 percent in 1993, higher than expected, European spending "moderated" to a slower-than-market growth rate in 1994 after multinationals (Intel) substantially completed the majority of their expansions in 1993. The growth of 44 percent in 1994 is nonetheless extremely healthy, primarily being fueled by the European companies themselves—the ever-present SGS-Thomson, Philips expanding in Nijmegen, the Netherlands, and Ericsson equipping its expansion.

Europe continued to attract capital in 1995, growing 65 percent. Large multinationals are still present, with Motorola upgrading the Scotland fab bought from Digital Equipment Corporation, the new IBM/Philips venture in Germany, Analog Devices' expansion in Ireland, Texas Instruments' continued expansion in Italy, and the IBM/Siemens fab's continued ramp of 16Mb DRAMs in France. The key expansion is Siemens' new fab in Dresden, which was the key driver pulling Siemens into the top 10 in capital spending worldwide in 1996. Like the United States, Europe is experiencing slowdowns this year. Although SGS-Thomson and Siemens remain strong, Philips and the Japanese companies have pulled back investment in capacity significantly. We are looking for continued growth in 1996 of 15 percent as production continues to ramp from these and eight new fabs, most notably by GEC Plessey and TEMIC. However, in part because we do not believe that Siemens can sustain its current spending, we are calling for an 11 percent decline in spending in Europe for 1997 and a flat-to-down 1998 because we expect multinationals will ramp domestic memory fabs before Europe. Samsung has announced a fab to come on line in Europe but as yet is undecided about the exact location or timing.

Europe is viewed as a strategic location for production longer term to take better advantage of European and 16Mb DRAM growth in the future, driven by the PC production boom, without import tariffs. We therefore expect Europe to be a nearly average investment region in the long term, with a six-year CAGR of 12 percent.

## Asia/Pacific Investing Focusing on Foundry as DRAM Falls

The often erratic but sustained semiconductor capital spending growth in the Asia/Pacific region continued at the explosive rate of 113 percent in 1995. We expect a "moderated" growth of about 26 percent in 1996 as several new fab projects are built and equipped. However, the tide has turned in the DRAM area, and we are forecasting the Asia/Pacific region to be hit the hardest in 1997, with a 27 percent decline in capital spending. Longer term, we expect Asia/Pacific to exhibit among the most aggressive growth in capital spending of any region. Dataquest forecasts a 1995-through-2001 CAGR of 17.2 percent.

Spending in 1995 and early 1996 came primarily from two areas, DRAMs and foundry capacity. The Korean conglomerates are continuing their relentless DRAM capacity expansion plans, although more moderately in 1996. We do expect these companies to succumb to the inevitable reality of overcapacity, with significant cutbacks for 1997.

The real story of interest in 1995 and 1996 is the new Taiwan players. Vanguard International brought on its new DRAM fab late last year, and PowerChip Semiconductor and Nan Ya Plastics, among others, brought new DRAM capacity on line late last year and early 1996. All of these are targeted at 16Mb DRAM running 200mm wafers. Current players such as TI/Acer and Mosel Vitelic were also increasing their spending with new projects. But the tide has turned quickly, likely accelerated by the fact that the Taiwanese stock market is very close to the U.S. stock market in its reaction to bad news. Many companies in DRAM are now cutting back feverishly to save near-term profitability.

However, Taiwan chip companies TSMC, Macronix, and United Microelectronics Corporation, along with Chartered Semiconductor in Singapore and Submicron Technology in Thailand, continue with their plans to expand foundry capacity. InterConnect Technology, with its new foundry fab in Malaysia, is part of what we believe will be several new entries into this business. The reason for the continued interest in spending capital in this area comes from the fact that the core business is dependent on logic and PC unit demand rather than DRAM. Further, Dataquest estimates that only about 32 percent of the contracted manufacturing of semiconductors originates from fabless companies. The remainder is from integrated device manufacturers (IDMs) that wish to place the manufacturing of lower value-added products away from their own facilities in order to maximize resources and cost, that wish to reduce investment risks using foundries as an extension of their own capacity, or that wish to use the more advanced technology of foundries (in some cases) as a growth strategy.


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The last few years have seen the flourishing of the dedicated foundry, mostly in Asia/Pacific. It is still believed that the largest concentration of foundry capacity in the world today, however, is in Japan, with companies like Rohm, Seiko-Epson, Sharp, and other large integrated companies. But with the investment trends in Asia/Pacific, the lead will likely change within the next five years.

However, the appetite for leading-edge foundries has caused another transformation. With the cost of capital increasing and with a higher level needed for leading-edge equipment, foundry companies have established longer-term contracts with customer companies, sometimes involving capital infusions toward production equipment and sometimes involving technology. In return, customer companies are looking for dedicated capacity allocations. Many joint venture have been announced in the last year, and we expect this trend to continue. The foundry industry is now a strategic industry rather than simply a tactical one. With this transformation nearly complete, we are starting to see the dedicated investment to build new foundry capacity.

## Who's Investing Where?

In our recently completed capital spending survey, Dataquest gathered information on how money is being spent. Table 2-4 summarizes how companies based in different regions are spending their money abroad for 1995, and Table 2-5 summarizes this for 1996. About 79 percent of the money spent went into domestic economies worldwide in 1995, and that ratio increased slightly to 80 percent in 1996 as companies tend to cut back externally first.

**Table 2-4**
**Regional Investment Patterns of Semiconductor Manufacturers in 1995**
**(Millions of U.S. Dollars)**

| | World | North America | Japan | Europe | Asia/ Pacific-ROW | Percentage of World Spending |
|---|---|---|---|---|---|---|
| American Companies | 13,863.3 | 10,135.2 | 655.1 | 1,423.3 | 1,649.6 | 36.1 |
| Japanese Companies | 12,042.3 | 1,328.7 | 9,247.7 | 738.7 | 727.3 | 31.4 |
| European Companies | 3,301.5 | 420.2 | 7.2 | 1,936.0 | 938.1 | 8.6 |
| Asia/Pacific Companies | 9,203.8 | 285.5 | 0 | 38.9 | 8,879.4 | 24.0 |
| All Companies | 38,410.8 | 12,169.5 | 9,910.0 | 4,136.9 | 12,194.4 | 100.0 |
| Percentage Growth from 1994 | 73.9 | 69.2 | 48.6 | 65.2 | 113.2 | |

Source: Dataquest (March 1997)


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**Table 2-5**
**Regional Investment Patterns of Semiconductor Manufacturers in 1996**
**(Millions of U.S. Dollars)**

| | World | North America | Japan | Europe | Asia/ Pacific-ROW | Percentage of World Spending |
|---|---|---|---|---|---|---|
| American Companies | 15,657.8 | 12,289.5 | 445.3 | 1,503.4 | 1,419.5 | 35.8 |
| Japanese Companies | 11,268.8 | 1,045.2 | 8,916.5 | 751.0 | 556.1 | 25.8 |
| European Companies | 3,802.0 | 359.7 | 0 | 2,446.2 | 996.1 | 8.7 |
| Asia/Pacific Companies | 12,978.5 | 490.0 | 0 | 54.9 | 12,433.5 | 29.7 |
| All Companies | 43,707.1 | 14,184.5 | 9,361.8 | 4,755.5 | 15,405.3 | 100.0 |
| Percentage Growth from 1995 | 13.8 | 16.6 | -5.5 | 15.0 | 26.3 | |

Source: Dataquest (March 1997)

Asia/Pacific companies have historically placed all their investments domestically, but 1994 was the first year of diversification, which continued in 1995. Asia/Pacific companies spent about 4 percent of their money abroad in 1995, increasing to about 6 percent in 1996. We would expect this ratio to increase significantly over the next two to three years. European companies have been the most aggressive capital exporters historically, placing only 59 percent of their investment inside Europe. This figure grew slightly to 63 percent in 1996 and should expand in 1997 as European companies rein in spending.

Japanese companies are very close to the worldwide average, with about 77 percent domestic investment in 1995, rising to 80 percent in 1996. Americas region companies are also high domestic spenders, with about 73 percent staying at home for both years.

The Americas and Japanese regions are net investors, while European and Asia/Pacific regions are net beneficiaries of that investment. This parallels those regions being net exporters and net importers of semiconductors, respectively.

Although all regions are spending in Asia/Pacific and all multinational regions are investing in Europe, only North American companies have the strategic vision to invest in Japan. Japanese companies are also investing on a worldwide basis. We believe this is one of the key elements necessary in a strategic plan for a semiconductor company to be competitive on a global basis.

# Chapter 3
# Capital Spending Analysis

The capital spending boom experienced in 1993 through the first half of 1996 is over, and the industry is now in what we would characterize as an 18-to-24-month pause, with investment in capacity initially declining and stabilizing as demand catches up to supply. The marked downturn in the DRAM investment cycle was triggered in part by the 1x16 configuration of the 16Mb DRAM achieving yields of about 60 percent to 65 percent, which occurred near the end of 1995.

In the second half of 1995, a complicating factor entered the picture—the larger-than-actual anticipated demand for memory created by the introduction of Windows 95, which, taken with the tight supply of memory last year, caused inventories to inflate to enormous levels. This situation started correcting in the final quarter of last year, slightly in advance, but essentially on top of, the yield trigger for the 16Mb DRAM conversion timing. Now we have a double-barreled driver (demand and supply) for the DRAM price slide and capital spending downturn. These events have increased the anticipated severity of the downturn.

The industry is now relying on the continued growth in personal computer unit sales, with added growth in telecommunications and networking products, to create a unit demand picture that will keep this slowdown short-lived from a historical perspective. The wafer fab capacity bubble has burst in all regions and for most semiconductor products, most notably DRAMs, mixed-signal devices, and analog devices. The 1995 spending growth was almost entirely driven by DRAM and microcomponent capacity purchases, 1996 was a year of transition, and 1997 is a year of investment in technology.

Based on how capacity is migrating among device types, Dataquest believes that the first area of spending recovery will be advanced logic, as early as mid-1997. Equipment companies positioned for these markets will have a more moderate slowdown and perhaps can grow through this time if they have advanced technology. The microcontroller (MCU), analog, mixed-signal, and telecom chip capacity will be next to recover, but this will probably not occur until the end of 1997 or early 1998. The DRAM segment, the root cause of the problem and the very last to recover, is not expected to resume robust spending until mid-to-late 1998. The next major and broad investment cycle will have momentum by 1999.

We believe that capital spending may be influenced in late 1997 through 1999 positively with facility construction and equipment purchases for the world's first 300mm wafer fab. We have built this infrastructure investment into our model.

Strategic semiconductor procurement organizations analyze the total makeup of their supply base starting with research and development expenditure, followed by capital spending plans and then on to quality, delivery, and ultimately, pricing issues. The current slowdown in capital spending directly correlates with last year's pricing debacle—from a supplier's perspective. Although supplies of semiconductors are expected to

remain good for the next six to eight quarters, strategic capital investments still are needed for many companies. Long-term decisions regarding semiconductor sourcing require suppliers with a solid technology foundation combined with the financial wherewithal to follow through with production once the technology is ready. Regular reviews of supplier capital spending plans and ratio analysis of spending compared with sales as well as comparing it with total expenses give a good picture of where a supplier plans to go. Doing a like analysis of R&D spending versus sales and total expenses is also helpful as an early indicator of potential problems. Often overlooked, capital spending is an important part of a total cost analysis. Regular reviews will prevent unpleasant surprises that may disrupt supply lines or cause supplier dislocations.

**For More Information...**

Mark Giudici, Director and Principal Analyst ..... (408) 468-8258
Internet address ..... mark.giudici@dataquest.com
Via fax ..... (408) 954-1780

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## DATAQUEST WORLDWIDE OFFICES

### NORTH AMERICA

**Worldwide Headquarters**
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: 1-408-468-8000
Facsimile: 1-408-954-1780

**East Coast Headquarters**
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6262

**Dataquest Global Events**
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

Sales Offices:
Washington, DC (Federal)
New York, NY (Financial)
Dallas, TX

### LATIN AMERICA

Research Affiliates and Sales Offices:
Buenos Aires, Argentina
Sao Paulo, Brazil
Santiago, Chile
Mexico City, Mexico

### EUROPE

**European Headquarters**
Tamesis, The Glanty
Egham, Surrey TW20 9AW
United Kingdom
Phone: +44 1784 431 611
Facsimile: +44 1784 488 980

**Dataquest France**
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: +33 1 41 35 13 00
Facsimile: +33 1 41 35 13 13

**Dataquest Germany**
Kronstadter Strasse 9
81677 München
Germany
Phone: +49 89 93 09 09 0
Facsimile: +49 89 93 03 27 7

Sales Offices:
Brussels, Belgium
Kfar Saba, Israel
Milan, Italy
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Madrid, Spain

### JAPAN

**Japan Headquarters**
Aobadai Hills 4-7-7
Aobadai
Meguro-ku, Tokyo 153
Japan
Phone: 81-3-3481-3670
Facsimile: 81-3-3481-3644

### ASIA/PACIFIC

**Asia/Pacific Headquarters**
Suite 5904-7, Central Plaza
18 Harbour Road, Wanchai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

**Dataquest Korea**
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

**Dataquest Taiwan**
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

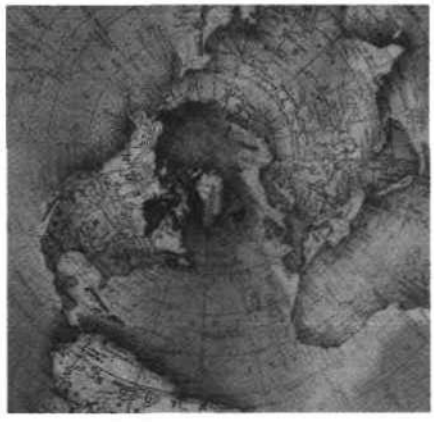
**Dataquest Singapore**
105 Cecil Street
#06-01/02 The Octagon
Singapore 069534
Phone: 65-227-1213
Facsimile: 65-227-4607

**Dataquest Thailand**
12/F, Vanissa Building
29 Soi Chidlom
Ploenchit Road
Patumwan, Bangkok 10330
Thailand
Phone: 662-655-0577
Facsimile: 662-655-0576

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# IC Assembly Update, Report 2: PCB and Packaging Aspects



Focus Report

**Program:** Semiconductor Supply and Pricing Worldwide
**Product Code:** SSPS-WW-FR-9701
**Publication Date:** March 3, 1997
**Filing:** Reports

# IC Assembly Update, Report 2: PCB and Packaging Aspects



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# Table of Contents

Page

1. Executive Summary ..... 1
   - Definitions—The Three Groups ..... 1
     - Objective of the Survey ..... 1
     - Management Summary: Chapter Content ..... 1
2. Survey Respondents Demographics ..... 3
   - Methodology ..... 3
   - Respondent Demographics ..... 3
   - Users versus Buyers of PCBs ..... 5
   - Procured PCB Spending ..... 6
   - Volume of PCBs ..... 7
3. PCB Packaging ..... 9
   - Overall Findings: Through Hole ..... 9
   - Overall Findings: Surface-Mount Technology ..... 10
   - Overall Findings: Advanced Technology ..... 10
   - Overall Findings: Will the Mix Change? ..... 10
   - The Three Groups: Through Hole ..... 12
   - The Three Groups: SMT ..... 13
   - The Three Groups: Advanced Technology ..... 14
   - The Three Groups: Will the Mix Change? ..... 14
   - Analysis of Findings ..... 16
4. Direct Chip Attachment ..... 19
   - Format ..... 19
   - Overall Findings ..... 20
     - Current Use: Overall ..... 20
     - Kinds of DCA Used: Overall ..... 20
     - Plans to Change to Using DCA: Overall ..... 21
   - The Three Groups ..... 22
     - Use of DCA: The Three Groups ..... 22
     - Kinds of DCA Used: The Three Groups ..... 23
     - Plans to Use DCA by the End of 1997: The Three Groups ..... 24
   - Comparison of the Three Groups with the Overall Results ..... 24
   - Analysis ..... 26
   - Possible Application Implications ..... 27
5. PCB Layers Used and Lead Times ..... 29
   - Number of Layers ..... 29
   - Changing the Mix ..... 31
   - Lead Time versus Layers ..... 31
   - Data Analysis ..... 32
6. Quality Issues—PCB Inspection and Defect Rate ..... 33
   - Target PCB Defect Rate ..... 33
   - Comparison of Results ..... 34
   - PCB Inspection ..... 35
   - Data Analysis ..... 36
7. Analysis and Conclusions ..... 39

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# List of Figures


| Figure | | Page |
|---|---|---|
| 1-1 | DCA Types Being Used Overall | 2 |
| 2-1 | Company Revenue Size Range among Survey Respondents | 4 |
| 2-2 | Number of Employees per Company | 4 |
| 2-3 | The Three Groups Surveyed | 5 |
| 2-4 | Procurement Spending on PCBs in 1996 | 6 |
| 2-5 | PCB Volumes Bought in 1996 | 7 |
| 3-1 | Current Through Hole Mix: Overall Findings | 10 |
| 3-2 | Current SMT Mix: Overall Findings | 11 |
| 3-3 | Current Advanced Technology Mix: Overall Findings | 11 |
| 3-4 | Current Through Hole Mix: The Three Groups | 12 |
| 3-5 | Current SMT Mix: The Three Groups | 13 |
| 3-6 | Current Advanced Technology Mix: The Three Groups | 15 |
| 4-1 | Types of DCA Used: Overall | 20 |
| 4-2 | Plans to Begin Using DCA by the End of 1997: Overall | 21 |
| 4-3 | Where the Three Groups Fit | 23 |
| 4-4 | Types of DCA Used: The Three Groups | 24 |
| 4-5 | Plans to Use DCA by the End of 1997: The Three Groups | 25 |
| 4-6 | Use of DCA: Comparison | 25 |
| 4-7 | Plans to Use DCA by the End of 1997: Comparison | 26 |
| 5-1 | PCB Layers for the Merchant Users | 29 |
| 5-2 | PCB Layers for the Captive Groups | 30 |
| 5-3 | Likelihood of Changing the Mix by the End of 1997 | 31 |
| 6-1 | Target Defect Rate for Merchant Users | 33 |
| 6-2 | The Captive Groups' Target Defect Rate | 34 |
| 6-3 | Checking All PCBs or Batches | 36 |

# List of Tables


| Table | | Page |
|---|---|---|
| 2-1 | Companies That Buy PCBs | 6 |
| 3-1 | Likelihood of a Different Mix by the End of 1997: Overall Findings | 12 |
| 3-2 | Likelihood That the Mix Will Change by the End of 1997: The Three Groups | 15 |
| 4-1 | Current Use of DCA: Overall | 20 |
| 4-2 | Use of DCA, by Group | 22 |
| 5-1 | Are Lead Times Different for Different Numbers of PCB Layers? | 32 |
| 6-1 | Physical Checking of PCBs | 35 |


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# Chapter 1
# Executive Summary

## Definitions—The Three Groups

Dataquest identified three distinct categories within the realm of IC assemblers. These three groups were:

- Merchant market IC assemblers—This group is the traditional IC assembly supplier. For the purpose of this survey, this group is know as the merchant market seller group.
- Merchant market buyers—This group buys and uses IC assemblies made externally by the merchant market sellers. Throughout this survey, this category of external buyers is referred to as the merchant market users group.
- Captive assemblers and users—This group covers companies that make and use IC assemblies. The IC assembly can be made and used within the same location or facility or by two divisions. This group does not source IC assemblies externally, nor does it sell IC assemblies externally.

### Objective of the Survey

The aim of the survey was to gather 50 percent of the responses from the merchant market and 50 percent from the captive market.

For this Focus Report, Dataquest surveyed users and suppliers of IC assembling. The overall survey covered commercial issue trends, importance and satisfaction ratings, packaging technology, printed circuit board (PCB) trends, and quality issues. For ease of use, the survey was split into two separate reports. Report 1 covered commercial importance and satisfaction issues and was published by Dataquest in December 1996 (SPSG-WW-FR-9603). This report, Report 2, deals with packaging technology trends, PCB trends, and quality issues.

### Management Summary: Chapter Content

This report is broken into seven parts. Chapters 1 and 2 highlight the scope of the report, participant demographics and methodology used, and groups identified and summarizes the overall findings. Chapter 3 looks at PCB technology mixes and trends, both the overall survey average and for each group. Chapter 4 explores the findings on direct chip attachment—who uses DCA and what types are used. The mean results are compared with the findings for the three groups. In Chapter 5, PCB layer mix on procured PCBs is examined, along with the associated lead times. The quality issues are covered in Chapter 6—inspection methods and target defect rates. For both Chapters 5 and 6, the PCB buying subgroups are used. The report concludes in Chapter 7 with an analysis of findings.


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**Summary**

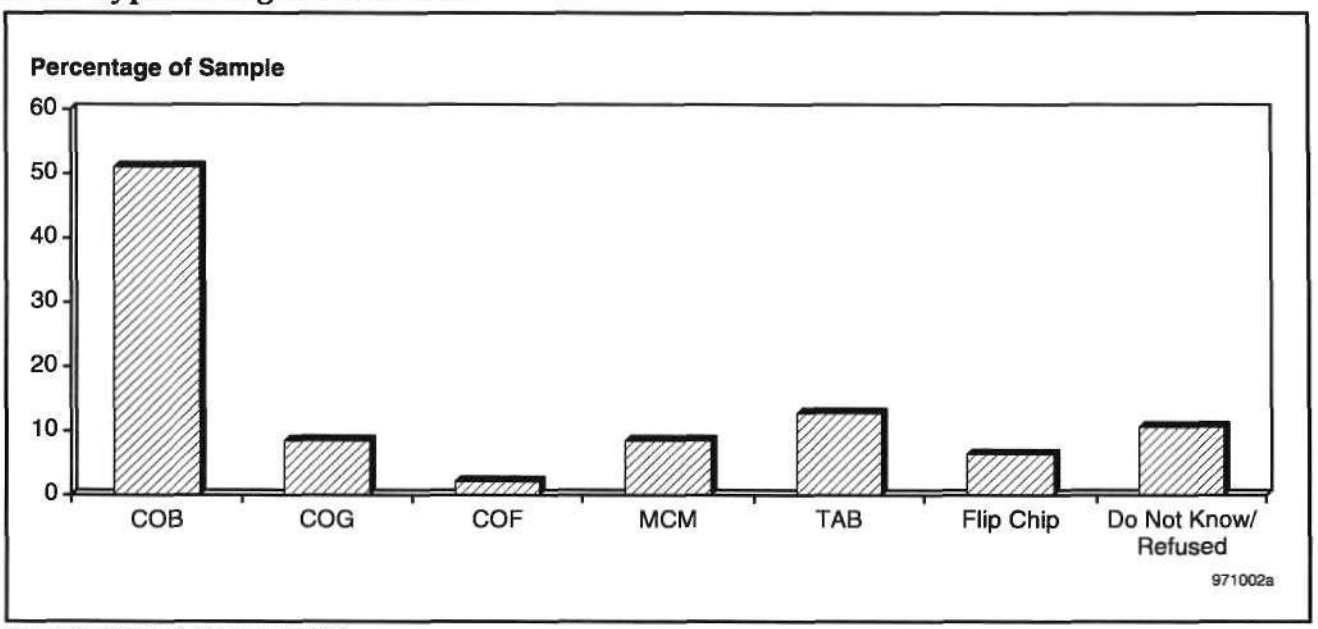
Dataquest has completed a survey of IC assembliers, incorporating the assembler and user groups in both the merchant and captive arenas. This surveyed group had combined IC assembly spending of over $1.6 billion for 1996 and direct PCB procurement spending of over $554 million for the same period. All participants were located in North America.

A number of interesting findings were made in the area of direct chip attachment (DCA). Despite the fact that the survey was conducted in the American market, one-third of survey respondents currently use DCA. This is a high percentage when one considers the type of applications manufactured. More significant still is the range of types currently used—it demonstrates the sophistication of the survey base (see Figure 1-1).

The overall DCA trends were then broken into the three composite groups (merchant assemblers, merchant buyers, and captive community) and individually examined. Some startling differences in current and forecast uptake were discovered, in addition to the types used.

Others areas covered in great detail are PCB layers used and lead time correlations, quality controls (encompassing defect rates and inspection trends), and packaging types (covering through hole, surface mount, and advanced).

**Figure 1-1**
**DCA Types Being Used Overall**




Source: Dataquest (February 1997)

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# Chapter 2
# Survey Respondents Demographics

## Methodology

The survey questionnaire was developed by Dataquest's Semiconductor Supply and Pricing Worldwide program and comprised a total of 115 questions. Trained interviewers at Dataquest's field interviewing facility in San Jose, California, conducted the survey in October 1996 over the telephone. The sample list was obtained from Corporate Technology Information Services. Using the CorpTech database, Dataquest targeted the manufacturers of the following types of electronic devices for inclusion in this survey: voice and data communications, data processing or computers, office electronics, consumer electronics, industrial electronics, medical devices, transportation or aerospace equipment, and military/defense electronics. To qualify, the respondent company had to do at least one of the following activities: assemble boards for use by companies that manufacture electronic devices, manufacture electronic devices using boards obtained primarily from external assemblers, or manufacture electronic devices using boards obtained primarily from internal or in-house assemblers. The respondent had to be knowledgeable about the board assembly practices within this company.

More than 1,200 calls were made, of which 100 were completed—a hit rate of 8.3 percent.

Once Dataquest's field interviewing staff had completed its work, the information was passed to the Semiconductor Supply and Pricing Worldwide program, where the data was analyzed.

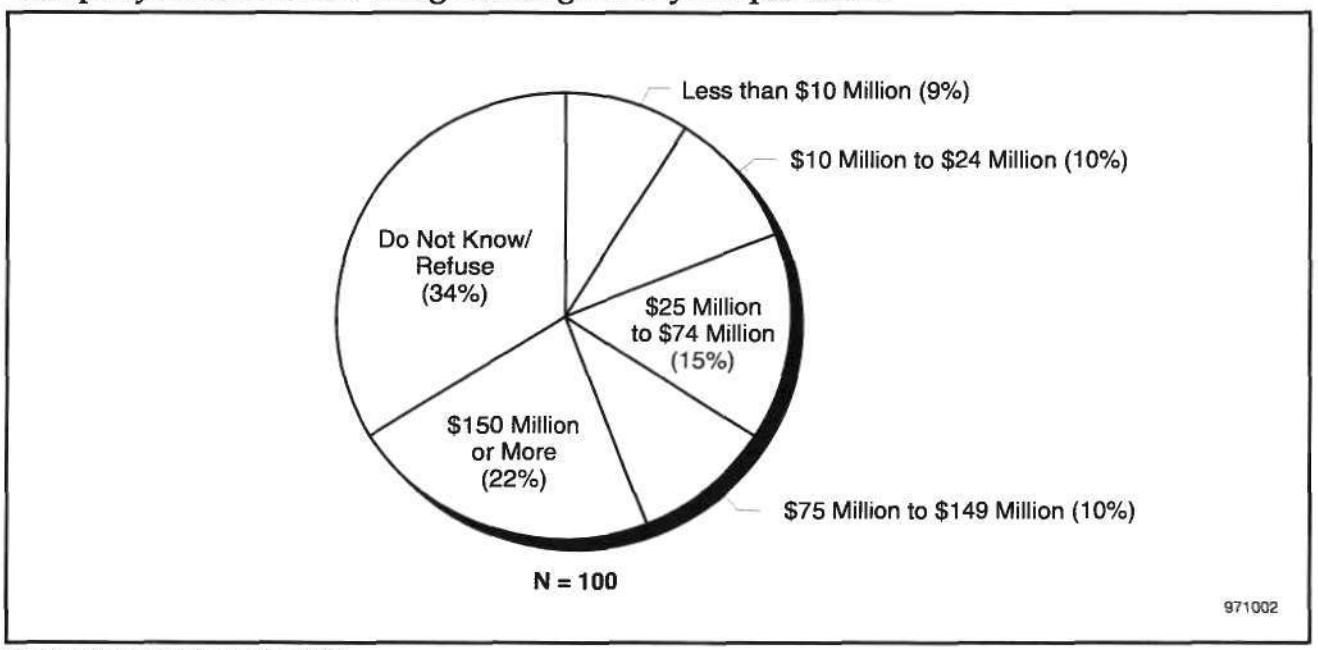
## Respondent Demographics

Figure 2-1 shows company revenue of the respondents for 1996. One-quarter of all respondents were from companies with revenue greater than $125 million, but 34 percent of respondents either did not know their companies' revenue or refused to answer the question. The captive group, on average, had the highest company revenue. Over 35 percent had revenue over $125 million.

The group was fairly mixed in company size. Half of the respondents were from companies with less than 500 hundred people and half from larger organizations. Figure 2-2 shows the overall split of respondents by number of employees at the moment. The merchant assemblers surveyed were, on average, smaller than the other two groups—68 percent were companies with less than 400 hundred employees. Well over 50 percent of external buyers and 67 percent of the captive group had more than 400 employees.

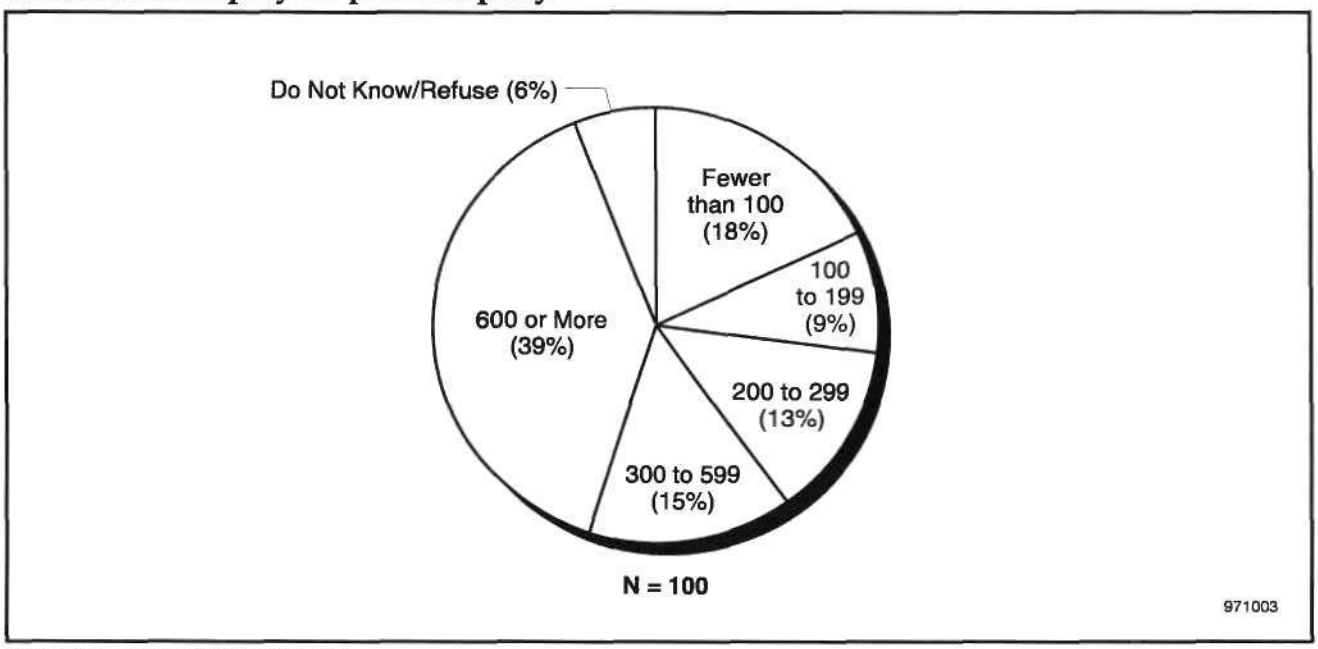

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## Figure 2-1
## Company Revenue Size Range among Survey Respondents




Source: Dataquest (February 1997)

## Figure 2-2
## Number of Employees per Company




Source: Dataquest (February 1997)


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We came very close to our original aim for this report, which was to have 50 percent of the respondents from the merchant market and 50 percent from the captive market. Figure 2-3 shows the actual split by market type: 49 percent of respondents were from the merchant community, split between IC assemblers and buyers/users, and 51 percent were from the captive community, companies that make IC assemblies for their own consumption.

## Users versus Buyers of PCBs

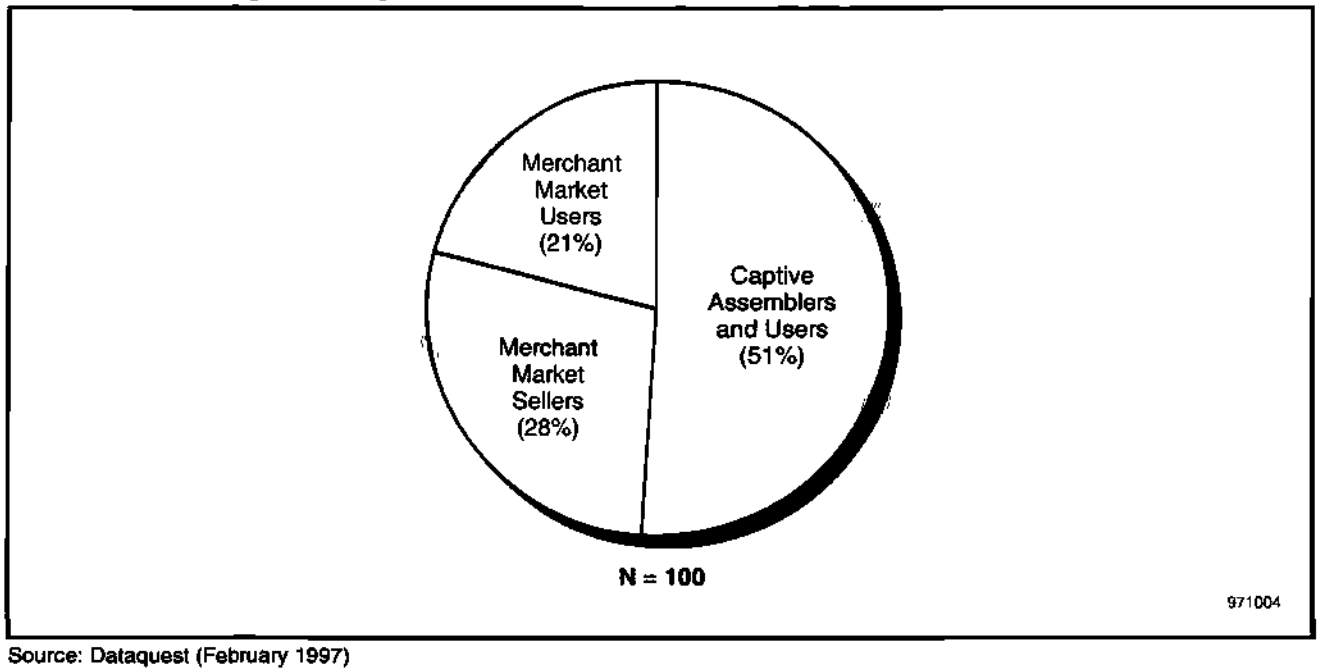
As noted previously in this chapter, the survey results on PCB and packaging issues come from the IC assembly study conducted by Dataquest in October 1996. All participants in the survey itself either were or used IC assemblers, externally or internally. Also, all respondents needed PCBs to do the IC assembly work.

Even though all respondents used or needed PCBs, not all actually procured PCBs themselves. Thus, there is a distinction made by Dataquest as to PCB users and PCB buyers. As the PCB buyers group forms a subgroup of the larger PCB users group, the number of respondents who qualified to answer certain questions is affected.

Throughout this report, it is stated at the start of each chapter which groups will be answering the questions.

Table 2-1 shows the results of the survey question determining which participants companies buy PCBs.

**Figure 2-3**
**The Three Groups Surveyed**




Source: Dataquest (February 1997)

**Table 2-1**
**Companies That Buy PCBs**

| | Merchant Market Assemblers | Merchant Market Users | Captive Assemblers and Users |
|---|---|---|---|
| Yes | 21.4 | 71.4 | 90.2 |
| No | 78.6 | 28.6 | 7.8 |
| Do Not Know / Refuse | 0 | 0 | 2.0 |

Source: Dataquest (February 1997)

Among the external suppliers group (the merchant market assemblers), well over 78 percent of the surveyed companies didn't buy PCBs. Thus, this group was not used for any PCB-specific questions, as clearly an insufficient number was qualified.

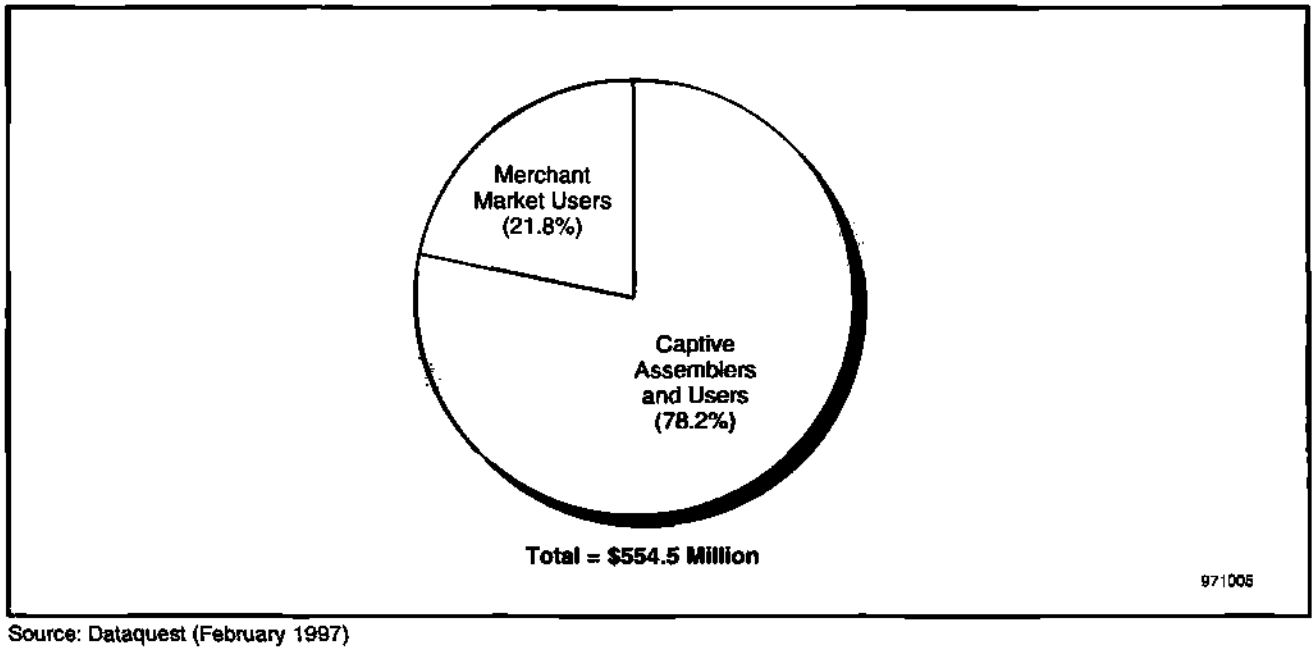
Of the external buyers group (the merchant market users), over 71 percent of respondents' companies procured PCBs. Among the captive group, over 90 percent of respondents said that their companies bought PCBs. Clearly, these two groups qualify to answer the PCB-specific questions, and so the results of these two PCB subgroups were used.

## Procured PCB Spending

As this question relates to the procurement spending on PCBs per company, the merchant assemblers group has not been included. This question was asked of the qualifying participants within the merchant users group and the captive group.

As can be seen from Figure 2-4, the total spending of the qualifying participants on PCBs for 1996 was estimated at $554.5 million.

**Figure 2-4**
**Procurement Spending on PCBs in 1996**



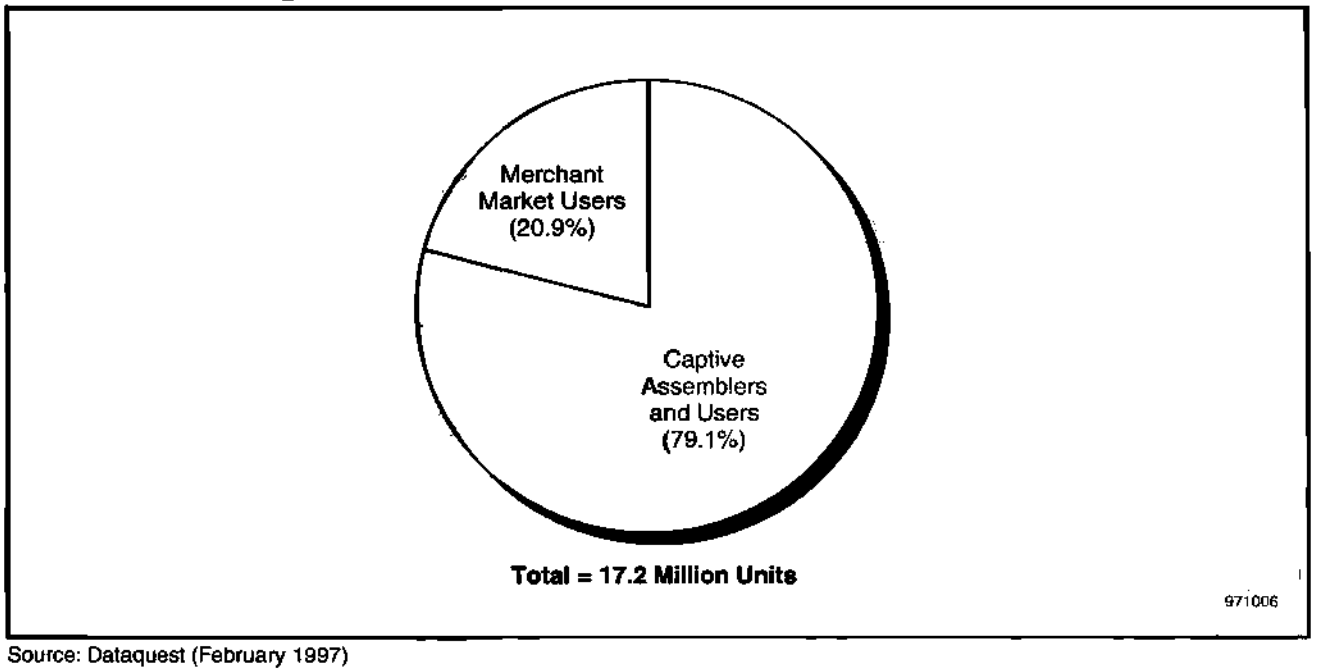

Source: Dataquest (February 1997)

## Volume of PCBs

Dataquest asked the qualifying participants to estimate how many PCBs they would buy in 1996.

Figure 2-5 shows the number of PCBs procured by the qualifying participants in 1996: 17.22 million units. It is worth remembering that, as this question concerns only the volume of PCBs directly procured in 1996, it is only a portion of all the PCBs used by the total IC assembly survey respondents.

**Figure 2-5**
**PCB Volumes Bought in 1996**




Source: Dataquest (February 1997)

# Chapter 3
# PCB Packaging

All IC assembly survey participants used PCBs. The assemblers need PCBs to do the physical IC connections; the buyers of IC assemblies use them as part of their product food chain. This is true both in the external market and internally. Thus, every IC assembly survey participant has a valid input in this chapter.

This chapter is broken into four sections, each analyzing the results of a different group. These four groups are:

- Overall findings
- Merchant market assemblers
- Merchant market users
- Captive assemblers and users

As every respondent who participated in the IC assembly survey qualified for this chapter, the overall findings are a useful representation of what is happening in the area of package technology. However, as all respondents fell into one of the three categories, it is also necessary to examine each group separately to determine their similarities and differences.

Let us first look at definitions. Although "through hole" is fairly self-explanatory, the surface-mount technology (SMT) and advanced technology (AT) forms need some clarification:

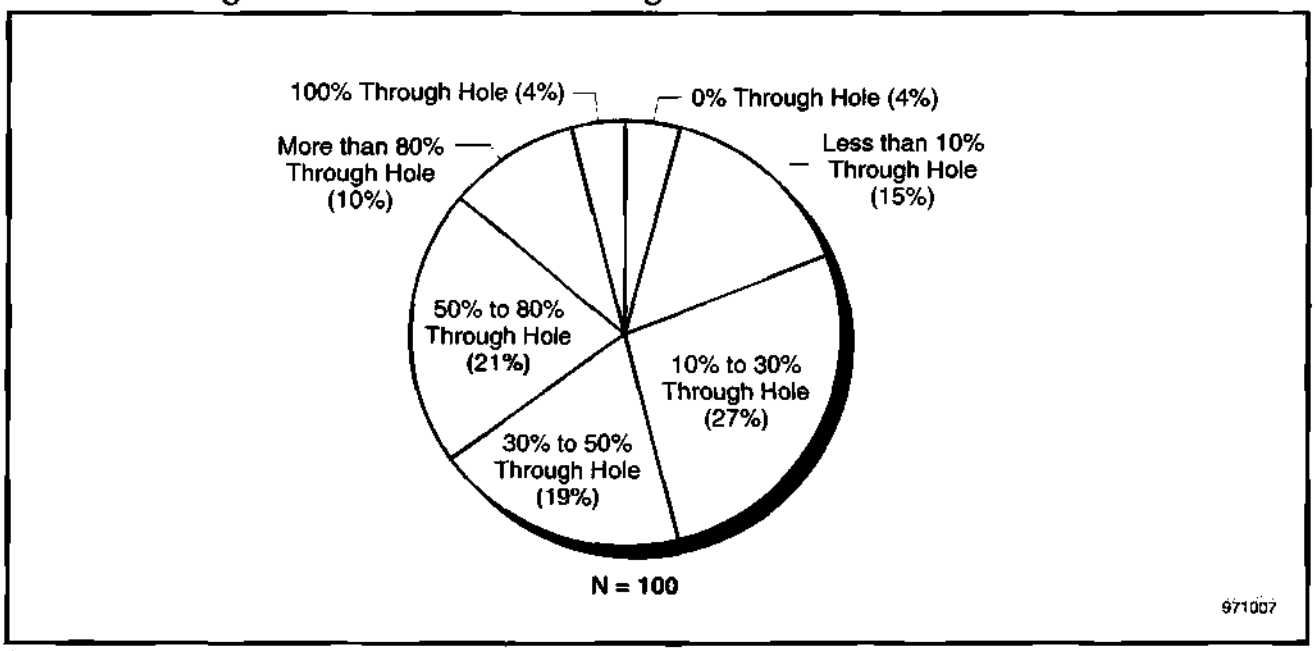
- Surface-mount technology includes small-outline package (SOP), thin small-outline package (TSOP), and chip on board (COB). COB is often referred to as chip on wafer (COW).
- Advanced technology includes very small outline package (VSOP), thin shrink small-outline package (TSSOP), very fine-pitch packages, plastic ball-grid array (PBGA), enhanced PBGA (EPBGA), tape-automated bonding (TAB), and flip chip.

The overall finding are examined first.

## Overall Findings: Through Hole

As can be seen from Figure 3-1, 65 percent of respondents use less than 50 percent through hole. Of this, about one-quarter use less than 10 percent through hole, about 40 percent use between 10 and 30 percent, and nearly 30 percent use between 30 and 50 percent through hole. Five percent of this group used no through hole. Twenty-one percent of replies said that through hole accounted for between 50 and 80 percent. Over 80 percent use of through hole was ticked by one-tenth of respondents. The percentage of respondents who used only through hole was very small—4 percent.

**Figure 3-1**
**Current Through Hole Mix: Overall Findings**




Source: Dataquest (February 1997)

## Overall Findings: Surface-Mount Technology

The profile for surface-mount technology is quite different from that of through hole for the same groups. As can be seen from Figure 3-2, 46 percent of those surveyed use less than 50 percent SMT (or surface-mount device—SMD). Seven percent use no SMT at present, while 39 percent use it to various degrees less than 50 percent . Thirty-eight percent of respondents use between 50 and 85 percent SMT, while 15 percent of participants use between 85 and 95 percent SMT. Only one respondent used all SMT.

## Overall Findings: Advanced Technology

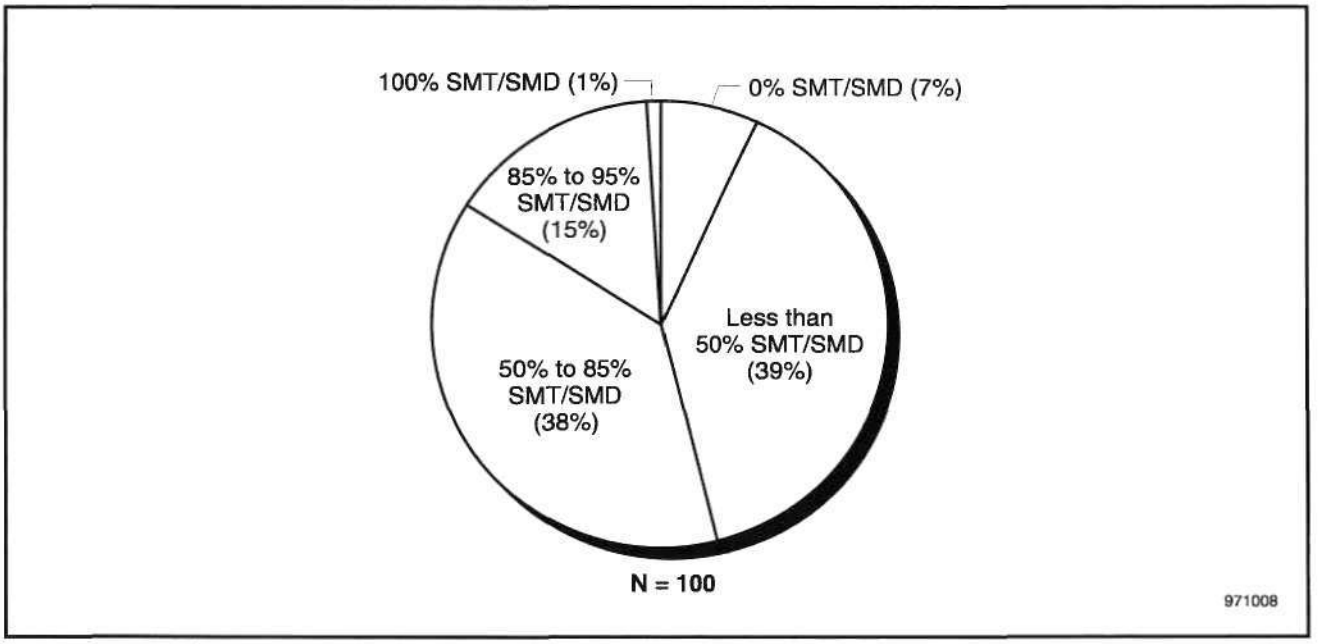
Advanced technology penetration, on the whole, was considerably less evolved. Figure 3-3 shows that 86 percent of participants use no form of advanced technology. Of the remaining 14 percent, half use less than 10 percent AT, about one-third use between 10 and 20 percent, 1 percent use 40 percent, and 1 percent use all AT.

## Overall Findings: Will the Mix Change?

Next Dataquest asked if this would be different by the end of 1997. Table 3-1 shows that a resounding 58 percent expected to change their mix. Only 39 percent said their mix would remain the same, while 3 percent either did not know or refused to speculate.

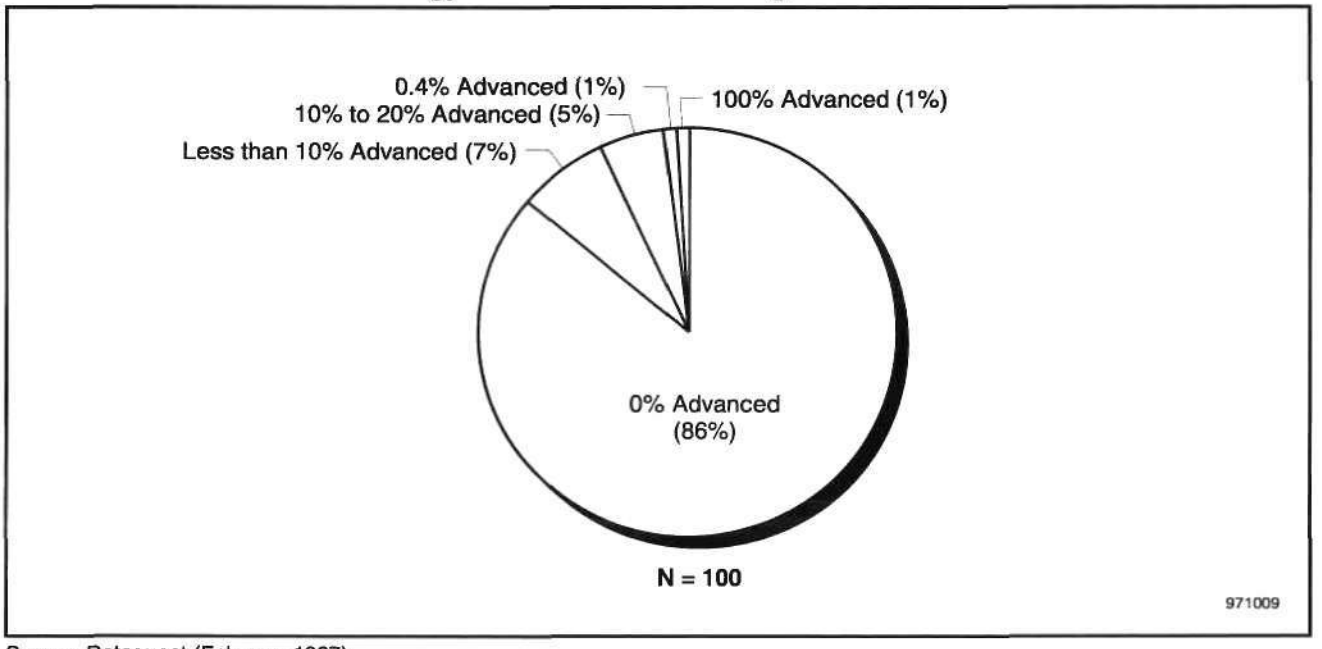
Let us now look in more detail at the three groups that make up the overall results (see Figure 3-4).

## Figure 3-2
## Current SMT Mix: Overall Findings




Source: Dataquest (February 1997)

## Figure 3-3
## Current Advanced Technology Mix: Overall Findings




Source: Dataquest (February 1997)


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**Table 3-1**
**Likelihood of a Different Mix by the End of 1997: Overall Findings (Percent)**

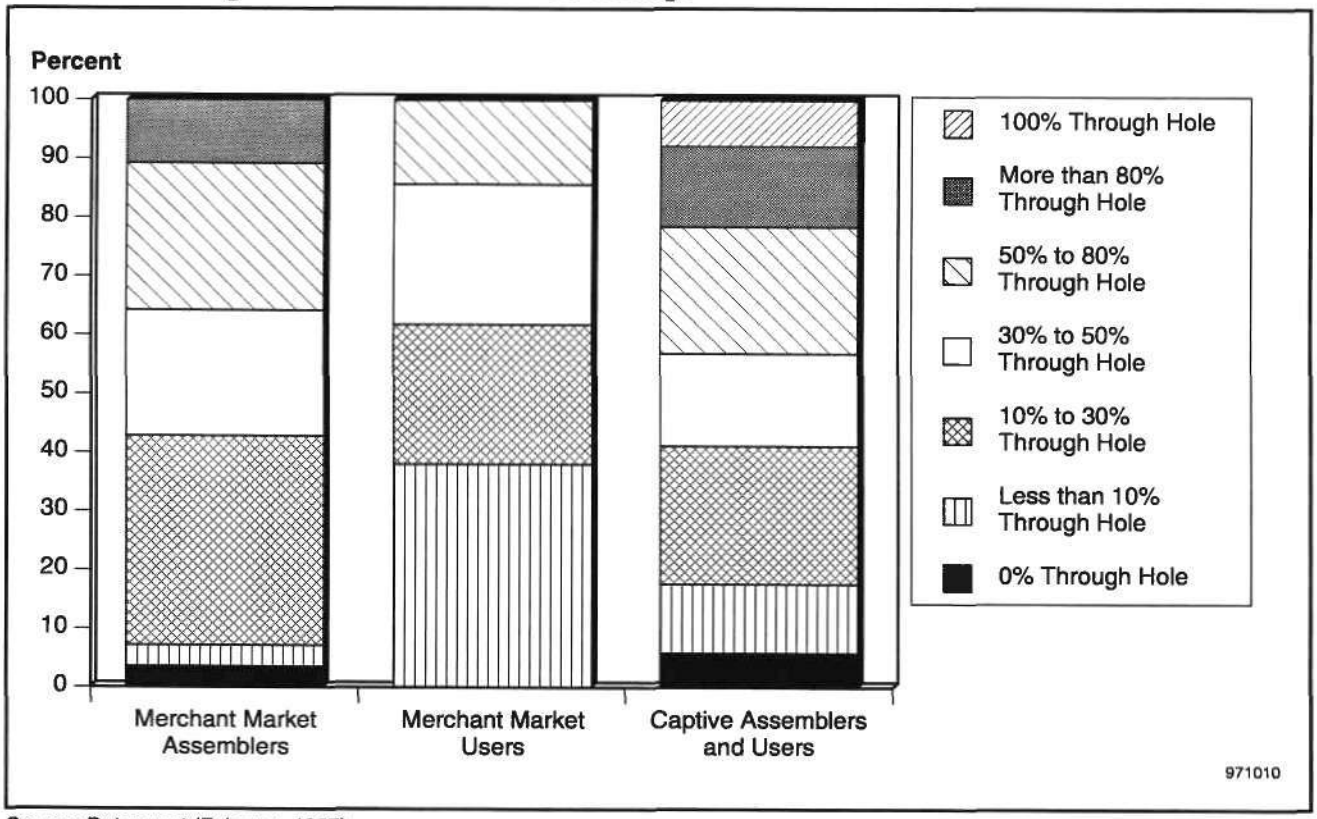
| | Mix Will Change |
|---|---|
| Yes | 58 |
| No | 39 |
| Do Not Know/Refuse | 3 |

Source: Dataquest (February 1997)

## The Three Groups: Through Hole

Figure 3-4 shows the results of the three different groups based on their through hole mix.

**Figure 3-4**
**Current Through Hole Mix: The Three Groups**




Source: Dataquest (February 1997)

Over 64 percent of all respondents in the merchant market assemblers group use less than 50 percent through hole. About 21 percent use between 30 and 50 percent, nearly 36 percent use between 10 and 30 percent through hole, 3.6 percent use less than 10 percent, and 3.6 percent use 10 to 30 percent. One-quarter of respondents used 50 to 80 percent through hole, and just under 11 percent used over 80 percent through hole.


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For the merchant market users groups, however, the results are different. Within this group, nearly 86 percent of respondents use less than 50 percent through hole technology. Breaking this into the three ranges chosen shows 38 percent using less than 10 percent, nearly 24 percent using between 10 and 30 percent, and nearly 24 percent using between 30 and 50 percent through-hole technology. The remaining respondents, who use over 50 percent market comes from the 50 to 80 percent ranges of which just over 14 percent of respondents use.

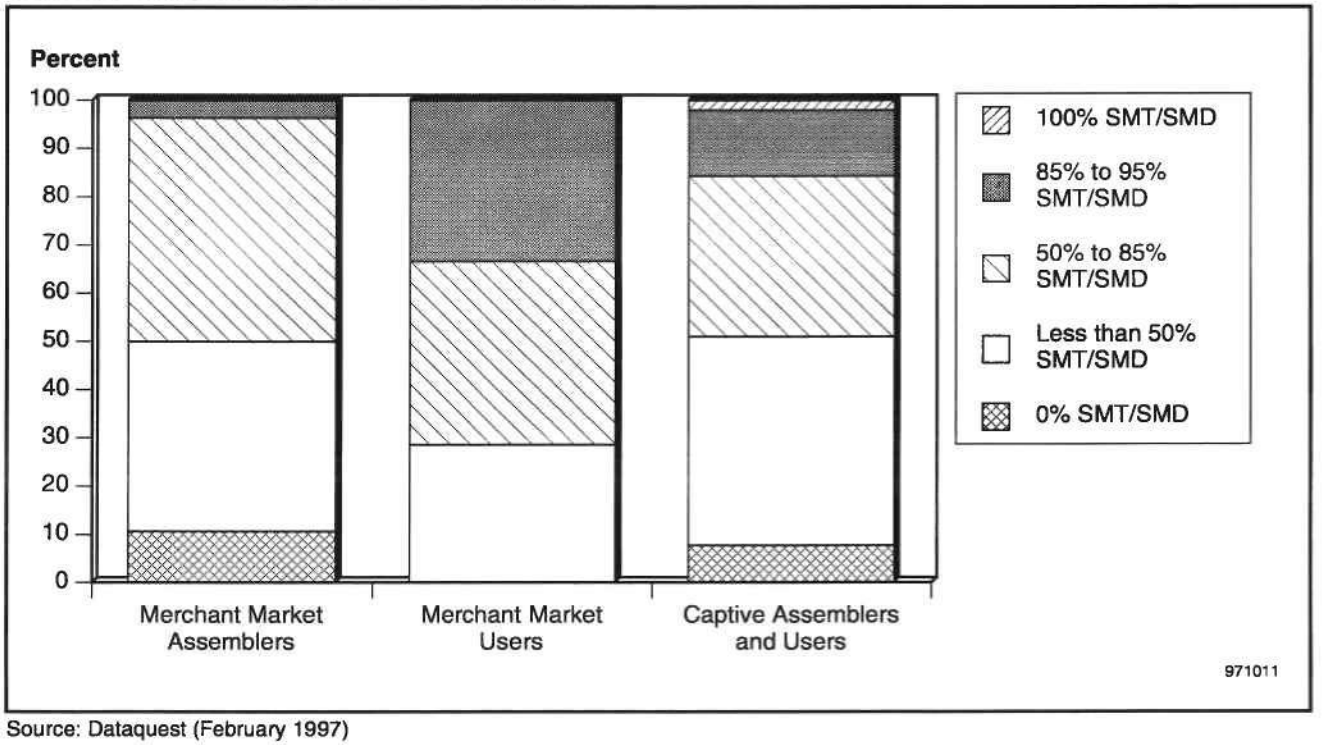
Finally, Dataquest examined the results of the captive group. Here, about 57 percent use less than 50 percent through-hole technology. This runs the full range—starting with nearly 6 percent who use no through hole, around 12 percent who use less than 10 percent, 23.5 percent who use between 10 and 30 percent, and 15.7 percent who use 30 to 50 percent. Of the 43 percent who use more than 50 percent through hole technology, 21.6 percent use between 50 and 80 percent, 13.7 percent use over 80 percent, 7.8 percent use all through hole.

Next, the same three groups of participants were asked to categorize their SMT use within certain Dataquest-specified ranges.

## The Three Groups: SMT

The results of the question on surface-mount technology use by the three groups are shown in Figure 3-5.

**Figure 3-5**
**Current SMT Mix: The Three Groups**




Source: Dataquest (February 1997)

Of the merchant assemblers surveyed, the split was exactly 50/50; that is, 50 percent of respondents in this group use less than 50 percent SMT and 50 percent use more than 50 percent SMT. A full 10.7 percent of respondents use no SMT, although with 39.3 percent using more than zero but less than 50 percent SMT. The biggest single grouping is in the 50 to 85 percent range, with 46.4 percent of respondents. Between 85 and 95 percent, the response was 3.6 percent.

The captive group shows a profile similar to the merchant market assemblers group, with 51 percent of respondents using less than 50 percent SMT and 49 percent of users using over 50 percent SMT at the moment. Of the group reporting below 50 percent use, 7.8 percent use no SMT at present and just over 43 percent use more than zero but less than 50 percent. A third of all respondents in this group use between 50 and 85 percent SMT, while 13.7 percent use between 85 and 95 percent. Two percent of participants in this group use all SMT at present.

The merchant market users, again, show quite a different profile from the other two groups. In this group, slightly more than a quarter of those surveyed use less than 50 percent SMT. This means that over 70 percent of respondents use more than 50 percent SMT—slightly over 38 percent use between 50 and 85 percent SMT, with a third of respondents using between 85 and 95 percent.

Finally from a technology use stance, the groups were asked whether they now use advanced technology.

## The Three Groups: Advanced Technology

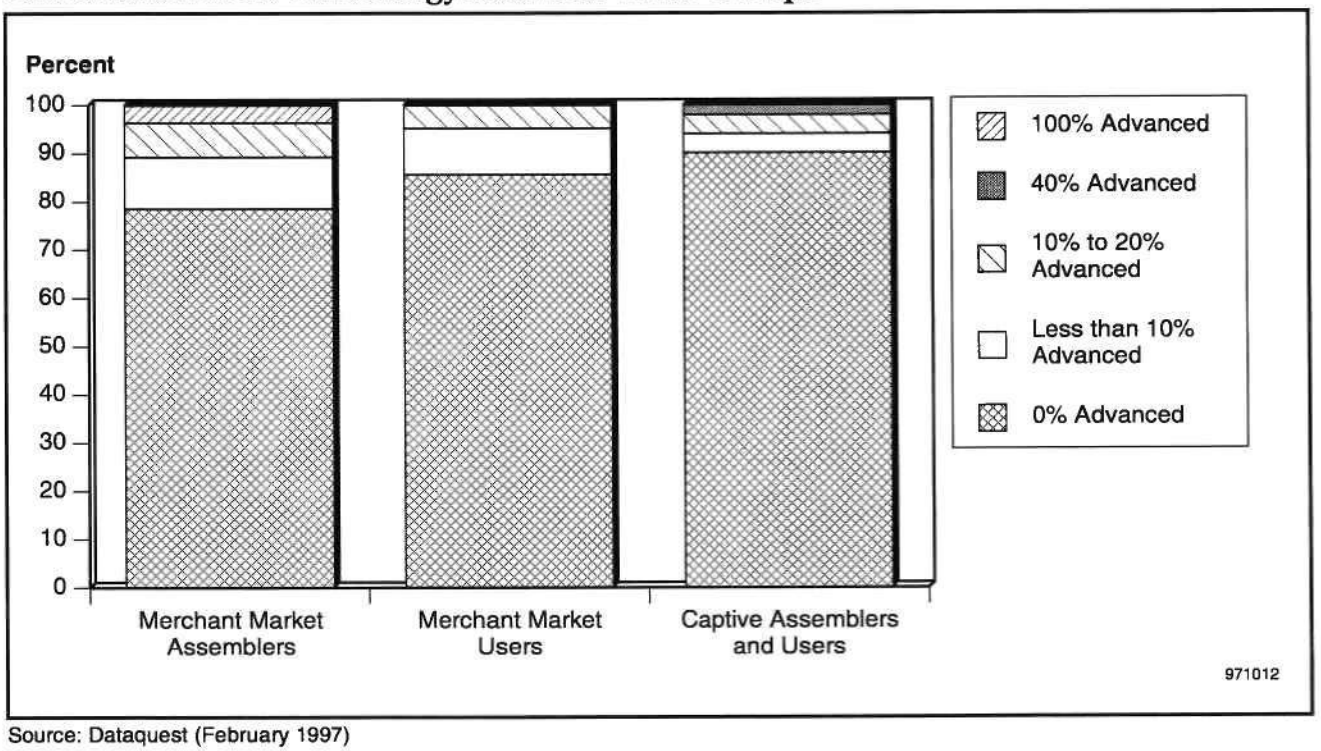
Here, all three groups had something in common—the vast majority of all surveyed did not use advanced technology. Analysis of the results shows that it was simply a question of degrees. Figure 3-6 shows that the merchant assemblers group gave a 78.6 percent "no" vote, the merchant users, 85.7 percent "no," and the captive group came in screaming with a 90 percent "no" vote. It is easier to look at the limited "yes" vote. The captive group's 10 percent is split among three ranges—under 10 percent (with a 4 percent response), 10 to 20 percent (again getting 4 percent), and 40 percent (the rest—2 percent). The merchant users had a 14.3 percent affirmative response, split between two ranges—under 10 percent (9.5 percent of respondents) and 10 to 20 percent (4.8 percent). The merchant assemblers had the largest affirmative vote—21.4 percent. This was split among three ranges—under 10 percent (10.7 percent), 10 to 20 percent (7.1 percent), and 100 percent (3.6 percent).

## The Three Groups: Will the Mix Change?

Dataquest asked all respondents if they planned to change the mix for the end of 1997. Table 3-2 shows the results.

From Table 3-2, it can be seen that the majority surveyed from all three groups plan to change the technology mix by the end of 1997. The merchant assemblers were the most positive—nearly 68 percent of those surveyed plan to change their mix, compared to 28.6 percent who will keep it the same. Only 3.5 percent refused to speculate or did not know. The captive group voted nearly 55 percent that they would change, 43 percent

**Figure 3-6**
**Current Advanced Technology Mix: The Three Groups**




Source: Dataquest (February 1997)

**Table 3-2**
**Likelihood That the Mix Will Change by the End of 1997: The Three Groups (Percent)**

| | Merchant Market Assemblers | Merchant Market Users | Captive Assemblers and Users |
|---|---|---|---|
| Yes | 67.9 | 52.4 | 54.9 |
| No | 28.6 | 42.9 | 43.1 |
| Do Not Know / Refuse | 3.5 | 4.7 | 2.0 |

Source: Dataquest (February 1997)

would not change, and a 2 percent refused or did not know. In the merchant users group, 52.4 percent will change by end of 1997, but just shy of 43 percent will not, and 4.7 percent refused to answer or did not know.

Dataquest asked the groups how they planned to change their mix. The main ways in which groups planned to change were to decrease use of through hole and increase use of SMT. They had no plans to use more advanced technologies by the end of 1997.

Also, analyzing those who will change and those who will not made it obvious quickly that those who will not be changing are already using more than 50 percent SMT.

## Analysis of Findings

There was a clear move from through-hole technology toward surface-mount technology from all three groups. However, one striking point was the degree to which the three groups have made this transition, based on Dataquest's survey base. The merchant market assemblers group most closely resembles the overall findings. These two sets had 64.3 percent and 65 percent of respondents, respectively, using less than 50 percent through-hole technology at present. Only 58.9 percent of the captive group used less than 50 percent through hole. By contrast, nearly 86 percent of merchant buyers (the merchant users group) were using less than 50 percent through hole. This would indicate that the merchant buyers group was the group that had the strongest momentum going in the move from through hole to SMT.

This technology shift among the merchant users is given more weight by the fact that, when asked whether the current mix would change by the end of 1997, this group was the least positive. Only 52.4 percent said that they would change their mix, compared to 67.9 percent of merchant assemblers. Clearly, for the merchant sellers, the coming 12 months will be significant in the technology move.

What is surprising is the result from the captive group. Here, both buyers and sellers of the assemblies work for the same company. One would imagine that, as they share common goals and corporate directions, they would find it easier to adopt newer technologies through cost splitting and shared design responsibilities. Not so. This group has the highest percentage of respondents using more than 50 percent through-hole technology, the lowest number using more than 50 percent SMT, and the strongest antiadvanced technology replies. And yet, only 54.9 percent of those surveyed plan to alter their technology mix by the end of 1997. Conservatism appears to rule in the captive environment.

Returning to technology transitions and to emphasize the polarization of realities from the three groups, it can be seen that the merchant buyers were more flexible. They had the highest percentage using more than 50 percent SMT. Theirs was also higher than the overall average (71.4 percent versus 54 percent). By contrast, the other two groups would appear less flexible in their technology mix. Both other groups had less than the overall average usage of SMT—currently, 50 percent of the merchant assemblers and 49 percent of the captive group use more than 50 percent SMT.

According to the sample base of this survey, the volume move to advanced forms of technology has not yet occurred. Only a minor number (and percentage) of all groups use a form of technology that can be classified as advanced. Also, based on feedback received on their likelihood of change within the next 12 months, none expressed the goal of increasing its share. Yet the hype drones on.

For applications where lower height is essential, there is no getting away from SMT. However, for commodity devices, where a price point is key, through hole continues to be the choice. Also, some older technology devices have been made only in dual in-line package (DIP) designs, which makes an SMT move impossible.

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Another point to bear in mind is that all survey participants are based in North America. This region has been a lot slower to move toward SMT than other regions in the world, for example, Japan, which embraced it more wholeheartedly. This is in part because of the fact that the focus here is more industrial, which requires a more conservative approach to technology migration than, say, consumer applications (mainly in Japan).

For the industrial segment, for example, moving to SMT may necessitate product recalls if any issues occur. Recalling a product is both tedious and very costly. In a different vein, but to illustrate the same goal, automotive applications want the best cost solution for their application, which still comes from through hole. These two examples help explain the hesitancy to move to SMT.


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# Chapter 4
# Direct Chip Attachment

Direct chip attachment is a name applied to any of the chip-to-substrate connections used to eliminate the first level of packaging.

It strives to eliminate the expense associated with package assembly by affixing the chip directly to the board or substrate. For the purposes of this survey, Dataquest has included the following DCA methods:

- Chip on board: In its most general term, this refers to the direct attachment of a bare chip to a board using wire bonding. However, it may also include TAB or solder interconnections.
- Chip on glass (COG): Generally speaking, this means the direct attachment of the bare chip to a glass substrate.
- Chip on flex (COF): Here, the bare chip is attached directly to a flex substrate.
- Multichip module (MCM): This is a module or package capable of supporting several chips on a single package. Most multichip modules are ceramic.
- Tape automated bonding: Silicon chips are joined to patterned metal on polymer tape using thermocompression bonding and subsequently attached to a substrate or board by outer lead bonding.
- Flip chip: Here a bare die is attached to a substrate upside down after spheres of solder (50µm to 125µm in diameter) are bumped in an array on the bottom of the chip before attachment to the substrate. It was originally referred to as the IBM C4 process (controlled collapse chip connection).

## Format

Dataquest wanted to determine whether DCA was being used by the survey respondents and, if so, which types of DCA were used. Those not using the technology were asked about plans to use DCA by the end of 1997.

Dataquest asked this question of all survey participants in all three groups—merchant assemblers and users and the captive group. As DCA is a technology being much talked about and gaining much publicity, Dataquest has presented the findings four ways:

- Overall survey findings
- Merchant market assemblers
- Merchant market users
- Captive assemblers and users

The overall survey findings analysis is useful to get a "big picture" of the technology, on a macro level, while the individual analysis of the three groups surveyed facilitates the study on a more micro level. Thus, it can be determined if there is a greater use of DCA among any of the specific groups of respondents.

## Overall Findings

Dataquest asked all participants in the IC assembly survey a number of questions about DCA.

### Current Use: Overall

Dataquest asked the 100 survey participants whether they currently used DCA. Table 4-1 shows the results.

**Table 4-1**
**Current Use of DCA: Overall**

| | Number of Respondents | Percentage |
|---|---|---|
| Yes | 33 | 33 |
| No | 66 | 66 |
| Do Not Know/Refuse | 1 | 1 |

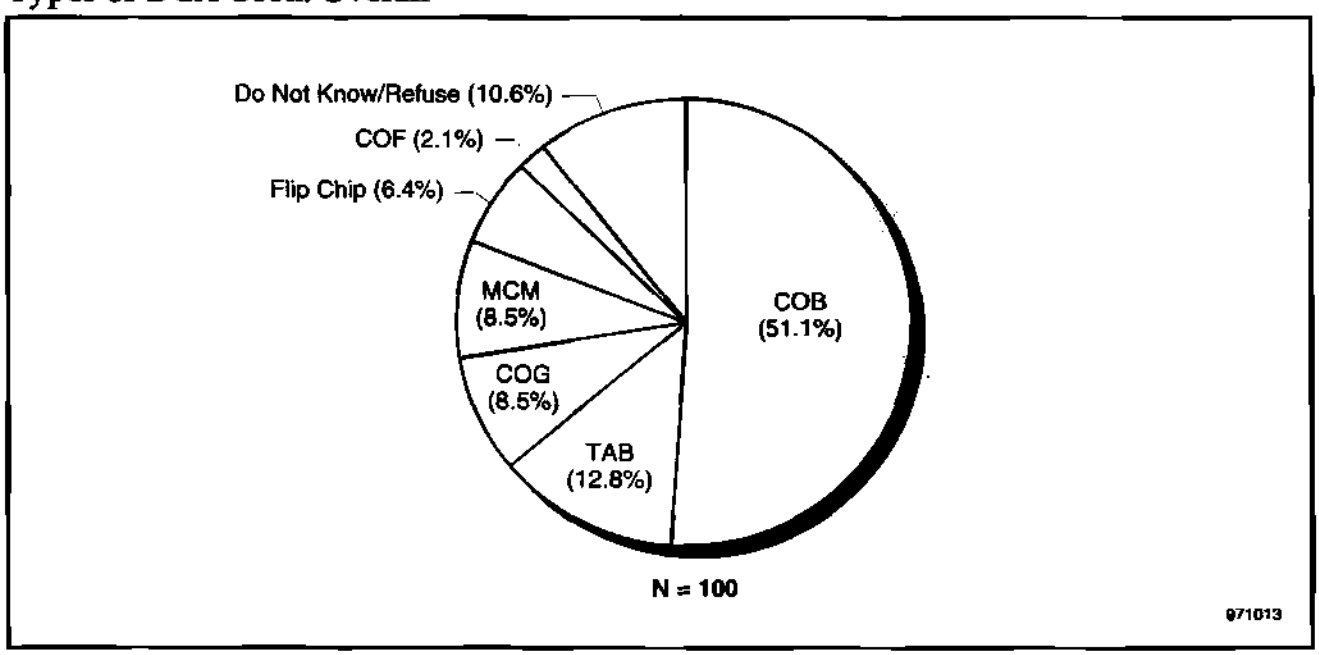
Source: Dataquest (February 1997)

Clearly, the majority of participants do not currently use DCA—a full two-thirds said no. however, one-third do currently use DCA.

### Kinds of DCA Used: Overall

Next, of the one-third of participants who do use DCA, Dataquest asked what types were being used. This was done, obviously, to determine if any one type was more popular among the survey participants. Figure 4-1 shows the results.

**Figure 4-1**
**Types of DCA Used: Overall**




Source: Dataquest (February 1997)


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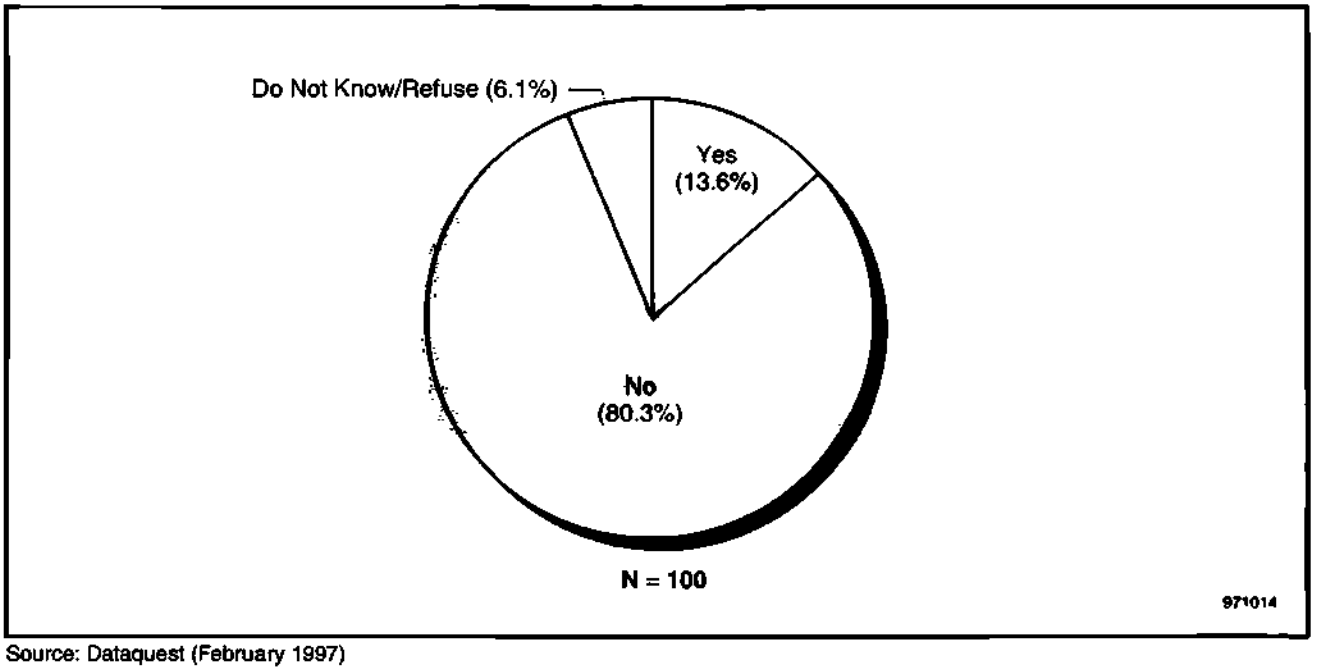
Of those surveyed who use DCA, clearly the majority use COB—over 51 percent. Trailing considerably is TAB, which is used by nearly 13 percent of respondents. Tying for third place on the "most used" list are COG and MCMs. Flip chip is fifth, with 6.4 percent using this form of DCA. Only 2.1 percent are currently using COF. Of those who now use DCA, 10.4 percent either refused to answer or did not know what form they were using.

## Plans to Change to Using DCA: Overall

Those who do not use DCA were asked if they planned to adopt it by the end of 1997.

As can be seen from Figure 4-2, the majority of those who do not use DCA now have no plans to change by the end of 1997. The negative option got over 80 percent of the respondents' votes. A mere 13.6 percent plan to adopt DCA by the end of 1997; 6.1 percent refused or did not know if they planned to use DCA by the end of 1997.

**Figure 4-2**
**Plans to Begin Using DCA by the End of 1997: Overall**




Source: Dataquest (February 1997)

## The Three Groups

The overall results are now broken into their three group categories—merchant market assemblers/suppliers, merchant market users/buyers, and the captive group. The groups' results are compared to see whether there are any overall trends or whether each demonstrates markedly different patterns.

### Use of DCA: The Three Groups

The first point to establish is how many respondents from each group now use DCA. Table 4-2 shows the results of this question by group, expressed in percentages. The only common thread among all three groups is that the majority in each does not now use DCA.

The merchant market assemblers have the closest split between those who use DCA and those who do not. Over 46 percent of this group use DCA at the moment, while just under 54 percent do not. Of the merchant market users group, a resounding 81 percent do not go outside for DCA use at present, with just 19 percent using it. This shows a staggering difference between the two merchant market groups surveyed.

Within the captive assemblers and users group, again the majority did not use DCA. However, while the nonusers were in the majority (with nearly 67 percent of the total vote), the DCA users accounted for over 31 percent of this group. Two percent of the captive group either did not know or refused to answer the question.

Figure 4-3 also shows that these three groups could easily be classified for DCA used based on a technology or corporate style.

In other words, the merchant assemblers have a high technology focus and are aggressive and quick in their adoption of DCA. This group has to be on the cutting edge, as its clients will be making the transition over time. Also, as this is cutting-edge stuff, their present client base is internationally based.

The merchant users group, however, has a lower technology focus toward DCA. However, even though the members of this group are not too bullish about their planned transition by the end of 1997, the merchant buyers will move over with medium speed. This group has a variety of suppliers that are capable of doing DCA—they merely need designs that include DCA. Even on this they have help.

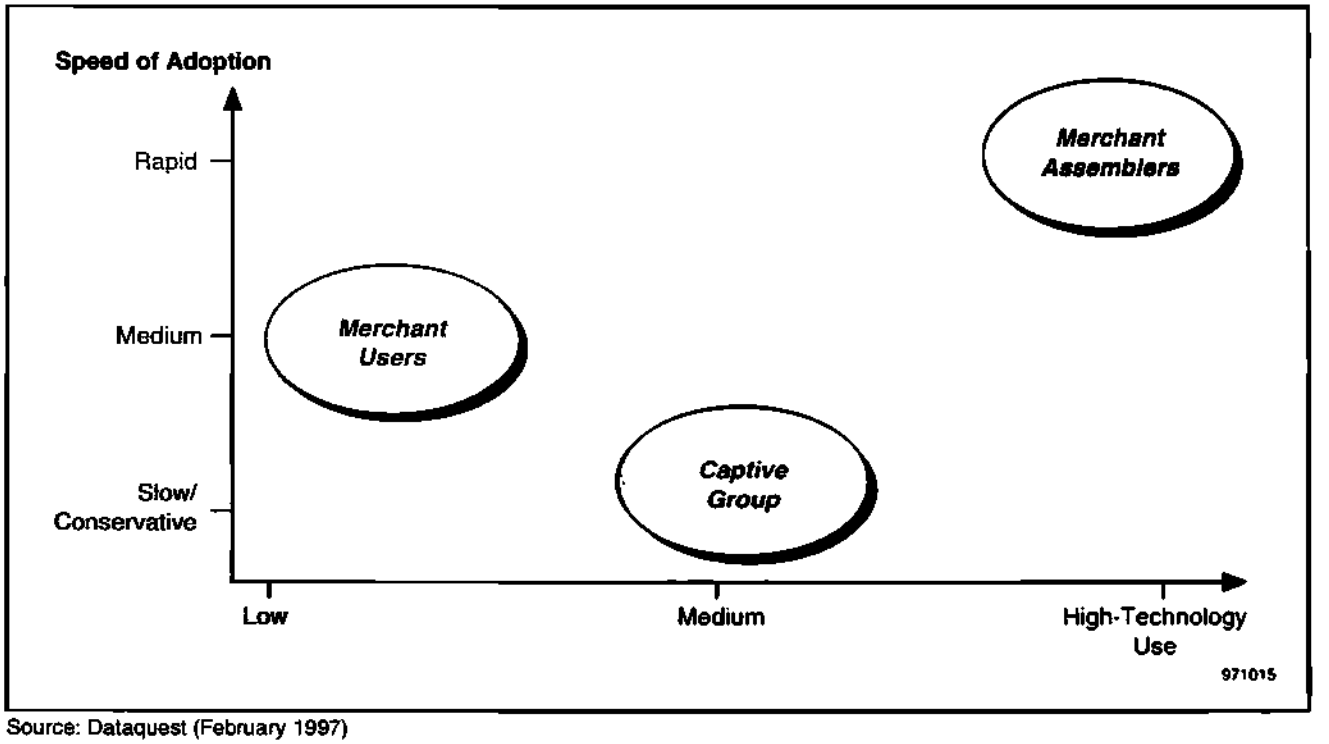
**Table 4-2**
**Use of DCA, by Group (Percent)**

| | Merchant Market Assemblers | Merchant Market Users | Captive Assemblers and Users |
|---|---|---|---|
| Yes | 46.4 | 19.0 | 31.3 |
| No | 53.6 | 81.0 | 66.7 |
| Do Not Know/Refuse | 0 | 0 | 2.0 |

Source: Dataquest (February 1997)


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**Figure 4-3**
**Where the Three Groups Fit**




Source: Dataquest (February 1997)

The captive group is hybrid. This group has a moderately high technology focus toward DCA but, as it continues to source it only in a proprietary manner, it is faced with more conservatism in its overall adoption classification. The only way around this is to source externally to begin with.

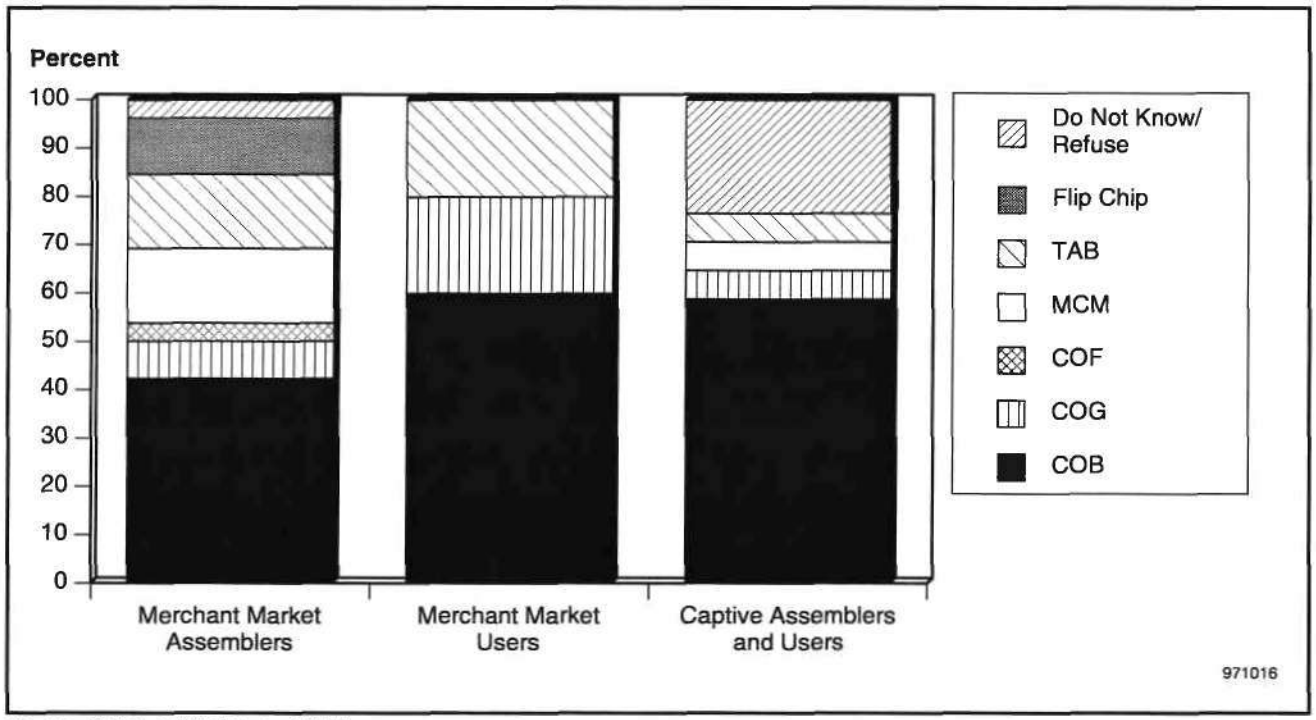
## Kinds of DCA Used: The Three Groups

After having established which respondents from each group currently use DCA, Dataquest asked which kinds of DCA they used. Figure 4-3 shows the results.

Figure 4-4 shows that COB is the most popular type of DCA used by all groups. Nearly 60 percent of both the captive group and merchant users group use it. This compares with about 42 percent of merchant assemblers. One-fifth of all merchant users sampled use COG, compared with less than 6 percent for the captive group and nearly 8 percent for the merchant assemblers. The captive group also used about 6 percent MCM and TAB, while the only other form used by the merchant users was TAB (at 20 percent).

The merchant assemblers group has the most depth of the three groups in terms of current DCA use. In addition to the COB and COG use mentioned above, there is also a significant use of MCM and TAB, both at 15.4 percent of the total sample. Flip chip was used by 11.5 percent of the sample group, which is extremely positive in light of its complexity, and COF was lowest, at just below 4 percent.

**Figure 4-4**
**Types of DCA Used: The Three Groups**




Source: Dataquest (February 1997)

### Plans to Use DCA by the End of 1997: The Three Groups

Dataquest asked all three groups whether those not using DCA had plans to use it by the end of 1997.

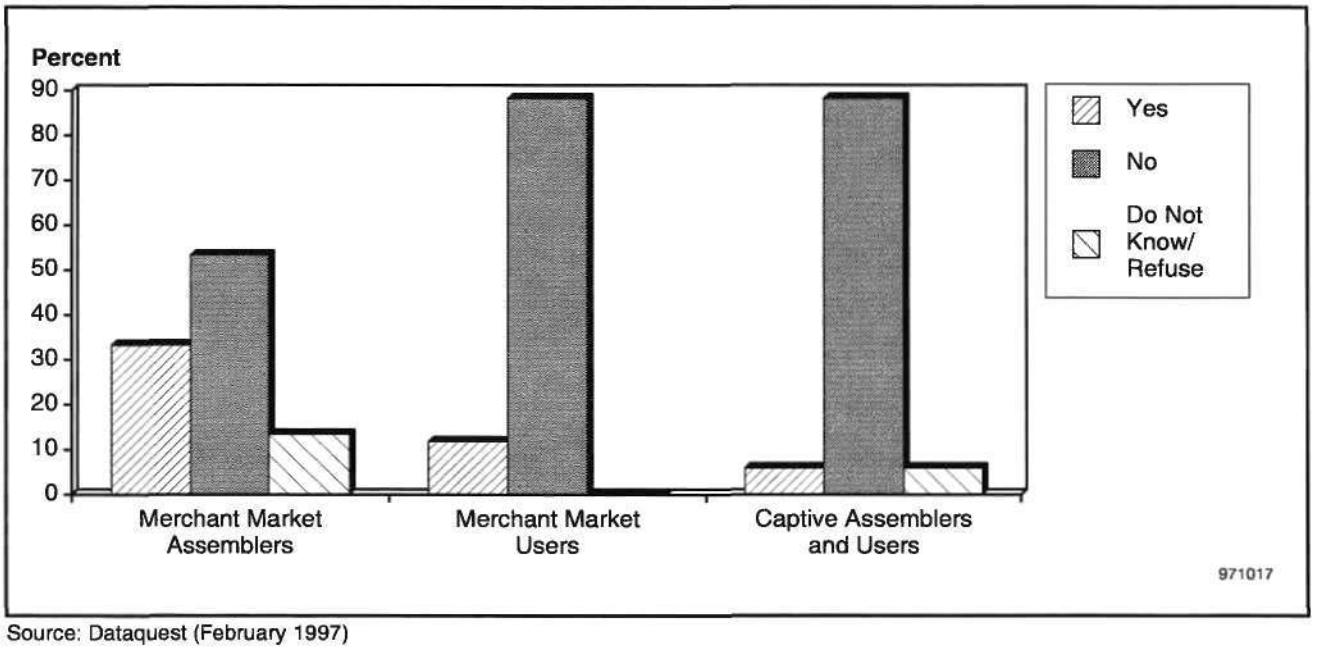
Figure 4-5 shows the results. Again, while there is quite a range of replies, the majority who do not use it at present have no plans to adopt it by the end of 1997. In both the merchant market users and the captive groups, over 88 percent have no plans to start using DCA. The line "Why fix it if it's not broken?" would spring to mind.

The merchant market assemblers group again had a majority of those not using DCA and having no plans to start using it by the end of 1997. However, within this group, the negatives and affirmatives were less polarized. Although 53.3 percent had no plans to use DCA, over 33 percent were planning to use it by the end of 1997. The remainder (13.3 percent) either did not know their companies' plans or refused to answer.

## Comparison of the Three Groups with the Overall Results

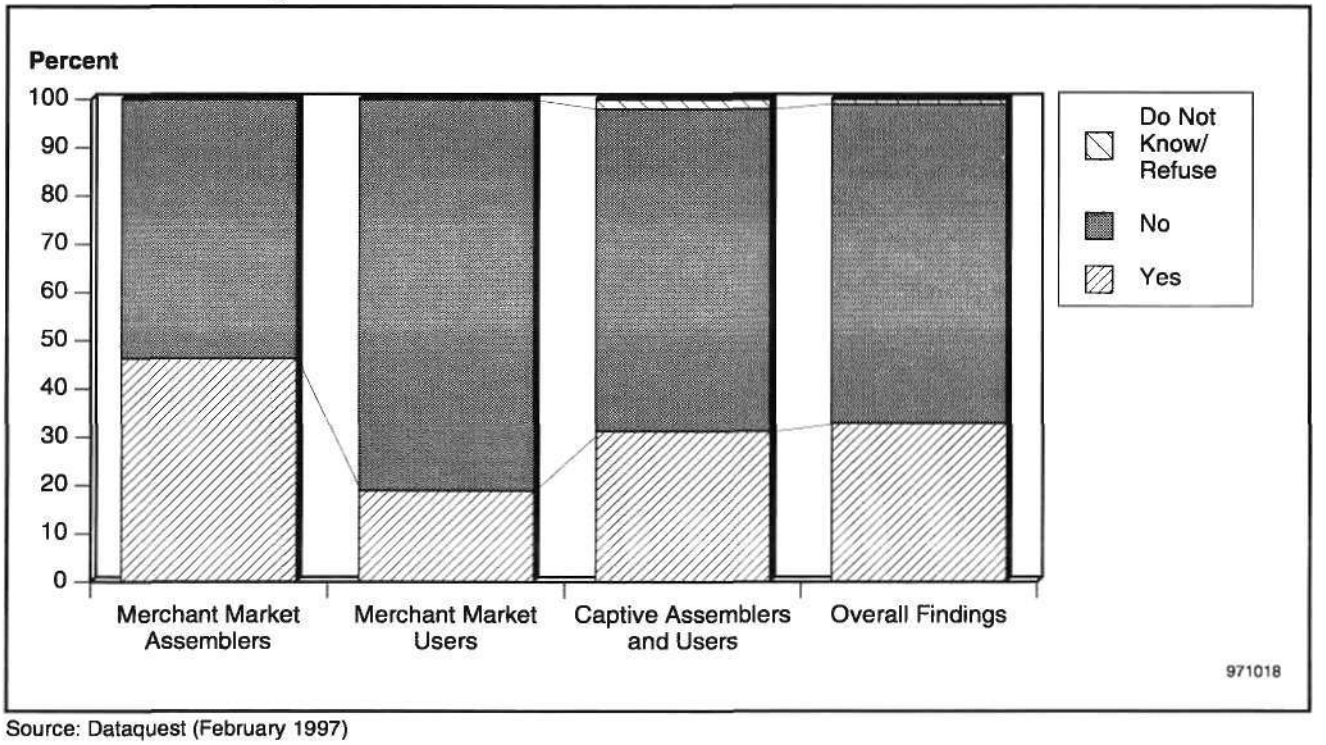
Figure 4-6 clearly shows that the captive group most closely matches the overall results. Both are split about one-third yes, two-thirds no. The merchant market groups vary wildly, both between each other and from the overall/captive split. In the users group, that is, the open market buyers group, well over 80 percent do not use DCA and less than 20 percent do use it. The merchant assemblers, however, are nearer the 50/50 mark. Here, over 46 percent do use DCA and less than 54 percent do not at present.

## Figure 4-5
## Plans to Use DCA by the End of 1997: The Three Groups




Source: Dataquest (February 1997)

## Figure 4-6
## Use of DCA: Comparison




Source: Dataquest (February 1997)

Next, Dataquest compared the findings of those who do not use DCA now and their plans by end 1997.

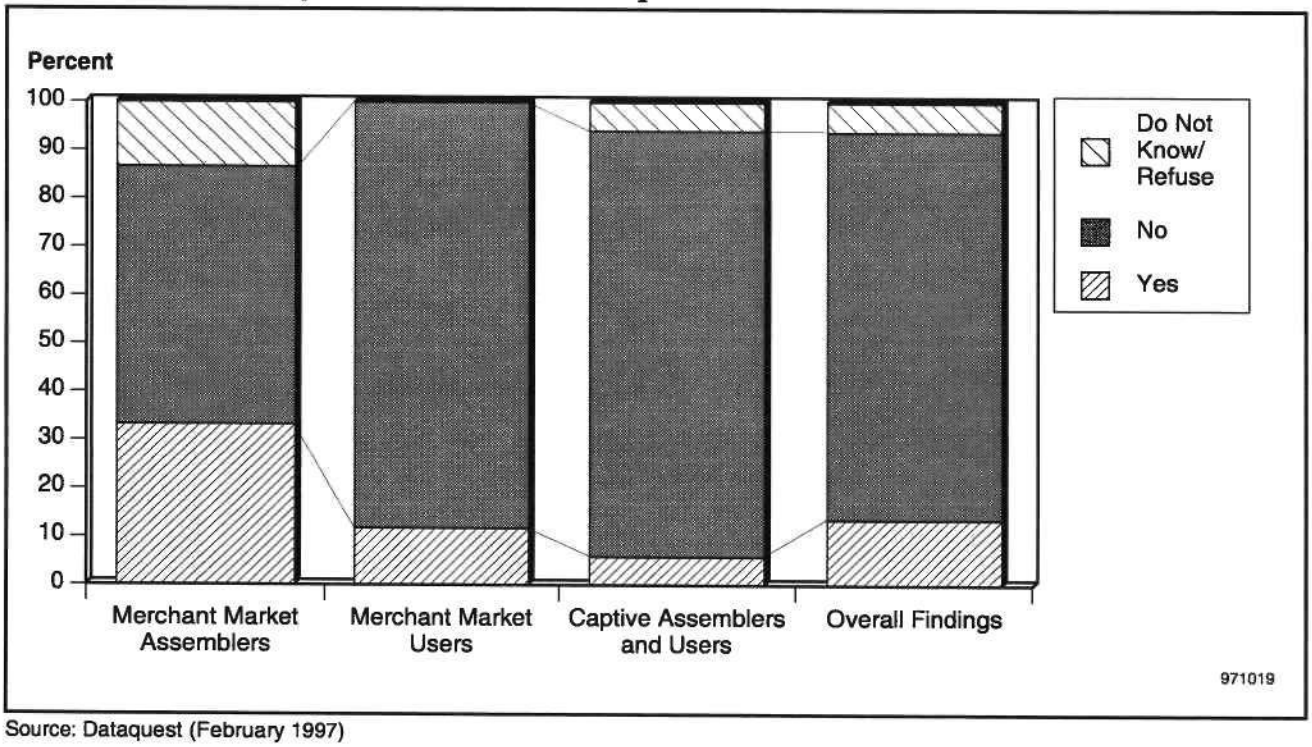
Figure 4-7 shows that there is a range of responses. However, it is the merchant users and the captive group that most closely follow the overall trend, in this case—over 80 percent with no plans to adopt DCA by the end of 1997. The overall figure is just over 80 percent, while 88 percent of both the merchant users and the captive groups gave a negative answer. The merchant assemblers are the exceptions here. Although over 53 percent have no plans to use DCA by the end of 1997, over 33 percent do plan to use it. A little over 13 percent do not know or refused in this group.

## Analysis

These findings are of interest. Although it is not surprising that a majority does not use DCA, it is significant that a third of respondents do. This is a lot higher than was expected for the North America survey, in light of the traditional applications in this region. DCA is a lot more widely used in Japan for consumer-type applications.

The fact that COB is the most popular form of DCA used, in the overall findings and among the captive and merchant users groups, is to be expected. This form of DCA has been around the longest and people feel most comfortable with designing with it or using it.

**Figure 4-7**
**Plans to Use DCA by the End of 1997: Comparison**




Source: Dataquest (February 1997)


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Significantly, as the DCA usage is greatest among the merchant assemblers, their sample percentage of COB is a lot lower than the average. This is largely a reflection of their use of other forms.

The really interesting finding is the percentage of the sample using the more "advanced" forms of DCA, for example, COG and flip chip. This is very telling and indicates the level of design functionality among respondents.

MCM use is also very high and extremely important. Over 15 percent of the merchant assemblers sampled use it. It is especially significant if one considers that this involves the use of bare die, test die, and known good die (KGD), depending on the applications.

TAB is also relatively high. This is obviously bigger in Japan than in the United States, but nearly 13 percent of the overall group sampled use it now.

## Possible Application Implications

Although each form examined falls into the DCA family, the typical and evolving applications of each specific form are different. The following is an outline of just some of the applications for DCA:

- COB: Most applications; often acts as an evolutionary stage before MCM
- COG: Optical semiconductors, LEDs
- COF: Telecom, radio frequency ICs (newer and more advanced)
- MCM: Data processing, industrial, telecom
- TAB: ASICs, laptops, handheld consumer products
- Flip chip: Automotive, data processing, telecom

# Chapter 5
# PCB Layers Used and Lead Times

Dataquest primarily surveyed the IC assembly market. However, all respondents were asked if they procure or use PCBs. Those who did form a subgroup within the overall survey. As very few from the merchant market assemblers group buy or use PCBs directly, this group has been left out of this chapter. The two remaining groups, merchant market users and captive assemblers and users, were surveyed and analyzed.

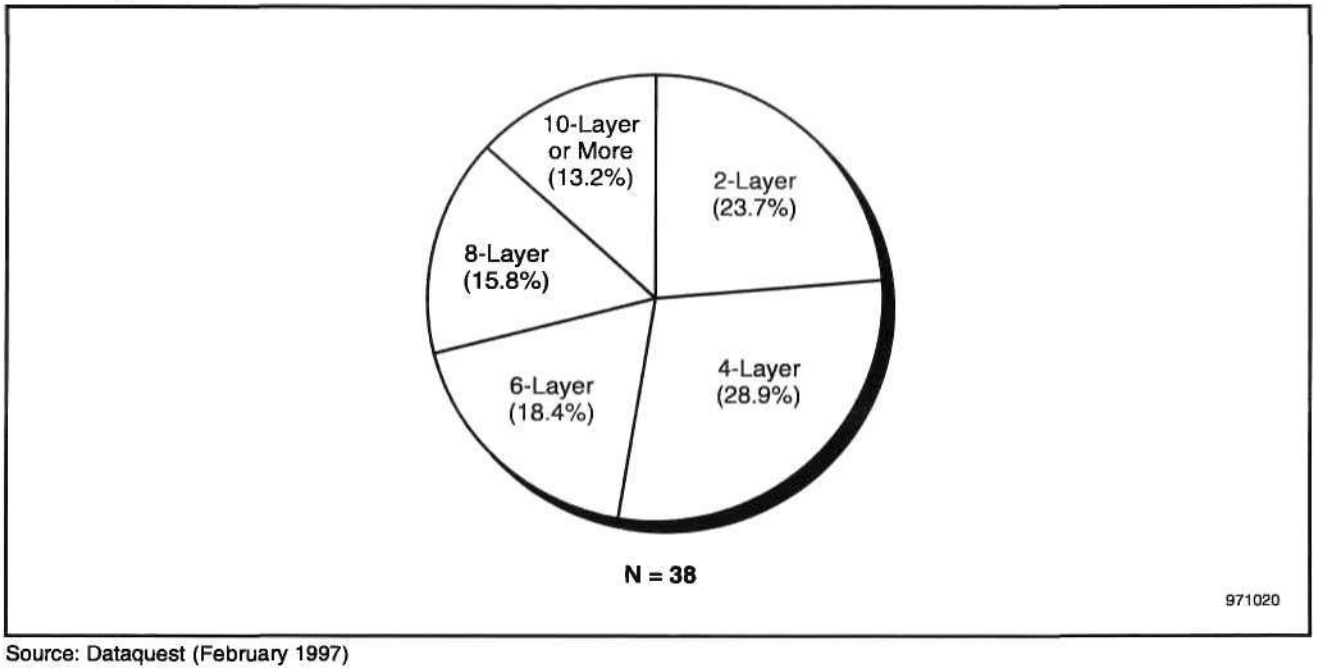
Dataquest wanted to establish what mix of PCB layers was being purchased by the respondents at present and whether this would change in 1997. Also, Dataquest wished to see if lead times differed depending on the number of PCB layers purchased.

## Number of Layers

Firstly, Dataquest sought to discover the PCB layer mix being used by the groups. The respondents were asked to state what they were using or buying at present.

Figure 5-1 shows the sample split for the merchant market users group. For this group, four-layer boards are ranked No. 1—nearly 29 percent of the sample. Two-layer PCBs were ranked second, constituting almost 24 percent of the sample. Thus, over half the sample uses or buys two- and four-layer boards.

**Figure 5-1**
**PCB Layers for the Merchant Users**




Source: Dataquest (February 1997)

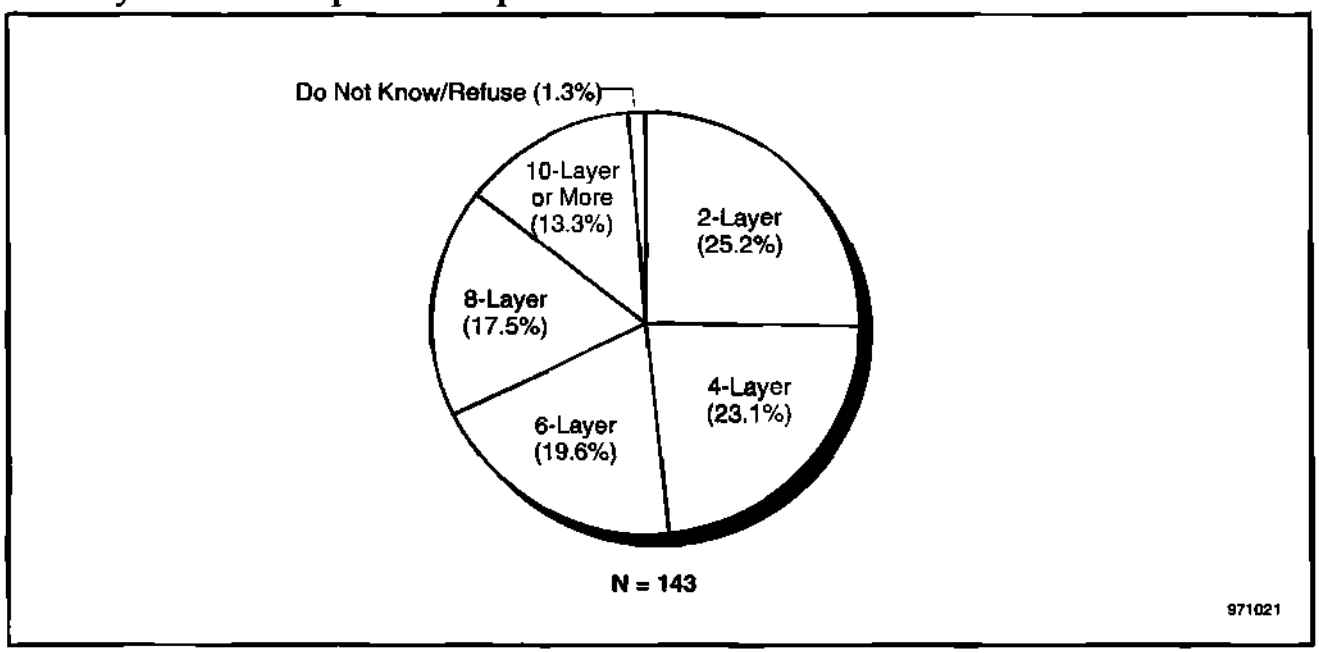
Six-layer boards represented over 18 percent of the sample, eight-layer boards were nearly 16 percent of the sample, and the balance (just over 13 percent) was made up of PCBs of 10 or more layers.

Figure 5-2 shows the sample mix for the captive group. One-quarter of all sampled used or bought two-layer boards, but four-layer boards made up about 23 percent. Thus, there is very little difference between two-layer and four-layer sample mixes. Combined, these make up over 48 percent of the sample.

Nearly 20 percent of the sample used six-layer boards, while over 17 percent bought eight-layer boards. PCBs with 10 or more layers constituted over 13 percent of the sample. In the captive group, just over 1 percent either did not know the boards bought or refused to answer.

Comparing the merchant users with the captive groups, the results are surprisingly similar. There are slight variations between two- and four-layer boards—the merchant users sampled buy more four-layer boards, with the captives buying more two-layer boards. That aside, two-layer and four-layer boards combine to make up nearly half the overall sample in both groups. Between six and 10 or more layers, the percentage in both groups is remarkably similar. One observation is that among the captive group, a higher percentage of the sample bought six-layer and eight-layer boards than the merchant user group. This could be because of proprietary design issues, which may dictate the need for high layer numbers.

**Figure 5-2**
**PCB Layers for the Captive Groups**




Source: Dataquest (February 1997)

## Changing the Mix

Next, Dataquest asked all respondents if their PCB layer mix would change by the end of 1997. The majority surveyed had no plans to alter their mix by then.

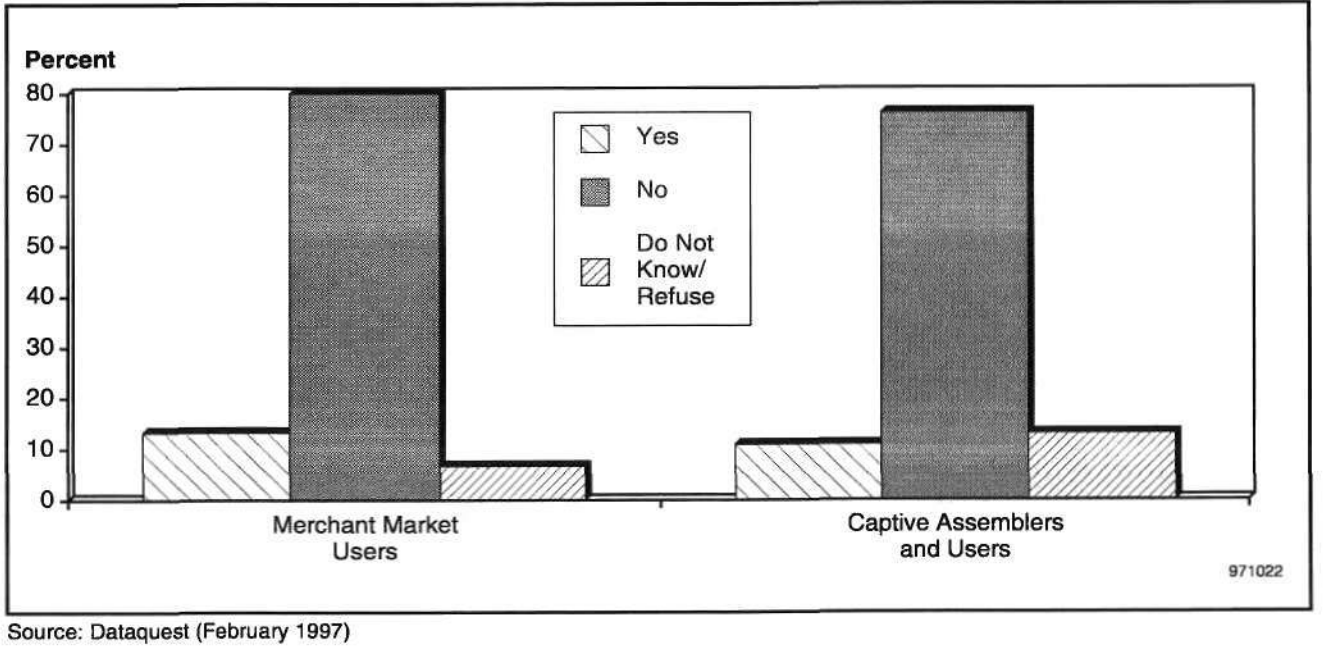
Figure 5-3 shows that well over three-quarters of respondents did not plan to change their mix by the end of 1997. Within the merchant users group, 80 percent had no plans to change, with only slightly over 13 percent planning to alter the mix by year-end. Nearly 7 percent refused to answer or did not know. For the captive assemblers and users group, the picture is similar. Over 76 percent have no plans to change the mix by the end of 1997, with just less than 11 percent planning a change. In this group, a full 13 percent either refused to comment or did not know if their company planned to alter the mix.

## Lead Time versus Layers

Dataquest wanted to see if PCB lead times changed depending on the number of layers.

As shown in Table 5-1, PCB lead times tend to be the same irrespective of the number of layers bought. Over 73 percent of the merchant buyers say that their lead times are the same, with 20 percent saying that lead time differences do exist. The picture was similar for the captive group, as well, with over 65 percent saying that lead times tend to be the same.

**Figure 5-3**
**Likelihood of Changing the Mix by the End of 1997**




Source: Dataquest (February 1997)


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**Table 5-1**
**Are Lead Times Different for Different Numbers of PCB Layers? (Percent)**

| | Merchant Market Users | Captive Assemblers and Users |
|---|---|---|
| Same | 73.3 | 65.2 |
| Different | 20.0 | 30.4 |
| Do Not Know/Refuse | 6.7 | 4.3 |

Source: Dataquest (February 1997)

However, over 30 percent said that some lead time differences exist according to number of PCB layers. This is 50 percent higher than was seen in the merchant users group. Perhaps, as the assemblers are captive, they feel justified in offering different lead times depending on the number of layers bought. Captive user be warned—the merchant market is different. It is perhaps timely to try to standardize lead times with internal PCB vendors.

## Data Analysis

Both groups clearly have a good mix in terms of PCB layers. The split for both merchant users and captives was 50 percent two- and four-layer boards and 50 percent six-layer or more layer boards. What was even more positive was that PCBs of 10 or more layers accounted for about 13 percent of total PCB volumes for both groups. This was certainly evidence that the sample group was at the cutting edge for volume applications and packs a high degree of design functionality in each board.

This has further significance in the area of CAD. For many applications, two-layer and four-layer PCB design can be conducted without the use of a software package. The six-layer PCB is the break point. For six or more layers, software support is required.

Another point that reinforces the conclusion that the current mix of both groups is advanced is that the vast majority had no plans to change the split by the end of 1997. These respondents do not need to play catchup just yet—their mix is well balanced and the penetration level is high.

A very high proportion of respondents obtain the same lead time from their PCB suppliers regardless of the number of board layers. This is a remarkable achievement and shows the degree of negotiating skill of the merchant and captive buyers. It is also, no doubt, related to the forecasting ability of both parties. It was seen in *IC Assembly Update 1996, Report 1* (SPSG-WW-FR-9603), that a strong link exists between shorter lead times and long-term forecasting of demand. It would follow that forecasting long term to book up capacity or warn suppliers of demand changes would make it easier for the supplier to offer common lead times irrespective of the type of board to be made.


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# Chapter 6
# Quality Issues—PCB Inspection and Defect Rate

*IC Assembly Update 1996, Report 1* found that quality was the most important criterion for PCB and IC assemblers' suppliers. In fact, all three groups sampled listed quality as their No. 1 criterion of 12, acknowledging that quality is king in this business. In this chapter, Dataquest wanted to ascertain how the PCB track within the IC assemblers group specifically managed quality-related issues.

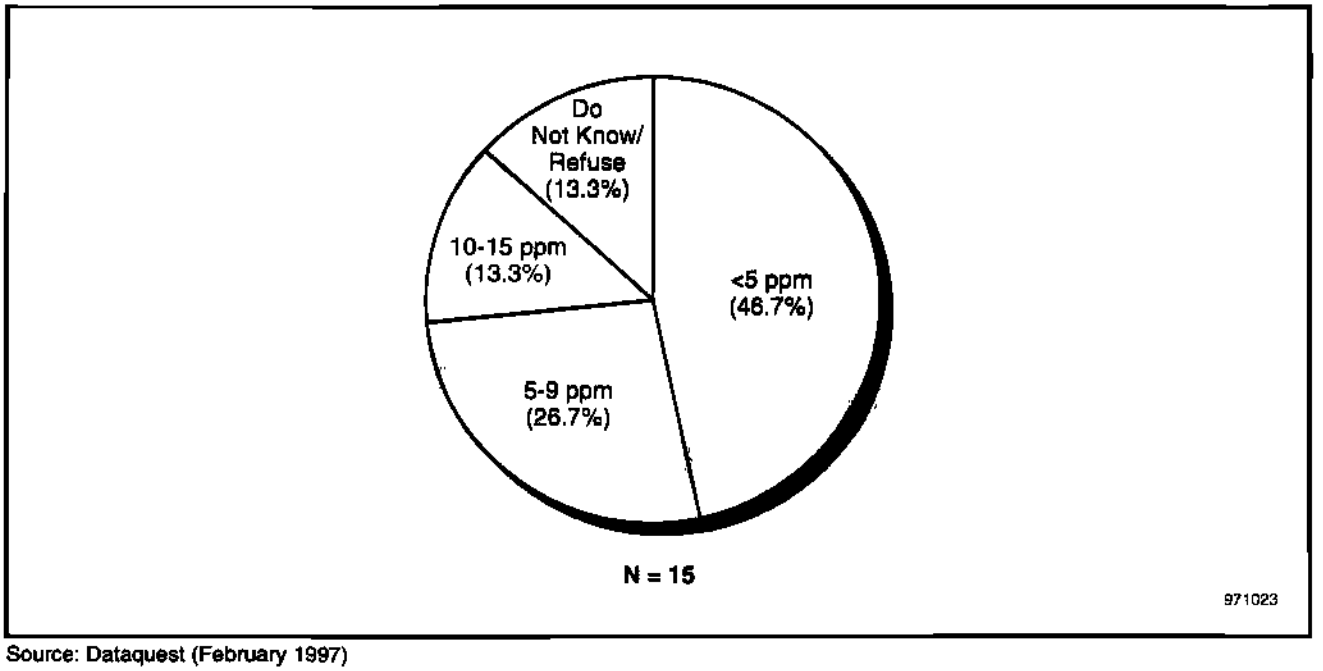
Again, as there was insufficient data from the merchant assembler group, Dataquest focused on the qualifying participants from the other two groups, the captive assemblers and users group and the merchant market users group. The qualifying respondents were asked what their target defect rates were and whether they physically check the PCBs (and if yes, how).

## Target PCB Defect Rate

Dataquest asked the qualifying survey participants what their target number of defects was per million PCBs shipped, expressed in parts per million (ppm), within a designated range.

The most popular defect rate for PCBs among the merchant market user community was under 5 ppm (see Figure 6-1). Nearly 47 percent of respondents chose this selection from the Dataquest ranges. In second place, based on merchant user selection, was the range between 5 ppm and 9 ppm. This was picked by over 26 percent of this survey group. About 13 percent of the sample had a targeted range between 10 and 15 ppm.

**Figure 6-1**
**Target Defect Rate for Merchant Users**




Source: Dataquest (February 1997)

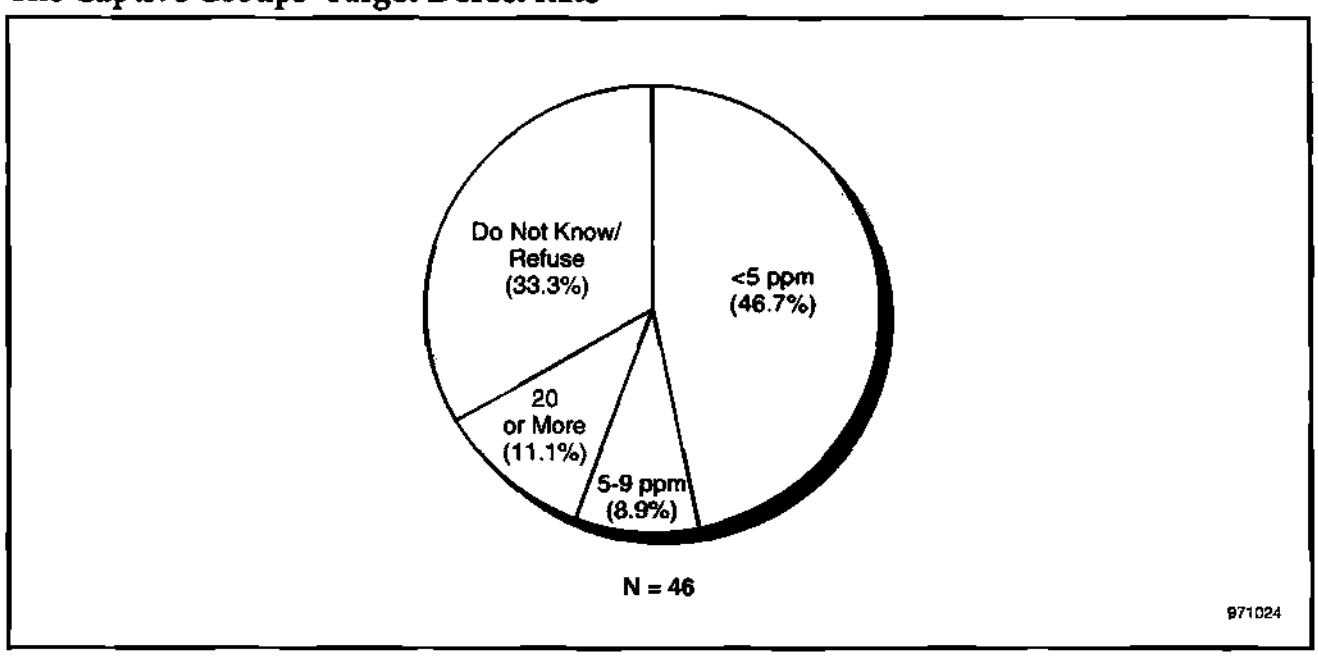
The captive group survey participants were also asked about their target defect rate for PCBs. Figure 6-2 shows that, again, nearly half surveyed had a target rate of under 5 ppm—good news. The second-highest polling came on the 20 ppm and above range, with over 11 percent. The range of 5 to 9 ppm showed slightly under 9 percent. Over 33 percent of those polled either refused to answer or did not know.

## Comparison of Results

Nearly half of the respondents from both groups had PCB defect rates of less than 5 ppm. This would indicate how quality conscious they are as PCB consumers. Also, as the ppm defect rate is meant to be a realistic objective for the PCB suppliers, it would indicate an exceptionally high level of PCB yields at present. These suppliers are obviously doing most things right. The users, by working with their suppliers, can put the necessary checks and measures in place to ensure that the PCBs coming out are almost defect free and thus meet the goal of fewer than five defects per million boards shipped.

One must always remember that the ultimate measure of quality is zero defects—a buyer needs to be fully confident that all parts received meet specifications and will work. No respondent surveyed had this as a current goal. Whether it will become a goal remains to be seen.

**Figure 6-2**
**The Captive Groups' Target Defect Rate**




Source: Dataquest (February 1997)

On the whole, however, the merchant users had higher defects standards. All participants who responded had targets below 15 ppm. The captive group appeared to be more lenient. Over 11 percent had a rate in excess of 20 ppm. Although this rate is not criminally high, it is certainly pushing the envelope of acceptable quality. Would this goal be acceptable if the supplier was external? Is it a case of one standard for an internal division, another for an external company?

Another concern is that one-third of all captive respondents either refused to answer or did not know what their target rate was, compared to about 13 percent in the merchant users group. The hope is that most of that number refused to answer, because the possibility that they did not know their defects rate is quite a worrying scenario.

One factor that should not be ignored is price and suitability. A PCB supplier has to be the correct fit for a company, and the cost per board should cover the quality checks necessary to minimize defect rates on finished PCBs. It is a futile exercise to select the supplier with the cheapest price and greatest defect rate and try to improve quality. The buyers may find out the hard way that the purchase price of the PCB is a fraction of the total cost of ownership. It is far more beneficial to work with a vendor to drive down individual board costs through layout changes, process refinements, and batch size optimization when the defect rate is low. Reliability is higher, and time and hard cash are saved.

It is worth noting, though, that in certain circumstances a higher than average defect rate is tolerable. This may be the case when a PCB layout is extremely complex (high line density) or a board is being prototyped. It may also be acceptable in high-volume, low-cost application where the fault can easily be detected with little or no impact to the buyer and end customer.

## PCB Inspection

Dataquest asked all qualifying respondents whether they physically inspected the PCBs. This check would be conducted at the supplier's premises, at the buyer's location, or at a third-party hub.

Table 6-1 shows the split of those who do and do not physically inspect PCBs bought. Well over 80 percent of both groups perform some form of check on PCBs.

**Table 6-1**
**Physical Checking of PCBs (Percent)**

| | Merchant Market Users | Captive Assemblers and Users |
|---|---|---|
| Yes | 86.7 | 82.6 |
| No | 13.3 | 15.2 |
| Do Not Know/Refuse | 0 | 2.2 |

Source: Dataquest (February 1997)

In the case of the merchant users group, over 86 percent do check the PCBs; about 13 percent do not check. In the captive group, well over 82 percent of those surveyed do check the PCBs procured, with slightly over 15 percent not checking and about 2 percent who did not know or refused to answer.

Those who do perform a physical inspection on the PCBs were asked whether they check all or batches of PCBs bought.

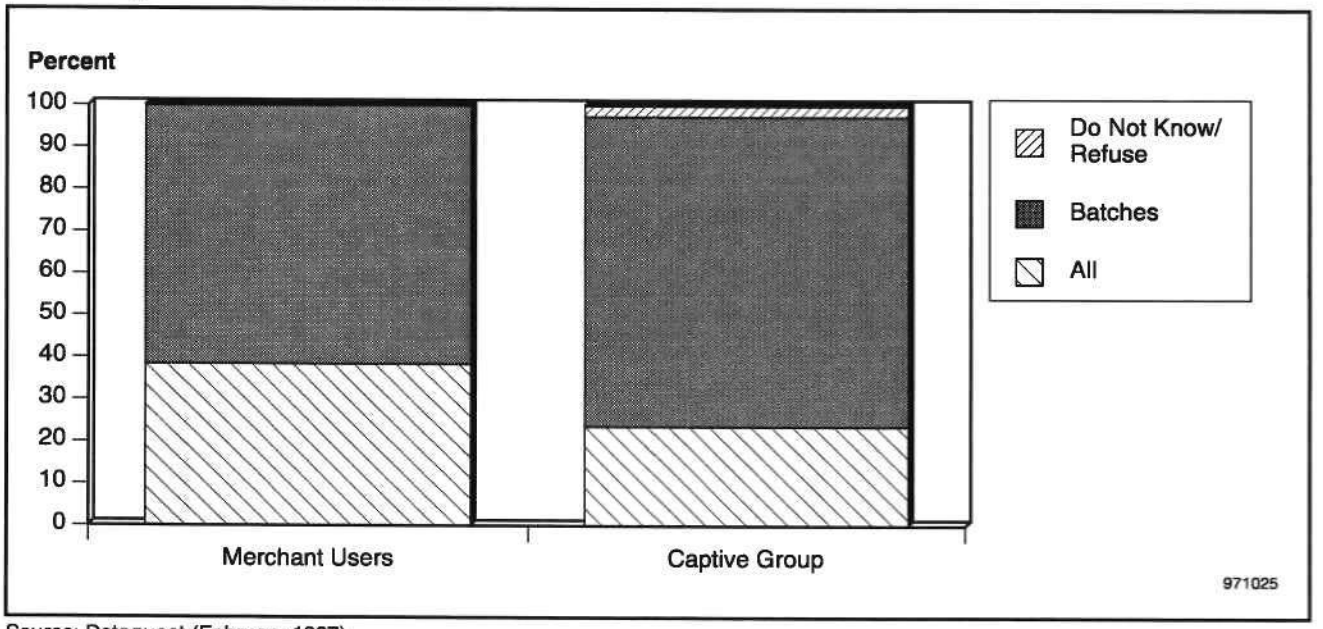
Figure 6-3 shows that the majority of both groups do perform batch inspections on PCBs. However, a significant percentage from both groups check all received PCBs. For the merchant users group, the split between inspecting batches and all PCBs is nearly 60/40. The captive group is more polarized—about one-quarter examine all received PCBs, with three-quarters performing batch inspections.

## Data Analysis

As Table 6-1 showed, a very significant portion of respondents from both groups do perform some form of quality inspection on incoming PCBs. From both groups, this was well over 80 percent.

Of those that perform some physical inspection, Dataquest asked whether batch or total inspection was done. It was imagined that nearly all respondents would conduct batch inspection. Interestingly, this was not the case. Although a majority did perform batch inspection, a significant portion of those surveyed do conduct a physical inspection of all PCBs—this portion was 38.5 percent for merchant users and 23.7 percent for the captive group.

**Figure 6-3**
**Checking All PCBs or Batches**




Source: Dataquest (February 1997)


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This has some interesting dimensions. As the percentage is higher among the external buyers, perhaps it is a reflection of their inherent distrust of their suppliers. Or, the reason could be that the quality history of their PCB suppliers is very poor, and thus a thorough inspection by the buyer's company or agents is the only way to guarantee quality. If this is the case, then clearly these buyers are using the wrong suppliers. It would be far more beneficial to work with suppliers that had a realistic chance of attaining a good quality record and meeting their target defect rate.

There is, of course, another possible explanation. It could well be that the PCB design the buyers' company is using is too difficult to manufacture successfully. If this is indeed the case, then it would reduce costs considerably if the design were re-engineered.

There is a flip side of this, however. There are cases where the trace widths on the PCB are extremely critical. As the designer is pushing the envelope further and further, a certain critical point is reached, and the manufacturer starts running into difficulties producing the boards using current design methods. In this case, there is no solution but to examine all PCBs.

Finally, in some solutions, design of the board is critical and a full inspection is needed. In these cases, this is a far cheaper solution than scrapping everything once a problem has been detected after assembly.

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# Chapter 7
# Analysis and Conclusions

Reviewing the findings of the PCB technology chapter reveals a polarization in technology transition types among the three groups. Although over half of all surveyed groups used less than 50 percent through-hole technology, the degree of use is quite varied among the captive group (under 60 percent), the merchant assemblers (just over 60 percent), and the merchant users (nearly 86 percent). Likewise, about half of the merchant assemblers and the captive group used more than 50 percent SMT, while over 70 percent of the merchant buyers are using more than half SMT.

There was a clear tie-in between a group's current percentage mix of through hole and SMT and any changes the respondents planned to make by the end of 1997. The merchant users group has made the biggest move away from through hole to SMT; they also gave the least positive response when asked if their mix would change. By contrast, over two-thirds of all merchant assemblers planned to change their mix.

What was of most surprise to Dataquest was the responses of the captive group. It was imagined that as assembly work was done internally and goals and company name were shared, a bigger shift toward newer technology forms would be evident. This was not the case—this group was the most conservative of all three surveyed. Also, when asked if they planned to alter their mix by end of 1997, only about 55 percent said they would.

One conclusion to be drawn from the above PCB technology analysis relates to the cost of capital equipment. The merchant users have made no investment in equipment and so can afford to be the most bullish in their migration to newer forms of technology. However, the merchant assemblers and the captive group both had to make investments in equipment that they are writing off over time. That said, though, the merchant assemblers are making a faster transition to SMT—they need to be flexible, or their customers will move business away. The captive group is far less flexible in its technology shift. The captive assembler group knows its customer base cannot go anywhere else and so is change resistant. A word of warning, however: times are changing. There are few guarantees in life—apart from the sun always rising in the east and setting in the west. Captive customers today may be merchant customers in the future as many companies restructure.

Interestingly, advanced forms of technology get a lot of talk time, but Dataquest's sample showed that only a very minor number use a technology that can be classified as advanced. This was true of merchant users, as well, indicating that IC assembler buyers are not requiring more advanced technology forms yet for volume production. Perhaps in a year, as the prototype designs that may now be using advanced forms increase to reasonable volumes, this mix will change.

The results of the direct chip attachment section are also very interesting. Overall, over two-thirds do not use DCA and a resounding majority (over 80 percent) have no plans to do so by the end of 1997, but, again, a considerable uptake variation was seen in the three individual groups. Here, it

was the merchant assemblers who were the most high tech and aggressive in their DCA adoption. Over 46 percent currently use it, and a third of those who do not now use it plan to do so by the end of 1997. The merchant buyers group was the least high tech (under 20 percent of the group use DCA at the moment), while the captive group followed the middle course more often (less than a third use it). These two group are also conservative in their adoption plans—88 percent of those not using it now have no plans to use DCA by the end of 1997.

Not surprisingly, the most popular form of DCA overall was COB. This is a familiar form and one a lot of designers feel comfortable with. Far more significant was the high use of TAB, flip chip, COG, and MCM among the merchant assemblers group. This group is really at the bleeding edge of technology in the North American context. It is clearly seen that this business remains specialized on a global basis. Even though DCA uptake was low among the merchant buyers, the merchant assemblers will continue to find customers internationally, and a large number not currently using it are planning to start to by the end of 1997.

In the mix of PCB boards bought by the groups (by volume), there is quite a wide range. For the captive group, under 50 percent of its total procured volume comprises two-layer and four-layer boards, with the rest at six, eight, and 10 layers and above. The merchant users bought slightly over half at two or four layers, and, again, the rest was at six layers and above. It can be concluded that designs produced by the groups require a large number of layers and as such have a high functionality.

Interestingly, when asked if lead times were the same irrespective of the number of layers bought, most said yes. However, the affirmative response among merchant users (73 percent) was a lot stronger than among the captive group (65 percent). The merchant buyers are trained to reduce total cost of ownership, of which lead time is a significant part. If they cannot get a good lead time from one supplier, they will move else where. Thus, on the whole, their lead times are the same for all. The captive group seemed considerably more limited in its sphere of vision. This group's buying world ends at its sister division. The captive group needs to be more aggressive and demand lead time parity, regardless of the number of board layers. This can significantly reduce ownership costs and will bring this group into line with the outside world.

The findings of the PCB procurement quality section are quite interesting. About half of respondents from both the merchant buyers and the captive groups had a target defect rate for PCBs of less than 5 ppm. This is good news all around, as it demonstrates the high focus procured quality gets within their organizations. It also has echoes of Dataquest's *IC Assembly Update 1996, Report 1*, which showed that quality was the most important criterion for all groups. In order for a target defect rate of less than 5 ppm to be valid, however, it has to be a realistic and attainable goal for the PCB suppliers. The PCB buyers must work with their suppliers to improve quality and acknowledge that "you get what you pay for." A high-quality supplier will usually not have the cheapest sales price per board but will reduce total cost of ownership. Similarly, as half of the PCBs bought by both groups surveyed are six or more layers, complexity increases and the need for a low defect rate increases.

Dataquest asked if the respondents physically inspected PCBs and, surprise, most did—well over 80 percent of both groups. However, a very high percentage inspected all PCBs bought. Either this means that the groups are paranoid about quality or their suppliers have a quality problem. Inspecting all PCBs is a very time- and labor-intensive process and would not be undertaken unless there was a pressing reason. Perhaps, these participants need to:

- Examine who they buy from—is it the correct fix to minimize total cost of ownership?
- Determine a realistic defect rate target and work with suppliers to achieve it
- Simplify board design, where possible, if a board is proving difficult to manufacture
- Regularly audit PCB suppliers to vet quality levels independently
- Do a critical cost analysis and continue to inspect all only as long as it remains cheaper to do this than to scrap finished assemblies

Buyers, however, must acknowledge that some designs are just too difficult to make with low defect rates, as they are at the leading edge of manufacturability. In these cases, only inspection of all will determine the quality level.

Reassuringly, though, the overall majority do inspect PCBs in batches, no doubt having predetermined pass and fail criteria. One interesting point, however: no buyer had a target defect rate of zero. The true measure of quality is zero, meaning the product delivered meets specifications 100 percent of the time. Although this measure of quality is a great idea, the real world would make it very difficult to achieve. Another interesting observation is that none of the buyers, be they captive or merchant, trusted the suppliers' quality inspection and performed no quality check. This shows that it does not matter in what organization buyers sit, they still never fully trust their suppliers. Although this would seem to be a reflection of human nature, it is also an older-fashioned way of purchasing—it would be considerably simpler for the supplier to own the products and be responsible for the goods made until they are used and the end product finally tested. This is a method used in many car factories. If these buyers can achieve this with their suppliers, it may be worth exploring by nonautomotive buyers. If it won't fly, Wilbur, then a way of getting the supplier to pay for the test cost and lost productivity should be instigated. When a buyer hits a supplier where it hurts most (that is, in the bottom line), the supplier has an added incentive to strive to meet quality goals.

A resounding echo from all the data is that the processes of chip design, chip packaging, and PCB production are at vastly different evolution points. It is fair to say that chip design is aeons ahead of volume PCB manufacturing capability. As long as this remains the case, there will be a host of new, advanced PCB design and manufacturing houses springing up like mushrooms. These outfits can meet the challenges of working at the design coal face.

Also, as the volume manufacturers get more and more requests from their clients for newer forms of product, the acquisition of small PCB design houses by larger manufacturers will continue. The hope is to offer a three-punch solution to current problems under the same umbrella—board design, prototype production, and volume production.

Pulling the threads from all the chapter together leads to the conclusion that the coat being woven may be complex, but so far, the pattern is pleasing to the eye.


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**For More Information...**

Evelyn Cronin, Senior Industry Analyst..... (408) 468-8075
Internet address..... evelyn.cronin@dataquest.com
Via fax ..... (408) 954-1780

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## DATAQUEST WORLDWIDE OFFICES


**NORTH AMERICA**

**Worldwide Headquarters**
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: 1-408-468-8000
Facsimile: 1-408-954-1780

**East Coast Headquarters**
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6262

**Dataquest Global Events**
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

Sales Offices:
Washington, DC (Federal)
New York, NY (Financial)
Dallas, TX

**LATIN AMERICA**
Research Affiliates and Sales Offices:
Buenos Aires, Argentina
Sao Paulo, Brazil
Santiago, Chile
Mexico City, Mexico

**EUROPE**

**European Headquarters**
Tamesis, The Glanty
Egham, Surrey TW20 9AW
United Kingdom
Phone: +44 1784 431 611
Facsimile: +44 1784 488 980

**Dataquest France**
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: +33 1 41 35 13 00
Facsimile: +33 1 41 35 13 13

**Dataquest Germany**
Kronstadter Strasse 9
81677 München
Germany
Phone: +49 89 93 09 09 0
Facsimile: +49 89 93 03 27 7

Sales Offices:
Brussels, Belgium
Kfar Saba, Israel
Milan, Italy
Randburg, South Africa
Madrid, Spain

**JAPAN**

**Japan Headquarters**
Aobadai Hills 4-7-7
Aobadai
Meguro-ku, Tokyo 153
Japan
Phone: 81-3-3481-3670
Facsimile: 81-3-3481-3644

**ASIA/PACIFIC**

**Asia/Pacific Headquarters**
Suite 5904-7, Central Plaza
18 Harbour Road, Wanchai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

**Dataquest Korea**
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

**Dataquest Taiwan**
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

**Dataquest Singapore**
105 Cecil Street
#06-01/02 The Octagon
Singapore 069534
Phone: 65-227-1213
Facsimile: 65-227-4607

**Dataquest Thailand**
12/F, Vanissa Building
29 Soi Chidlom
Ploenchit Road
Patumwan, Bangkok 10330
Thailand
Phone: 662-655-0577
Facsimile: 662-655-0576

Research Affiliates and Sales Offices:
Melbourne, Australia
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