Dataquest

a company of
The Dun & Bradstreet Corporation

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

December 1992

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Please move the 1992 Market Statistics, Vendor Profiles, and Dataquest Perspectives into the new binder behind the appropriate tabs.

Attached you will find a checklist of what should be included in the new 1992 binder after the documents have been filed.

You will soon be receiving your 1993 Dataquest binders for storage of all 1993 deliverables.

If you have any questions please contact me at (408) 437-8320.

Sincerely,

Kimberlie C. Southern

Kimberlie C. Southern
Operations Coordinator

1992 Binder 3/24/1993

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Microcomponents *Worldwide*

Dataquest

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

United Kingdom
Dataquest UK Limited
Roussel House,
Broadwater Park
Denham, Nr Uxbridge,
Middx UB9 5HP
England
0895-835050
Telex: 266195
Fax: 0895 835260-1-2

France
Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
(1)48 97 31 00
Telex: 233 263
Fax: (01)48 97 34 00

Germany
Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
West Germany
011 49 89 93 09 09 0
Fax: 011 49 89 930 3277

Japan
Dataquest Japan Limited
Shinkawa Sanko Building 2 Fl
1-3-17 Shinkawa
Chuo-kuTokyo 104
Japan
011-81-3-5566-0411
Telex: 781-32768
Fax: 011-81-3-5566-0425

Korea
Dataquest Korea
Dacheung Building Room 1105
648-23 Yorksam-dong
Kangnam-gu, Seoul 135-80
Korea
011-82-2-552-2332
Fax: 011-82-2-552-2661

Dataquest Incorporated
Ledgeway/Dataquest
The Corporate Center
550 Cochituate Road
Framingham, MA 01701
(508) 370-5555
Fax: (508) 370-6262

Focus: Embedded Processors

User Wants and Needs

Microcomponents *Worldwide*
MCRO-SEG-UW-9201
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Chapter 1
Executive Summary

This first *User Wants and Needs* report from Dataquest's Semiconductors Worldwide Microcomponents service focuses its attention on the ubiquitous embedded processor. Although it does not receive the widespread public attention of its programmable brethren, the embedded processor market is much larger in terms of revenue and unit shipments, more application-focused, and, from a marketing point of view, much more challenging. Because of its diversity and application specificity, the embedded processor marketplace is still filled with opportunity.

It seems fitting to begin this summary with a brief discussion on the importance of cost. Across all three word widths on which this survey focused—8-, 16-, and 32-bit—total system cost was of paramount concern. No other measure of importance received such a high rating. The next closest rating of importance was again cost related. Designers of 8-bit systems place considerable weight on the cost of the processor. Designers of 16- and 32-bit systems also consider processor cost as important, but there is a much larger differential between total system cost and the importance of processor cost for these higher-end embedded processors.

In what appears to be a direct contradiction to the cost issues discussed previously, performance was the overwhelming first choice of all designers when asked what one critical factor would cause them to switch to another processor architecture. Although the designers typically were not using exceedingly high clock rates, it was apparent that quick response to external events and/or interrupts as well as the ability to execute a particular time-critical control loop was of paramount performance. Simply increasing clock speed causes a number of first-order effects: processor cost increases, support component costs increase, power consumption increases, and printed circuit board layout becomes more complex and costly. Each of these adverse effects increases the No. 1 area of concern, total system cost. Solving the performance problem without significantly raising the total system cost is a major opportunity for embedded processor vendors.

Virtually none of the designers surveyed was using fuzzy logic in today's applications, while in excess of 40 percent of these same designers expected to be using fuzzy logic in two years' time. The large majority of designers had definite ideas about what they expected from fuzzy logic. These benefits included increased performance, less program code, and shorter development time.

However, about 15 percent admitted that they did not know why they would be using fuzzy logic, and a few honest souls admitted that it was a requirement from marketing that fuzzy logic be used. Does this mean that we will be bombarded with advertisements and sales collateral extolling the fact that "This system has fuzzy logic inside," without being able to explain what this does for the end user? Let us hope not.

Only a few designers were using a 3V power supply on current designs. However, in two years this increases to the range of 15 to nearly 40 percent, dependent upon processor word width. Applications that can afford the presence of a voltage regulator will be happy to know that JEDEC has officially passed a specification covering a regulated 3.3V power supply. The unregulated committee is still a long way from resolution. Battery-specific issues such as maximum and typical operating voltage as well as useful end-of-life voltage much be taken into consideration. Both suppliers and users of embedded processors should give serious attention to participating in these discussions. This attention can vary from active participation to simply observing. The participation will provide you advance notice of any forthcoming standards as well as offer the chance to steer the committee's decision.

For the sake of readability and overall document size, not all responses could be included in this document. We have endeavored to select those that would provide the most usefulness to our current and future clients. Feedback is welcome and will be taken into consideration for our next *User Wants and Needs* document. Clients of the Dataquest Microcomponents service are welcome to call with questions. Dataquest is also able to perform specific single-user consulting projects relating to this project. For more information on this service, call the Semiconductor Consulting group at (408) 437-8272.

Chapter 2
Introduction

This report focuses on the embedded processor requirements of designers of systems requiring such processors. It comes from a user's perspective. No information gathered for this report, other than suggestions for types of questions, came from a supplier.

The primary sources of data for this report came from an extensive survey conducted by Dataquest's Research Operations group as well as from personal interviews conducted by analysts in Dataquest's worldwide semiconductor organization.

During the development of the questionnaires used for this report, valuable input received by Dataquest's client base was included in the finished survey.

The results are presented in five chapters, as follows: facts about embedded processors, relative merits for choosing an embedded processor, the importance of development tools, factors impacting the processor selection process, and application code. Each section is laid out by first providing a a brief description of results on a given question, which is then followed by a graphical representation of the data, broken out by word width. In almost every instance the data are represented in terms of today's usage as well as the design requirements two years down the road.

Both users and vendors of embedded processors should benefit from the information contained in this report. Vendors will be able to compare their current product offerings against the spectrum of what designers are using. They can then use the two-year outlook to serve as a guideline for product planning. Users of embedded processors will be able to see how they fit in the current user profile, and the two-year outlook will give them a good idea of how close to the mainstream their future microprocessor requirements will fall. Because small consumers do not always receive the same attention from vendors as do large consumers, small users might also use the results of this report with a specific supplier as leverage for providing some new features or capabilities on next-generation embedded microprocessors.

Chapter 3
Facts about Embedded Processors

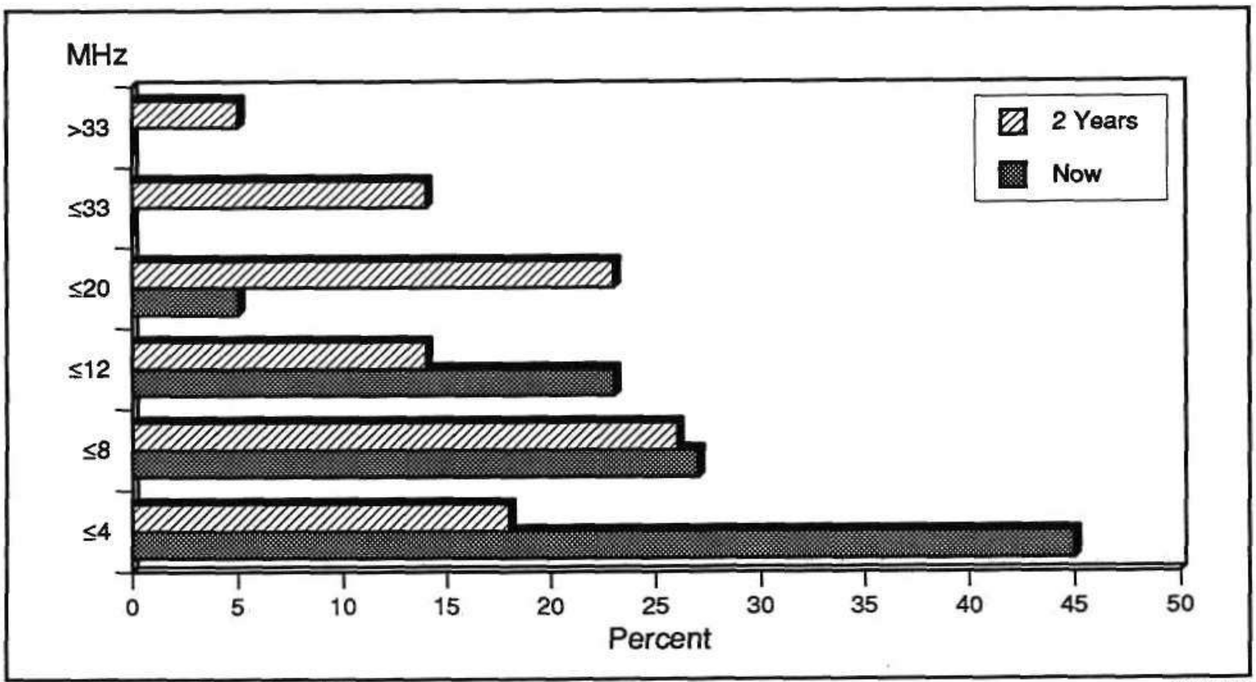
This chapter deals with specific facts relating to the embedded processors: How they are being used and how they will be used in two years.

External Clock Frequency

A correlation exists between processor word width and clock frequency (see Figures 3-1 through 3-3). In the extremely cost-sensitive 8-bit applications, more than 95 percent of the designs operate at or less than 12 MHz. About 40 percent of 16-bit applications operate at or less than 12 MHz, and this can be nearly doubled by offering parts at 20 MHz. In contrast, in the 32-bit environment only 16 percent of the applications can be addressed by a 12-MHz clock. This increases to only 30 percent if the speed is increased to 20 MHz.

For each word width category, designers expect to use much higher performance devices in two years. It is our belief that, although speed requirements are increasing, the rate of change to the higher speeds is slightly exaggerated. This exaggeration is particularly noticeable at the 8-bit level, where 8-bit usage in 4-MHz designs is expected to fall from 45 percent to less than 20 percent in two years. The 32-bit expected growth is less exaggerated because these devices are typically used where performance and cost are more equally weighted.

Figure 3-1
External Clock Frequency, 8 Bit



Source: Dataquest (December 1992)

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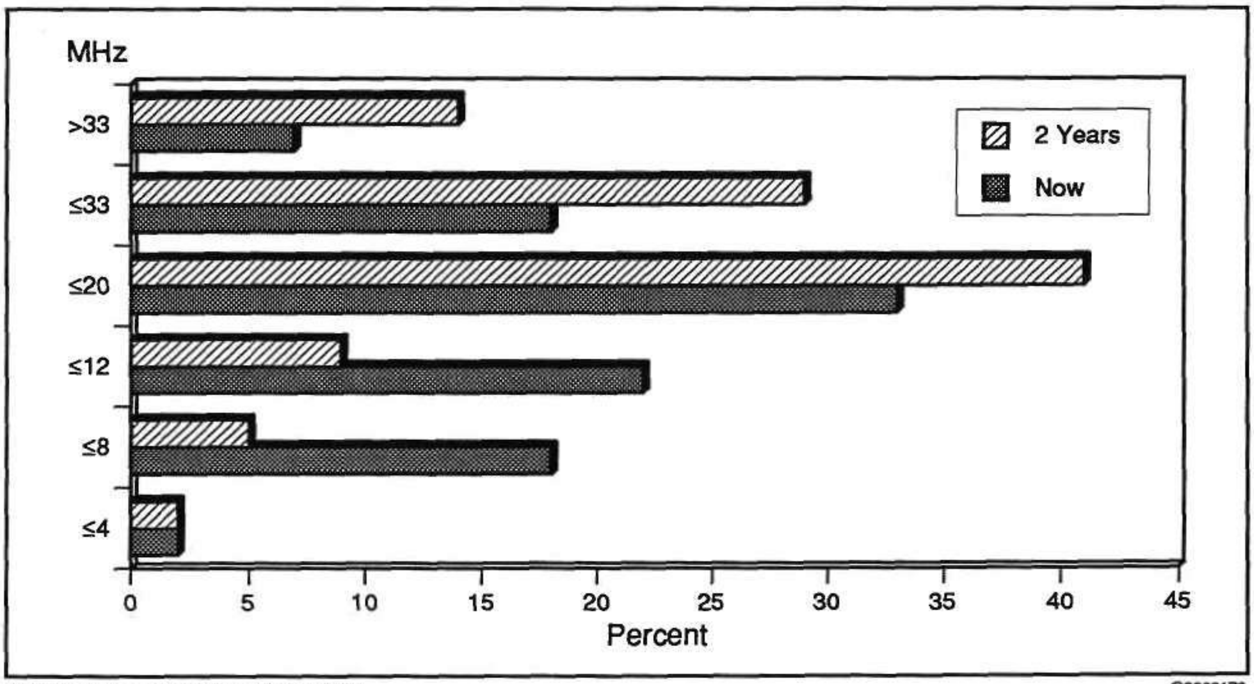
Figure 3-2
External Clock Frequency, 16 Bit



Source: Dataquest (December 1992)

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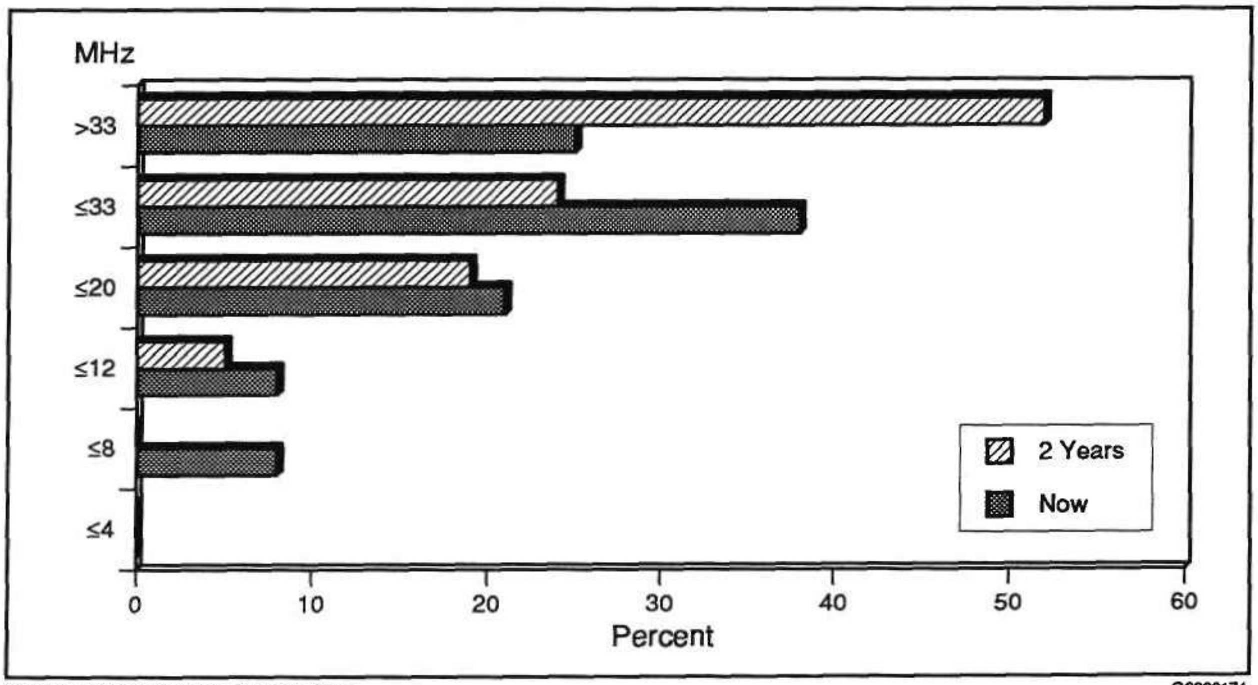
Figure 3-3
External Clock Frequency, 32 Bit



Source: Dataquest (December 1992)

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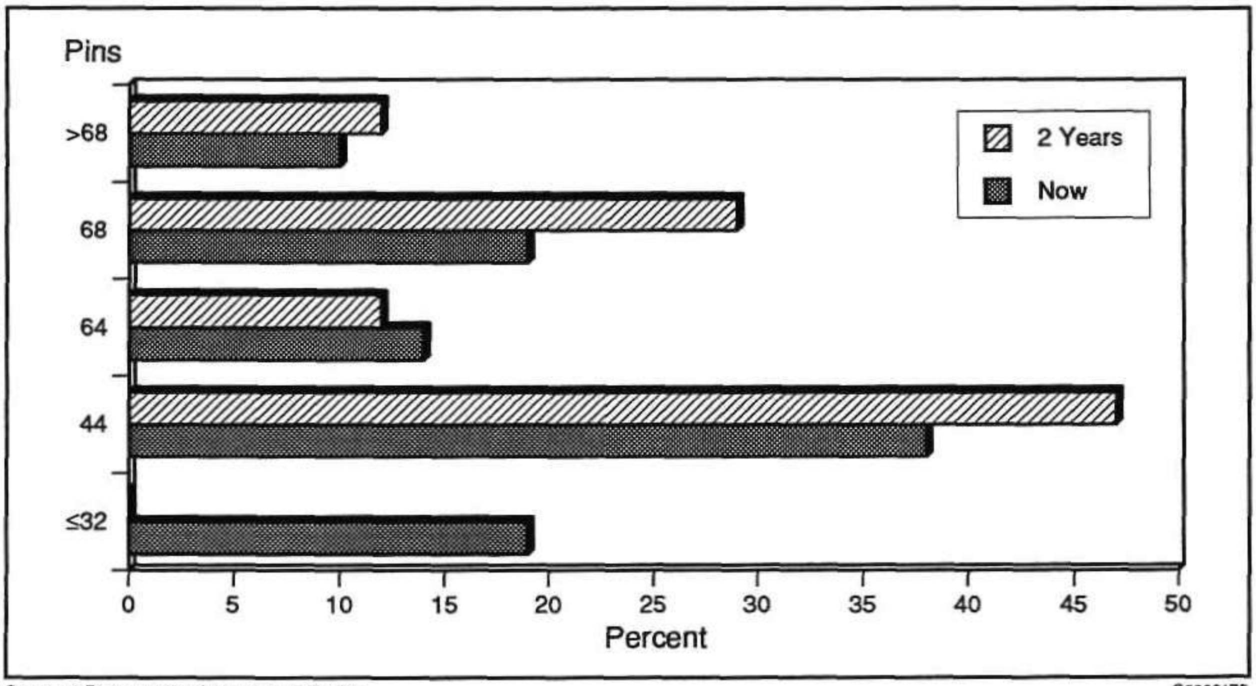
Package Pin Count

Because of the word width, functionality, and cost required of 8-bit processors, more than 50 percent of the applications can be addressed by 44-pin packages (see Figure 3-4). At 68 pins, 90 percent of all 8-bit applications are satisfied.

In the 16-bit world, the 50 percent usage point is reached at 64 pins, but to reach 90 percent application coverage, packages with more than 68 pins are required (see Figure 3-5). The most common pin counts of more than 68 pins were listed as 84 and 100 pins, respectively.

The 32-bit devices clearly require very high pin count packages. The scope of this survey does not adequately cover this high-end requirement where only 20 percent of all 32-bit applications can be satisfied by a package of 68 pins or less (see Figure 3-6).

Figure 3-4
Package Pin Count, 8 Bit



Source: Dataquest (December 1992)

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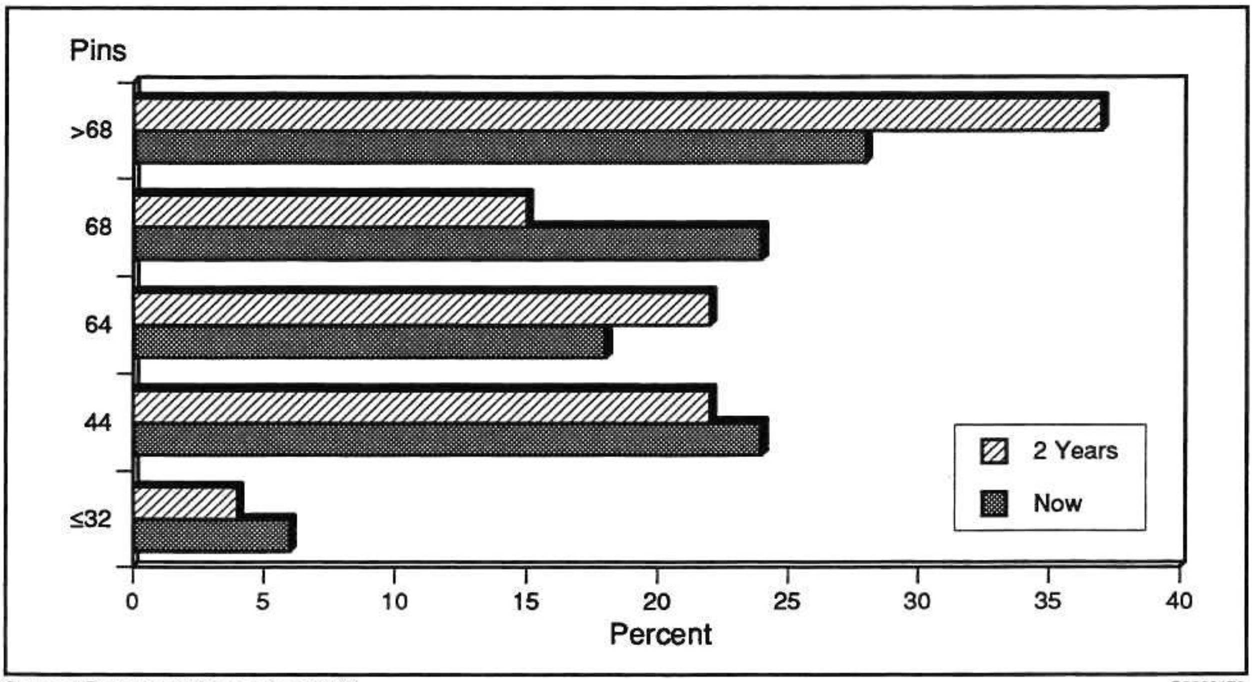
Figure 3-5
Package Pin Count, 16 Bit



Source: Dataquest (December 1992)

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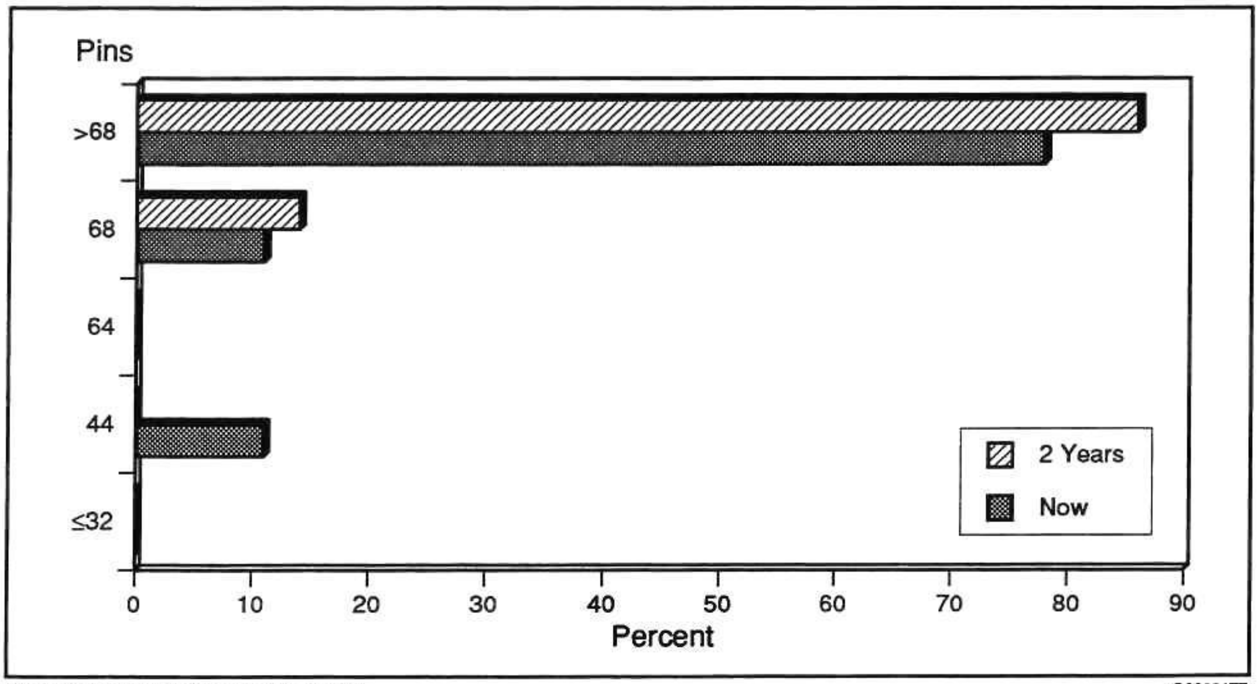
Figure 3-6
Package Pin Count, 32 Bit



Source: Dataquest (December 1992)

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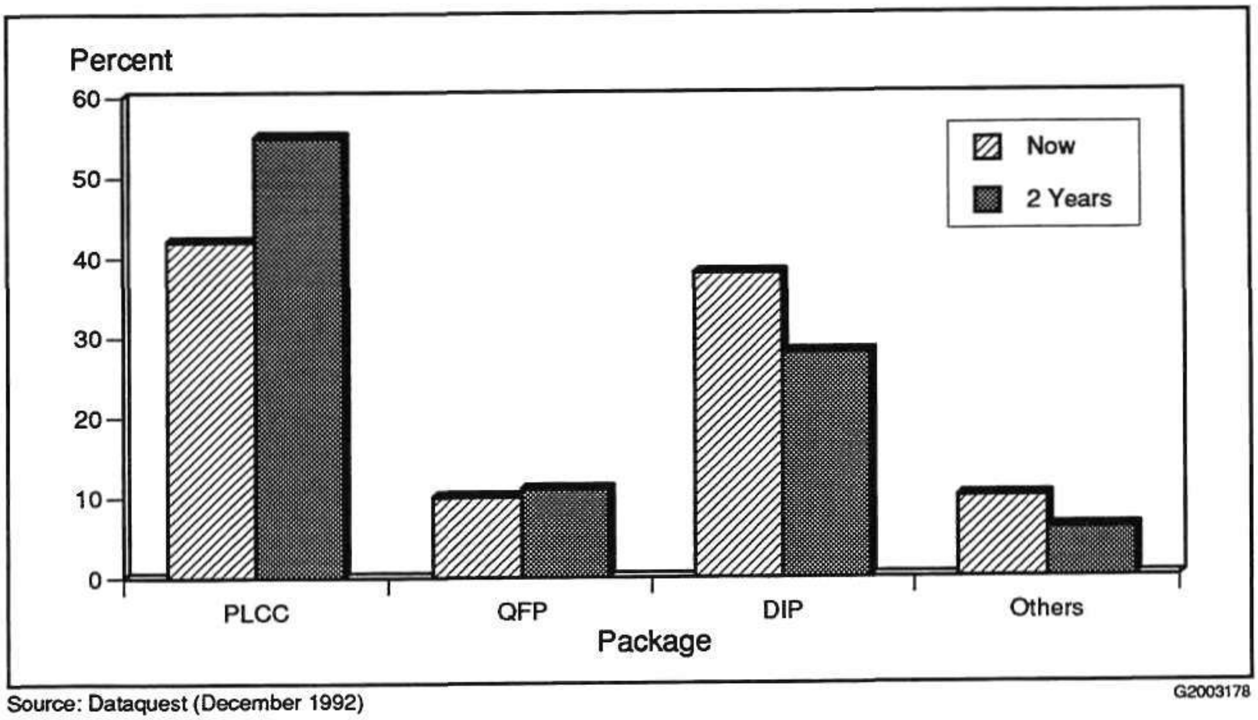
Package Type

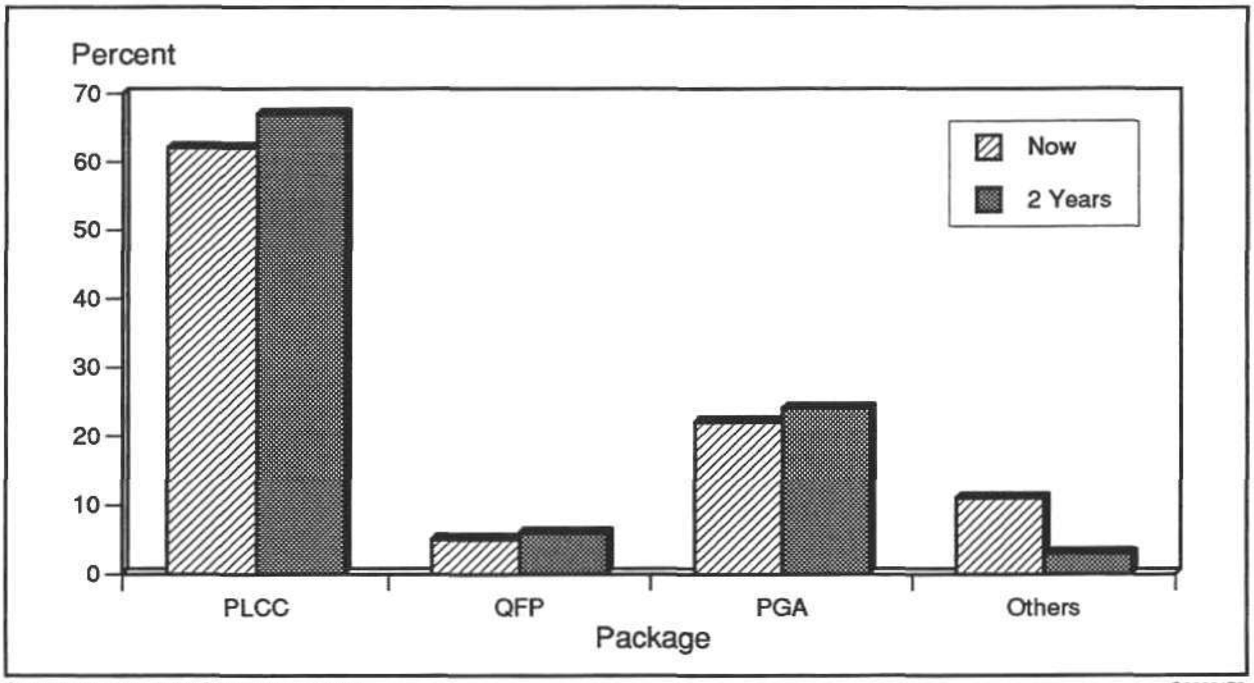
Figures 3-7 through 3-9 address the package types of the various word width embedded microprocessors. Because of their relatively low pin count and low cost requirements, 8-bit processors can typically fit into low cost dual-in-line packages (DIPs) and plastic leaded chip carriers (PLCCs). These two package types cover 80 percent of all 8-bit applications. This same application coverage is still expected in two years' time, but the mix will move from 50/50 to 56 percent PLCC and 28 percent DIP. This is no doubt driven by the fact that the 44- and 68-pin PLCCs are well understood by the manufacturing community and that they provide adequate pin count for most 8-bit applications. The pin-count requirements of 16-bit processors require a slightly different mix than that of 8-bit processors (see Figures 3-7 and 3-8); 84 percent of 16-bit applications can be satisfied using PLCC or pin grid array (PGA) solutions. PLCCs are the package of choice by a ratio of nearly 3:1 over PGAs. This same relationship is expected to continue over the next two years, with slight growth for both package types. The high pin count and performance requirements of 32-bit processors require a different package mix than either 8- or 16-bit devices. Because of their superior performance capabilities and high pin count offerings, PGAs are preferred by a ratio of more than 2:1 over quad flat packs (QFPs). Because of recent advances in QFP packaging in the areas of both performance and power dissipation, it is expected that QFP usage will grow to nearly match the usage of PGAs in just two years.

Figure 3-7
Package Type, 8 Bit



Source: Dataquest (December 1992)

Figure 3-8
Package Type, 16 Bit



Source: Dataquest (December 1992)
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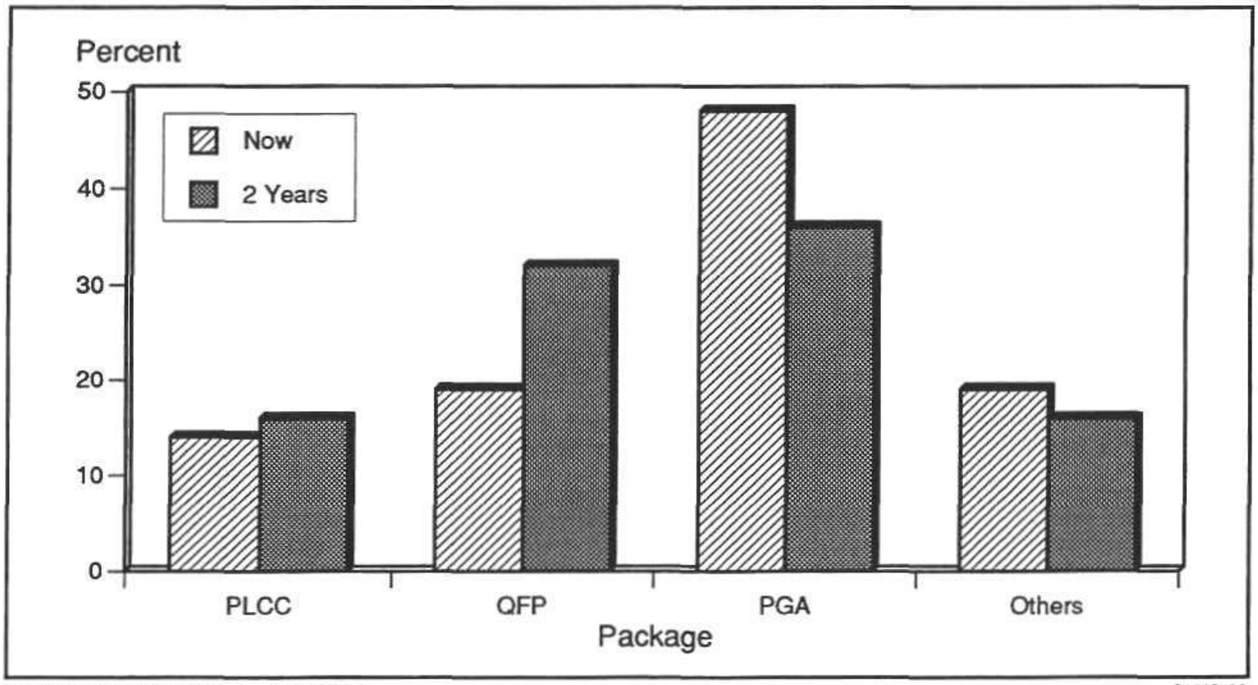
Figure 3-9
Package Type, 32 Bit



Source: Dataquest (December 1992)
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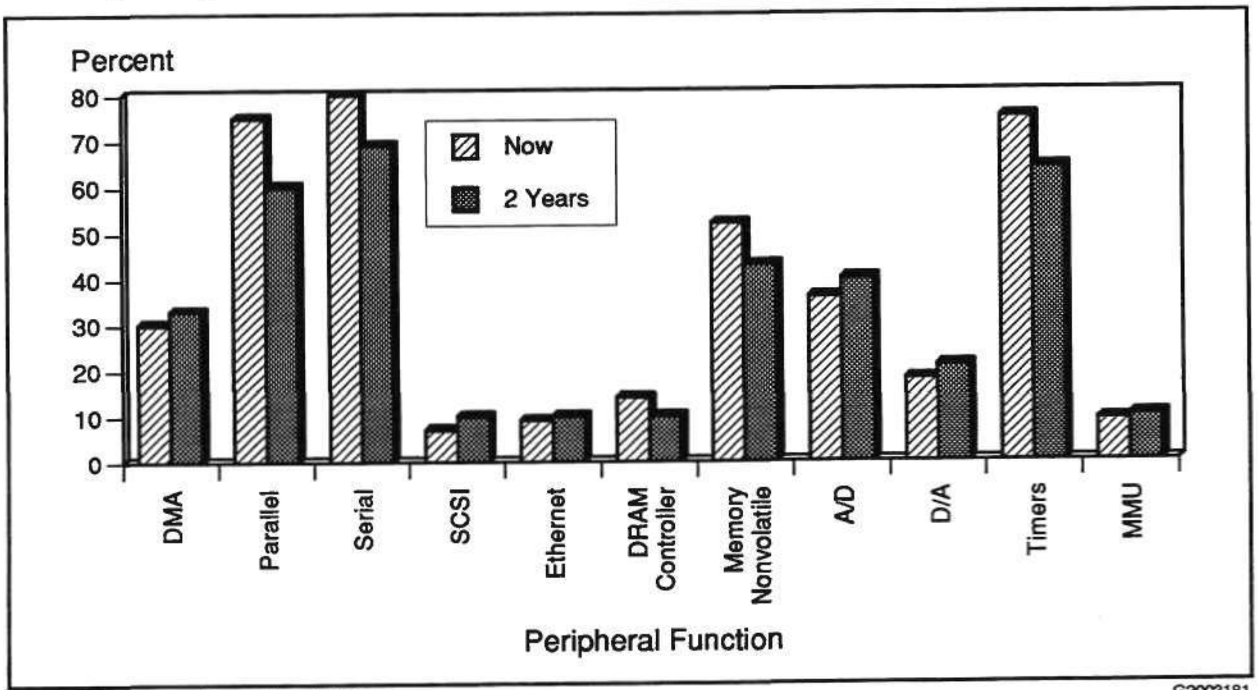
On-Chip Peripheral Functions

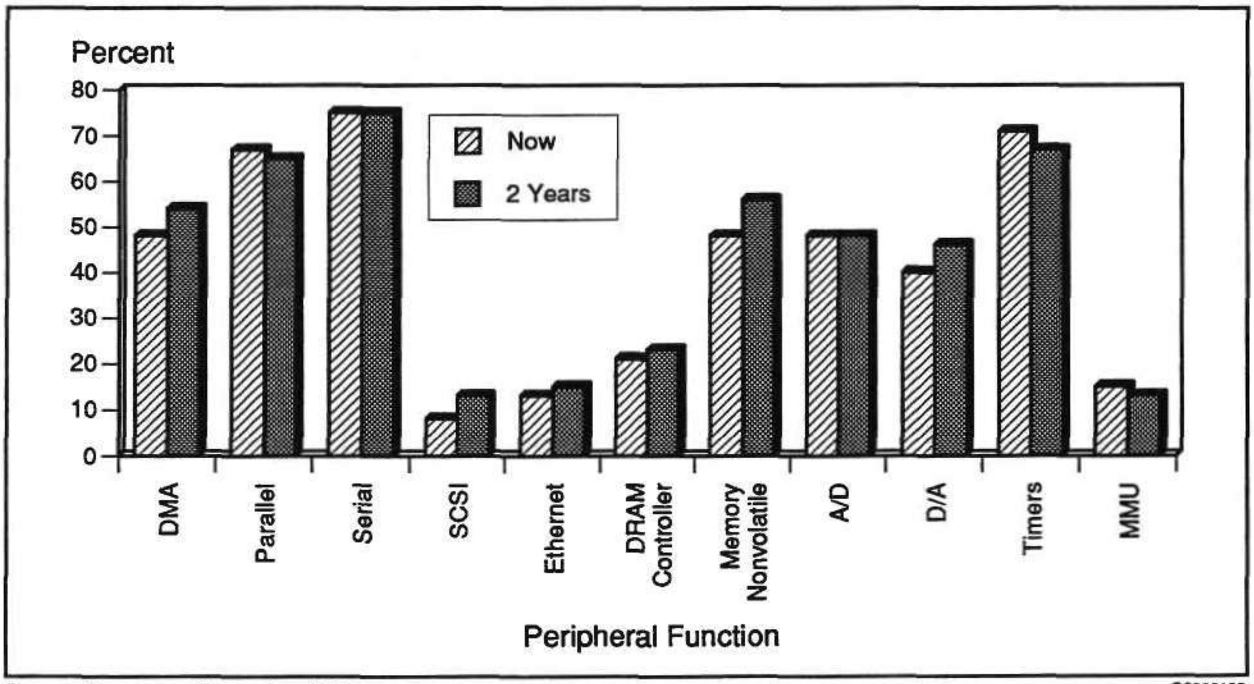
All word widths rely upon serial ports and timers (see Figures 3-10 through 3-12). With the development of the controller area network standard, we expect increased reliance upon serial communication. In both the 8- and 16-bit applications we see a strong requirement for parallel ports. These processors are more efficient at bit manipulation and are more cost-effective for many control tasks than are 32-bit devices. The high DMA usage of 32-bit processors indicates that these processors are more involved with the movement of large amounts of data than are their smaller cousins. The lower requirements for parallel ports in 32-bit processors seem to support the assumption that they typically work in conjunction with one or more 8- and/or 16-bit processors. The 32-bit processors are used for the computation-intensive and high-speed data movement tasks and the smaller processors are more directly involved with specific control functions that require fast interrupt response, efficient timing control, and bit manipulation, among others. Of the 40 to 60 percent of processors that require on-board nonvolatile memory (NVM) for program store, most designers expect their next-generation product to contain a cost-efficient electrically erasable memory such as flash. The electrically erasable requirement increases with processor cost. The next most common on-chip peripheral functions required are analog-to-digital and digital-to-analog converters, respectively; across all word widths, 30 to 50 percent of all embedded processors require the ability to convert an analog signal to a digital representation of that signal. Only 18 to 40 percent expect to perform the reverse conversion on-chip. The processors that do employ a digital-to-analog conversion reply primarily upon a pulse width modulated (PWM) approach. Another

Figure 3-10
On-Chip Peripheral Functions, 8 Bit



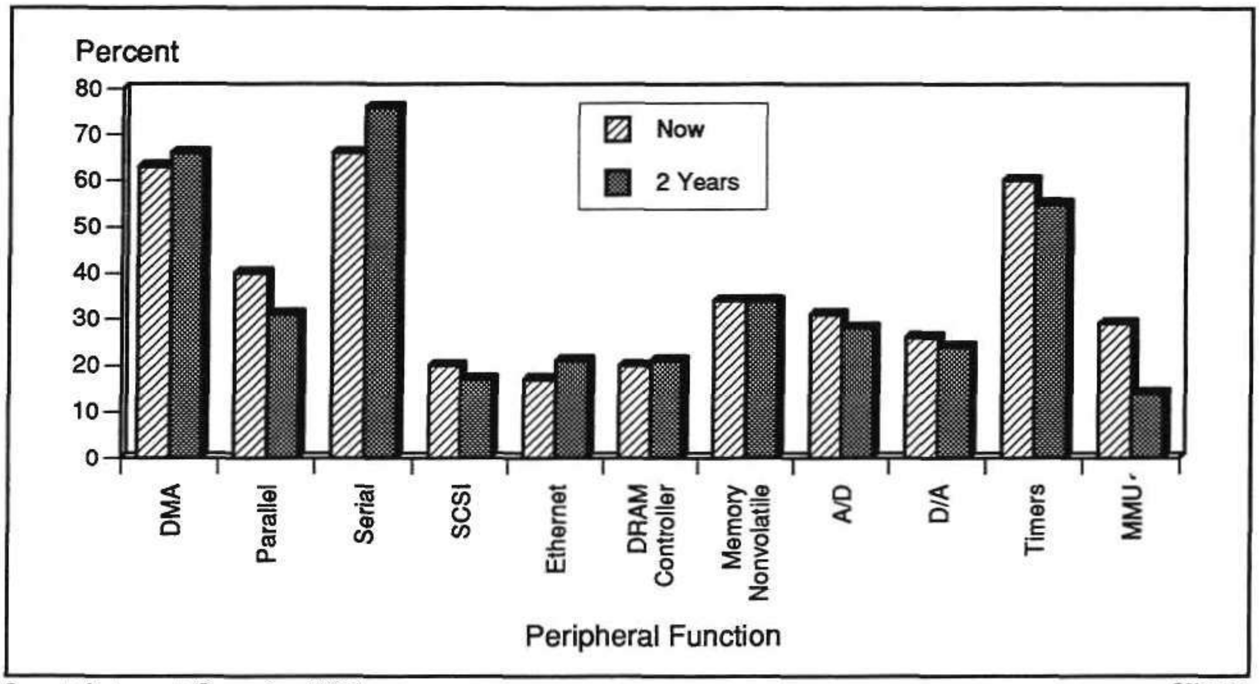
Source: Dataquest (December 1992)

Figure 3-11
On-Chip Peripheral Functions, 16 Bit



Source: Dataquest (December 1992) G2003182

Figure 3-12
On-Chip Peripheral Functions, 32 Bit



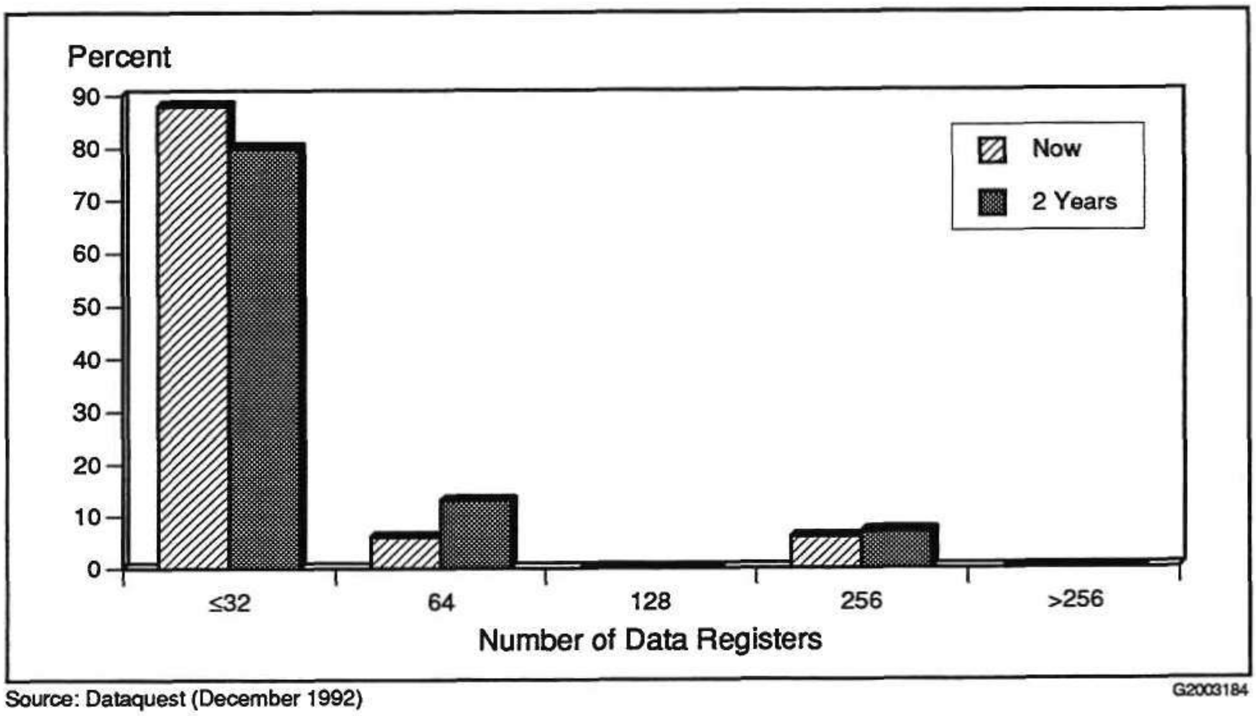
Source: Dataquest (December 1992) G2003183

alternative to digital-to-analog conversion is offered by several processors that provide a PWM output and rely upon system designers to implement their own analog conversion.

On-Chip Data Registers

On-chip data registers typically are a part of the basic architecture of the processor, but while a majority of designers are getting along with 32 data registers (see Figures 3-13 through 3-15), the high-level languages being used for software development today typically are more efficient in a register/accumulator-based machine. Because most embedded processor applications contain at least one timing critical control loop, it would seem that compilers and architectures need to be jointly fine-tuned to provide the most efficient solution.

Figure 3-13
On-Chip Data Registers, 8 Bit



Source: Dataquest (December 1992)

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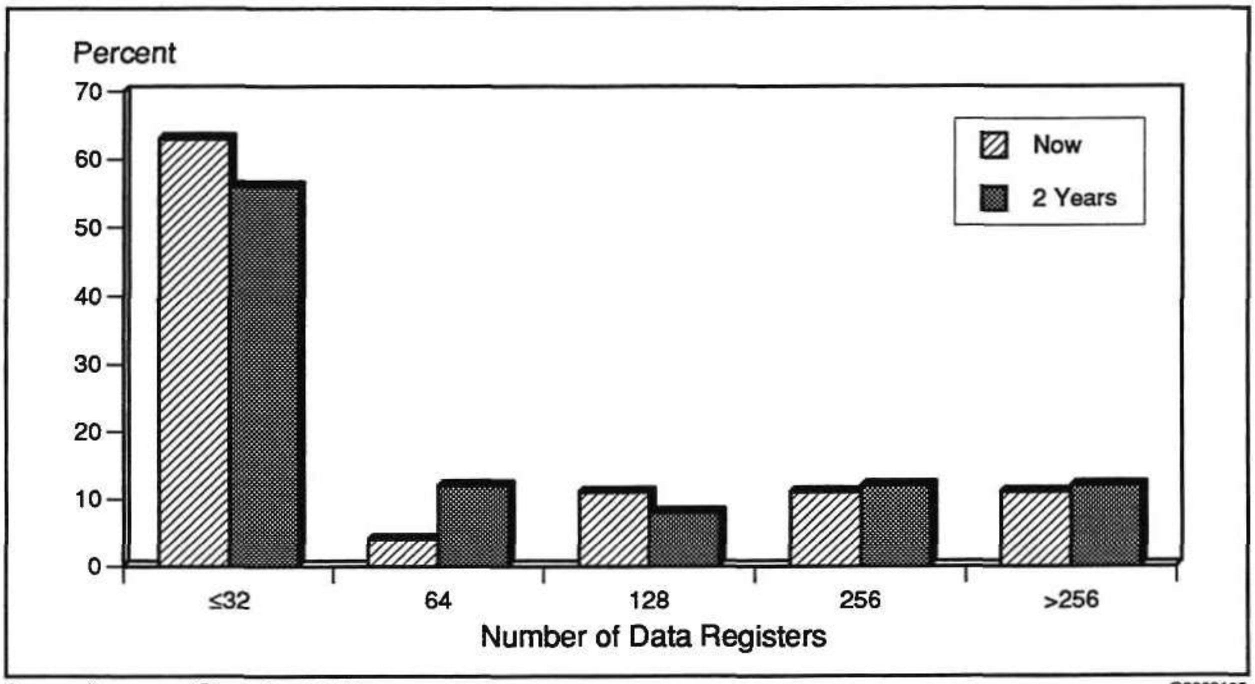
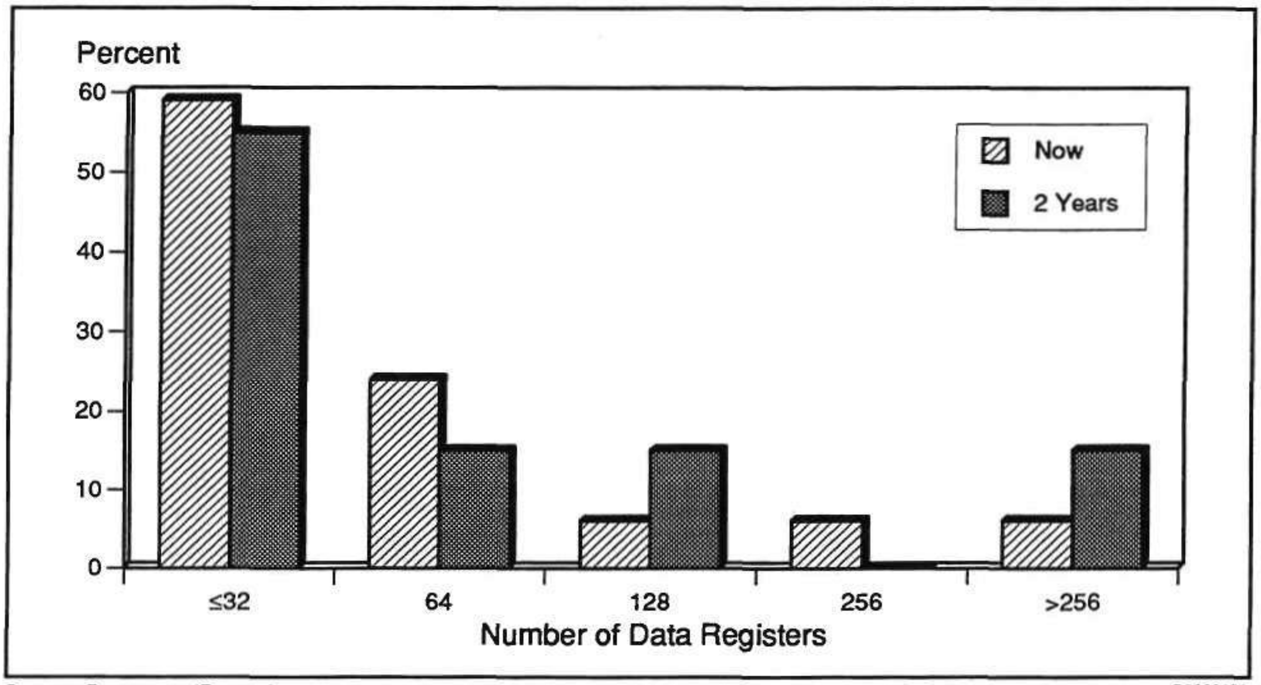
Figure 3-14
On-Chip Data Registers, 16 Bit



Source: Dataquest (December 1992) G2003185

Figure 3-15
On-Chip Data Registers, 32 Bit



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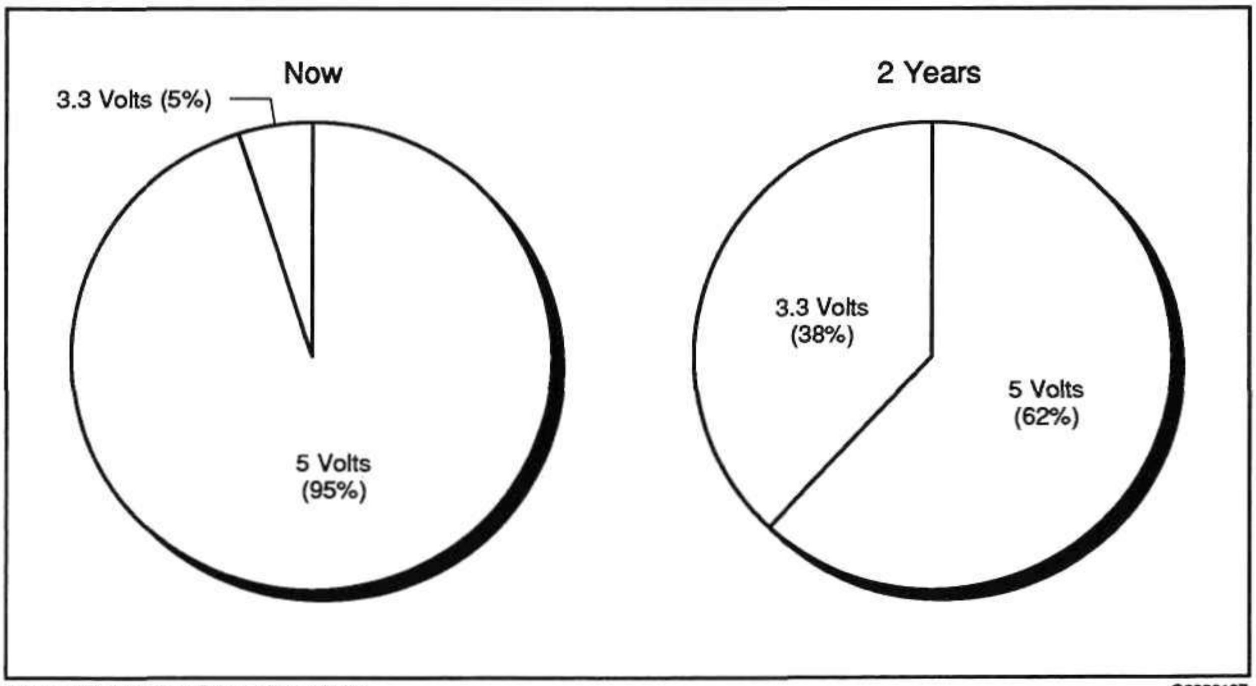
Supply Voltage

Although relatively few applications require 3V operation today (see Figures 3-16 through 3-18), that is expected to change significantly in the next two years. The conversion to 3Vs in the embedded processor world has already occurred in some portable devices, but the mainstream move is still awaiting general availability of 3V-compatible products. This issue should be addressed by the recent adoption of a regulated 3V standard by the JEDEC council. Many suppliers were waiting for a standard to be formally adopted before spending the resource dollars required to convert products to a 3V supply. On the downside, many 8-bit hand-held applications operate from an unregulated 3V supply consisting of two "AA" or NiCad batteries. Unfortunately, the JEDEC standard does not cover the unregulated environment.

Some level heads on the unregulated 3V JEDEC committee finally convinced the majority of the committee members to first listen to battery manufacturers before putting a standard together. Unregulated 3V is not a simple matter. It is not uncommon for fully charged NiCad batteries to reach 1.6V, which translates to 3.2V in a typical two-cell system. Under a load, both NiCad and alkaline batteries quickly discharge to their nominal operating voltage of 1.2V, or 2.4V for two AA cells. Each of these batteries has a useful end of life voltage of about 0.9V. Under this simple scenario, an IC would have to be able to operate over a voltage range of 1.8V to 3.2V in a typical two-AA-cell system. Thus far, the JEDEC committee has not considered a

Figure 3-16
Supply Voltage, 8 Bit



Source: Dataquest (December 1992)

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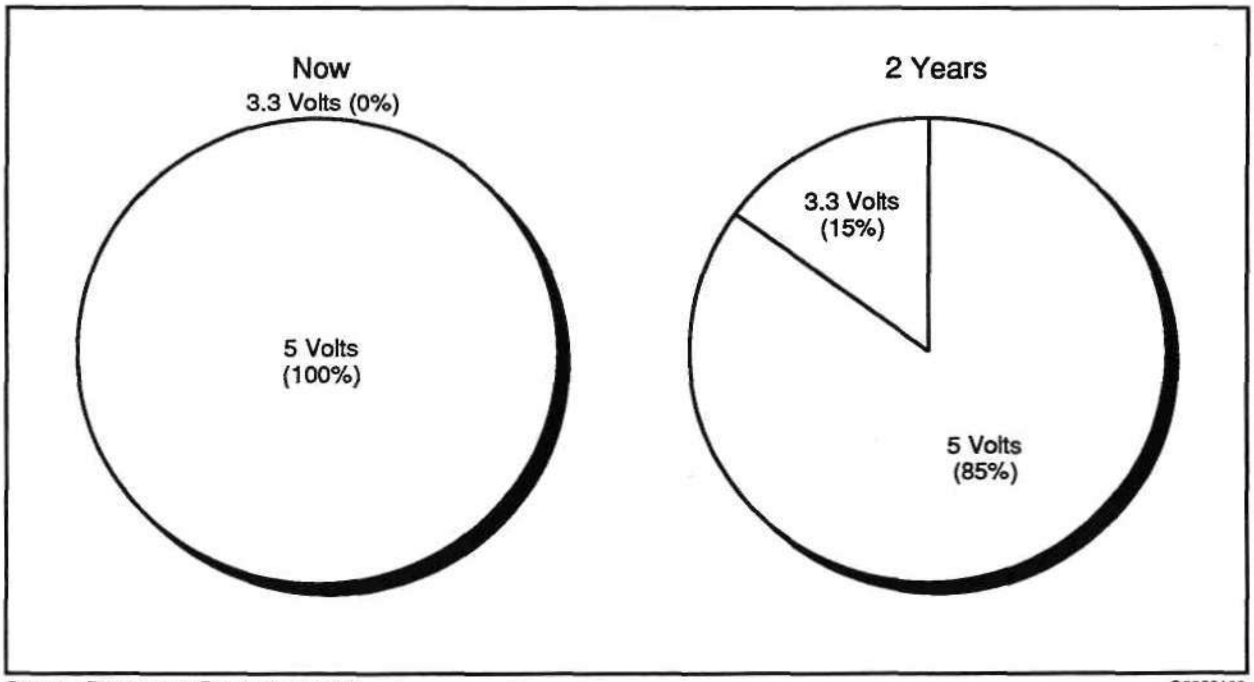
Figure 3-17
Supply Voltage, 16 Bit



Source: Dataquest (December 1992)

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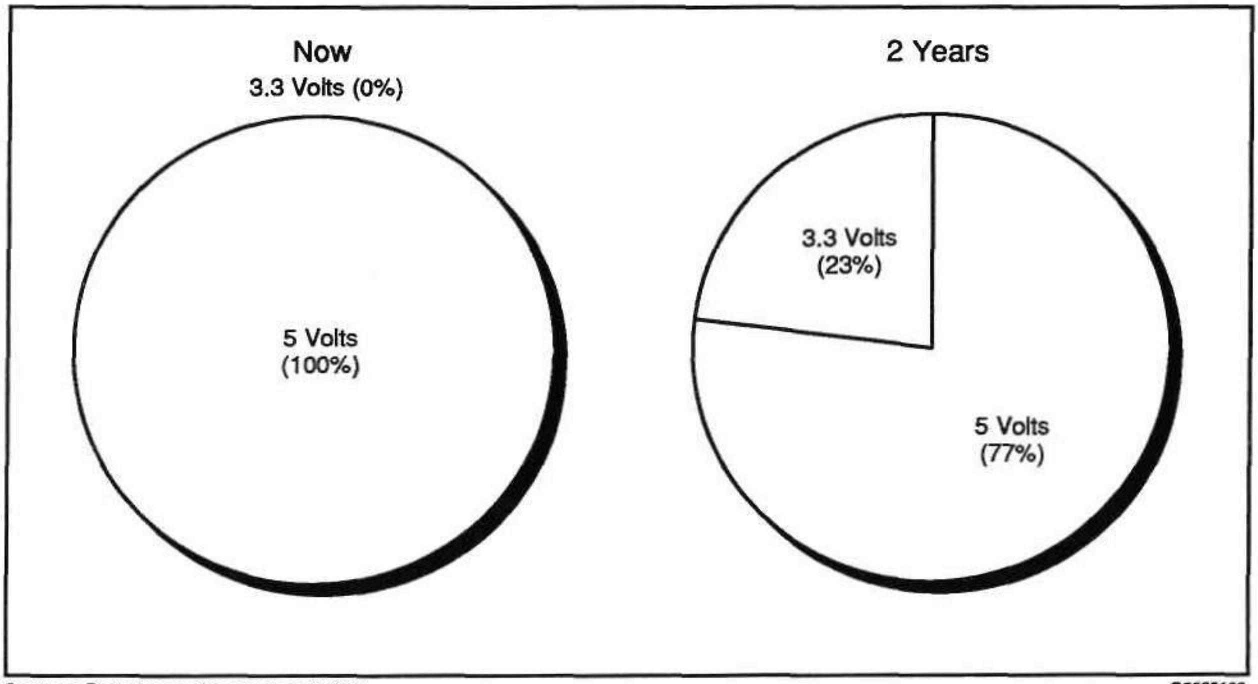
Figure 3-18
Supply Voltage, 32 Bit



Source: Dataquest (December 1992)

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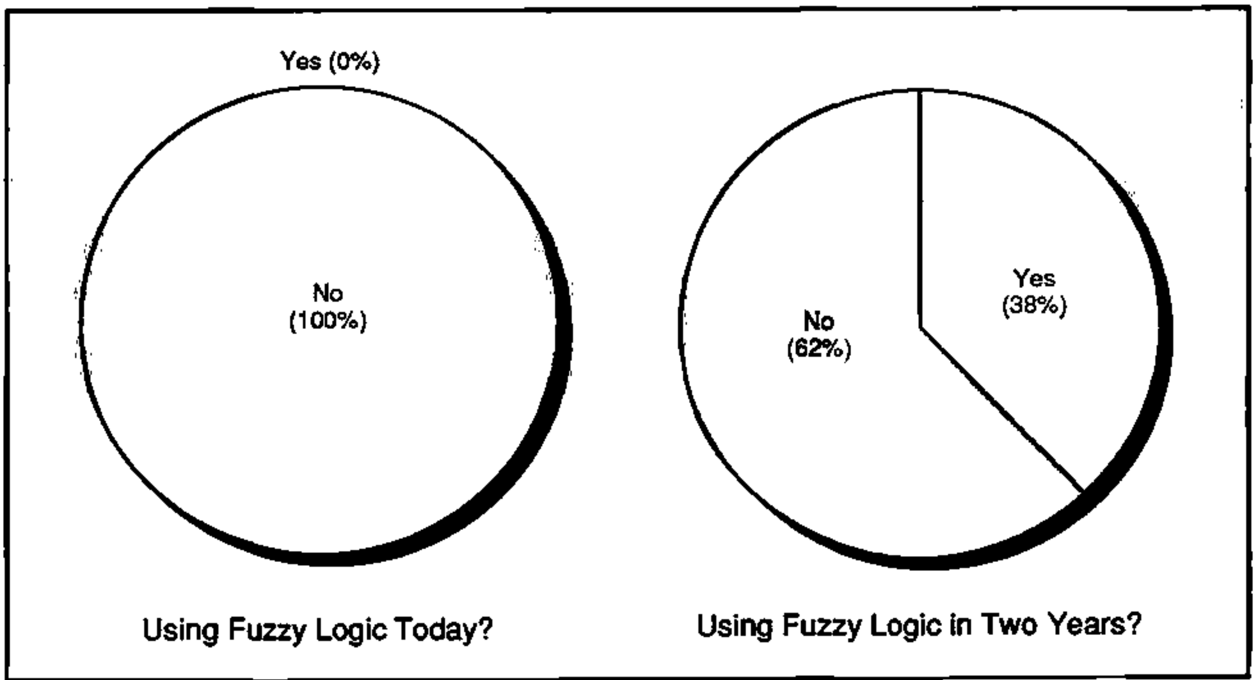
proposal of less than 2.5V. An alternative solution of a three-cell system would handle the low end of the voltage spectrum but would create new hurdles at the high end as well as take more space, add weight, and add cost to these small form factor, cost-sensitive applications. Some embedded processor companies (for example, Microchip and Philips) have not waited for a standard because they have been driven by customer demand to offer 1.8V product.

Fuzzy Logic Use/Planned Use with Embedded Processor

Although an almost unmeasurable number of designs employ fuzzy logic, a tremendous number of designers expect to be using fuzzy logic in two years (see Figures 3-19 through 3-21). The percent of designs expected to use fuzzy logic is virtually identical for all three word-width categories.

This step function increase again appears to be overly optimistic. Although fuzzy logic clearly appears to offer some real advantages in some specific applications (such as balancing three brooms end to end in a 2-dimensional environment), it is not yet understood well enough by enough designers to allow them to put it to good use. Designing-in fuzzy logic will require suppliers to educate the users about the benefits of using fuzzy logic. It will also require significant system expertise to determine when and how fuzzy logic can be used to best advantage. Given these considerations, we believe that fuzzy logic's penetration into embedded applications will be somewhat slower than is here indicated.

Figure 3-19
Fuzzy Logic Use with Embedded Processor, 8 Bit



Source: Dataquest (December 1992) G2003190

Figure 3-20
Fuzzy Logic Use with Embedded Processor, 16 Bit

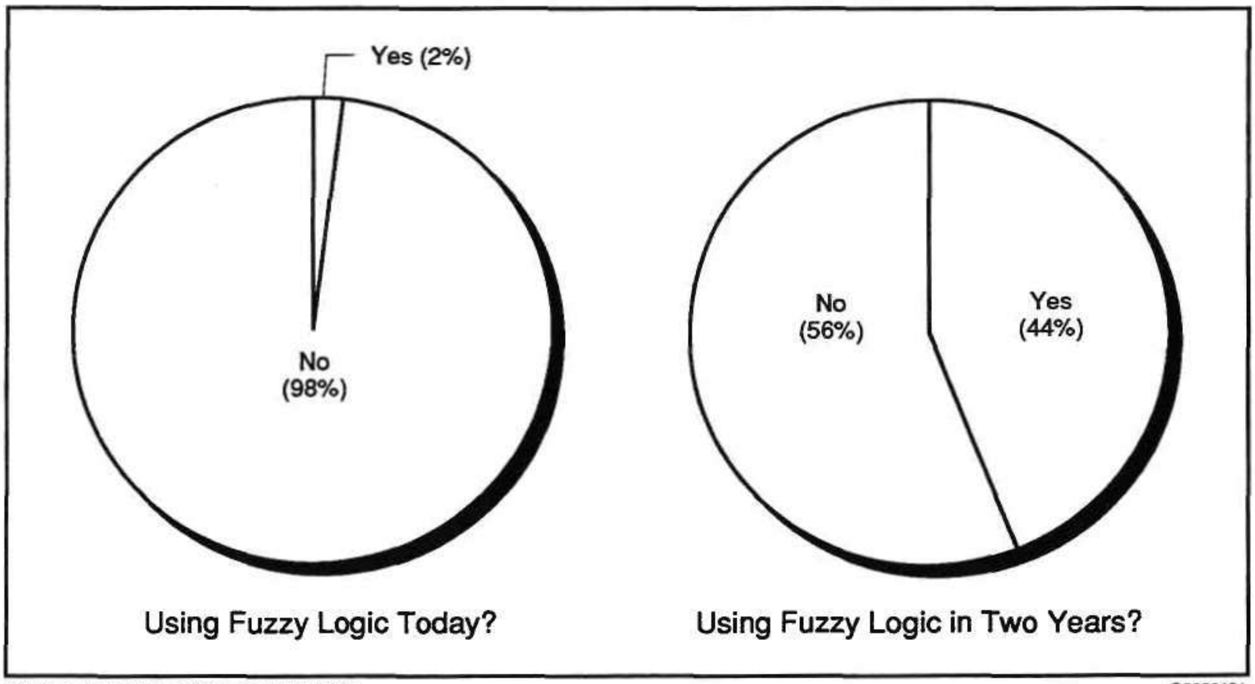


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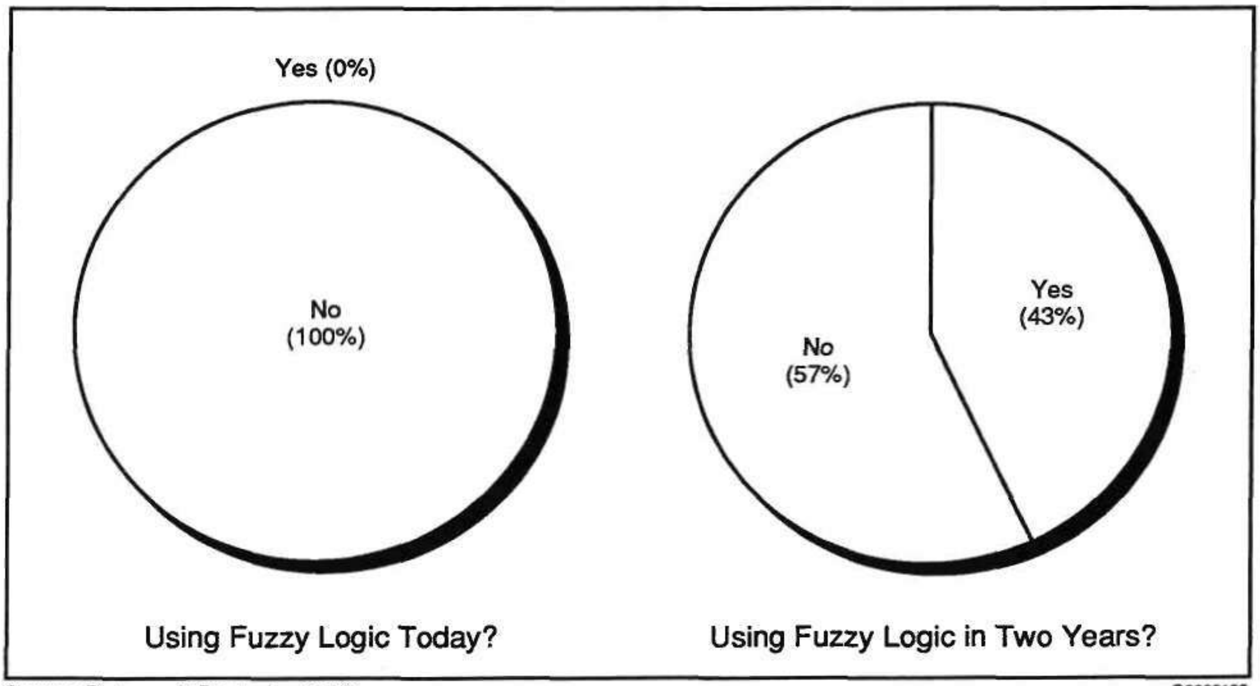
Figure 3-21
Fuzzy Logic Use with Embedded Processor, 32 Bit



Source: Dataquest (December 1992)

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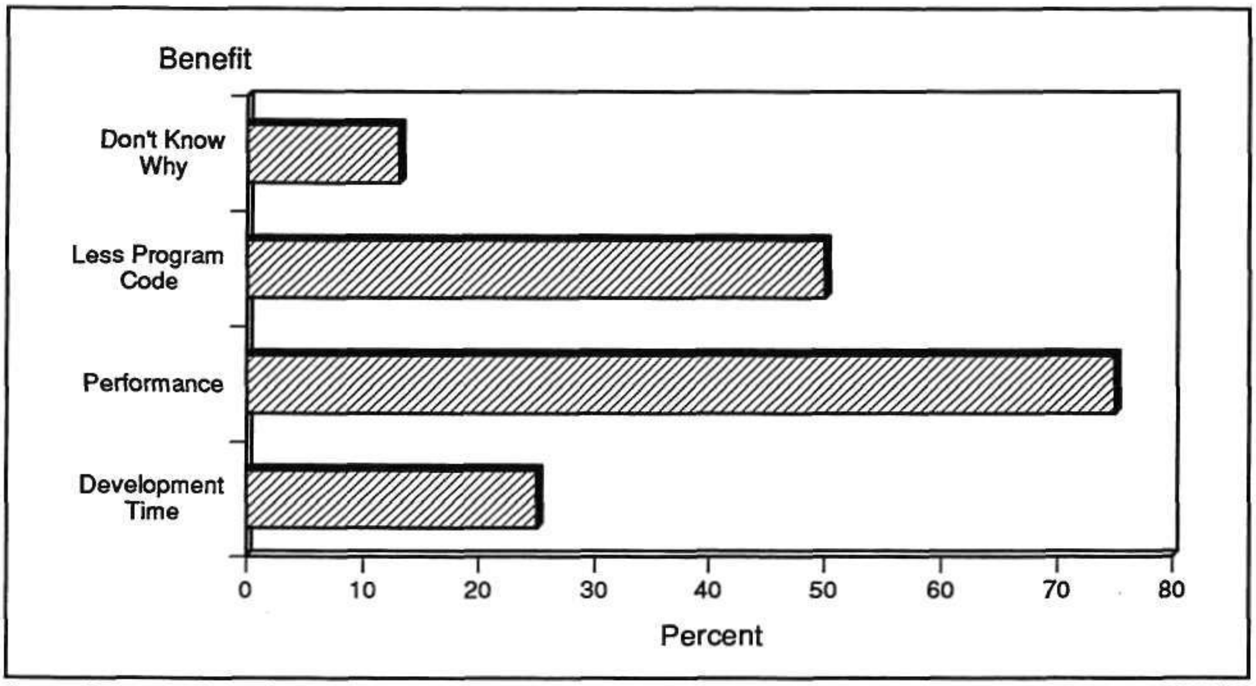
Expected Fuzzy Logic Benefits

Depending upon processor word width, 10 to 15 percent of the designers who expect to use fuzzy logic in the next two years do not know why (see Figures 3-22 through 3-24). Some were honest enough to state that it was a marketing requirement that fuzzy logic be used (it was not specified by marketing how or for what purpose fuzzy logic would be used). Well more than half of the designers believed that performance would be improved. No. 2 on the list was a reduction in program code, with development time reduction coming in a distant third.

Although fuzzy logic has demonstrated some impressive statistics when compared to Boolean logic in some specific applications, it is not yet mature enough or understood well enough by mainstream designers to achieve all of the benefits claimed by its supporters. We are strong believers in the ultimate success of fuzzy logic, but we see a longer development period before it is able to achieve all of its claims.

Figure 3-22
Benefits Expect to Achieve from Using Fuzzy Logic, in 2 Years, 8 Bit



Source: Dataquest (December 1992)
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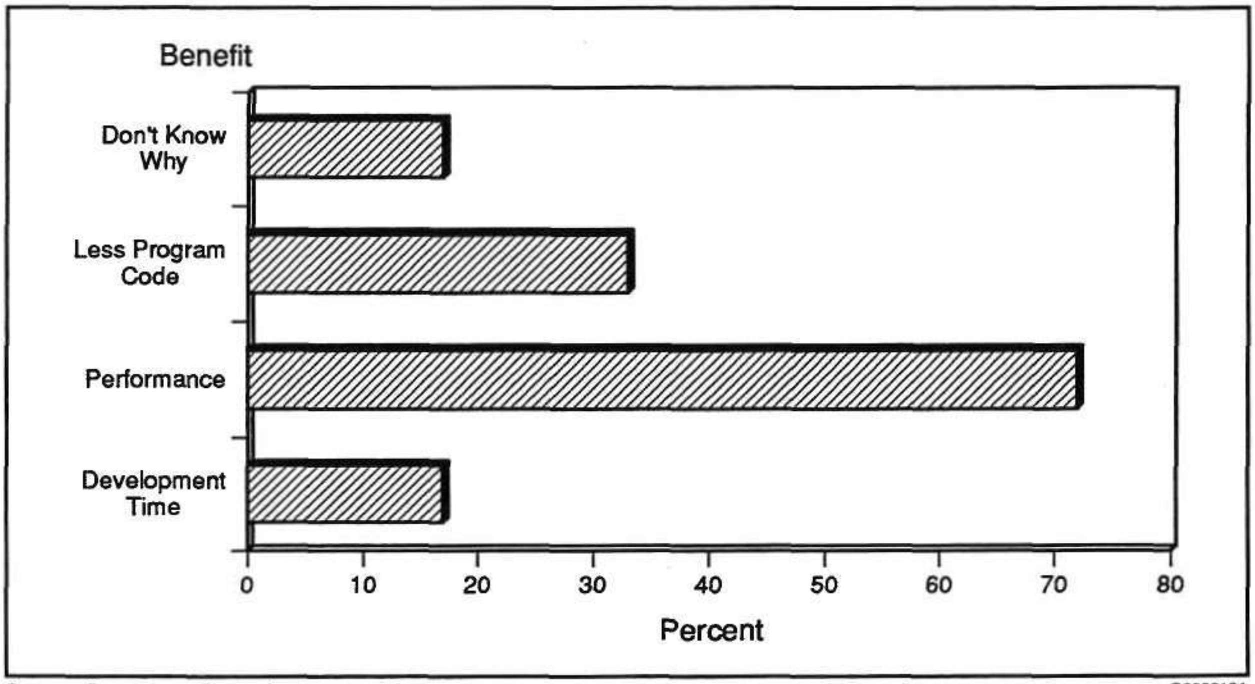
Figure 3-23
Benefits Expect to Achieve from Using Fuzzy Logic, in 2 Years, 16 Bit



Source: Dataquest (December 1992)

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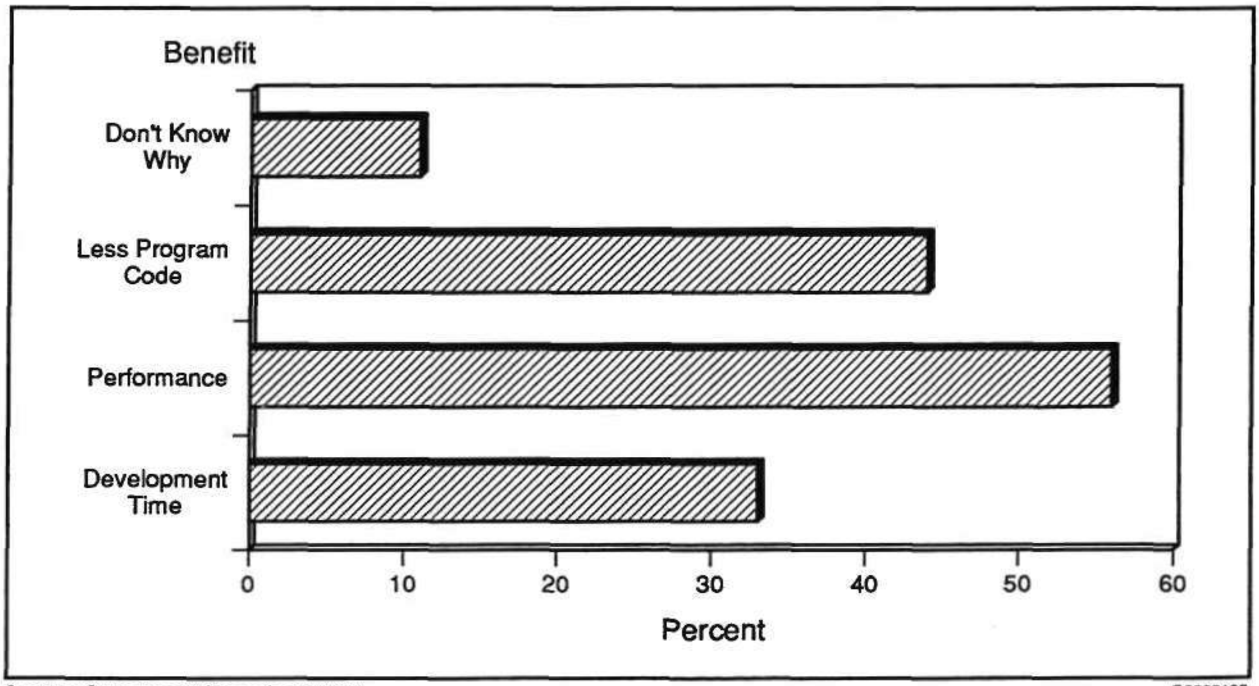
Figure 3-24
Benefits Expect to Achieve from Using Fuzzy Logic, in 2 Years, 32 Bit



Source: Dataquest (December 1992)

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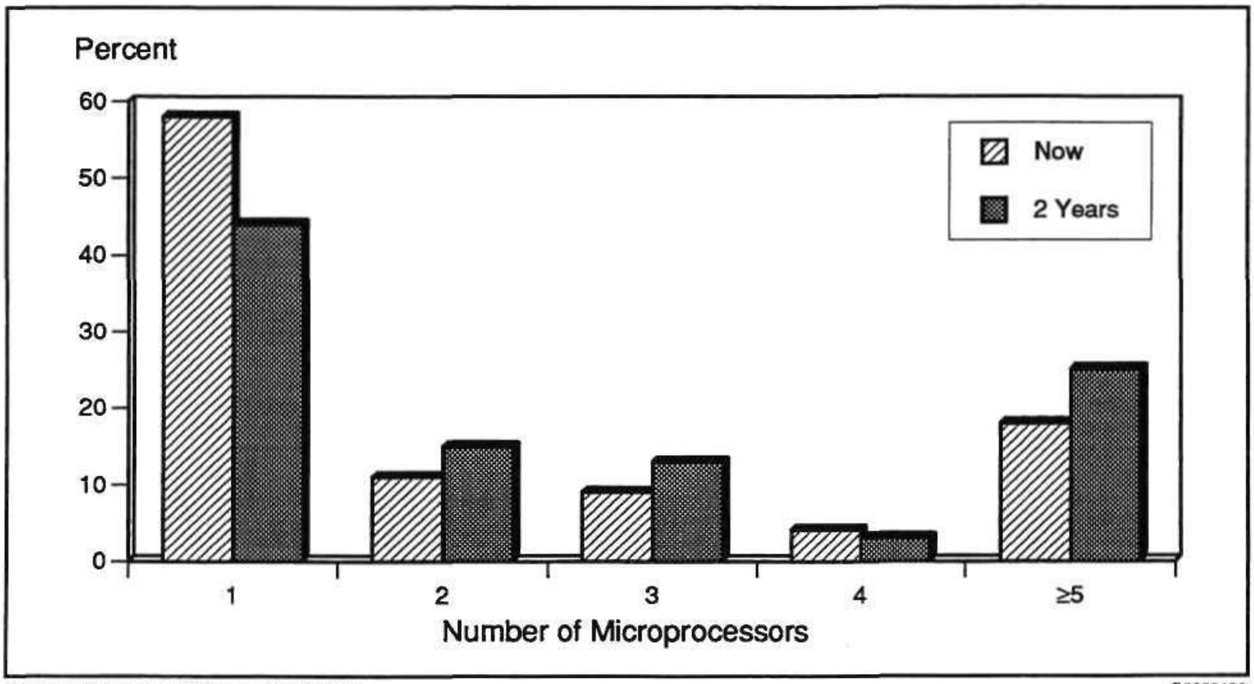
Embedded Microprocessors Used per System

Nearly 60 percent of the systems using 8-bit embedded processors today are uniprocessor systems (see Figure 3-25). The expectation is that in two years this percentage will drop below 50 percent, although this seems a little too rapid, given the long history of 8-bit uniprocessor systems.

The 8-bit results are in sharp contrast to the 16- and 32-bit results shown in Figures 3-26 and 3-27, where less than 30 percent of today's designs involve uniprocessor systems. Within the 16-bit category, the number of uniprocessor systems is expected to drop to nearly 15 percent in just two years. The number of processors per system in two years in a 32-bit environment is expected to maintain the same usage profile as today.

Embedded processor applications nearly always place cost as their No. 1 criterion, with performance coming in second. In the 8-bit arena this is reflected in the large number of uniprocessor systems, as shown in Figure 3-25. If more performance is needed, it is more likely that a designer will choose a 16- or 32-bit solution rather than attempt a multiprocessor design. 8-bit processors typically are not well suited for multiprocessing applications unless each process function is clearly defined and separated. Figure 3-27 shows a clear dichotomy between uniprocessor systems and multiprocessor systems in a 32-bit environment. At the high end of embedded applications, a designer will choose a 32-bit uniprocessor implementation because he or she

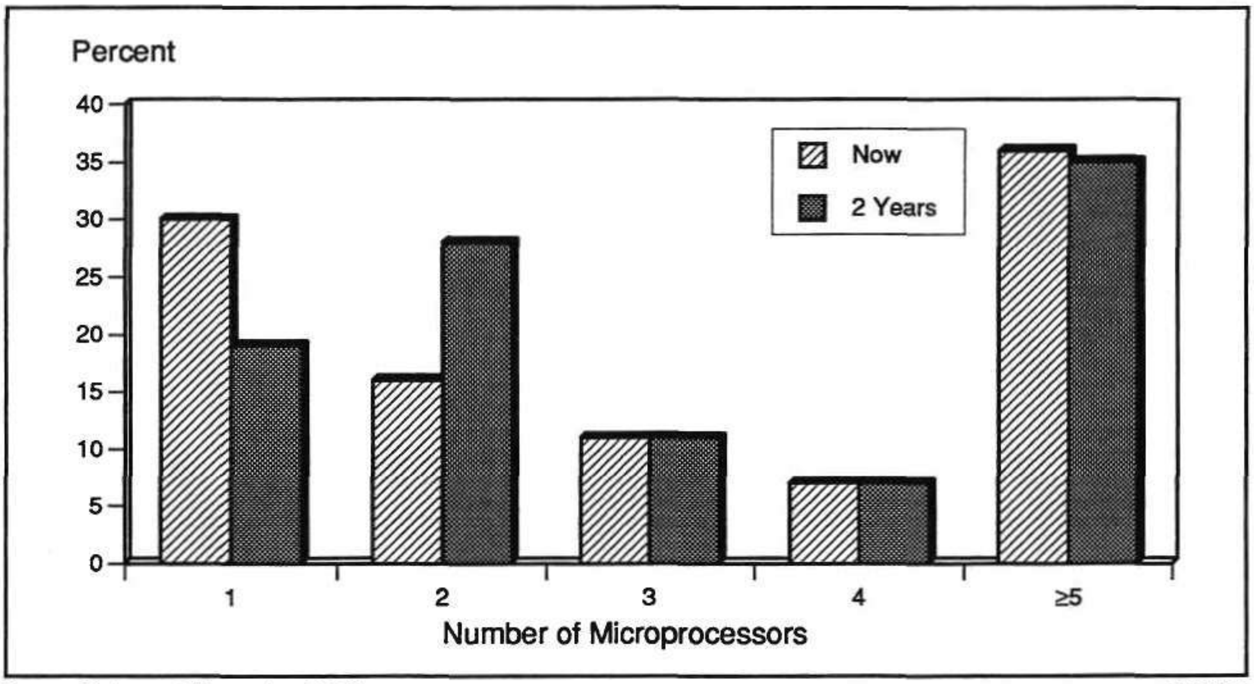
Figure 3-25
Embedded Microprocessors Used per System, 8 Bit



Source: Dataquest (December 1992)

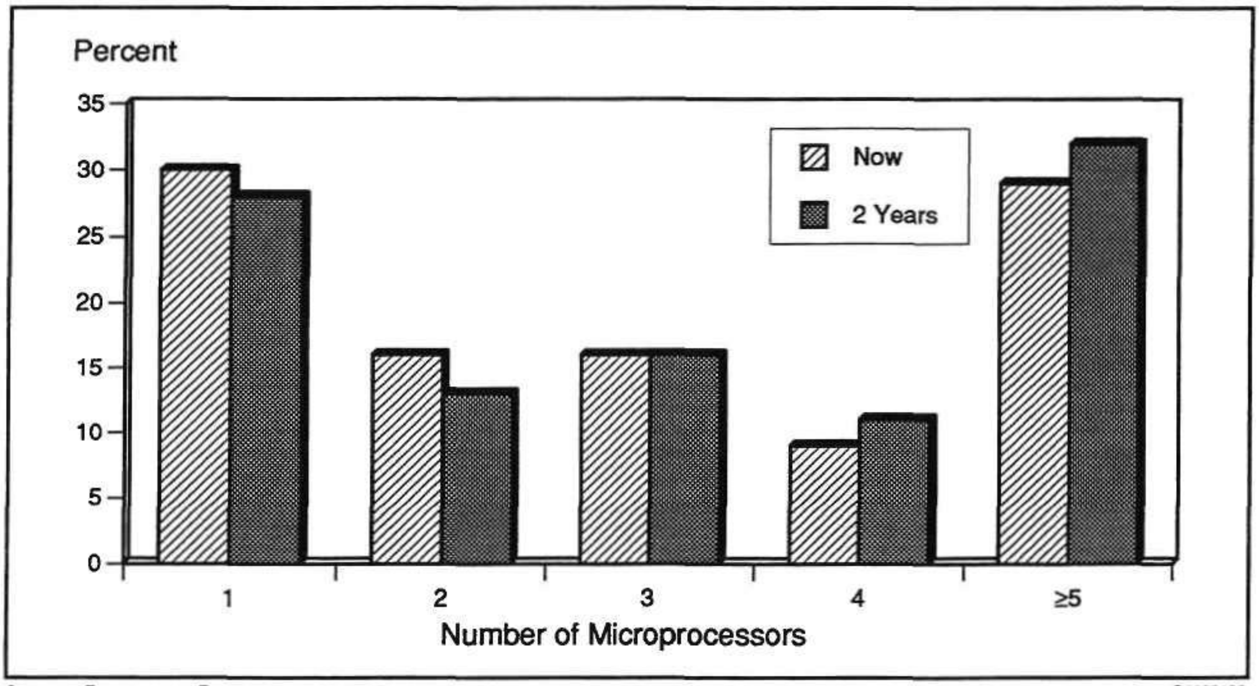
G2003196

Figure 3-26
Embedded Microprocessors Used per System, 16 Bit



Source: Dataquest (December 1992) G2003197

Figure 3-27
Embedded Microprocesssors Used per System, 32 Bit



Source: Dataquest (December 1992) G2003198

must get the most performance out of a limited space. If the application is not space- or cost-constrained, the designer will go for a large—greater than five—number of processors. These 32-bit processors typically are better suited for multiprocessing tasks than are their smaller cousins.

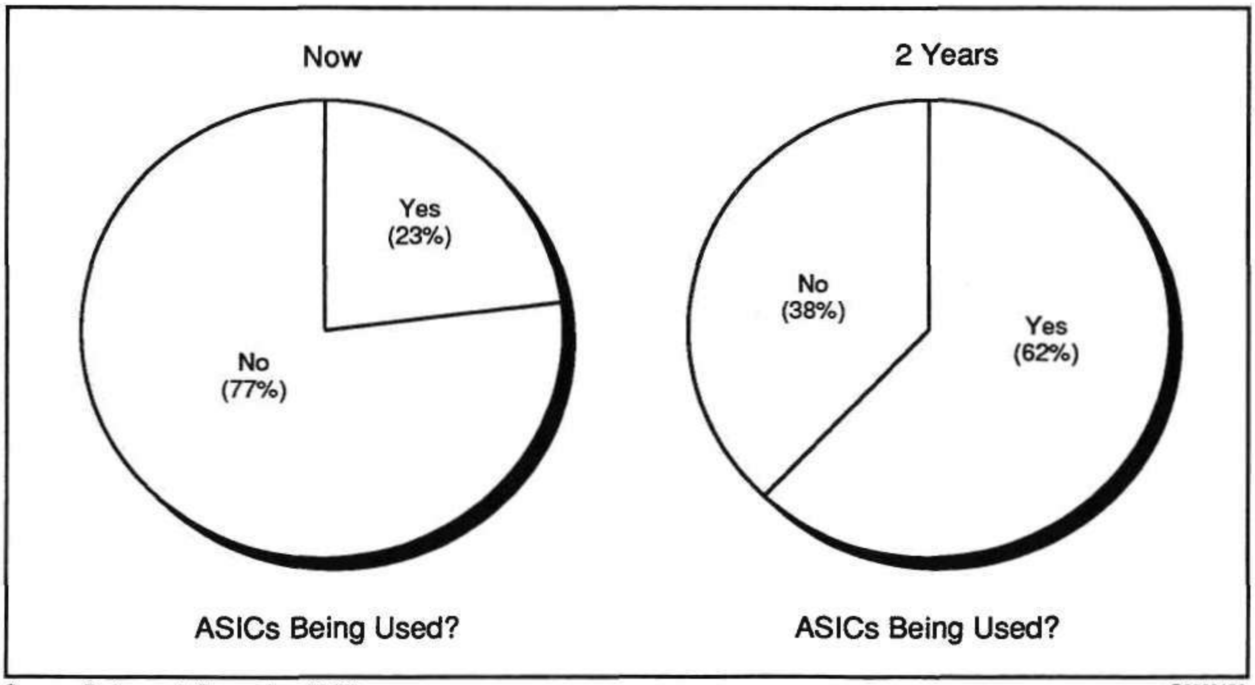
One point that will require future clarification is the word width of the other processors in the multiprocessing environments. It should not be assumed that they match the word width of the primary processor in all cases.

ASICs Required to Achieve Design Goals

As the word width of the embedded processor increases, so does the need for ASICs (see Figures 3-28 through 3-30). At the low end of the spectrum, less than one-quarter of the applications make use of ASICs in addition to the processor. This is because of the typically low cost and small form factor requirements in these applications. It appears that, for 8-bit applications, cost overrides all other considerations, including such basics as feature differentiation.

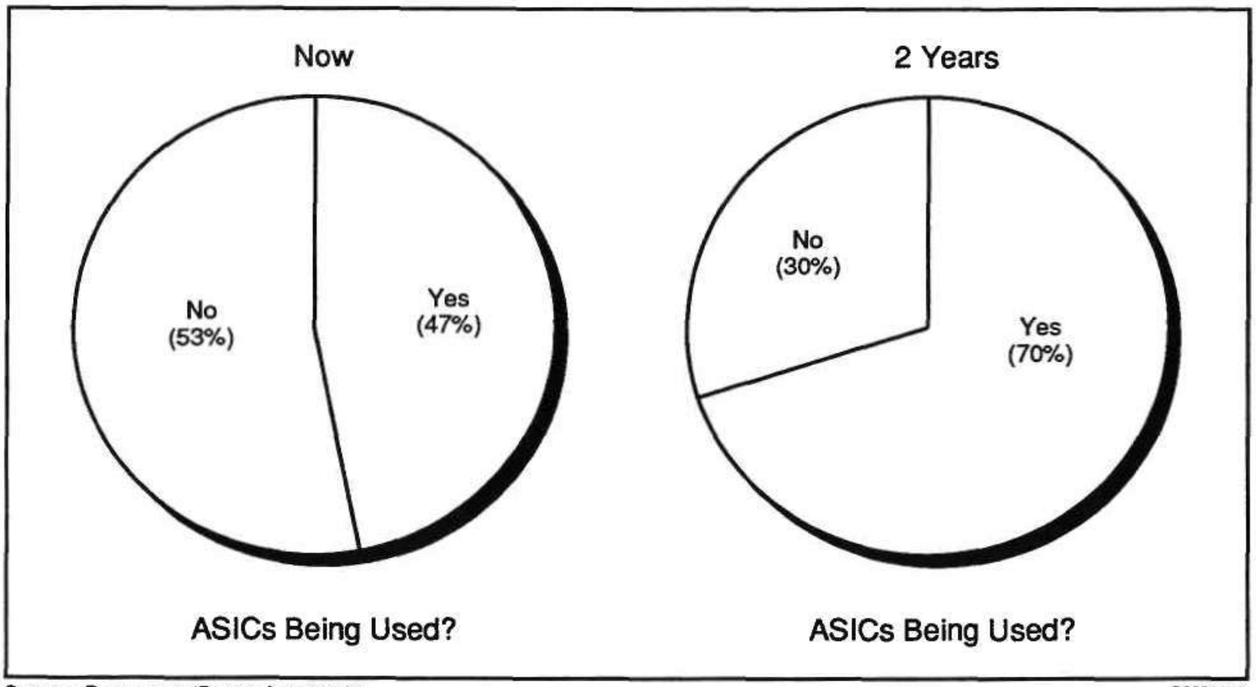
Both 16- and 32-bit applications make more use of ASICs. Nearly half of today's 16-bit applications use ASICs, while nearly three-quarters of the current 32-bit applications require ASICs.

Figure 3-28
ASIC Required in Addition to the Embedded Processor, 8 Bit



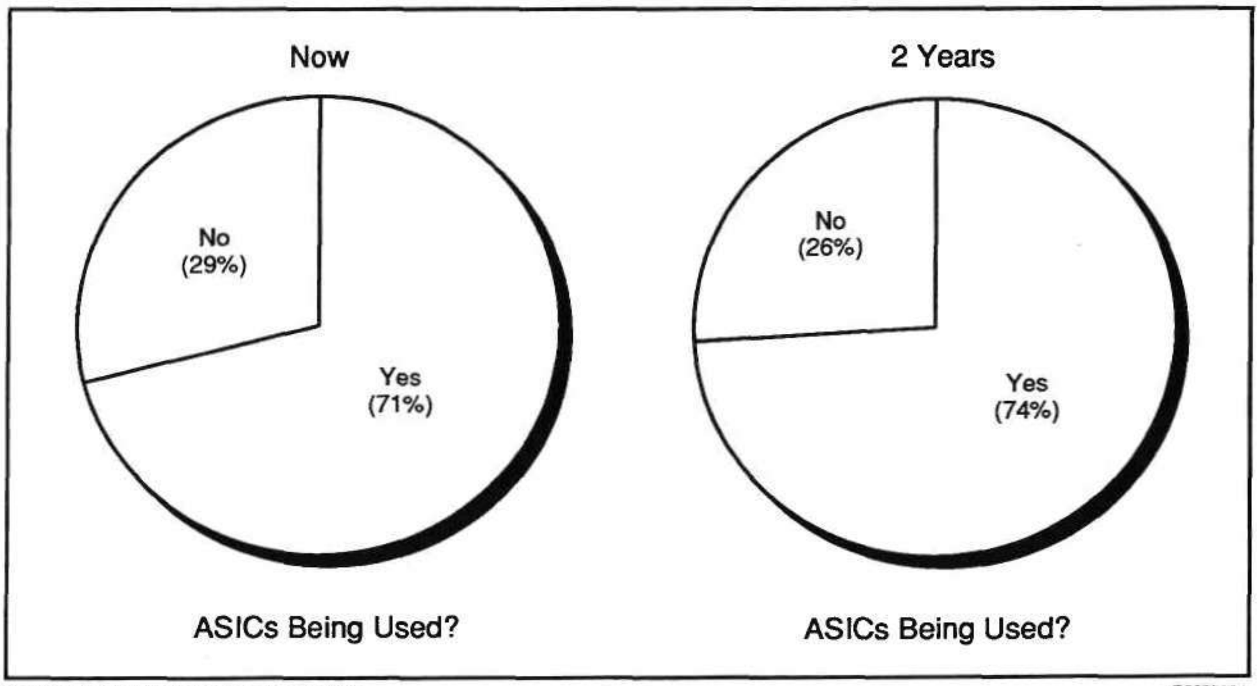
Source: Dataquest (December 1992) G2003199

Figure 3-29
ASIC Required in Addition to the Embedded Processor, 16 Bit



Source: Dataquest (December 1992)
G2003200

Figure 3-30
ASIC Required in Addition to the Embedded Processor, 32 Bit



Source: Dataquest (December 1992)
G2003201

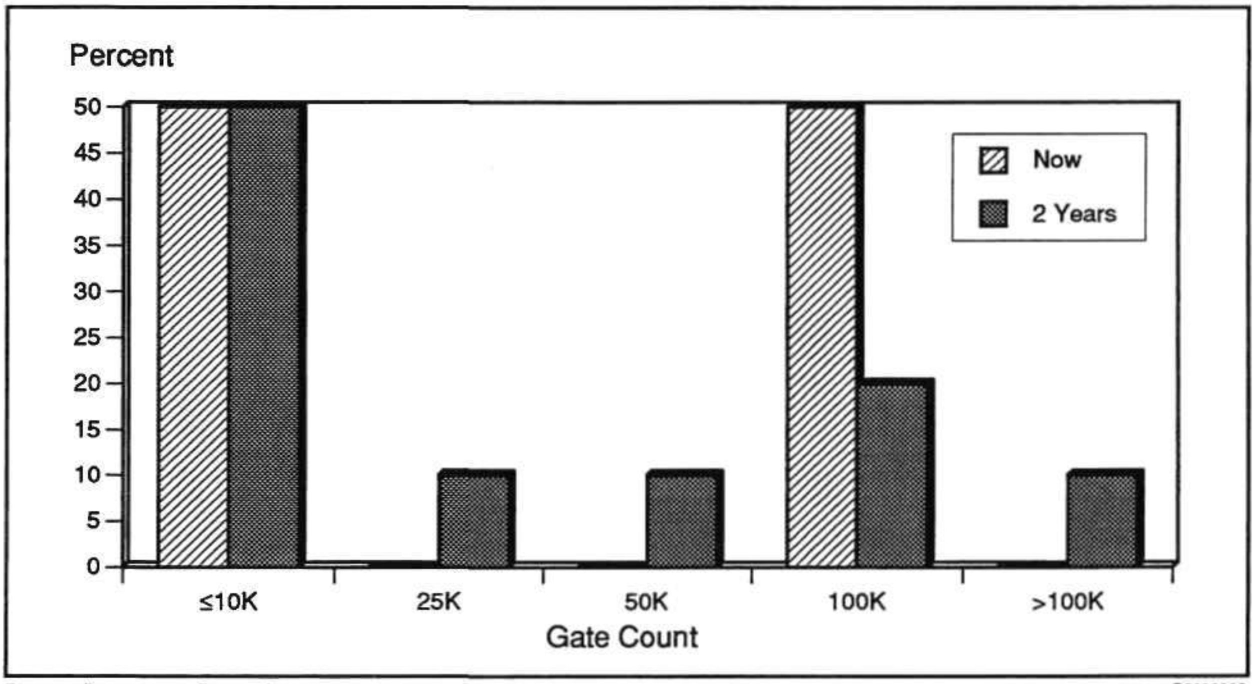
The two-year outlook for all three word widths calls for an increase in the use of ASICs. However, again we believe that it is necessary to moderate the 8-bit projection shown in Figure 3-28. There is no compelling evidence to suggest that 8-bit embedded processors will be used in such dramatically new ways that will require a drastic change from the past. As the rapid price erosion of gate arrays continues, we do expect ASICs to continue to become more cost-effective. However, this nearly step function increase from 23 percent to 62 percent in two years' time seems to come more from a designer's desire to use an ASIC than from the applications requirement.

The 32-bit application requirement shown in Figure 3-30 is indicative of the relatively higher costs and longer lead times associated with these systems. Although gate array costs and lead times are shrinking, they still require weeks to turn around prototypes and typically require a second pass design before all of the bugs are worked out. These additional months of development time can cause a company to miss the entire market window of some 8-bit applications, whereas 32-bit applications will normally have a longer window for development as well as for the market opportunity.

Total ASIC Gate Count Requirement Today and in Two Years

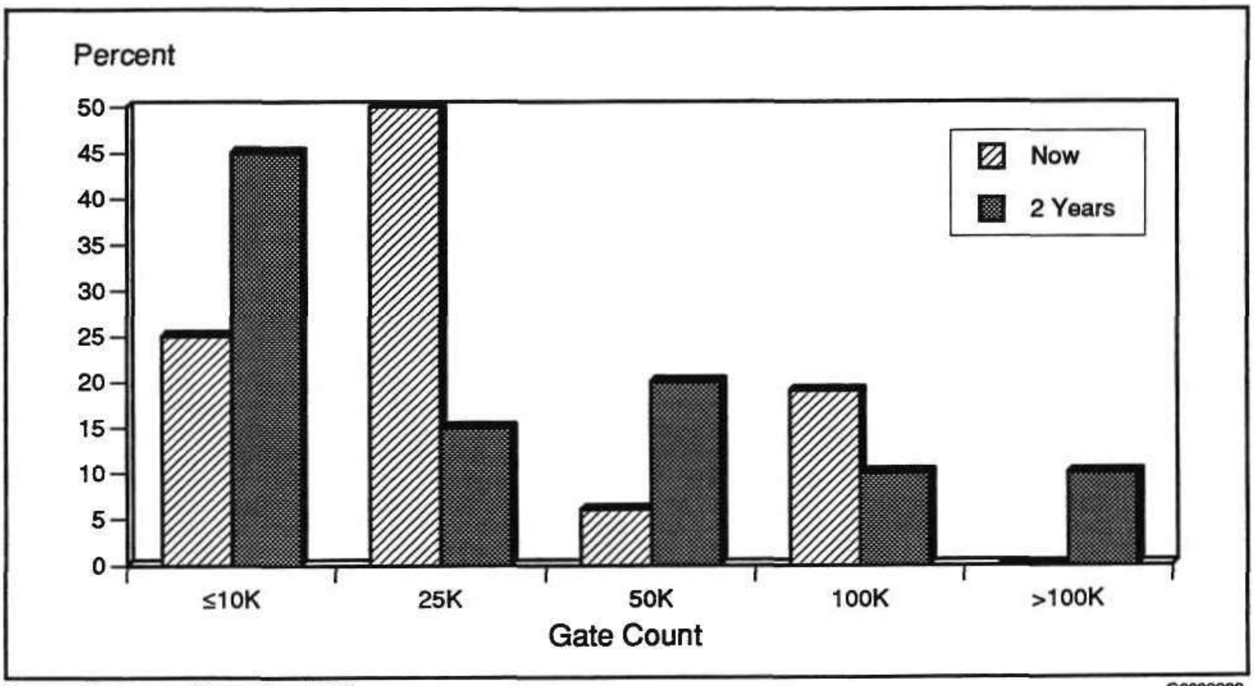
The total ASIC gate count requirement for 8-bit systems shown in Figure 3-31 demonstrates classic peak-valley-peak performance in gate

Figure 3-31
Total ASIC Gate Count Required, 8 Bit



Source: Dataquest (December 1992)
G2003202

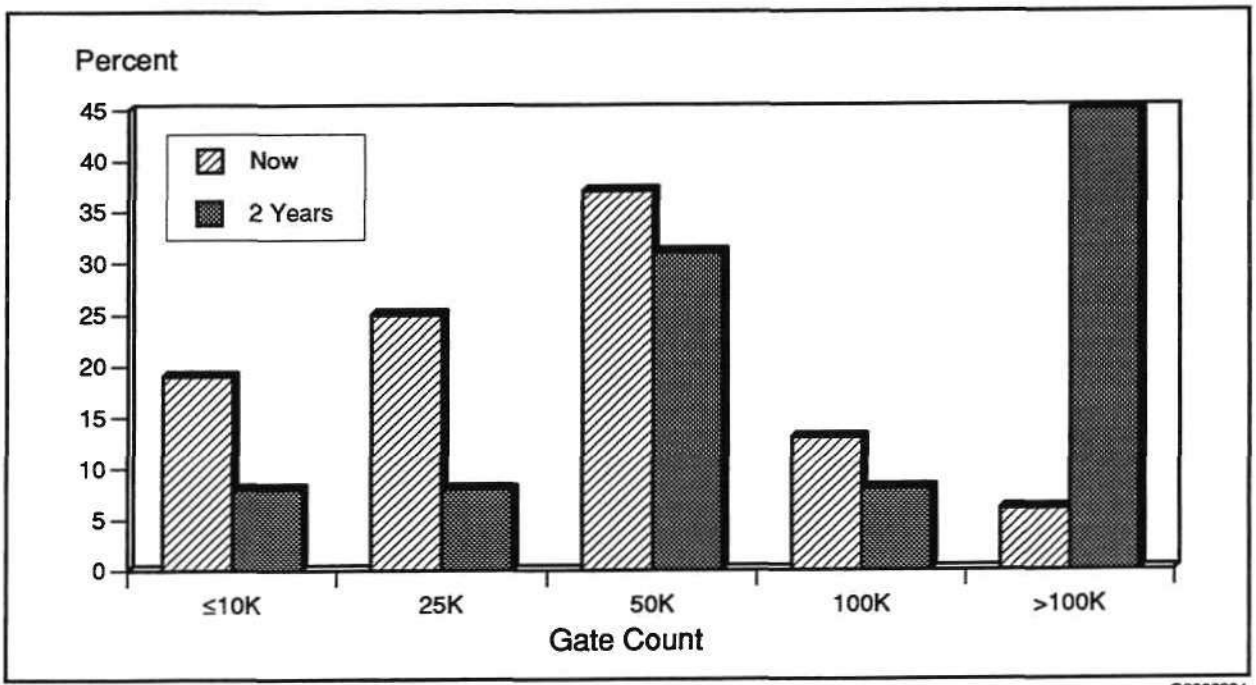
Figure 3-32
Total ASIC Gate Count Required, 16 Bit



Source: Dataquest (December 1992)

G2003203

Figure 3-33
Total ASIC Gate Count Required, 32 Bit



Source: Dataquest (December 1992)

G2003204

array design starts by density. Most low-end gate array designs use classical schematic capture and operate at the gate level. As density requirements increase, this classical approach is no longer viable because of time constraints. Designers are forced to use high-level design, which is more time efficient but much less gate efficient. This results in a rapid transition from sub-10,000-gate designs to greater than 50,000-gate designs. A paradigm for this is a letter attributed to Abraham Lincoln in which he opened by apologizing to his reader for writing such a long letter as he did not have the time to write a shorter one. Although the two-year outlook does not show such a dramatic dichotomy, it is skewed somewhat because of the designers who expect to use ASICs in the future. Many of these designers will be either forced to stay with a standard product solution or they will see how quickly a 25,000- or 50,000-gate design can balloon to a 100,000-gate design, because of the inefficiencies of design tools.

Many of the current 25,000-gate designs shown in Figures 3-32 and 3-33 for both 16- and 32-bit designs were just beyond the range of the 10,000-gate range and were then likely performed with traditional schematic capture techniques. The moderation of the peak-valley-peak forecast for the 16-bit applications is because of the expected use of ASICs by designers who are not using ASICs. We expect to see a sharper peak develop in the 100,000 density, in a two-year time frame, than is shown here. The 32-bit forecast for gate array/ASIC densities shown in Figure 3-33 is based upon a higher number of designers using ASICs than for either the 8- or 16-bit forecasts. The expectations of this relatively more experienced group begin to show the classic peak-valley-peak shape for their next generation of designs.

Chapter 4
Relative Merits for Choosing an Embedded Processor

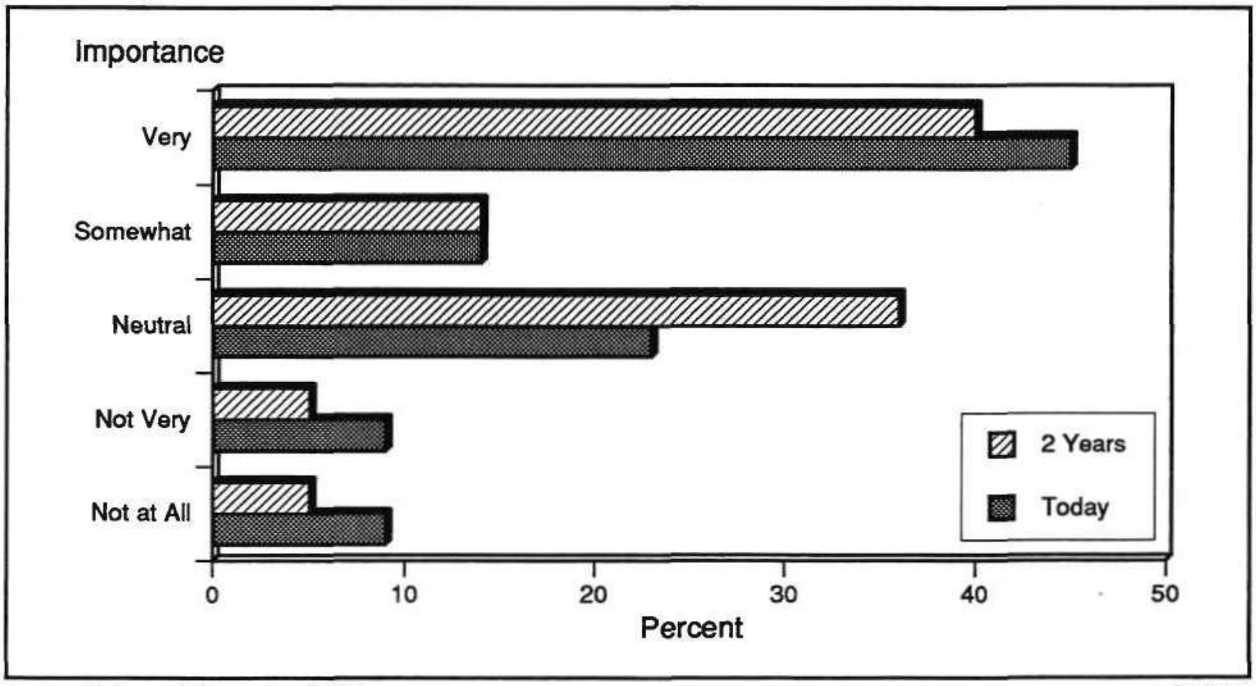
This chapter covers questions relating to the relative importance of various factors that might influence a designer's selection of a particular processor architecture. Respondents were asked to respond using a scale of one to five, with one being "not at all important" and five being "very important." Each question asked for their opinion regarding today's project and then asked them to speculate two years from now on the relative importance of each topic for some future project

Device and System Cost

Figures 4-1 through 4-6 refer to the No. 1-mentioned criterion for embedded applications: cost. It is interesting to note that the cost of the individual processor is given significant importance at the 8-bit level, but much less importance at the 16- and 32-bit level. This by itself is not too surprising, but all three word widths equally weight the importance of the ever-elusive total system cost. On the surface this would seem to indicate that the window is open for 8-bit vendors to integrate more functions or offer some unique solution in the attempt to offer an overall lower-cost solution to the user despite having a higher-priced 8-bit processor. Unfortunately, this is not so easily achieved. The 8-bit application community is pretty well trained to look for a low-cost processor and is extremely difficult to convince otherwise. Any such attempts must not rely too heavily upon the esoteric cost savings generally associated with higher integration, such as less board space, lower power, less inventory, and fewer pins. Although these are not trivial benefits, system designers have grown to expect to receive these benefits for free and if the highly integrated solution does not at least match the device cost of the older discrete solution, they are reluctant buyers. The lone exception to this rule are those that are space constrained. These designers are being forced to meet a small form factor (for example, a 1.8-inch hard disk drive) and are sometimes willing to accept a higher component cost, for a while.

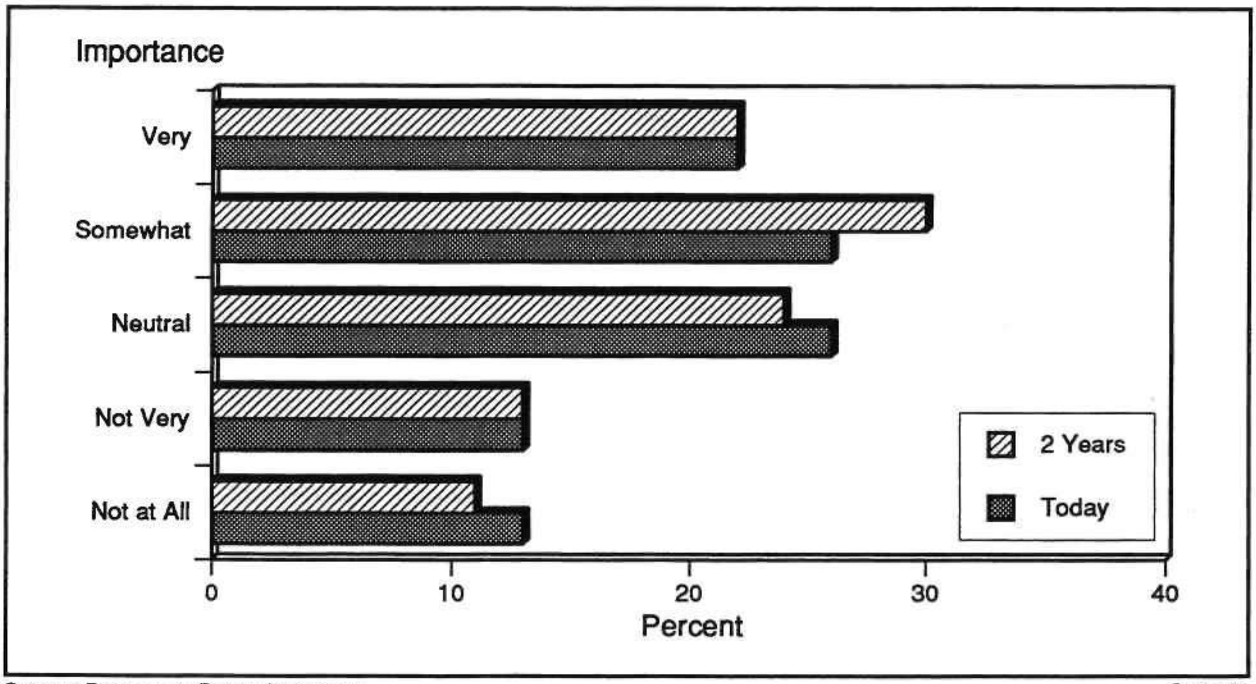
What is clear from these six figures is that cost is king. Any higher-cost solutions must have an overwhelmingly compelling reason to capture a design.

Figure 4-1
Importance of Device and System Cost, 8 Bit



Source: Dataquest (December 1992) G2003205

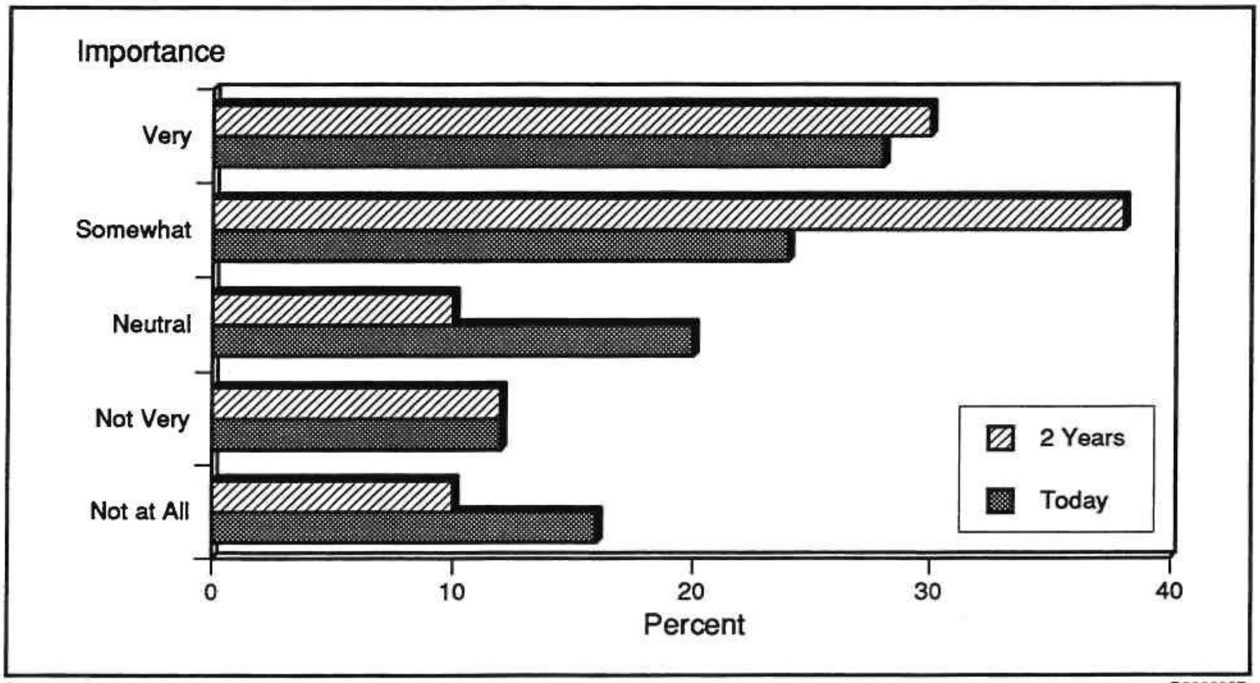
Figure 4-2
Importance of Device and System Cost, 16 Bit



Source: Dataquest (December 1992)

G2003206

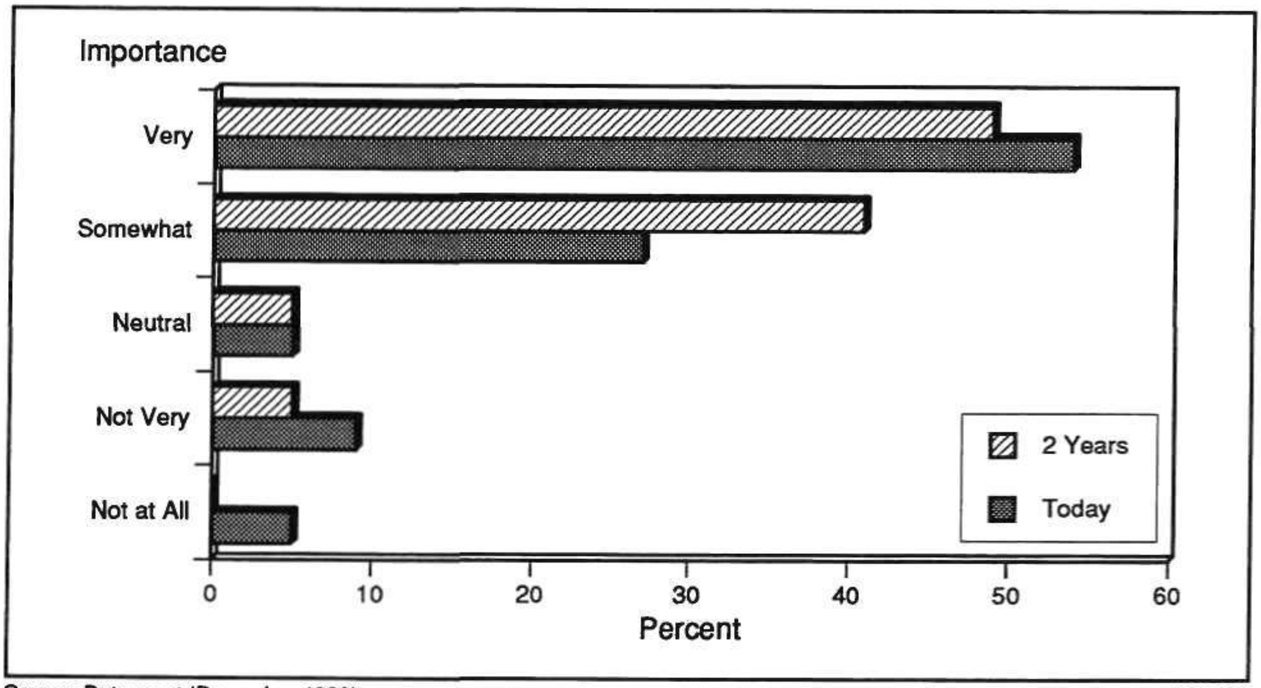
Figure 4-3
Importance of Device and System Cost, 32 Bit



Source: Dataquest (December 1992)

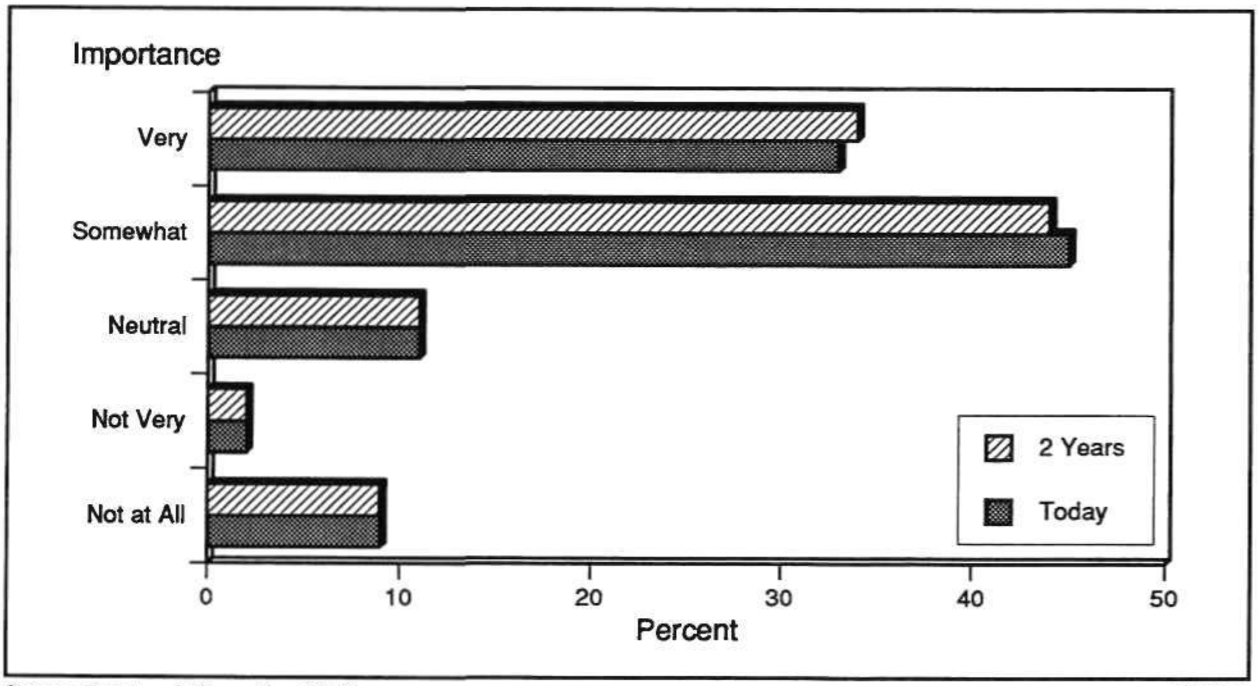
G2003207

Figure 4-4
Importance of Total System Cost, 8 Bit



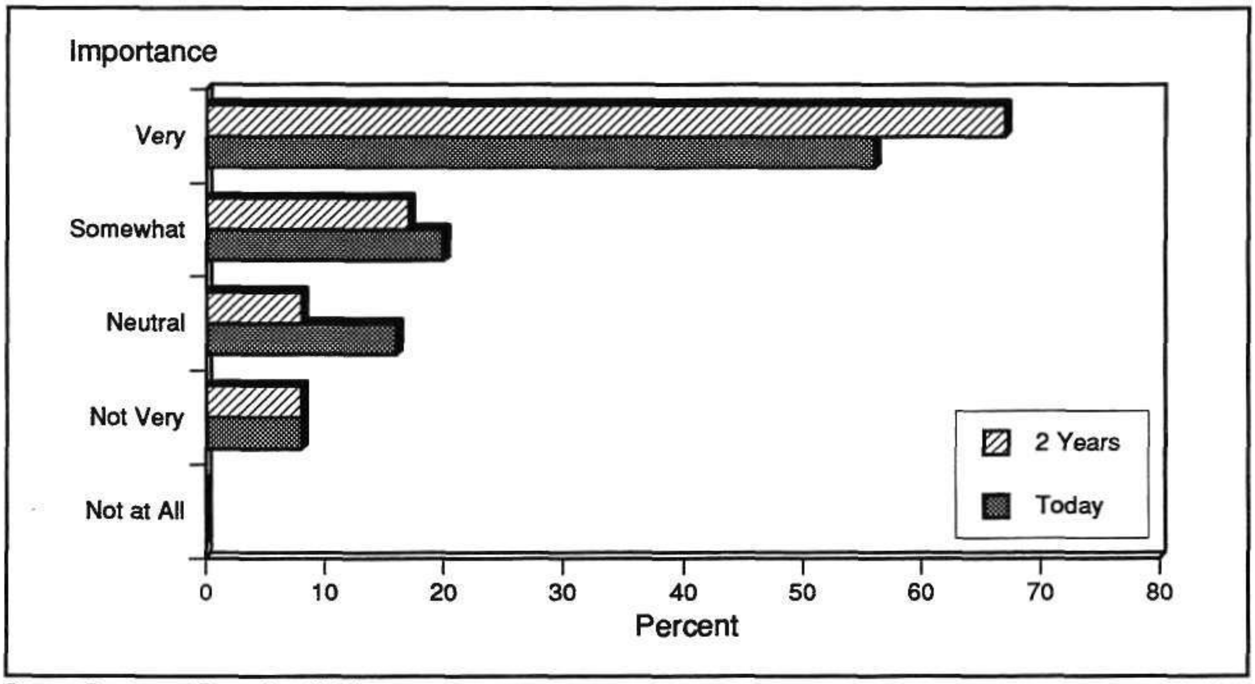
Source: Dataquest (December 1992)
G2003208

Figure 4-5
Importance of Total System Cost, 16 Bit



Source: Dataquest (December 1992)
G2003209

Figure 4-6
Importance of Total System Cost, 32 Bit



Source: Dataquest (December 1992)

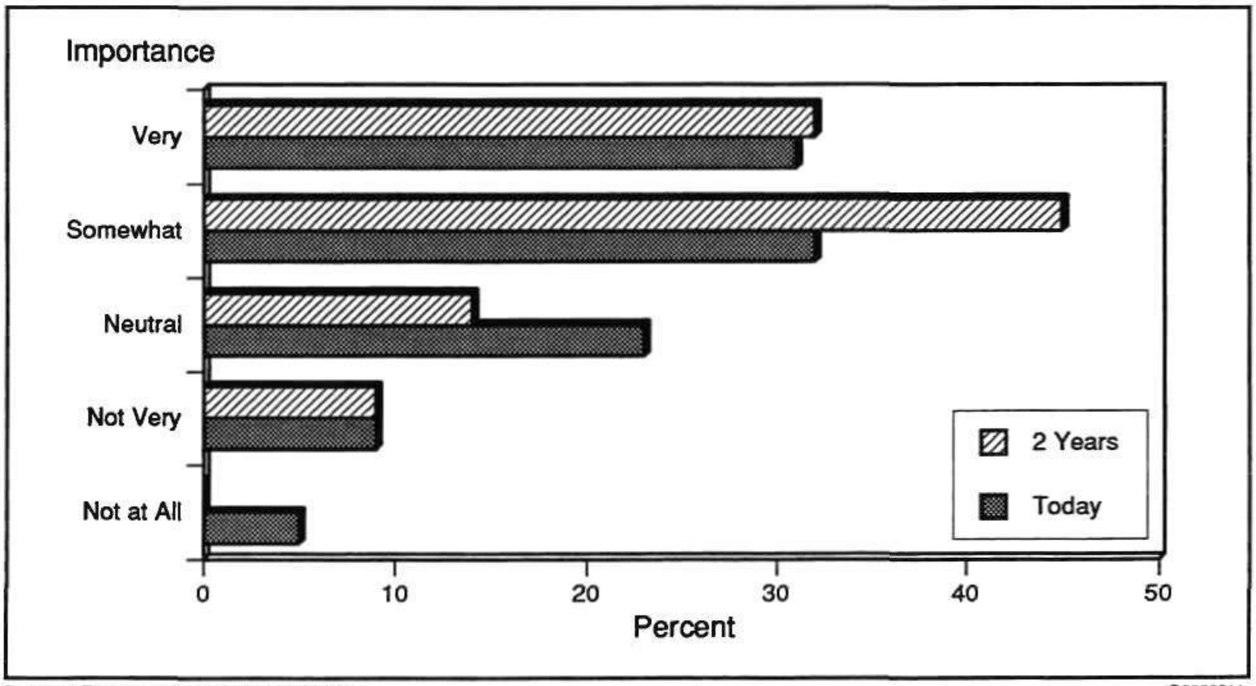
G2003210

Performance

Performance is the fundamental issue that troubles all designers of embedded systems as well as vendors of embedded processors. That issue can be characterized as follows: cost is king, but I need performance. Figures 4-7 through 4-9 indicate the relative importance of performance. Although it does not rate as high as cost, it is rated high enough so as to not be ignored. If the revenue stream from a value-added noncommodity product is the "Beauty" of embedded processors, then the dichotomy of cost versus performance is the "Beast." Increasing the clock rate of a processor typically will require a more advanced process, which in turn will not be as cost-efficient as an older, more stable process. Additionally, raising the processor clock rate will in turn require higher-performance memories and peripherals, which in turn will increase the overall system cost. Also, at some point in the frequency game more-sophisticated printed circuit board techniques must be used to eliminate noise and maintain system reliability and integrity. Increasing the clock rate of these typically CMOS-based systems will also have a dramatic effect on power consumption, which we will soon see is the third-most critical component.

Vendors are left with the never-ending chore of searching for ways to offer higher performance, lower power, and lower cost. This should sound fairly familiar to anyone who manufactures ICs. Unfortunately, the old tried and true techniques of "shrink it and it'll go faster" are no longer adequate. In many of these embedded applications,

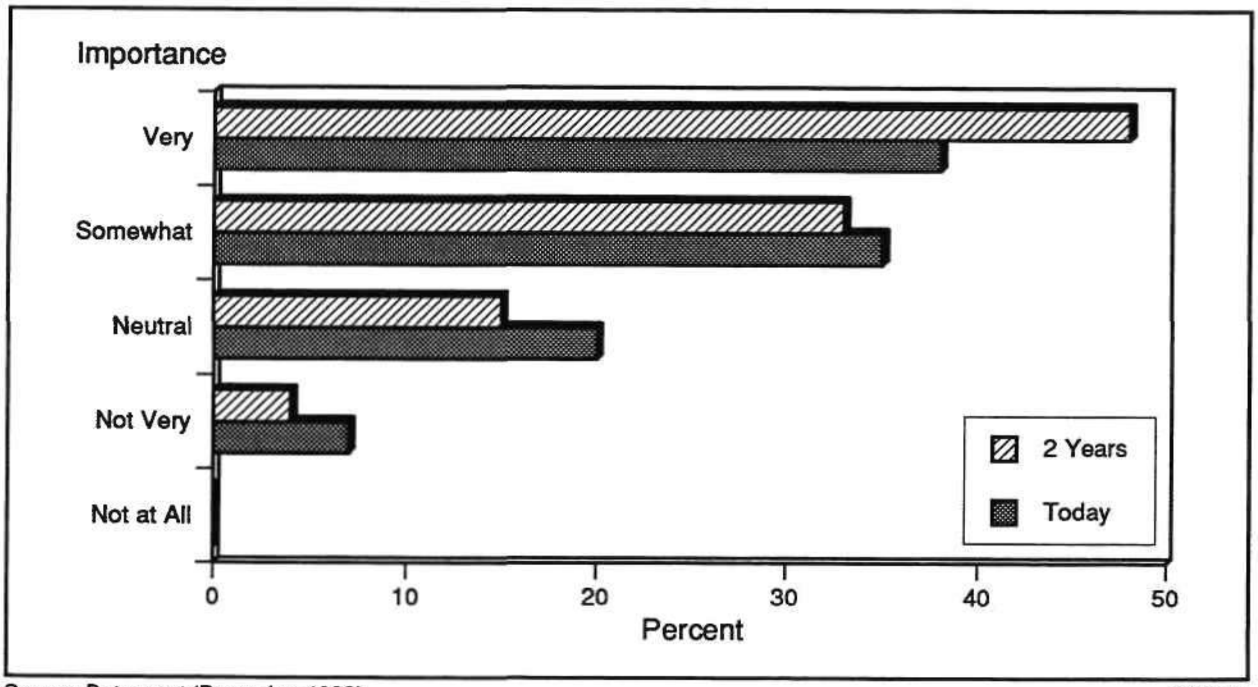
Figure 4-7
Importance of Performance, 8 Bit



Source: Dataquest (December 1992)

G2003211

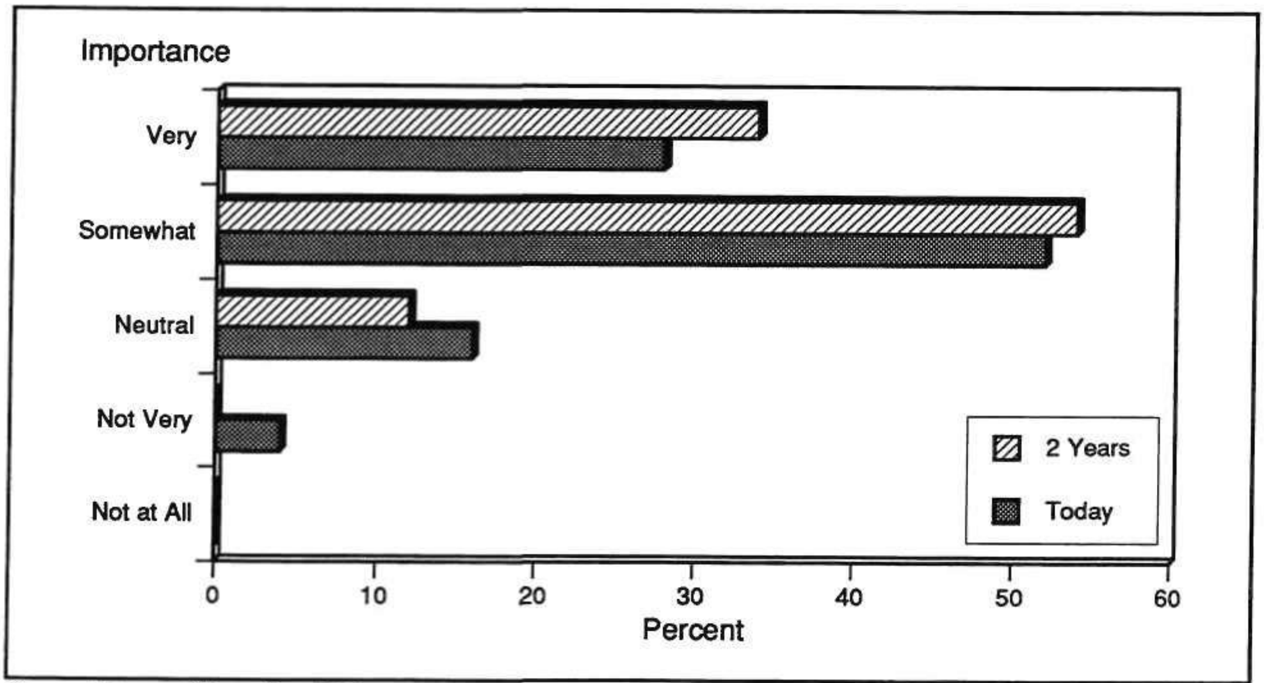
Figure 4-8
Importance of Performance, 16 Bit



Source: Dataquest (December 1992)

G2003212

Figure 4-9
Importance of Performance, 32 Bit



Source: Dataquest (December 1992)

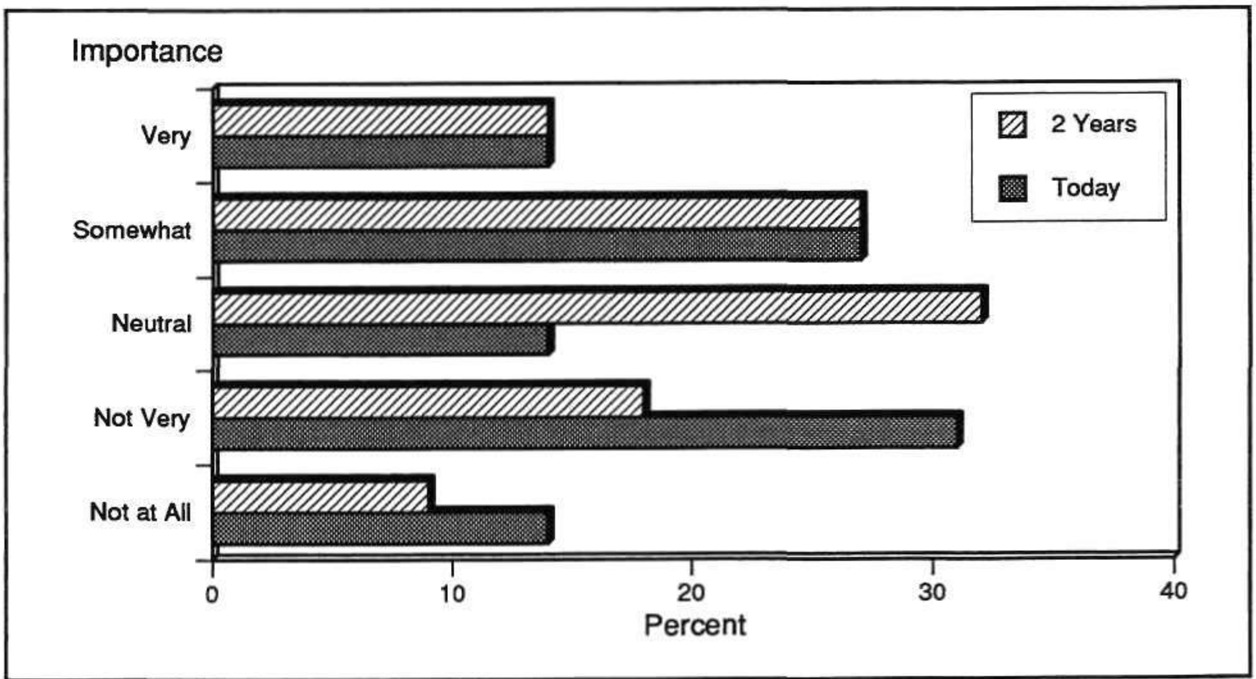
G2003213

particularly for 8- and 16-bit applications, performance is critical in specific control loops. In these relatively low-end applications, high-speed number crunching capability is not a requirement. What is needed is for the processors to react quickly to outside stimulus, such as an interrupt, perform some specific function, and then return to their normal monitoring and/or housekeeping chores. There are applications where the processor is running at full speed all of the time, but these are not the norm for most embedded applications. As a consequence, simply offering a device at a faster clock rate is not an appropriate solution for most applications. This is the beauty of embedded processors—the opportunity to offer nontraditional value. This nontraditional value typically is able to be protected intellectually and offers the vendor a unique advantage in the marketplace.

Power Consumption

Although the emphasis placed on power consumption is not as high as either cost or performance, its importance is increasing dramatically for all three word widths covered in this report. In the 8-bit realm, 41 percent of those who responded believe that power consumption is somewhat to very important (see Figure 3-10). Although this statistic does not change in the next two years, the number of people who believed that it was not very or not at all important decreased from 45 to 27 percent. Power consumption is somewhat or very important for 32 and 43 percent, respectively, for 32- and 16-bit processors. However, it is expected that this will increase to about 54 percent for both word widths in a two-year time frame (see Figures 4-11 and 4-12).

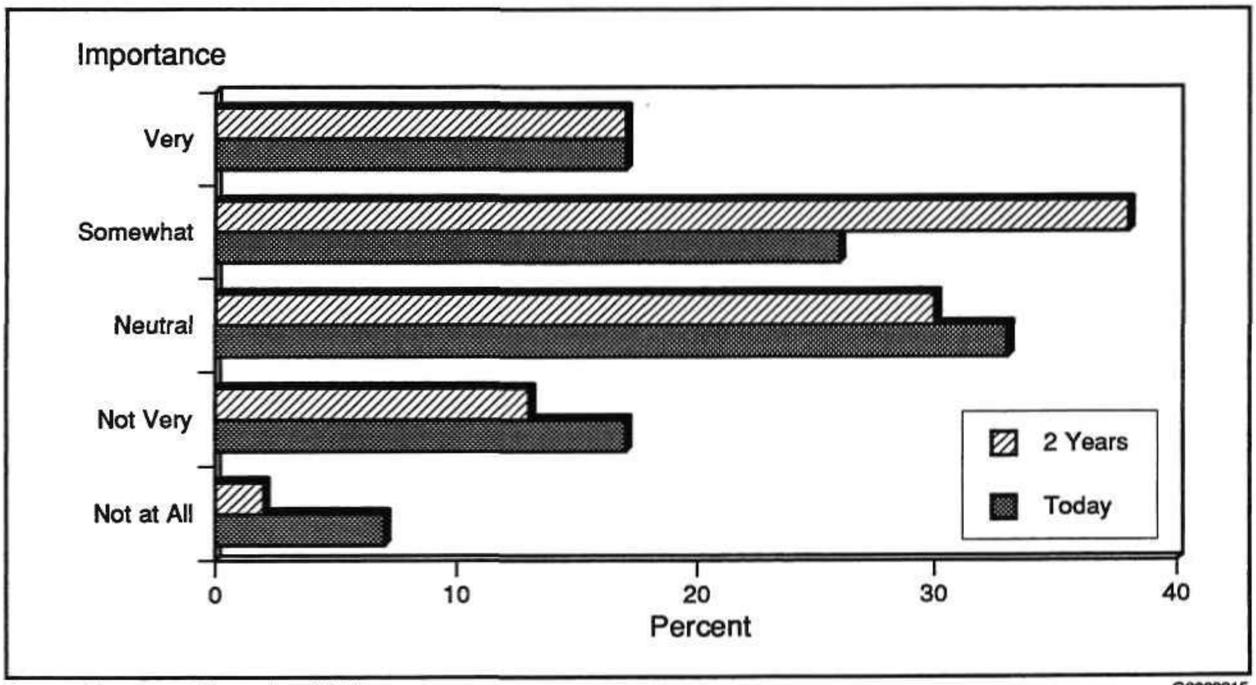
Figure 4-10
Importance of Power Consumption, 8 Bit



Source: Dataquest (December 1992)

G2003214

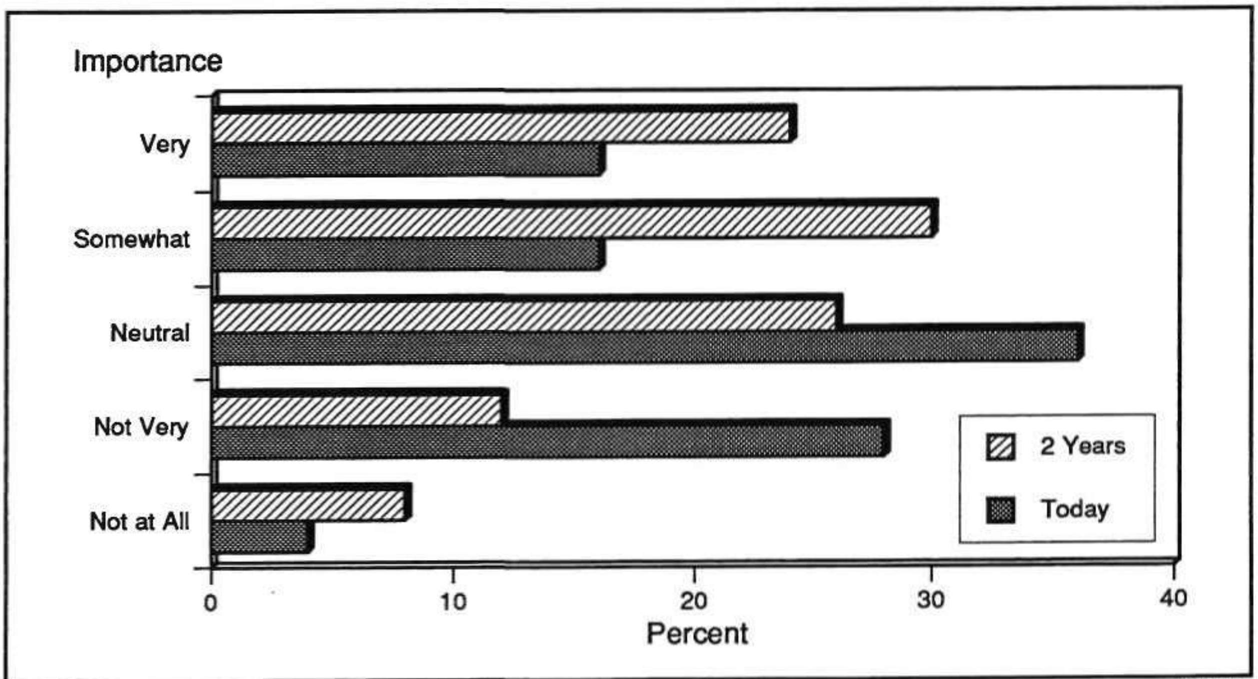
Figure 4-11
Importance of Power Consumption, 16 Bit



Source: Dataquest (December 1992)

G2003215

Figure 4-12
Importance of Power Consumption, 32 Bit



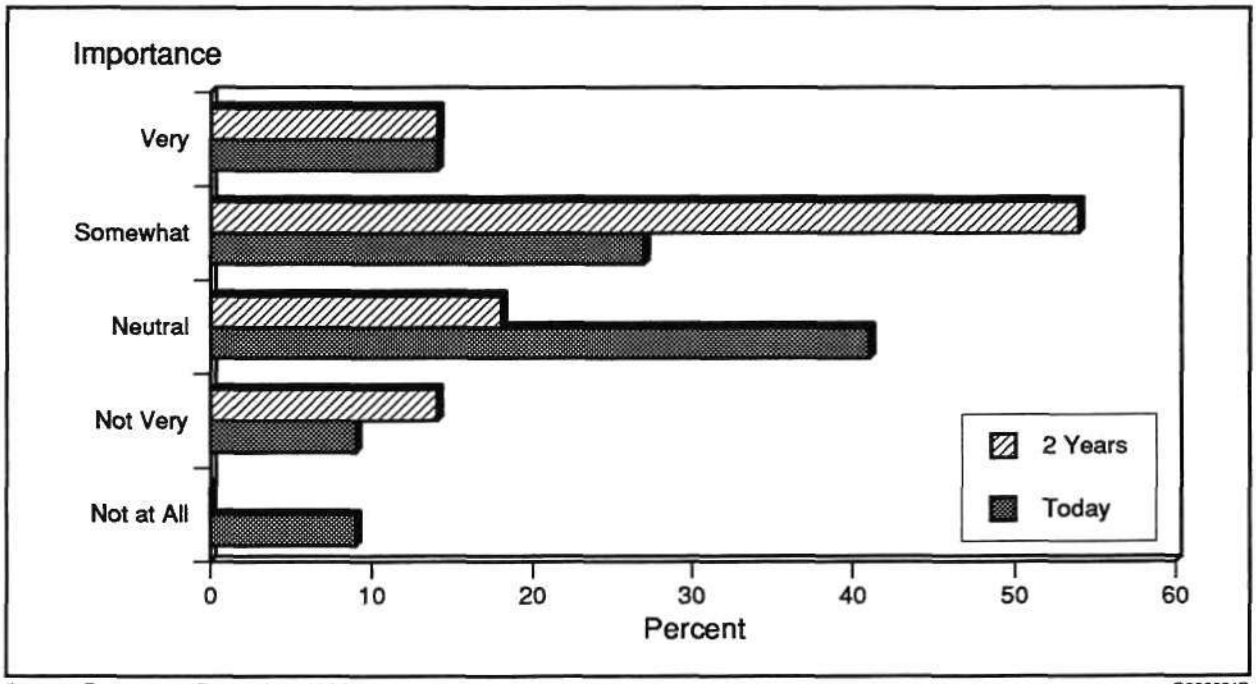
Source: Dataquest (December 1992)

G2003216

On-Chip Functionality

On-chip functionality did not receive an overwhelming number of very or somewhat important votes; the range was from 41 to 52 percent (see Figures 4-13 through 4-15). But it did receive an extremely low incidence of not at all or not very important votes, ranging from 13 to 20 percent. Also, in every case the combination of "not at all" and "not very" respondents decreased in the two-year time frame and the number of "somewhat" or "very" respondents jumped dramatically. This might indicate that a wise vendor would actively solicit new product input from its major customers as well as input from major noncustomers in markets that the vendor would like to penetrate. It appears that designers are able to get by with the on-chip functions they now have, but they would like something more suitable for future designs.

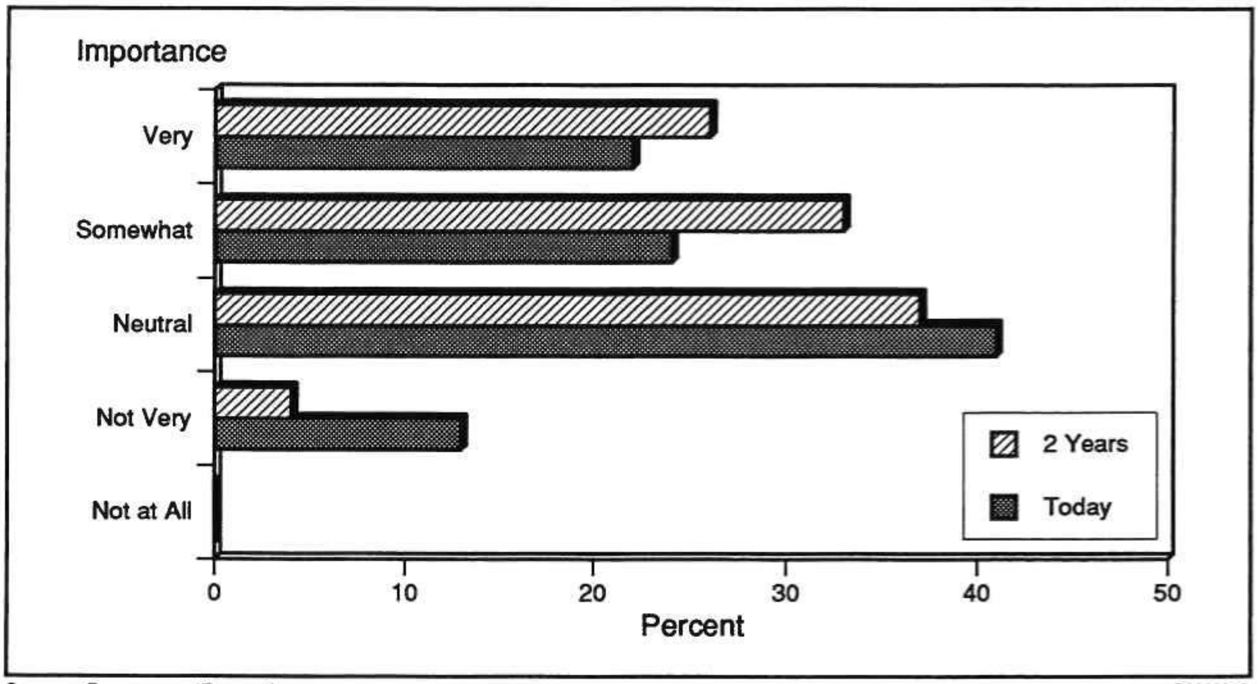
Figure 4-13
Importance of On-Chip Functionality, 8 Bit



Source: Dataquest (December 1992)

G2003217

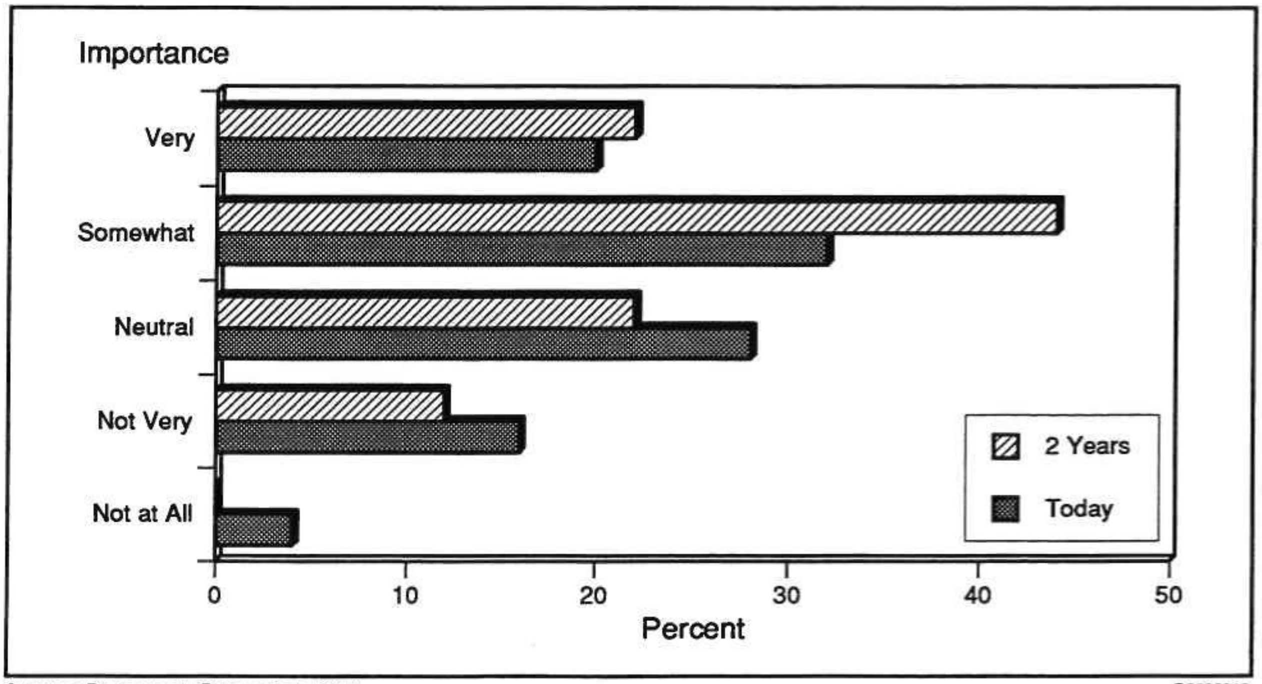
Figure 4-14
Importance of On-Chip Functionality, 16 Bit



Source: Dataquest (December 1992)

G2003218

Figure 4-15
Importance of On-Chip Functionality, 32 Bit



Source: Dataquest (December 1992)

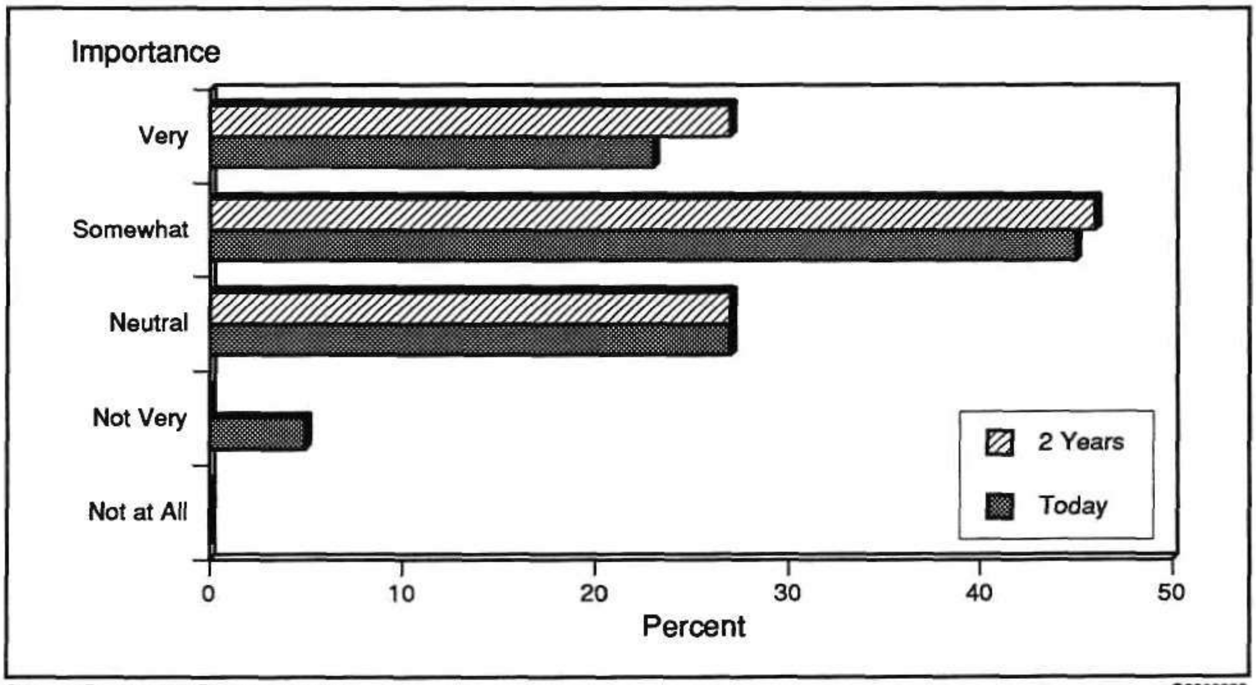
G2003219

Vendor Stability

The heavy weighting given to the importance of vendor stability at the design engineer level did come as a surprise (see Figures 4-16 through 4-18). Less than 10 percent of the respondents, in any word width category, rated this topic not very or not at all important. It appears that the days of a designer going for the most "elegant" solution have gone away. Designers have been trained to be concerned about a new unproven company.

Switching to a new architecture is not a trivial task. Switching to a new architecture and a new or unknown company will require considerable upfront corporate positioning on the part of the vendor if it wants a chance to show its wares to today's design community.

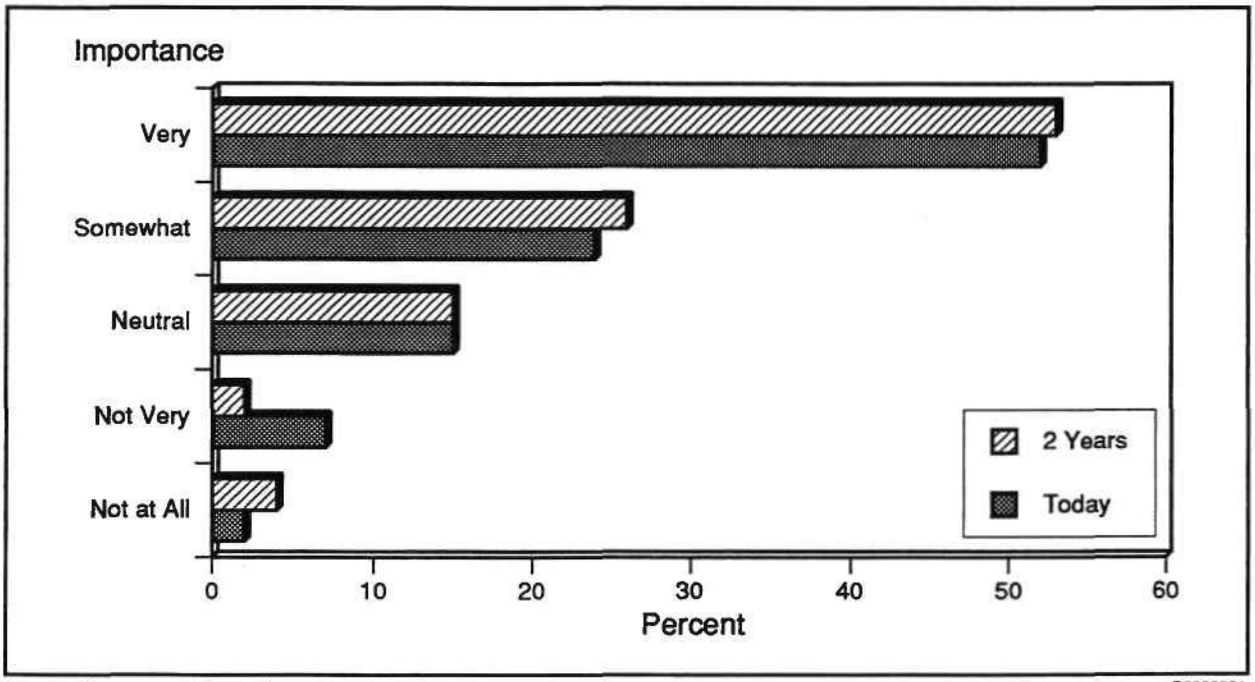
Figure 4-16
Importance of Vendor Stability, 8 Bit



Source: Dataquest (December 1992)

G2003220

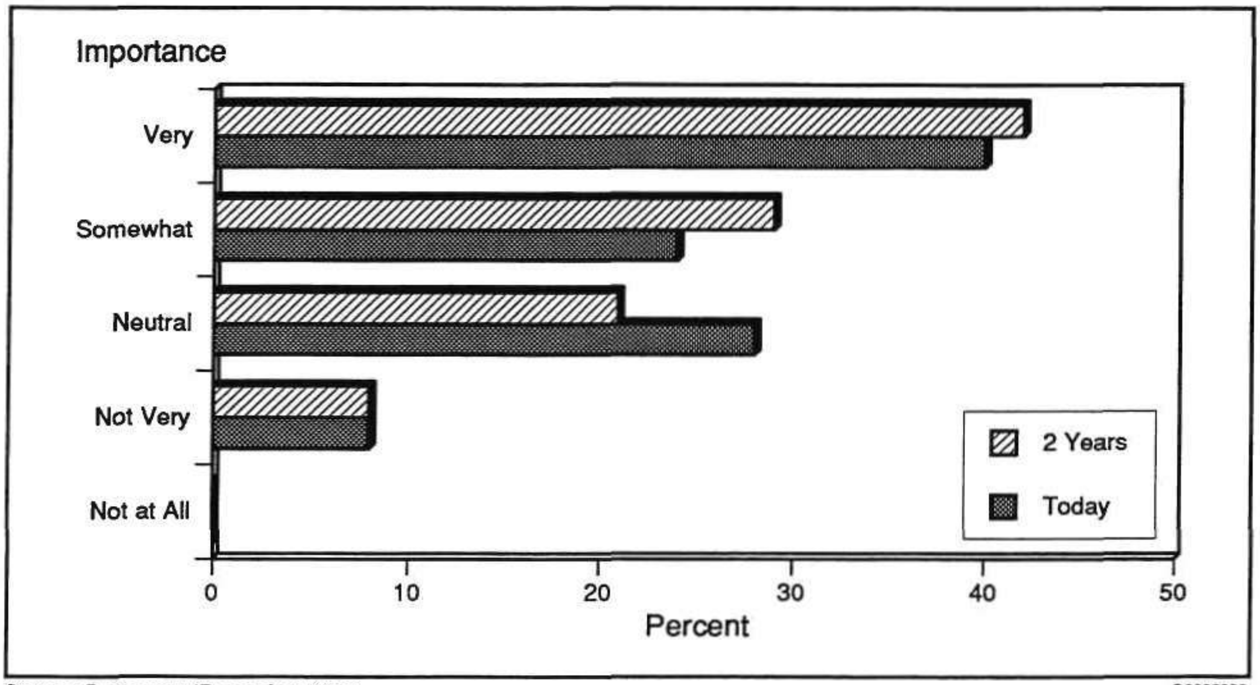
Figure 4-17
Importance of Vendor Stability, 16 Bit



Source: Dataquest (December 1992)

G2003221

Figure 4-18
Importance of Vendor Stability, 32 Bit



Source: Dataquest (December 1992)

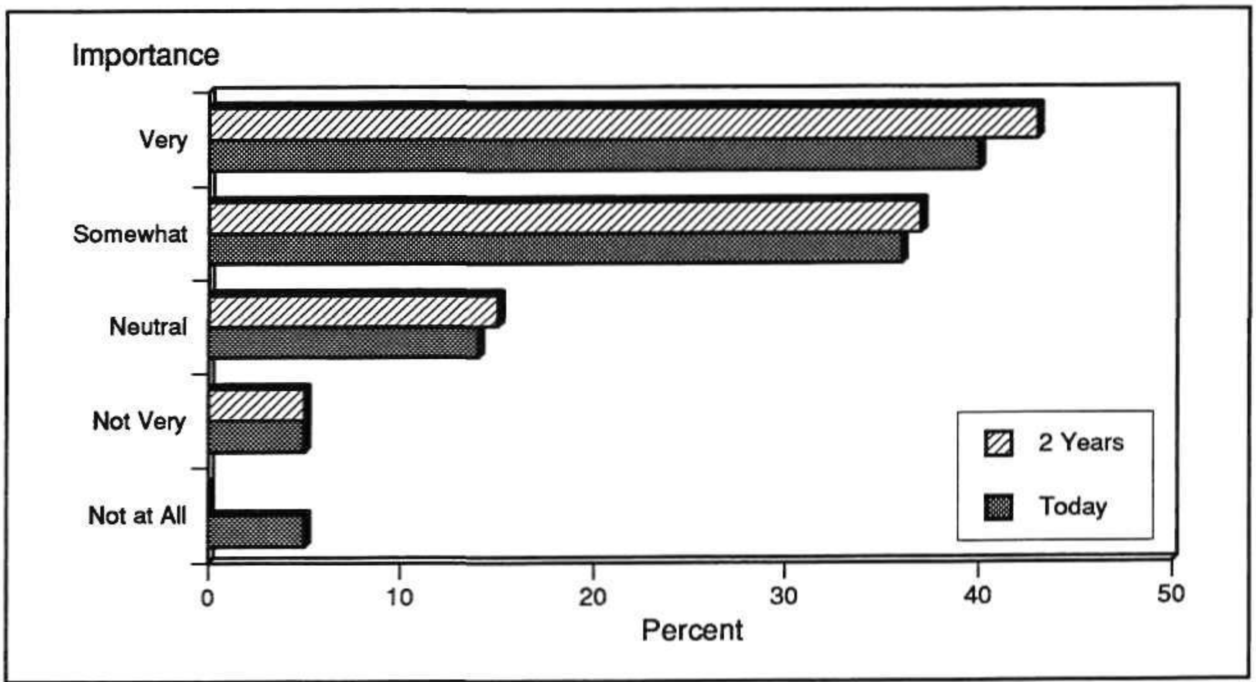
G2003222

Chapter 5

Development Tools

This chapter deals primarily with the importance of development tools and support. The questions were asked in the context of how important these various topics are in relation to selecting the particular architecture or vendor of the next embedded processor. Figures 5-1 through 5-3 simply confirm the importance of development tools when evaluating a new processor and/or vendor. The following sections delve into more depth on this issue.

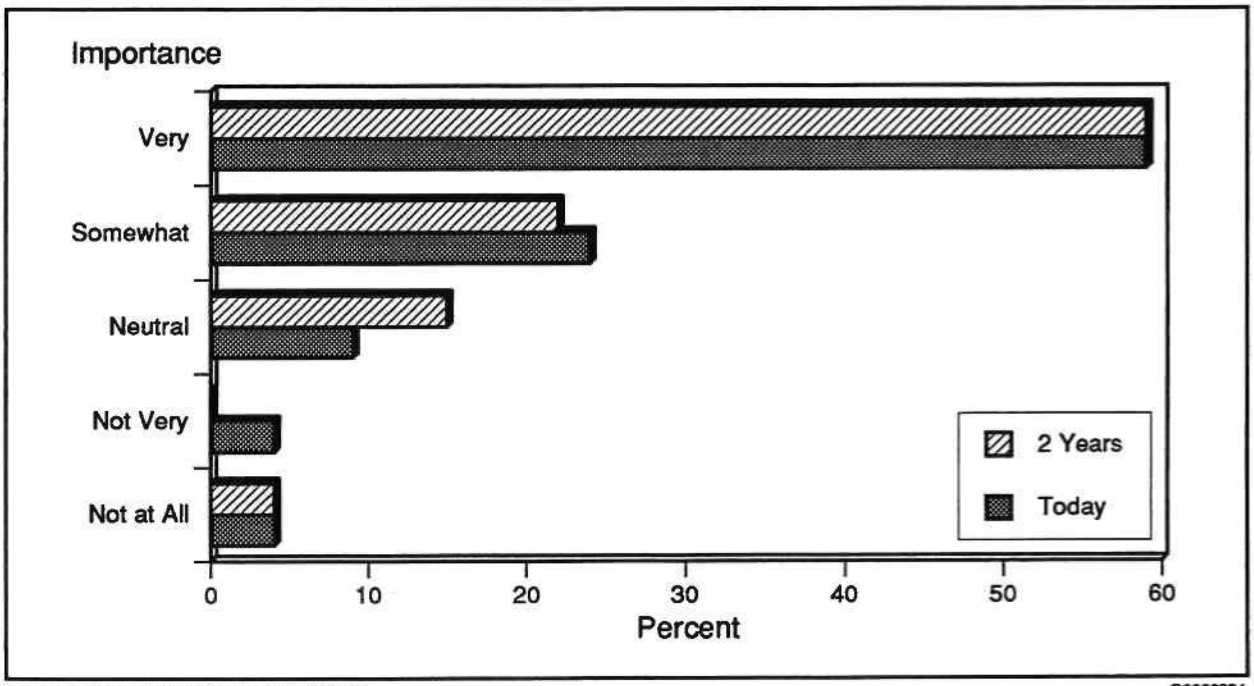
Figure 5-1
Importance of Development Tools, 8 Bit



Source: Dataquest (December 1992)

G2003223

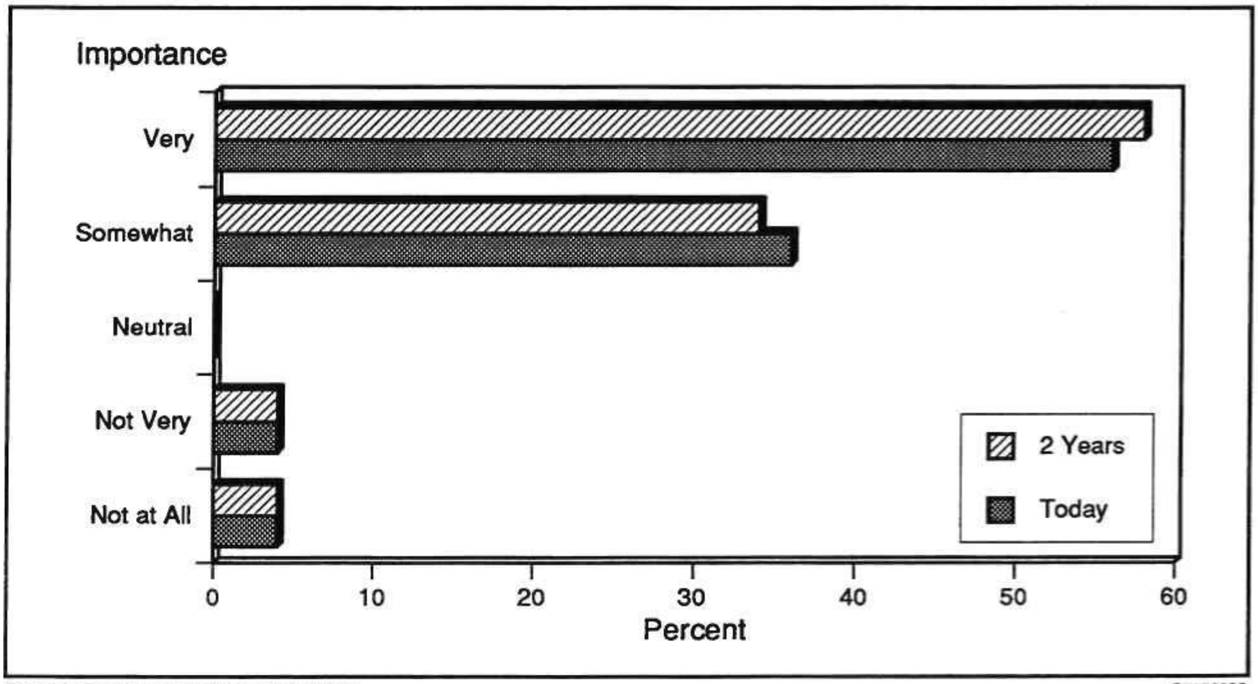
Figure 5-2
Importance of Development Tools, 16 Bit



Source: Dataquest (December 1992)

G2003224

Figure 5-3
Importance of Development Tools, 32 Bit



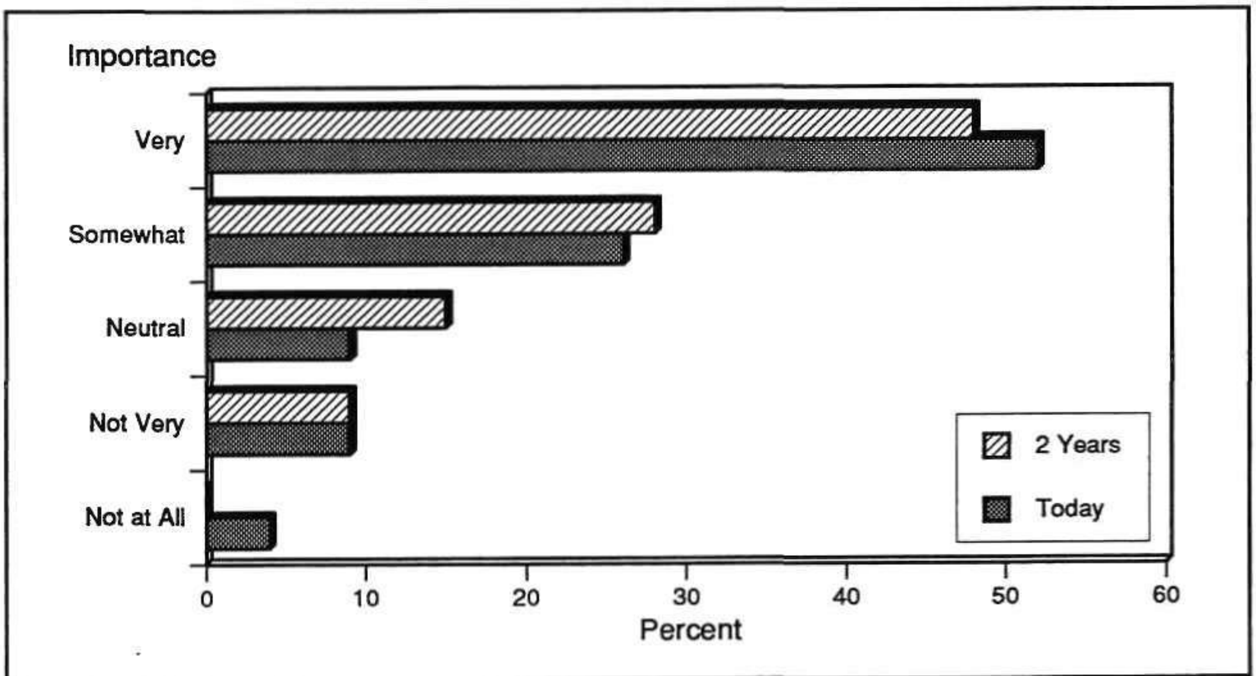
Source: Dataquest (December 1992)

G2003225

Importance of In-Circuit Emulators (ICEs)

Despite the volumes of articles being written by editors in the trade press and the marketing collateral being tossed by processor and software vendors about the capabilities of simulation models, the majority of today's designers still continue to use an in-circuit emulator. This preference holds for primarily 8- and 16-bit processors (see Figures 5-4 and 5-5). That is not to say that other development/debug tools are not used or considered valuable. It is just that they cannot completely displace the real-world environment of the target system. However, designers of systems using 32-bit processors are much less likely to require the availability of an ICE (see Figure 5-6).

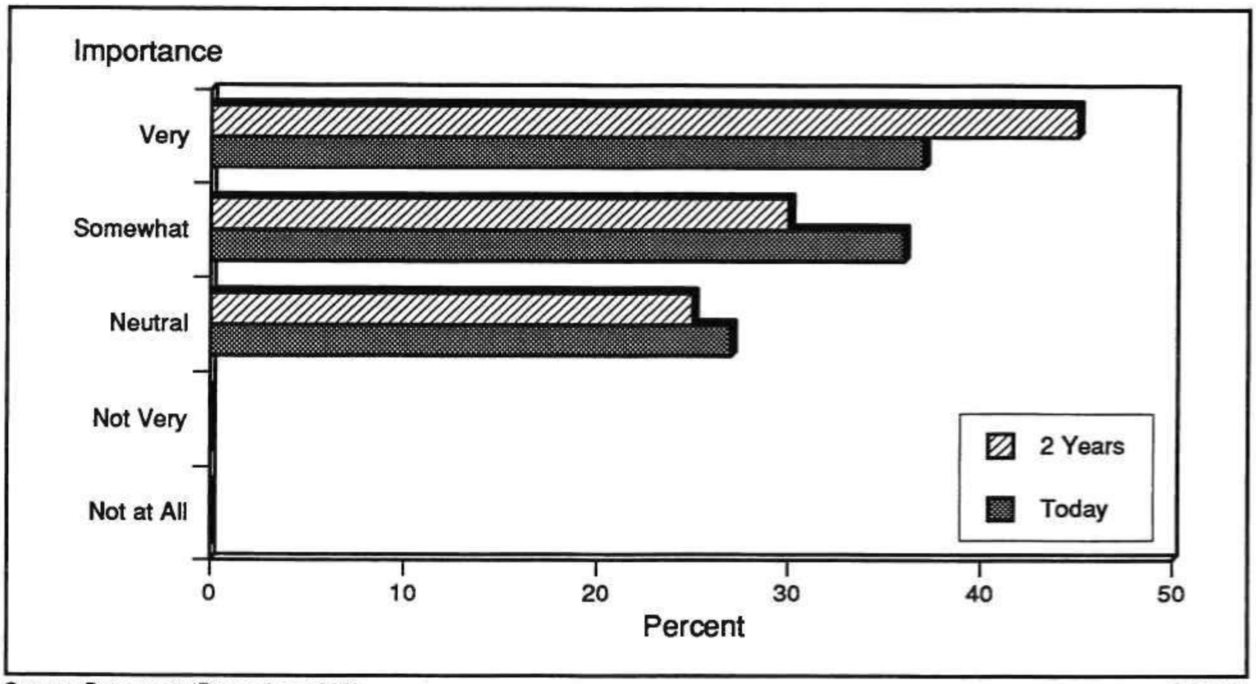
Figure 5-4
Importance of In-Circuit Emulators, 8 Bit



Source: Dataquest (December 1992)

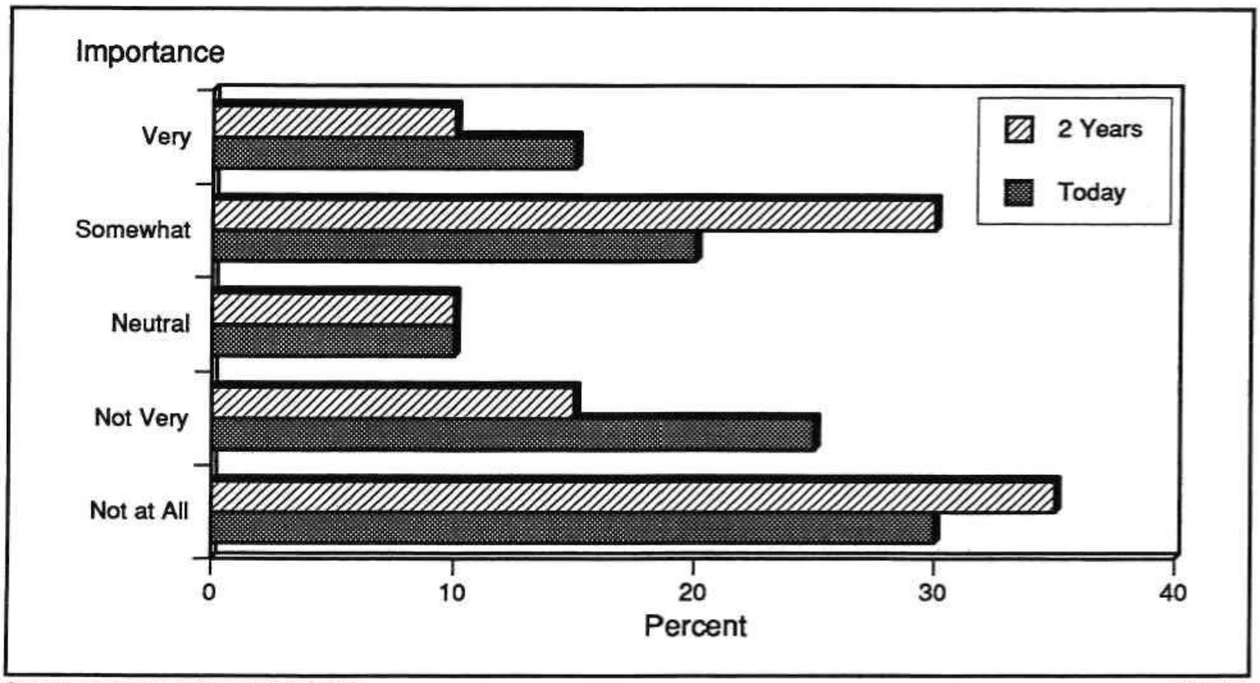
G2003226

Figure 5-5
Importance of In-Circuit Emulators, 16 Bit



Source: Dataquest (December 1992)
G2003227

Figure 5-6
Importance of In-Circuit Emulators, 32 Bit



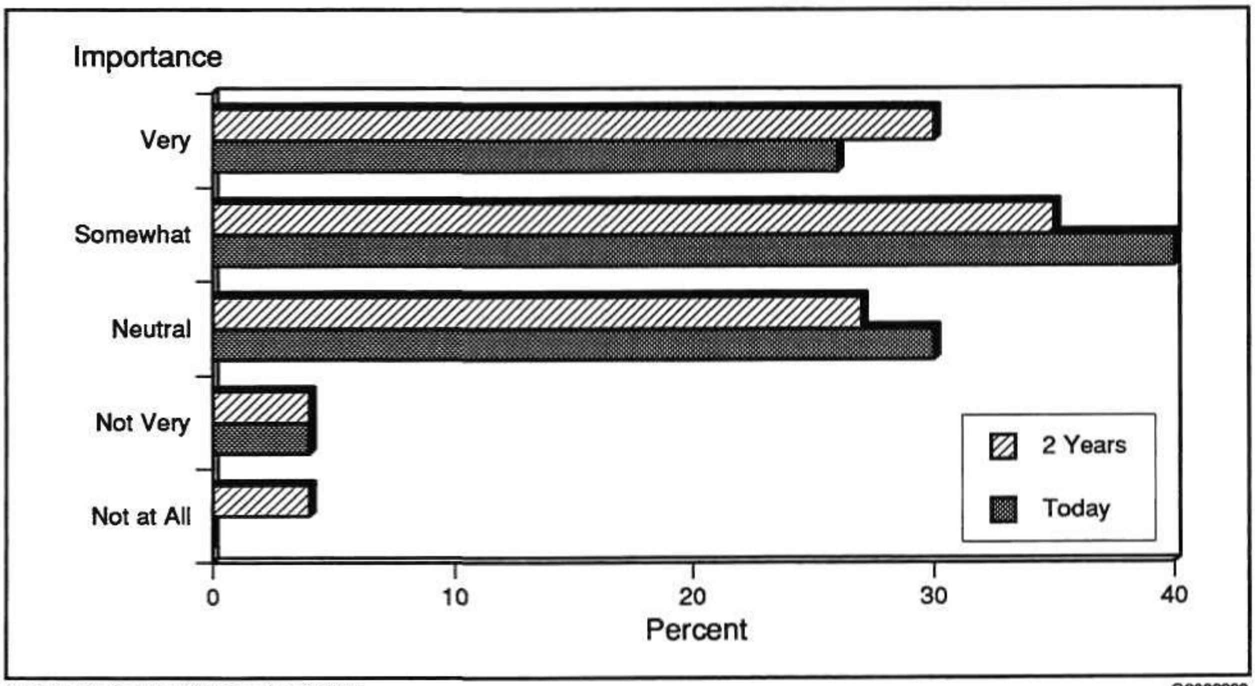
Source: Dataquest (December 1992)
G2003228

Importance of Software Development Tools

Software development tools are a critical factor for success in the embedded marketplace. It would be suicide to enter this arena without a comprehensive software tools program. This program must include a major effort in developing relationships with third-party tool developers. Most designers will revolt if they are forced to learn how to use yet another piece of software. It would go a long way toward eliminating a critical barrier if the software tool of a new processor had the same look and feel as the tools the designer is currently using.

As can be seen from Figures 5-7 through 5-9, the overwhelming majority of designers rate this category important in their processor selection criteria.

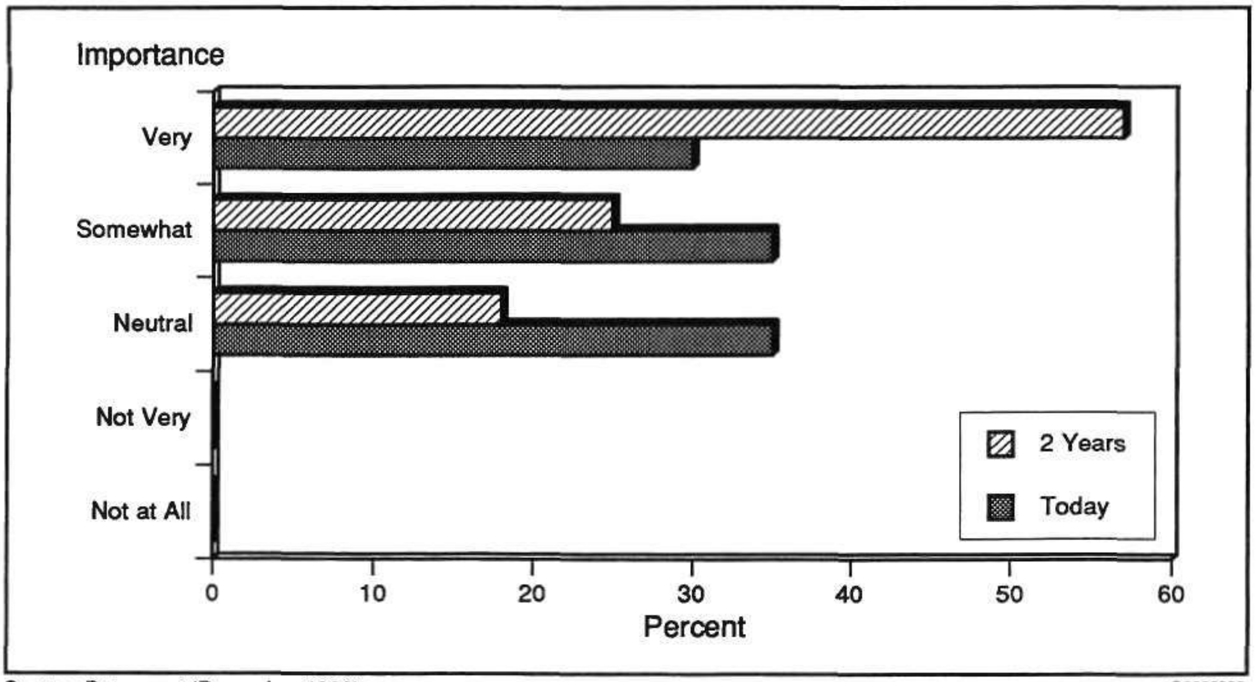
Figure 5-7
Importance of Software Tools When Selecting a Microprocessor, 8 Bit



Source: Dataquest (December 1992)

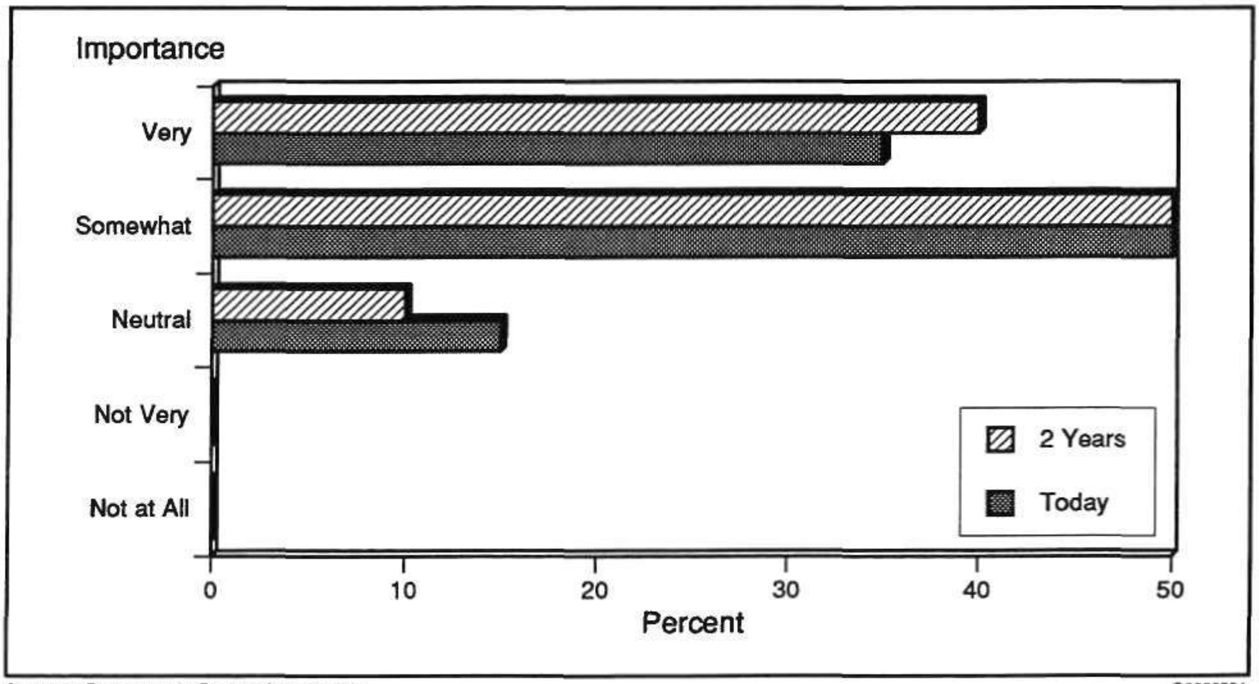
G2003229

Figure 5-8
Importance of Software Tools When Selecting a Microprocessor, 16 Bit



Source: Dataquest (December 1992)
G2003230

Figure 5-9
Importance of Software Tools When Selecting a Microprocessor, 32 Bit

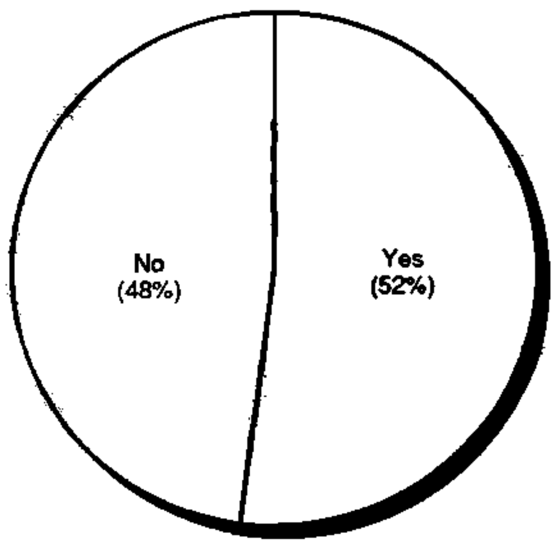


Source: Dataquest (December 1992)
G2003231

Evaluation Boards Used to Develop Application Software

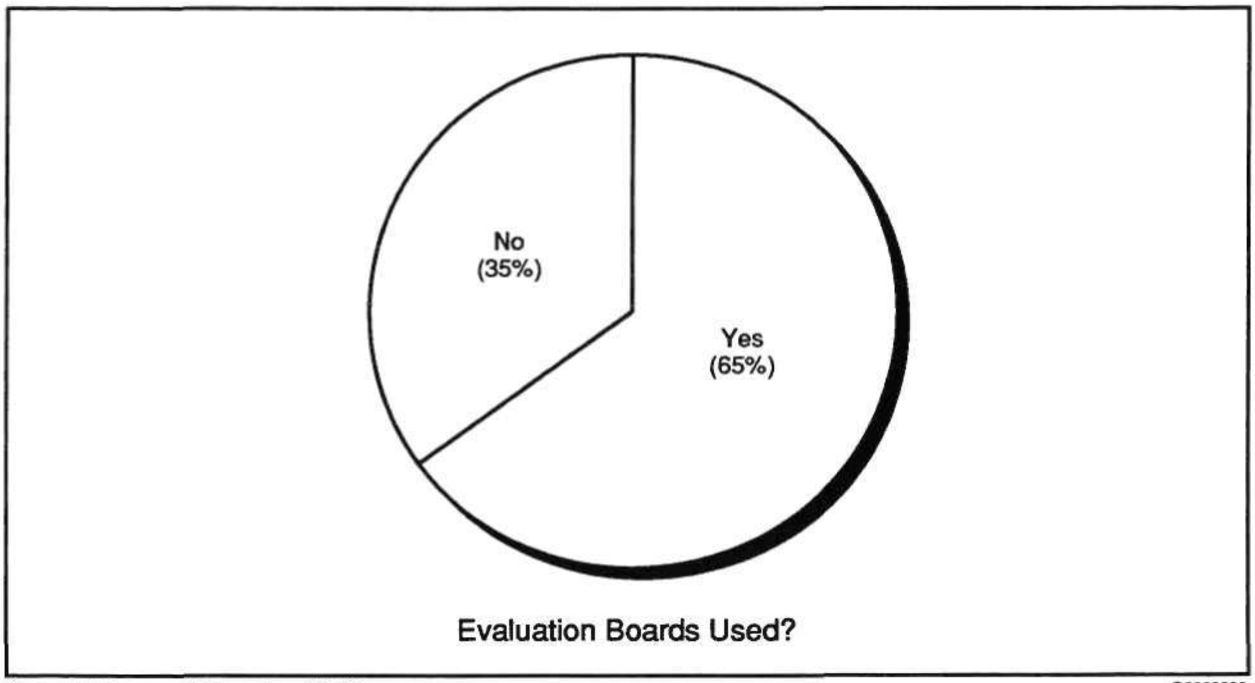
About 40 to 60 percent of the designers make use of an evaluation board when first developing the target code for the application (for details see Figures 5-10 through 5-12).

Figure 5-10
Evaluation Boards Used to Develop Application Software, 8 Bit



Source: Dataquest (December 1992) G2003232

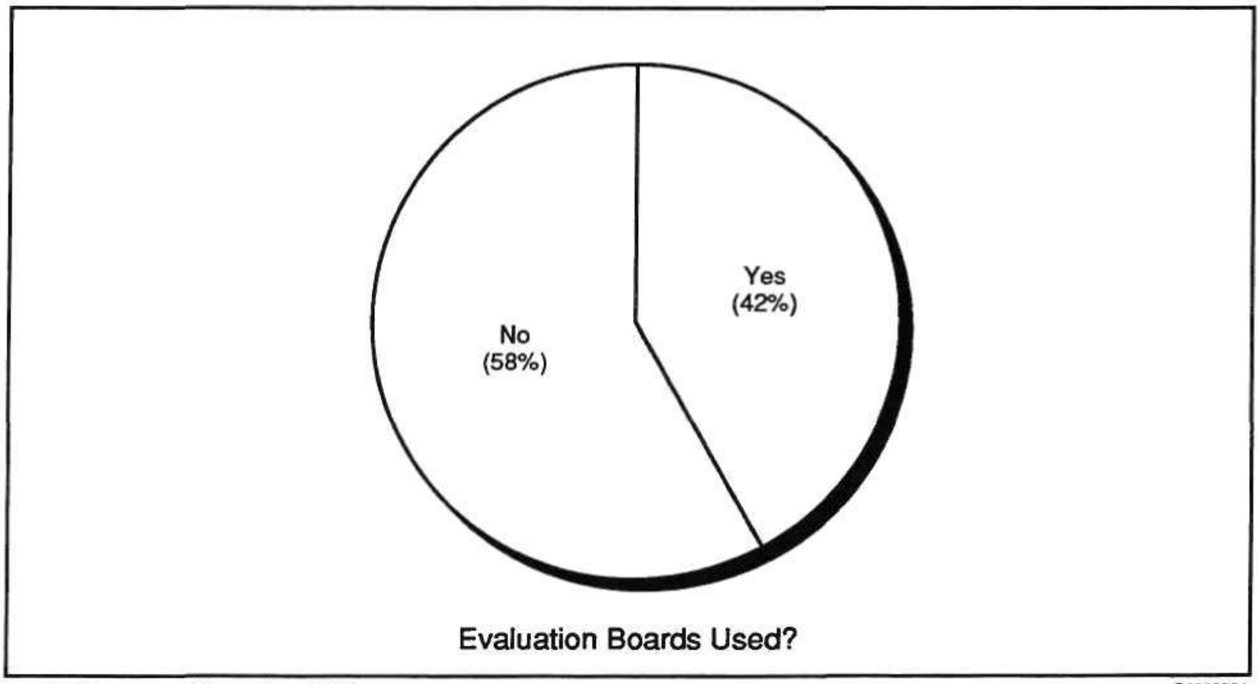
Figure 5-11
Evaluation Boards Used to Develop Application Software, 16 Bit



Source: Dataquest (December 1992)

G2003233

Figure 5-12
Evaluation Boards Used to Develop Application Software, 32 Bit



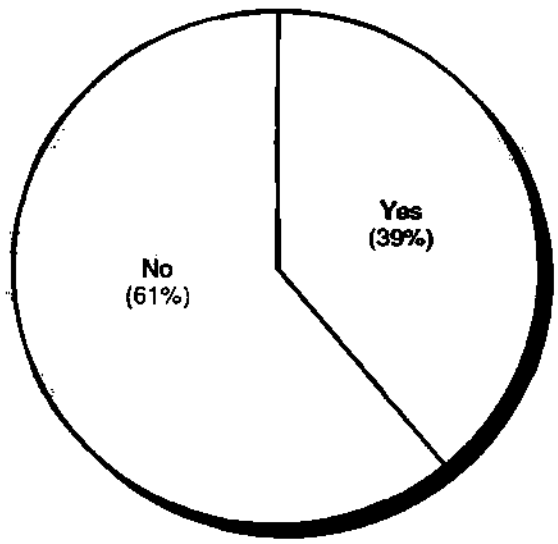
Source: Dataquest (December 1992)

G2003234

Simulation Models Used to Develop Application Software

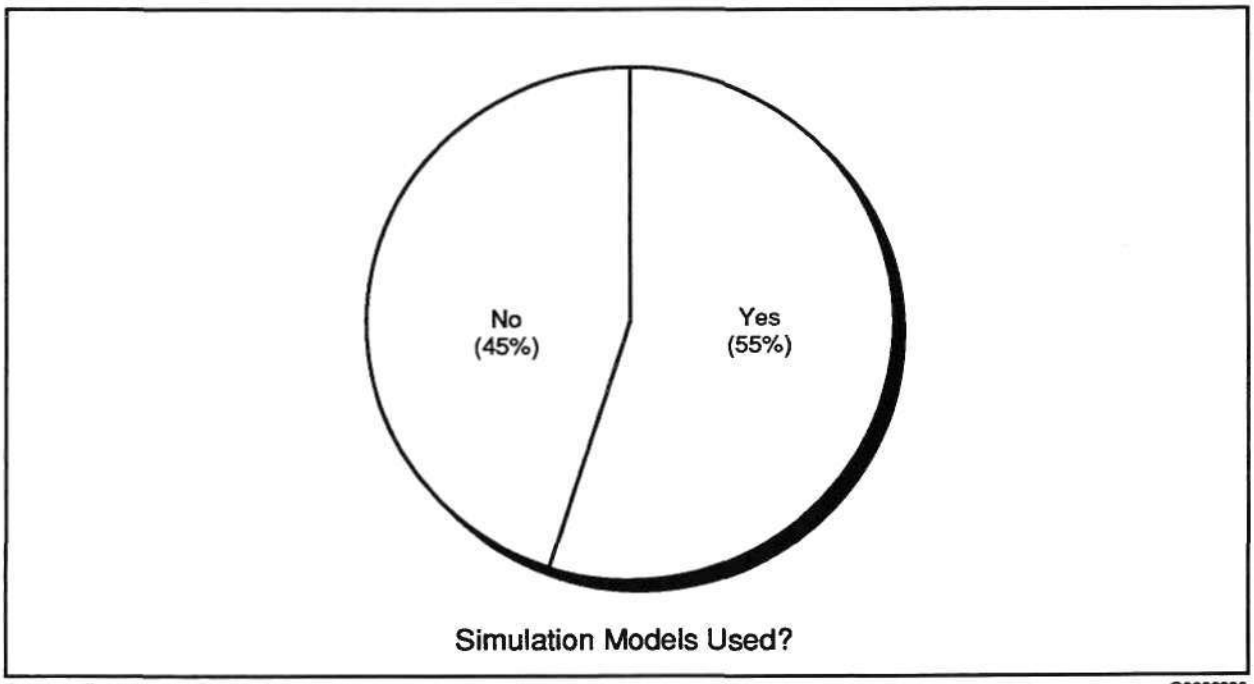
As the word width of the processor increases, we begin to see an increase in the reliance on simulation models (see Figures 5-13 through 5-15). Less than 40 percent of designers of 8-bit based applications make use of such tools; for 32-bit applications, this jumps to 60 percent. Across the entire survey, it became apparent that the designers of 32-bit systems were much more likely to use or require the use of higher-level tools than were designers involved with either 8- or 16-bit designs.

Figure 5-13
Simulation Models Used to Develop Application Software, 8 Bit



Source: Dataquest (December 1992)
G2003235

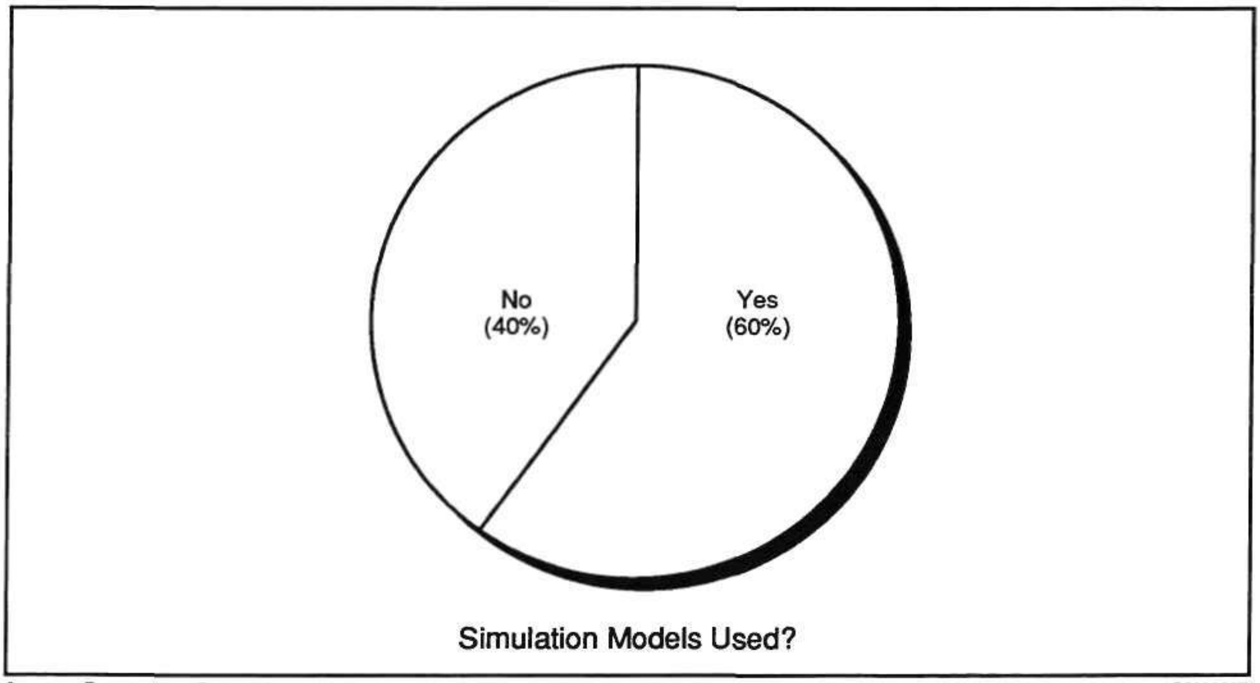
Figure 5-14
Simulation Models Used to Develop Application Software, 16 Bit



Source: Dataquest (December 1992)

G2003236

Figure 5-15
Simulation Models Used to Develop Application Software, 32 Bit



Source: Dataquest (December 1992)

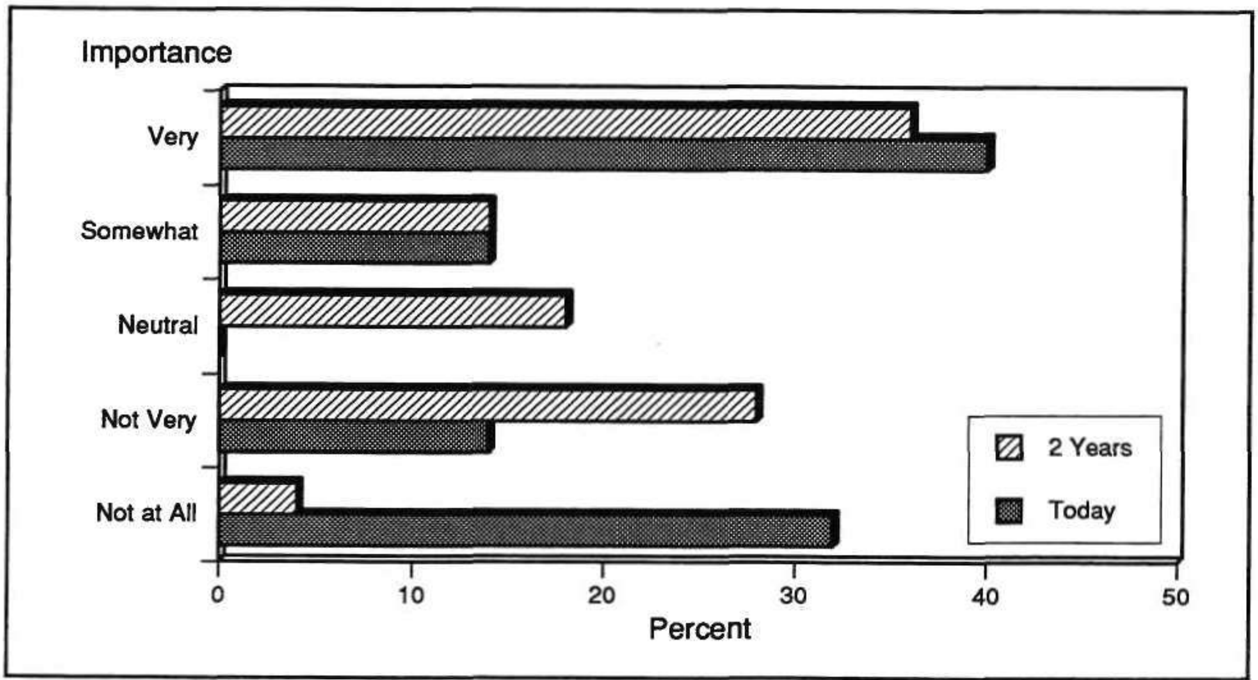
G2003237

Importance of a Real-Time Operating System

This report has shown that in the next two years designers will be much more interested in having the ability to transfer to another architecture. The ability to preserve as much existing application code as possible when transferring to another processor architecture is one driving force for the reliance upon a standardized real-time operating system (RTOS).

Designers of 32-bit systems have once again led the way, but designers for both 8- and 16-bit systems will approach the 32-bit world's reliance on RTOSs over the next two years (see Figures 5-16 through 5-18). No RTOS in the embedded marketplace has approached the dominance achieved by DOS or UNIX in the compute marketplace. This makes the task of the vendors of embedded processors that much more challenging, because they must court multiple third-party RTOS developers to cover as many possible applications as possible.

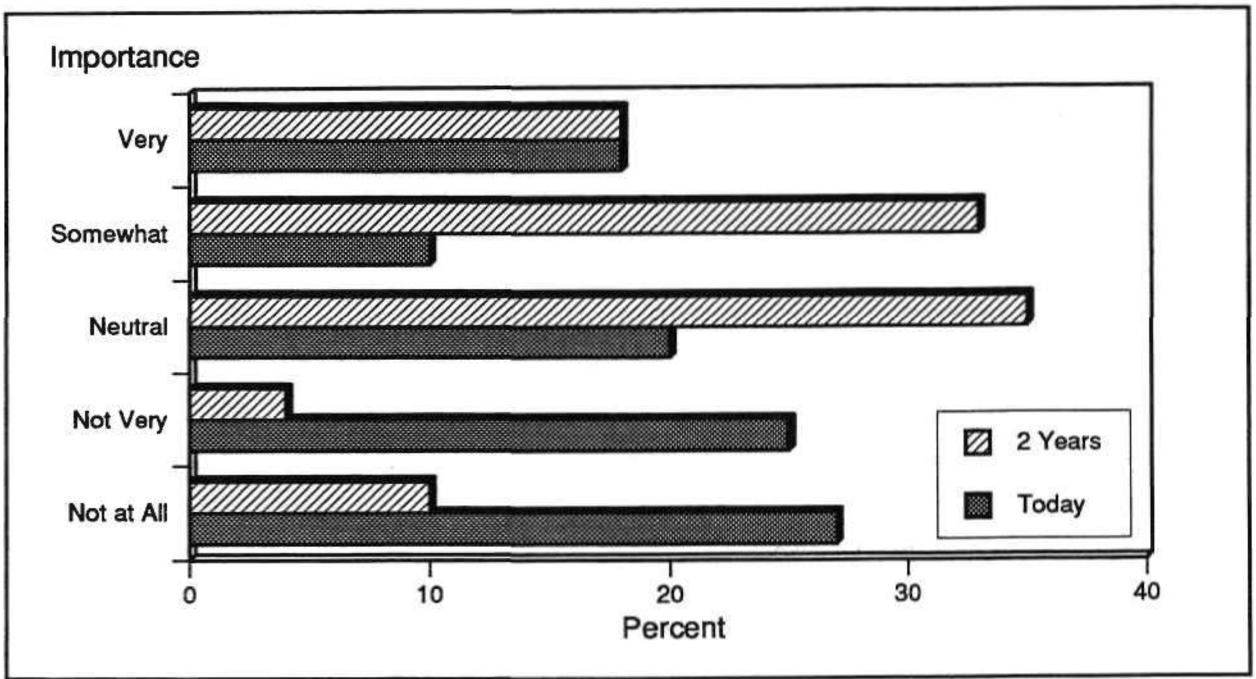
Figure 5-16
Importance of a Real-Time Operating System, 8 Bit



Source: Dataquest (December 1992)

G2003238

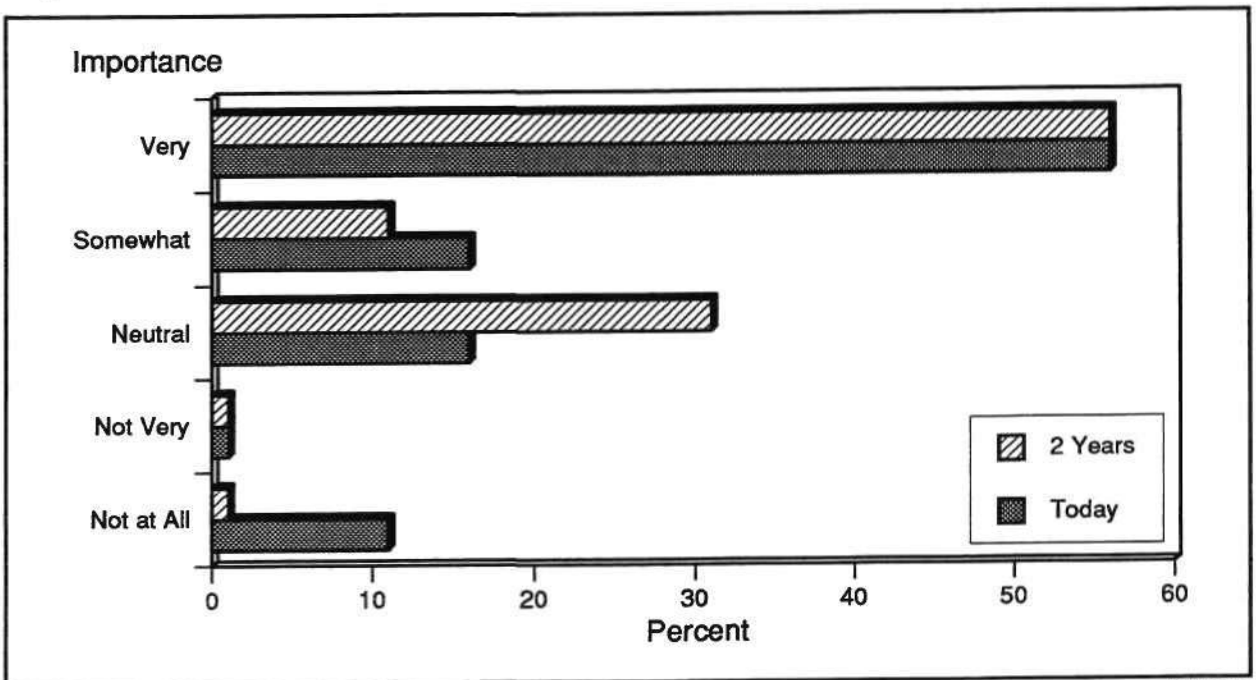
Figure 5-17
Importance of a Real-Time Operating System, 16 Bit



Source: Dataquest (December 1992)

G2003239

Figure 5-18
Importance of a Real-Time Operating System, 32 Bit



Source: Dataquest (December 1992)

G2003240

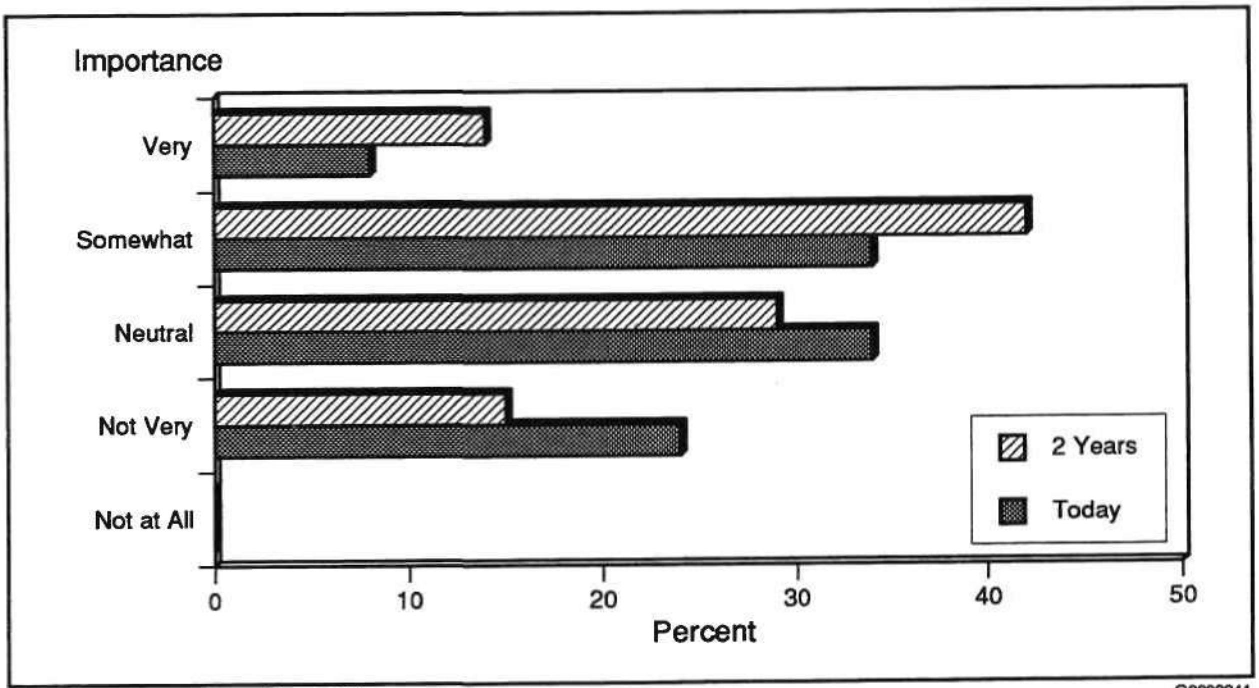
Chapter 6
Factors Impacting the Processor Selection Process

This chapter deals with key issues that a designer considers when choosing a particular embedded processor for an application.

Importance of Application Support

As the complexity of the processor increases, the importance of application support also increases. If a designer is using an architecture with which he or she is already familiar in the same way as used before, the designer does not believe that the support is needed. As soon as a new feature is added or if the architecture is being used in a different way or if it is a wholly new processor, then application support becomes critical. Basically, if a vendor wants to be a supplier of value-added product, then a design-in philosophy is critical. If a vendor's sole purpose is to clone someone else's standard architecture and feature set, then a design-in philosophy becomes far less important. Figures 6-1 through 6-3 demonstrate this fact. The long-time designer of 8-bit-based applications seems much more at ease operating without application support than does the designer of the 32-bit-based system.

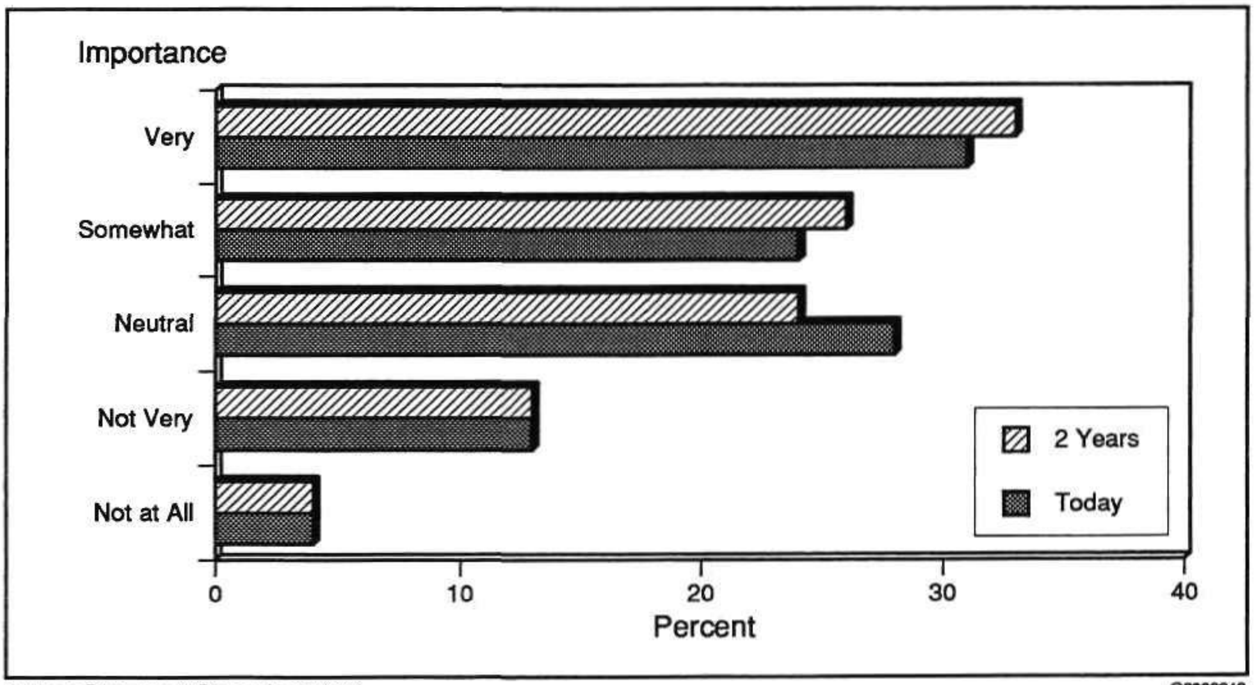
Figure 6-1
Importance of Application Support, 8 Bit



Source: Dataquest (December 1992)

G2003241

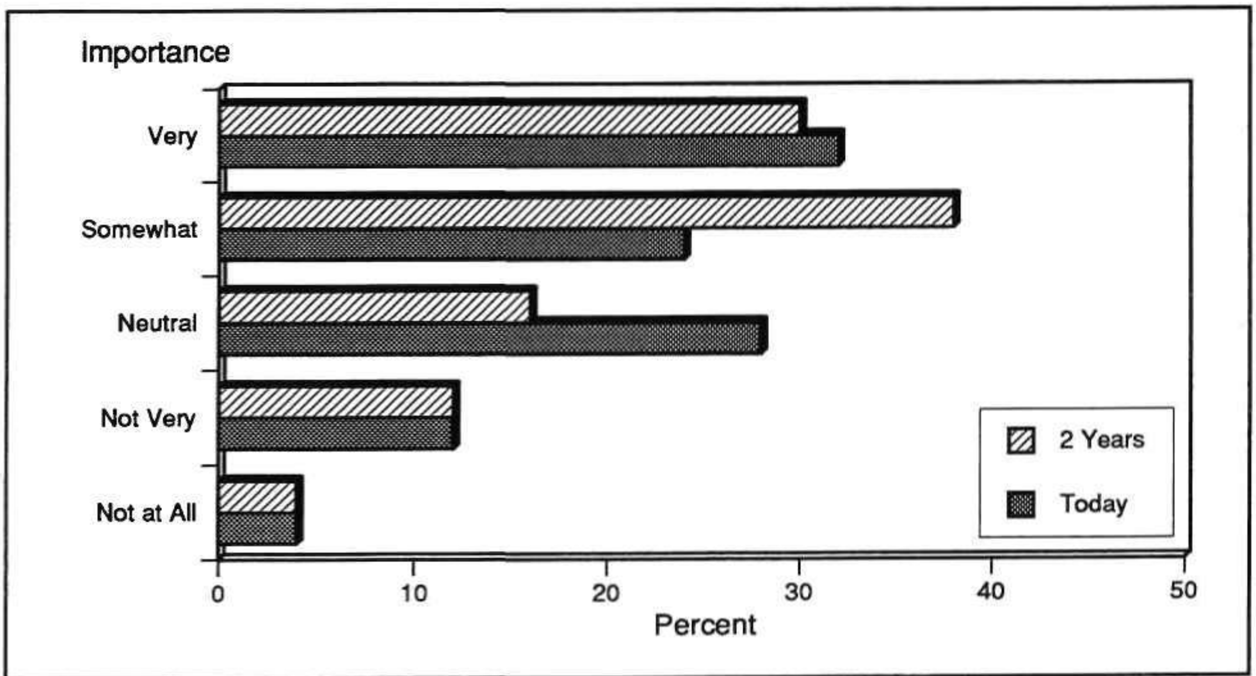
Figure 6-2
Importance of Application Support, 16 Bit



Source: Dataquest (December 1992)

G2003242

Figure 6-3
Importance of Application Support, 32 Bit



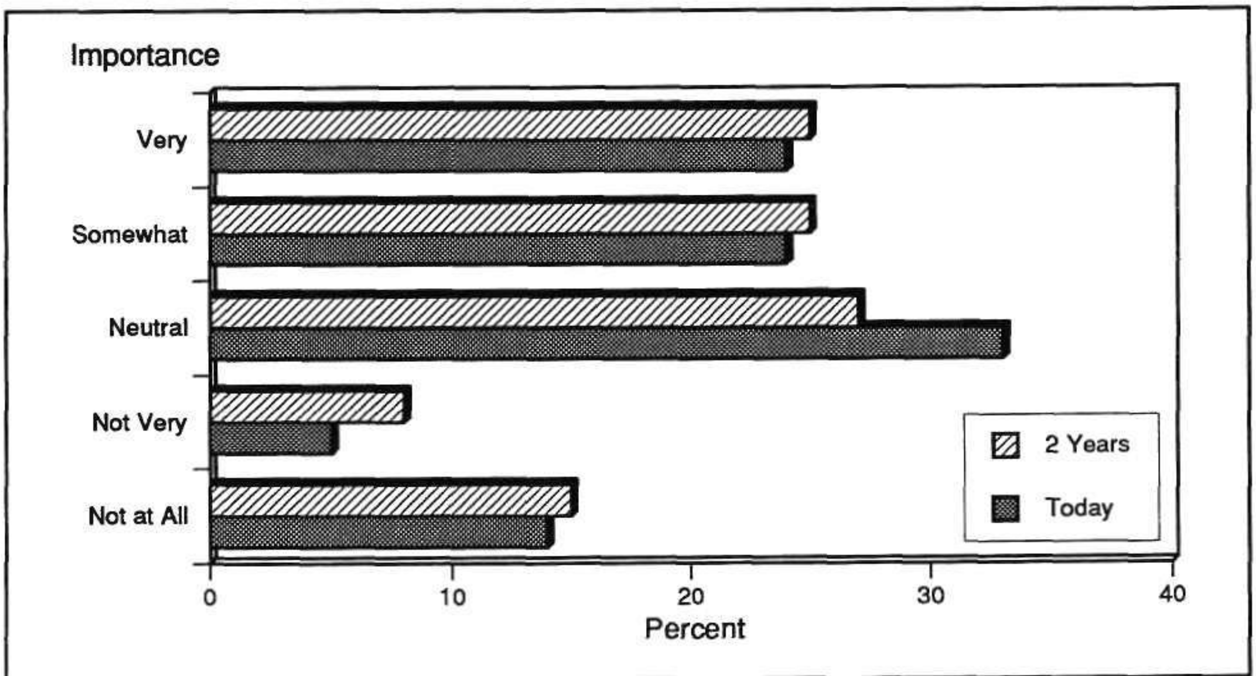
Source: Dataquest (December 1992)

G2003243

Importance of Pre-Existing Application Software

The results of the question on the importance of pre-existing application software at the 8-bit level seem to contradict real-life instances that required the transition from one architecture to another. The 16-bit respondents weighted pre-existing application code much more heavily than did the 8-bit respondents (see Figures 6-4 and 6-5). At the 32-bit level, less than one-third of the respondents believed that pre-existing application software was an unimportant consideration when considering the move to another processor architecture (see Figure 6-6). This response is backed up by the strong desire to standardize on a real-time operating system that we observed in Figure 5-18. It is again apparent that designers at the 32-bit level are more attuned to the concept of portable software than are those designing at the 8-bit level.

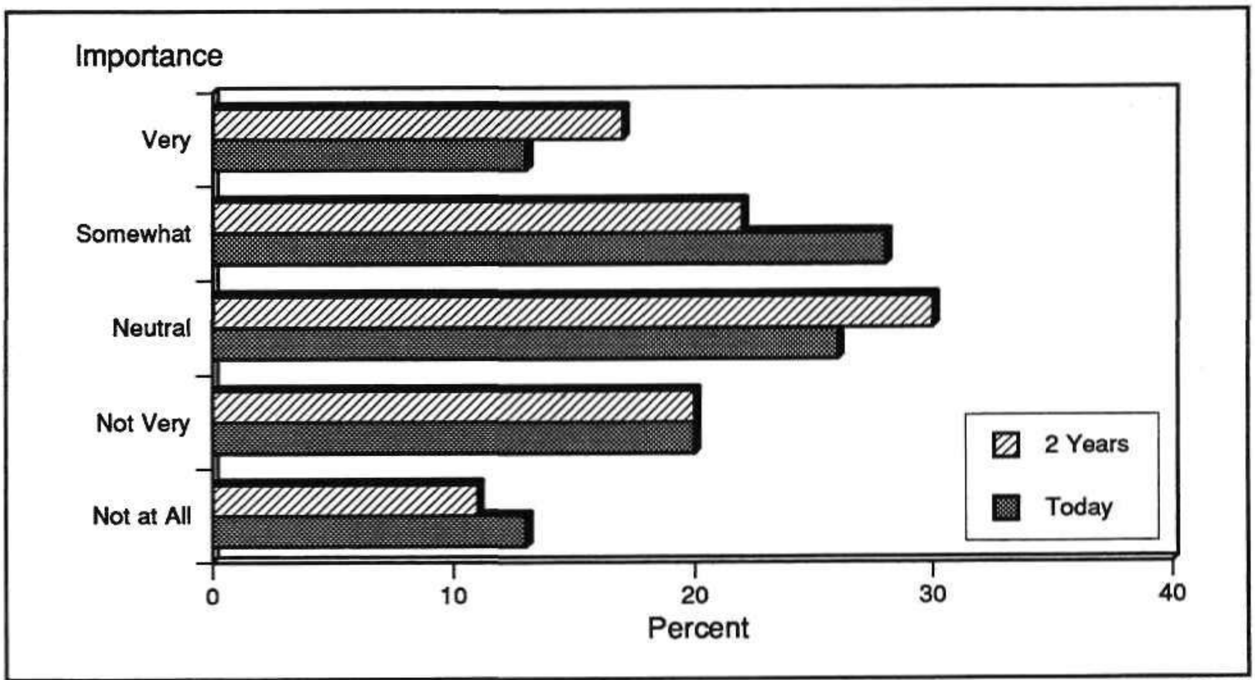
Figure 6-4
Importance of Pre-Existing Application Software, 8 Bit



Source: Dataquest (December 1992)

G2003244

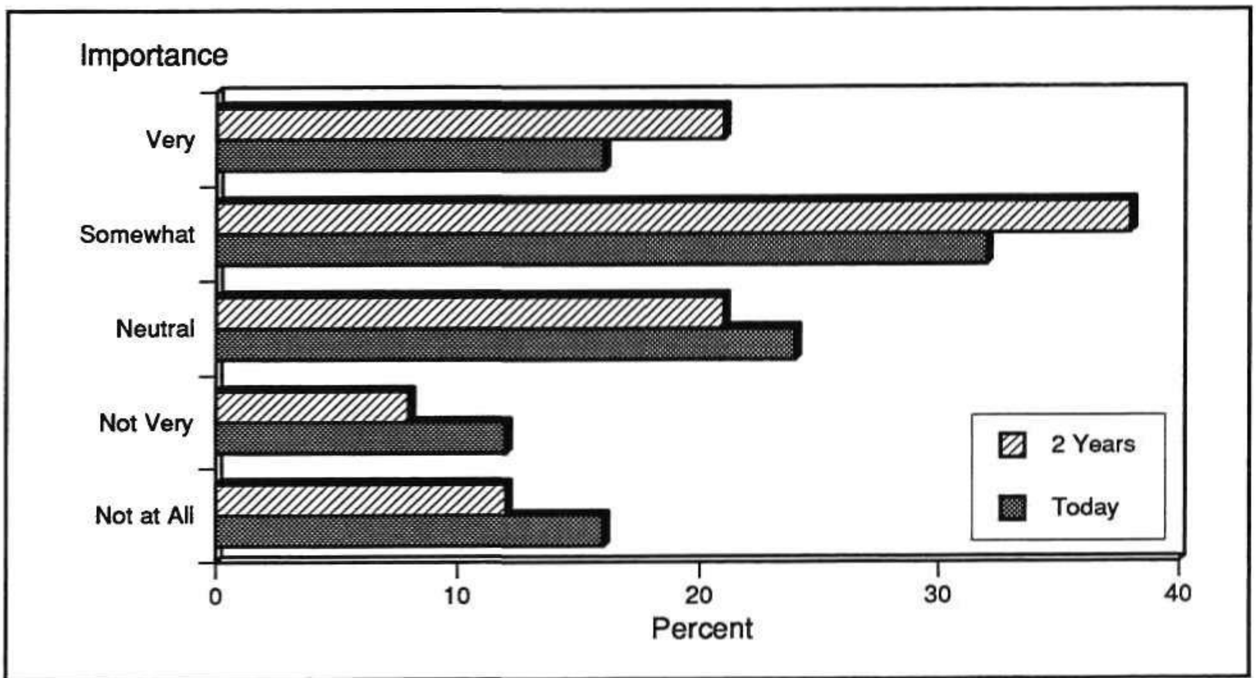
Figure 6-5
Importance of Pre-Existing Application Software, 16 Bit



Source: Dataquest (December 1992)

G2003245

Figure 6-6
Importance of Pre-Existing Application Software, 32 Bit



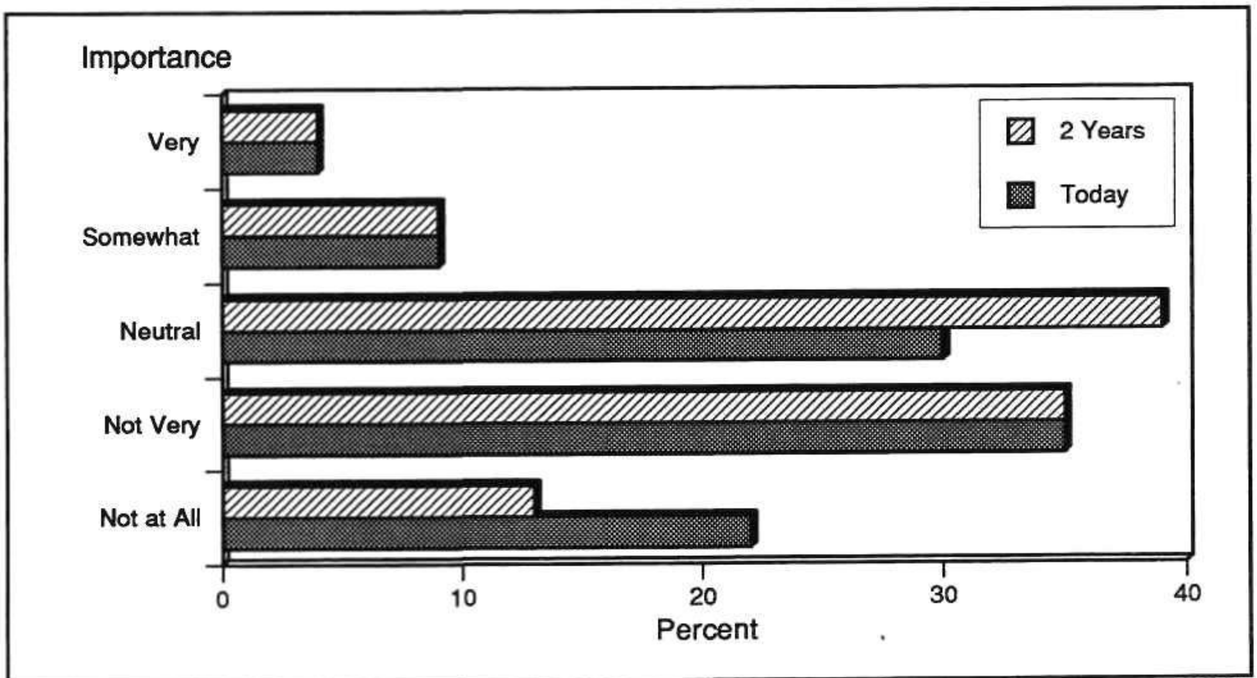
Source: Dataquest (December 1992)

G2003246

Importance of Being Able to Switch between Processor Architectures

This transition between processor architectures has been likened to giving birth to an elephant—long and painful. At the 8-bit level, less than 14 percent rate the ability to switch between processor architectures as either somewhat or very important, in part because 8-bit processors are well understood and their source of supply and support is a known commodity. The 16-bit respondents provided the most dynamic shift observed in the entire survey. Only 5 percent believe that this is somewhat or very important today. However, the percentage believing that it will be either somewhat or very important to switch in two years grows to 45 percent. This is no doubt because of the large number of 16-bit designers who expressed a desire to switch their design from 16- to 32-bit for the next-generation system. The respondents in the 32-bit category highly weight this capability as somewhat or very important, both today and in two years. This is consistent with the large number of respondents answering somewhat or very to the question regarding the importance of pre-existing application software shown in Figures 6-7 through 6-9.

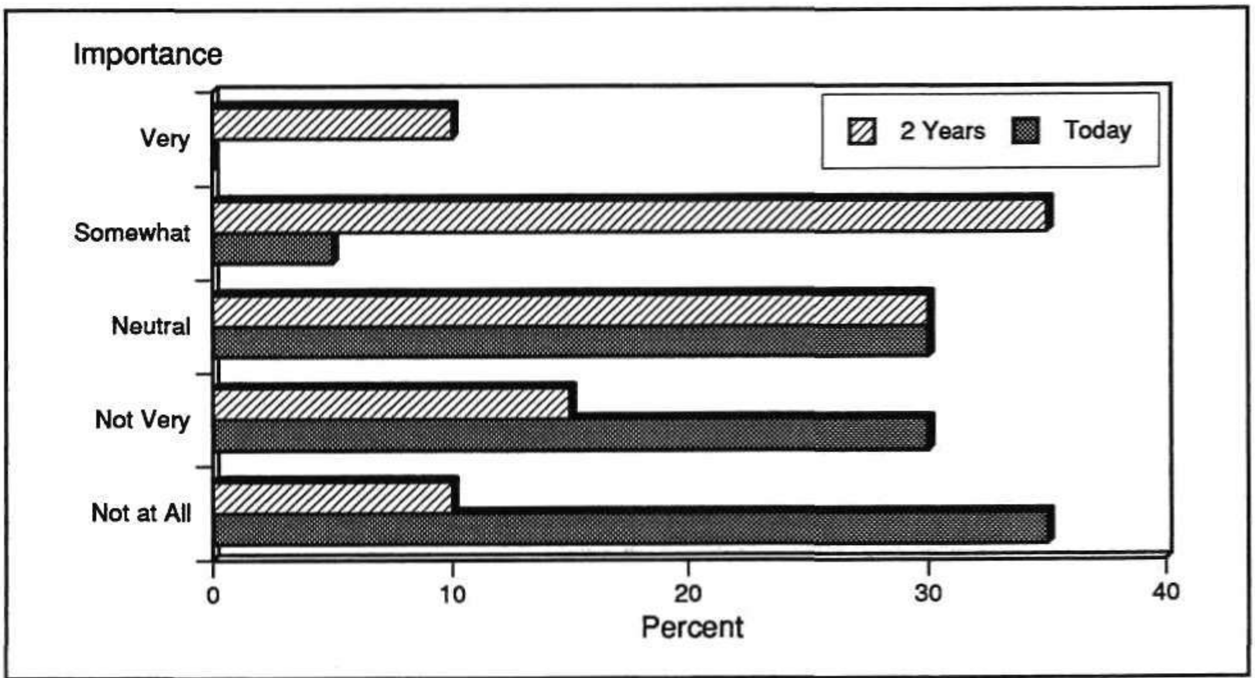
Figure 6-7
Importance of Being Able to Switch between Processor Architectures, 8 Bit



Source: Dataquest (December 1992)

G2003247

Figure 6-8
Importance of Being Able to Switch between Processor Architectures, 16 Bit



Source: Dataquest (December 1992)

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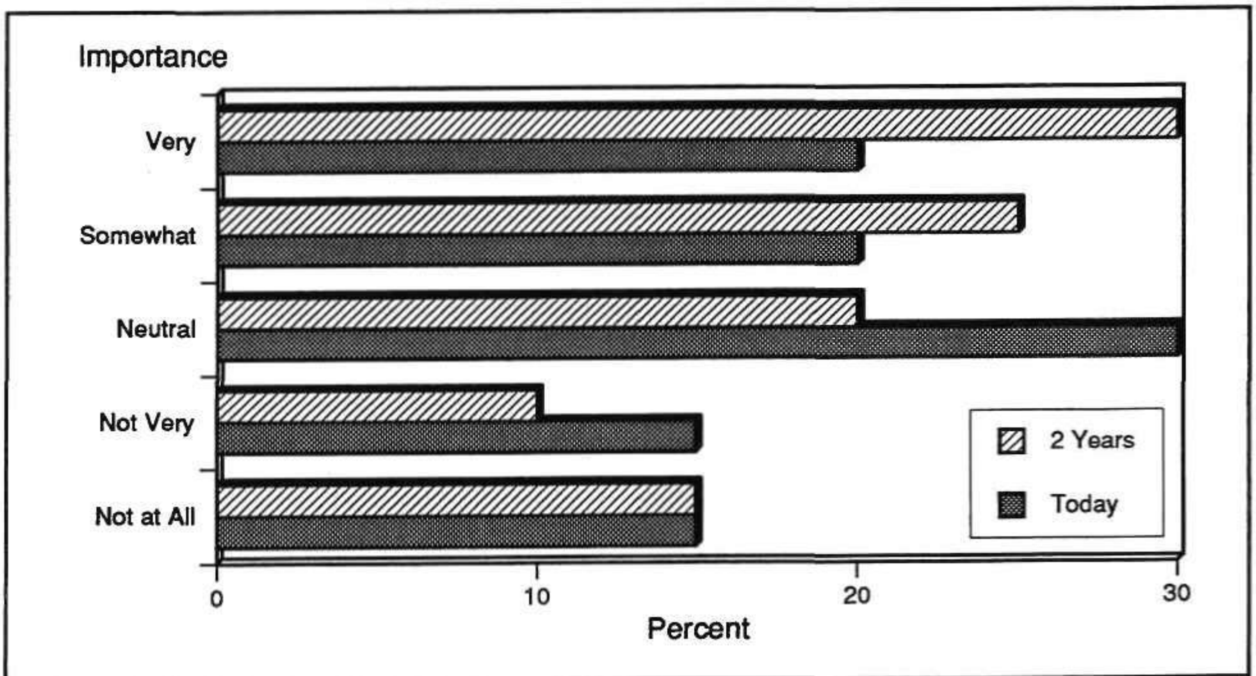
Figure 6-9
Importance of Being Able to Switch between Processor Architectures, 32 Bit



Source: Dataquest (December 1992)

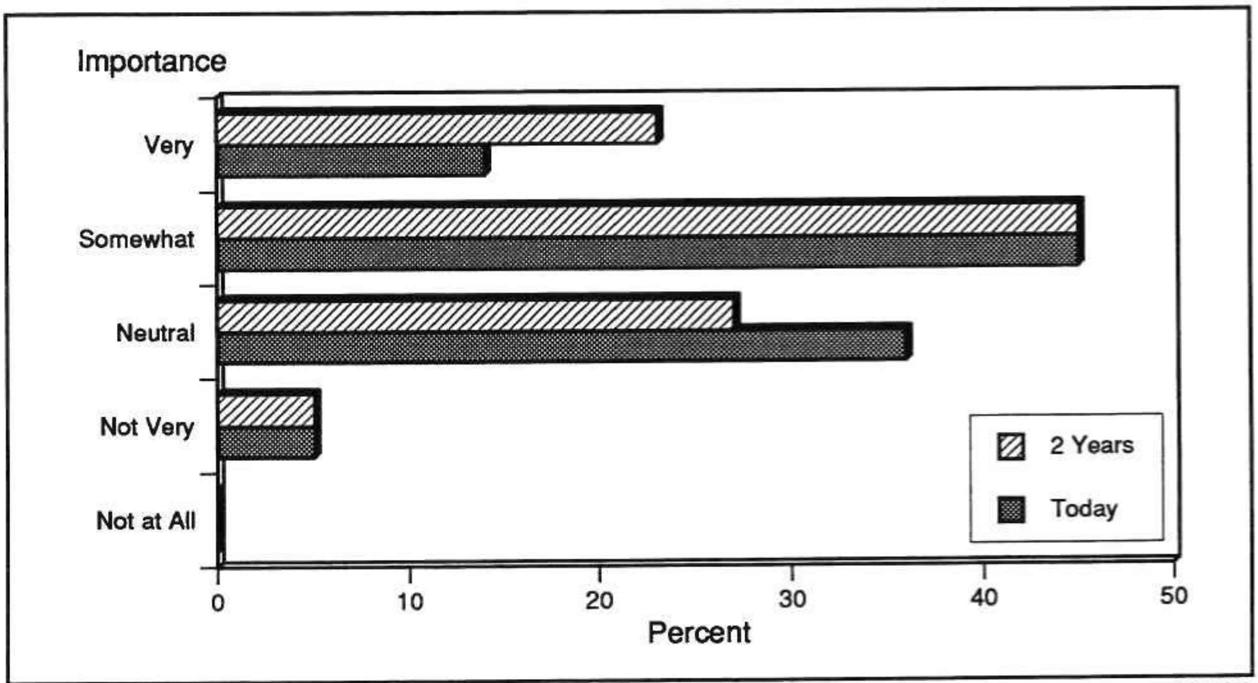
G2003249

Importance of Prior Experience with the Processor Architecture

Across all word width categories, responses to the question on the importance of prior experience with processor architecture was heavily weighted toward the somewhat or very important rating (see Figures 6-10 through 6-12). These results fall right in line with the question relating to the importance of pre-existing application software, which was also rated heavily on the important side of the scale. Factors such as quick time to market also come into play.

The heavy import given here underscores the fact that, when attempting to unseat the incumbent processor, a new vendor must make the change appear to be as painless as possible. This will require applications support, tools, and overall customer support during this sometimes traumatic experience.

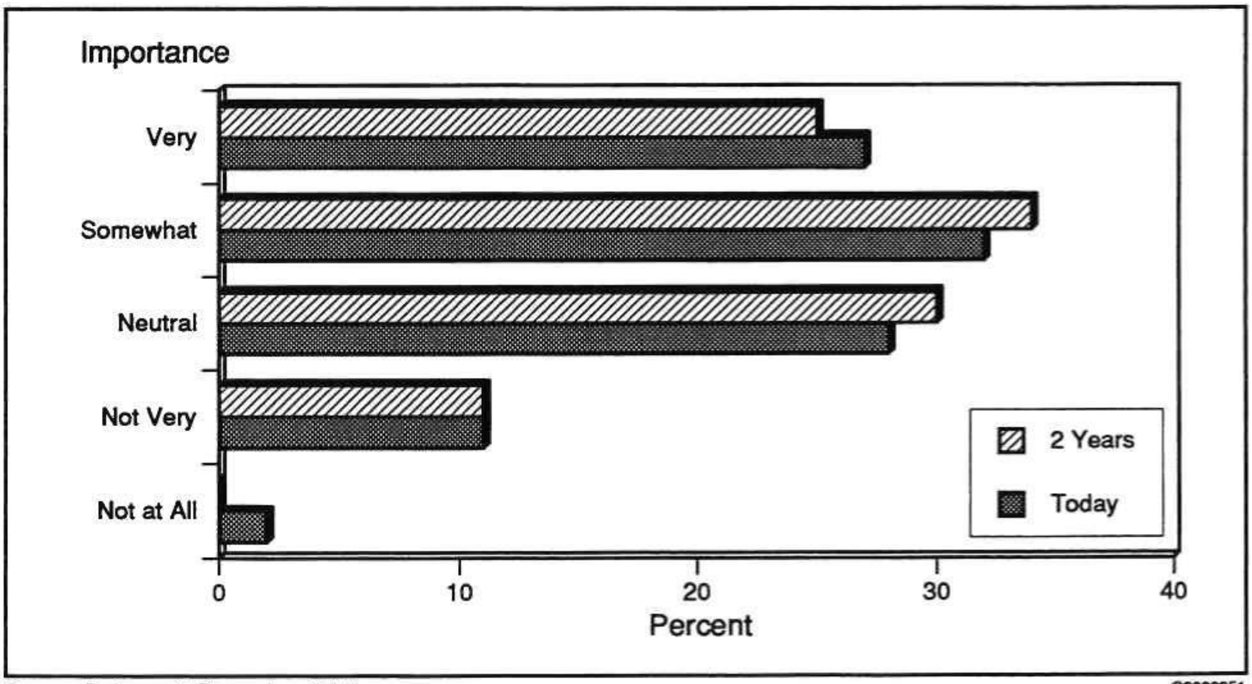
Figure 6-10
Importance of Prior Experience with the Processor Architecture, 8 Bit



Source: Dataquest (December 1992)

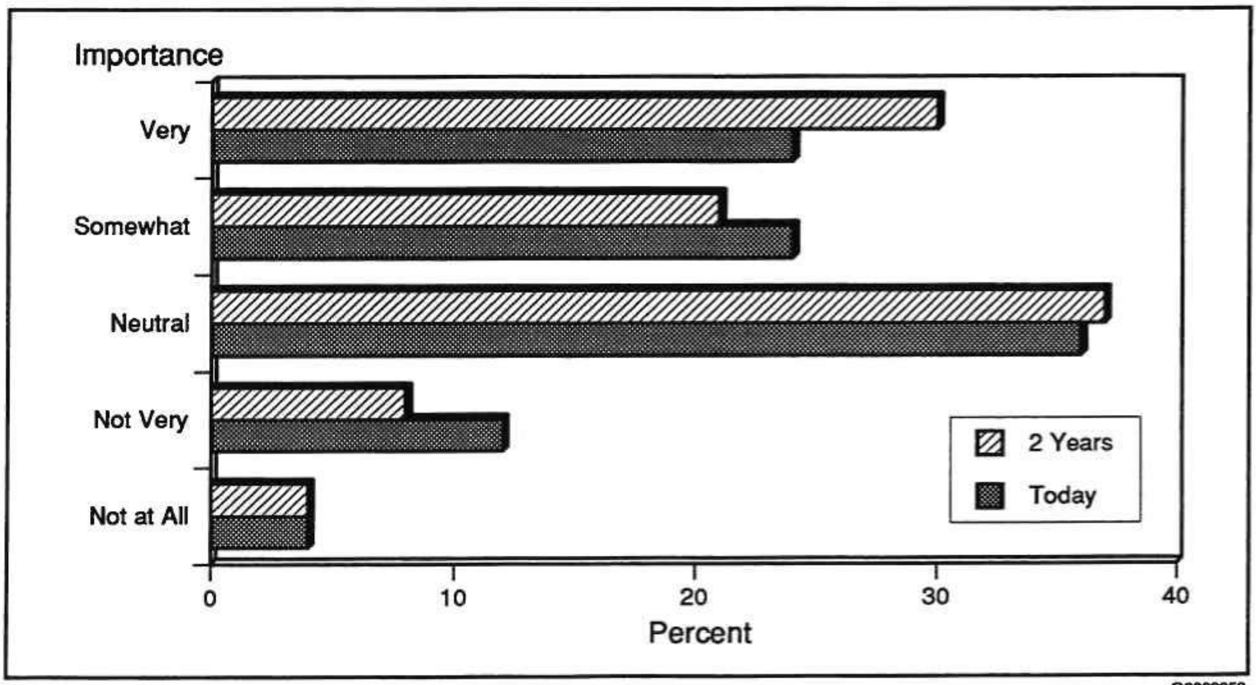
G2003250

Figure 6-11
Importance of Prior Experience with the Processor Architecture, 16 Bit



Source: Dataquest (December 1992)
G2003251

Figure 6-12
Importance of Prior Experience with the Processor Architecture, 32 Bit

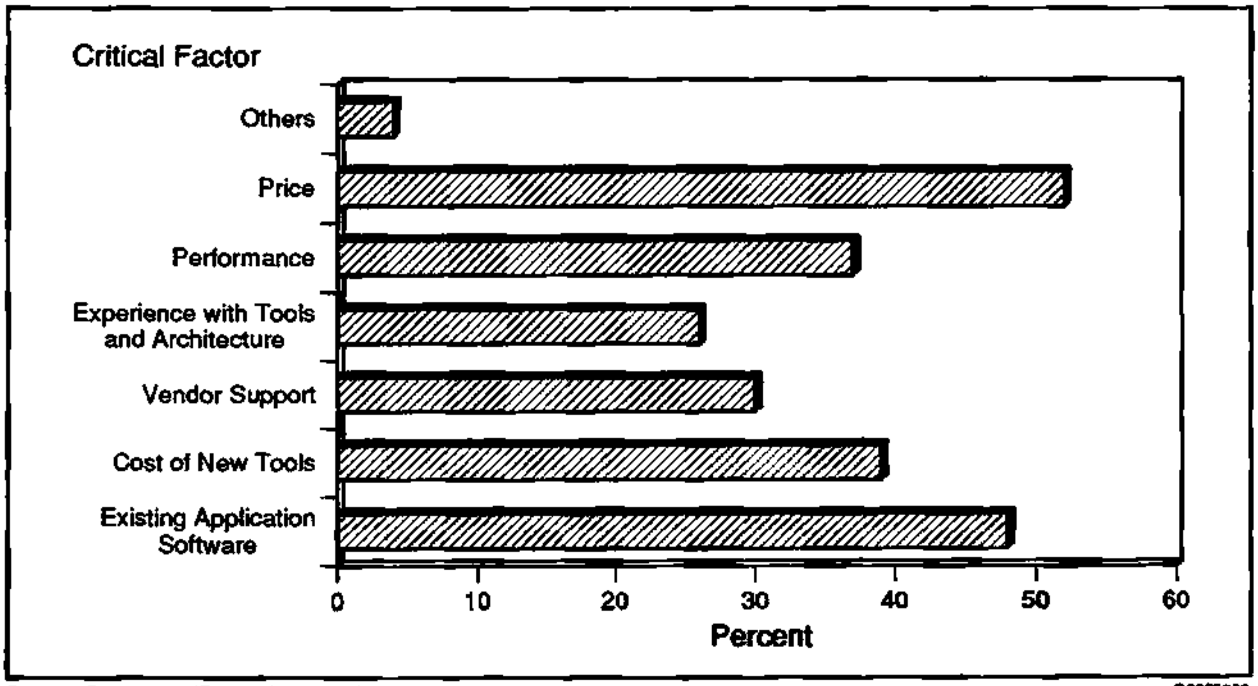


Source: Dataquest (December 1992)
G2003252

Critical Factors Prohibiting the Switch to Another Processor Architecture

The question on factors prohibiting the switch to another processor architecture combines many of the earlier questions that dealt with the importance of a particular topic on a standalone basis. Here we can see the relative weighting among various topics very clearly. Figure 6-13 supports the earlier results from 8-bit designers, which showed the importance of price and pre-existing application software and the relative unimportance of experience with the architecture. As expected, the overall leading factor in the 8-bit arena is price, followed closely by pre-existing application software. Figure 6-14 indicates the relative importance of performance, with price coming in a close third and experience with the existing architecture a closer second. And finally, Figure 6-15 shows an even wider delta between the No. 1-rated topic and that of price. This is consistent with our earlier findings, which show that designers of 32-bit systems are more concerned with a variety of topics than they are with price.

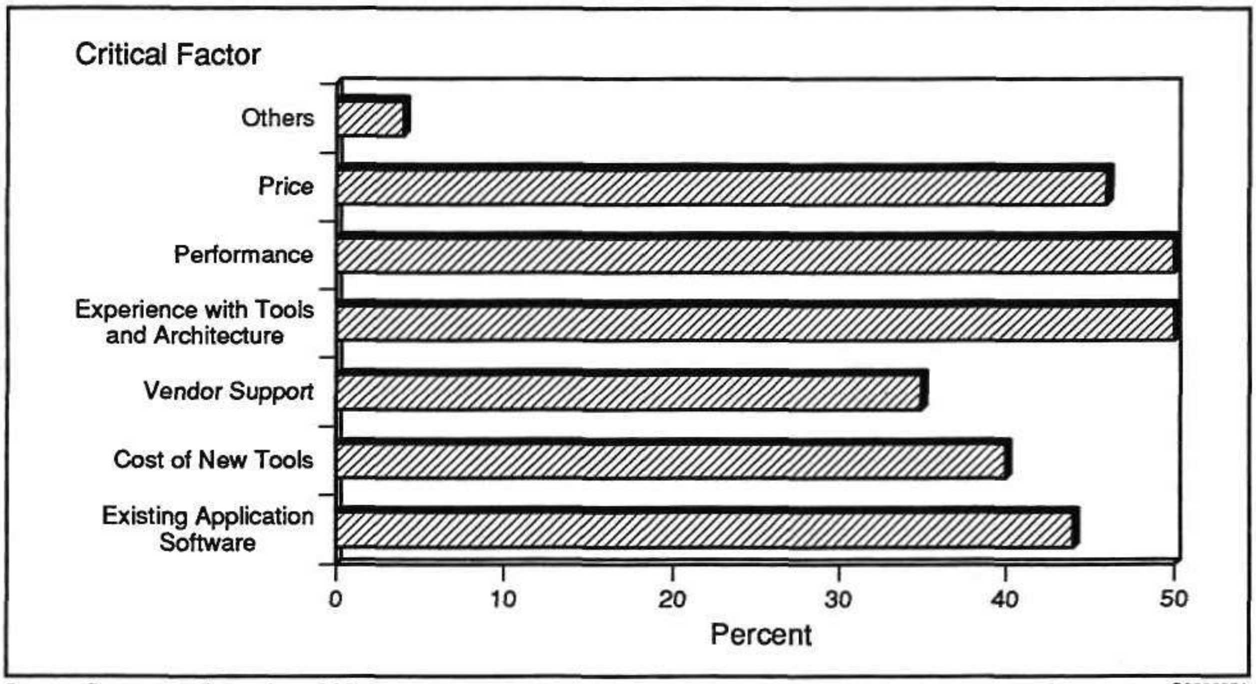
Figure 6-13
Critical Factors Prohibiting the Switch to Another Processor Architecture, 8 Bit



Source: Dataquest (December 1992)

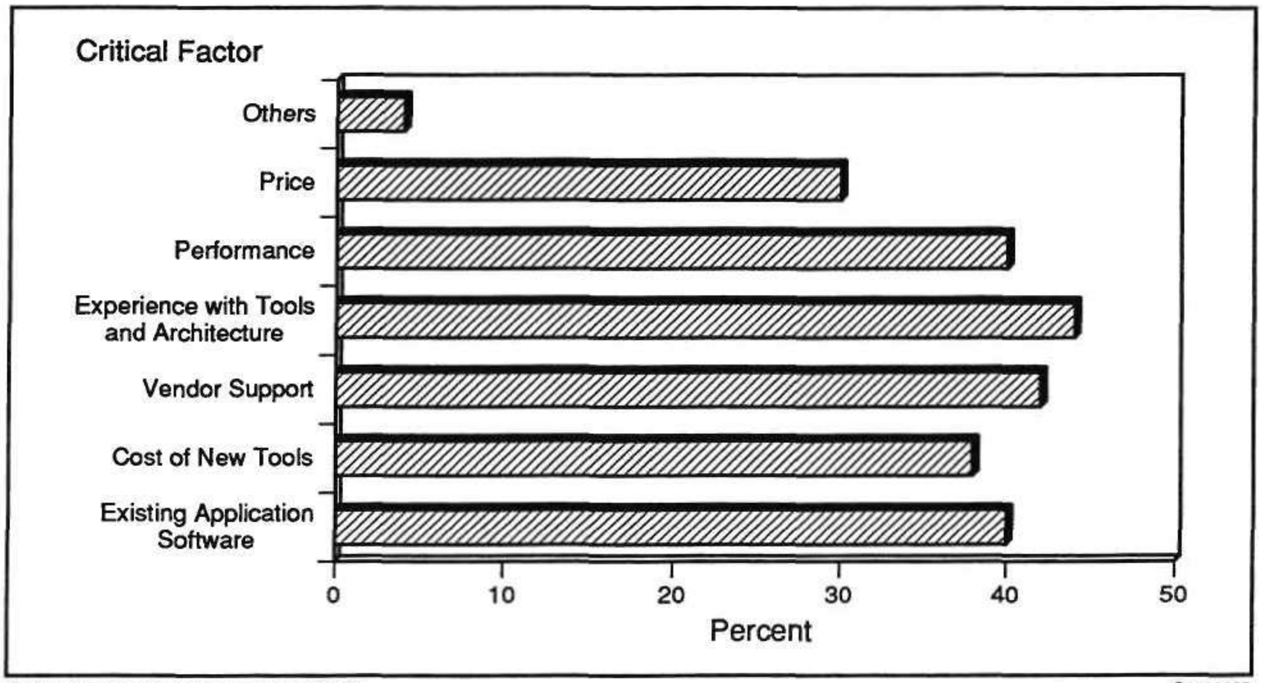
G2003253

Figure 6-14
Critical Factors Prohibiting the Switch to Another Processor Architecture, 16 Bit



Source: Dataquest (December 1992) G2003254

Figure 6-15
Critical Factors Prohibiting the Switch to Another Processor Architecture, 32 Bit

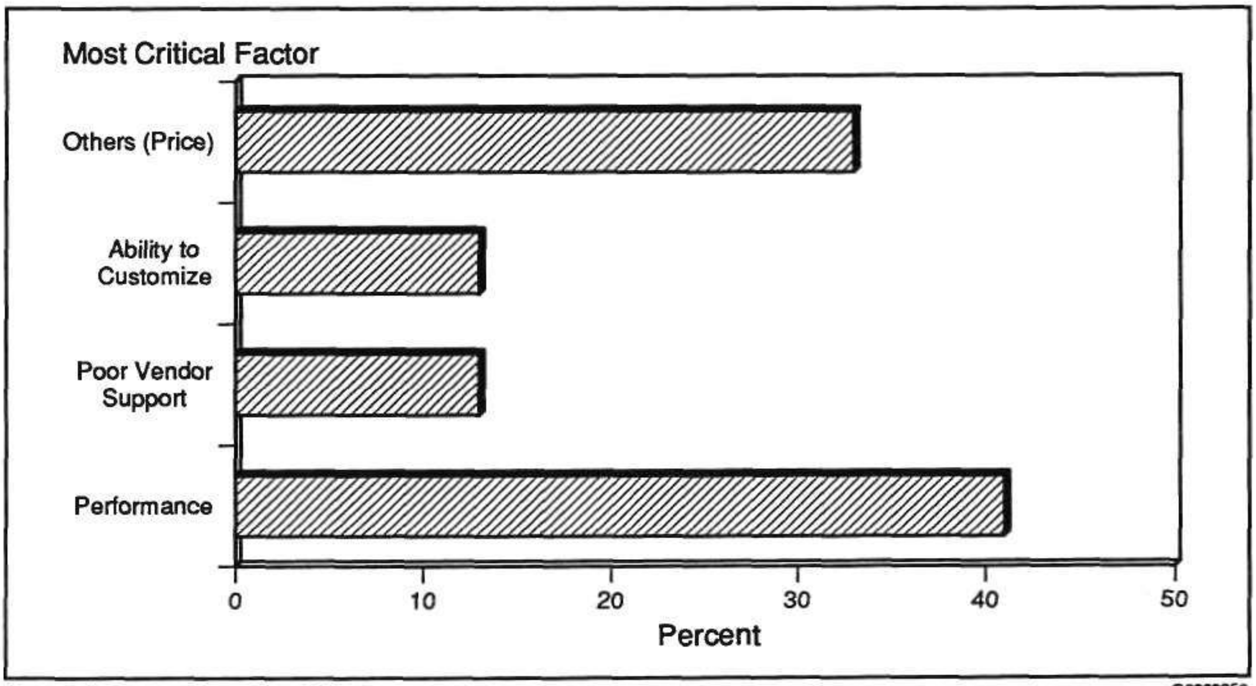


Source: Dataquest (December 1992) G2003255

The Most Critical Factor that Would Cause a Switch to Another Processor

The question on which is the most critical factor that would cause a switch to another processor forced the respondent to select the single most critical factor for which a switch to another processor architecture would be made. A short list was given, with an available "other" category. It is important to note that performance was the response given most frequently. This result includes the cost-sensitive 8-bit microcontroller applications where cost was given such a heavy weighting. Cost did place a respectable second for this question, and if price was given as one of the possible responses, it might have matched or displaced the position of performance as the most critical factor. For both 16- and 32-bit respondents, performance was an overwhelming response when selecting the one reason that would cause someone to switch architectures (see Figures 6-16 through 6-18).

Figure 6-16
Most Critical Factor that Would Cause a Switch to Another Processor, 8 Bit



Source: Dataquest (December 1992)

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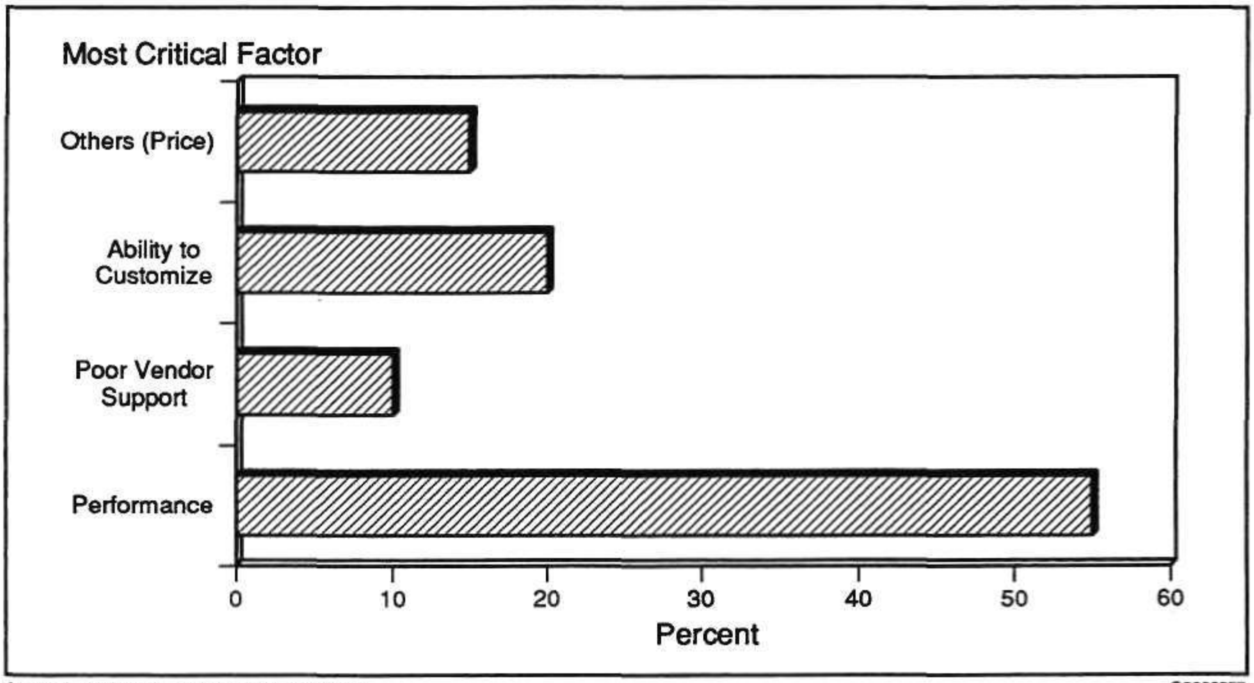
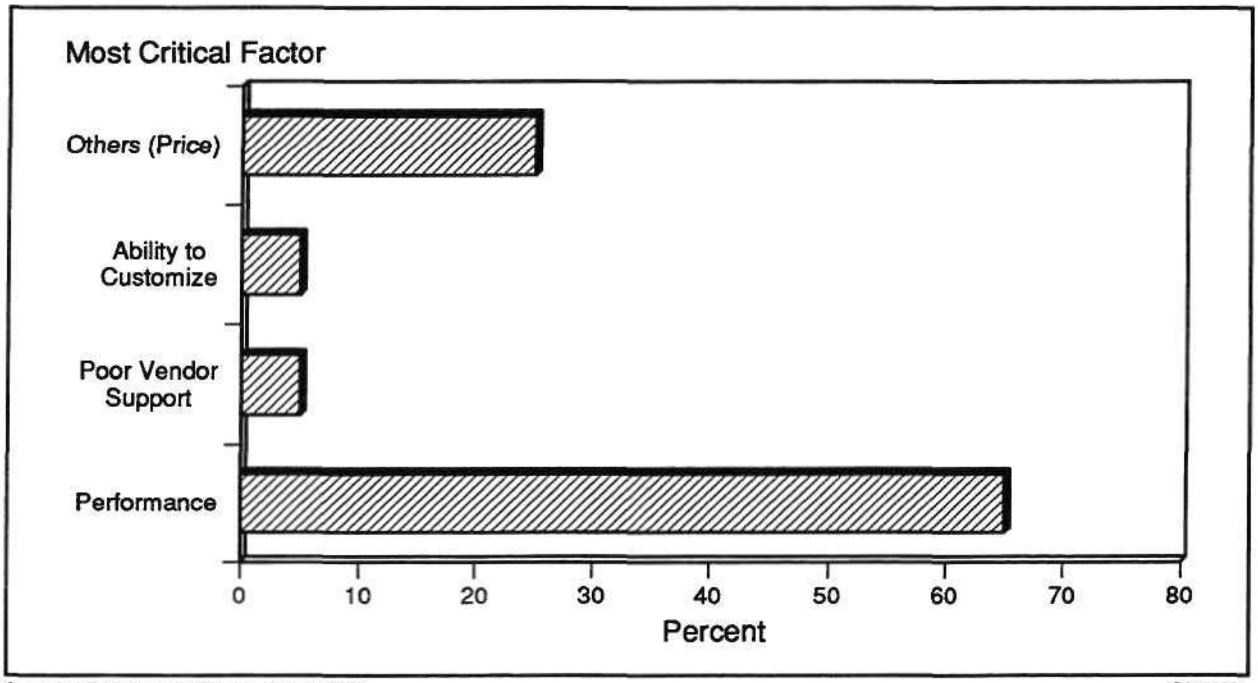
Figure 6-17
Most Critical Factor that Would Cause a Switch to Another Processor, 16 Bit



Source: Dataquest (December 1992)

G2003257

Figure 6-18
Most Critical Factor that Would Cause a Switch to Another Processor, 32 Bit



Source: Dataquest (December 1992)

G2003258

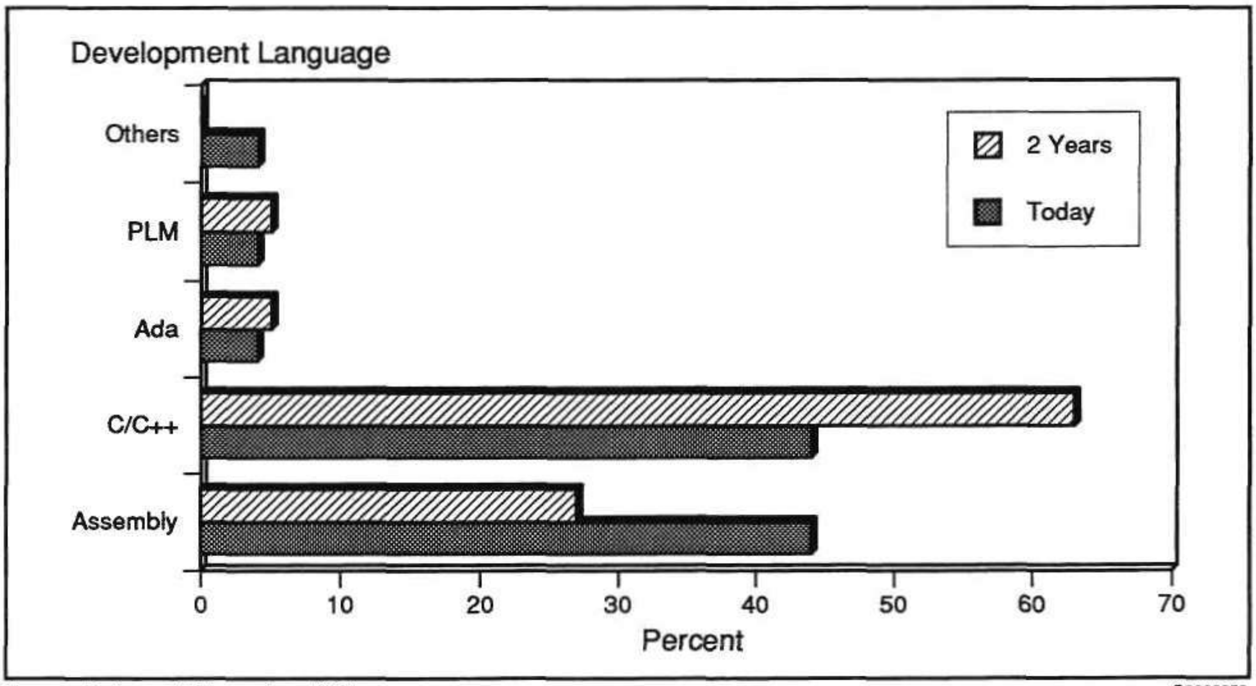
Chapter 7
Application Code

This chapter deals with the various types of programming languages used to develop application software for the target system, as well as the number of lines of code typically developed for each.

Language Used for Application Software Development

Figure 7-1 shows the heavy reliance designers of 8-bit systems place on using assembly language. However, this reliance is expected to fall off rapidly. The use of C or C++ is expected to grow. These high-level languages are efficient in the development of code for 8-bit microprocessors. It is much more likely that C or C++ is used for some nontime-critical portions of the application software and that assembly language is used to fine-tune the timing of the critical control subroutines. Designers of 16-bit systems have a somewhat easier task in converting over to C or C++ simply for architectural reasons. However, the rapid transition shown in Figure 7-2 seems more reflective of a designer's wishes than needs. Only in the 32-bit category were architectures fully developed with high-level languages in mind. Figure 7-3 shows the penetration that the high-level languages C and C++ have made into the 32-bit embedded processing world.

Figure 7-1
Language Used for Application Software Development, 8 Bit



Source: Dataquest (December 1992)

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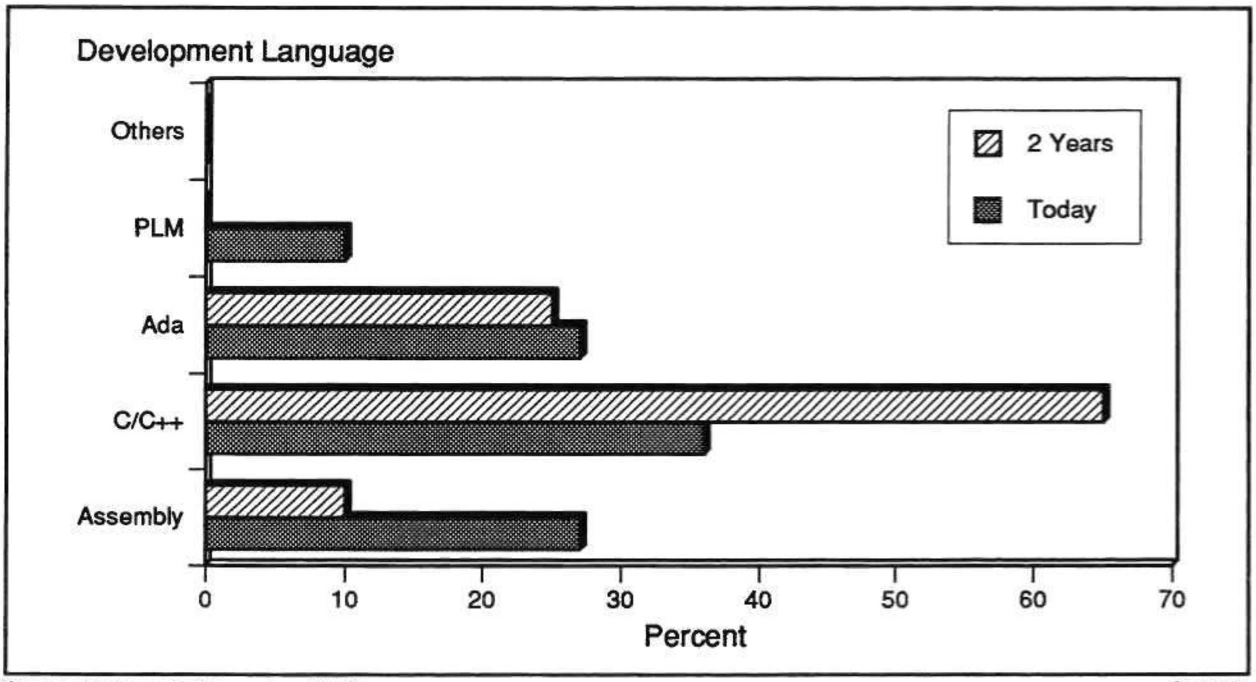
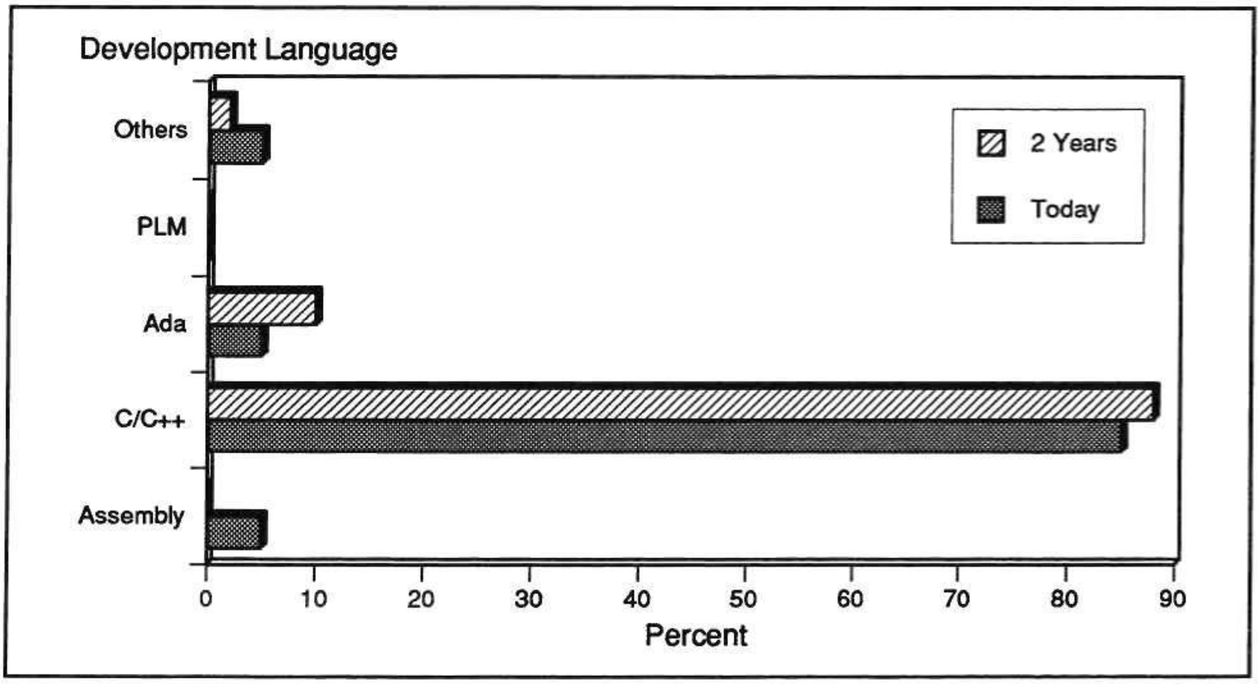
Figure 7-2
Language Used for Application Software Development, 16 Bit



Source: Dataquest (December 1992) G2003260

Figure 7-3
Language Used for Application Software Development, 32 Bit



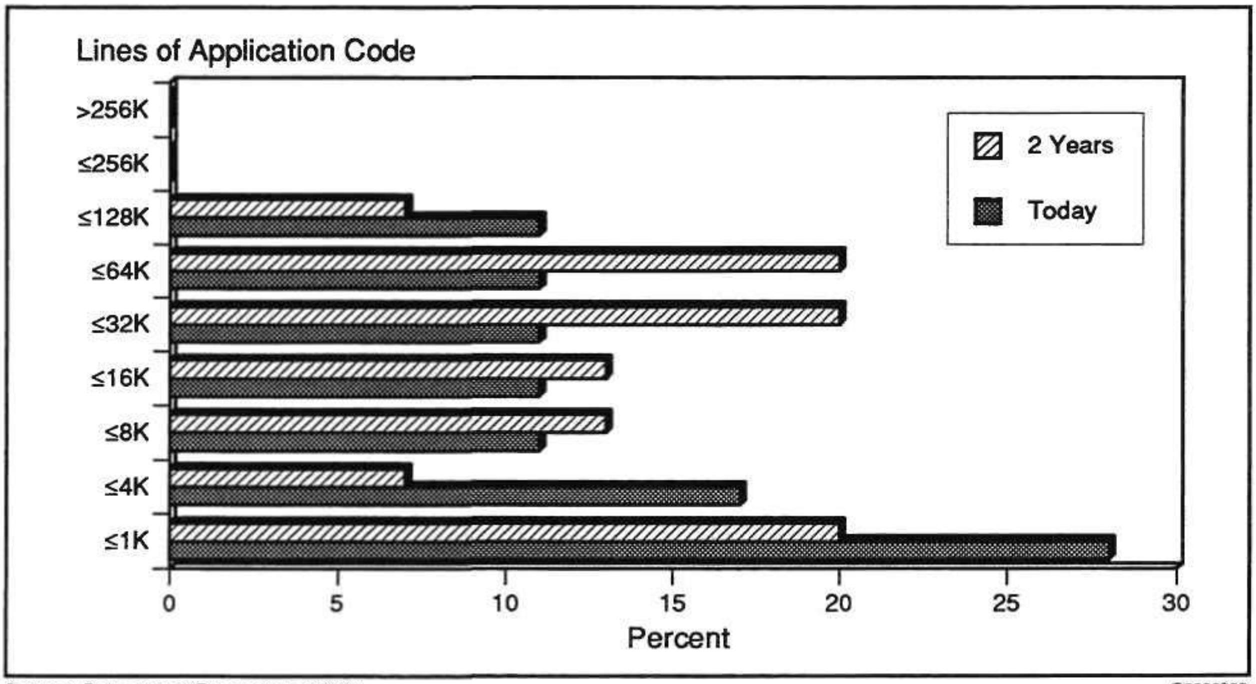
Source: Dataquest (December 1992) G2003261

Lines of Applications Software Written for the Application

Figures 7-4 through 7-6 show a wide range of lines of application software written for each processor word width. However, to capture a quick understanding of the relative lines of code for each word width, it is prudent to take a look at the 80 percent point—that is, find the number of applications code that would cover at least 80 percent of the applications for today and for two years out. Using this method, 8-bit applications currently require 32,000 lines, moving to 64,000 in two years; 16-bit applications jump from 64,000 lines to 128,000. 32-bit applications can get by with 128,000 lines today, but in two years the 80 percent point is pushed out to 256,000.

If we take this one more step and translate lines of code into the amount of nonvolatile memory required to implement this code, about 40 percent of all 8-bit applications require more code than can be placed on-chip. In the 16-bit world, about 90 of all applications require an external program store. Nearly 100 percent of all 32-bit embedded applications must use an external program store.

Figure 7-4
Lines of Application Software Written for the Application, 8 Bit



Source: Dataquest (December 1992)

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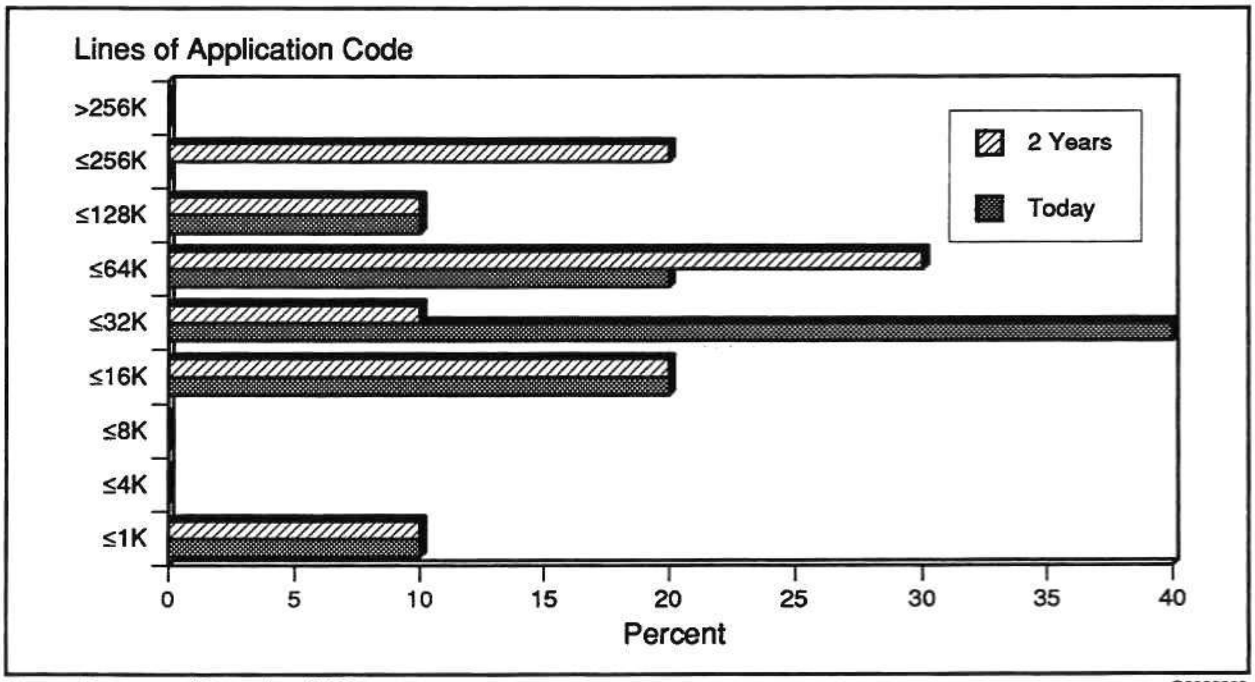
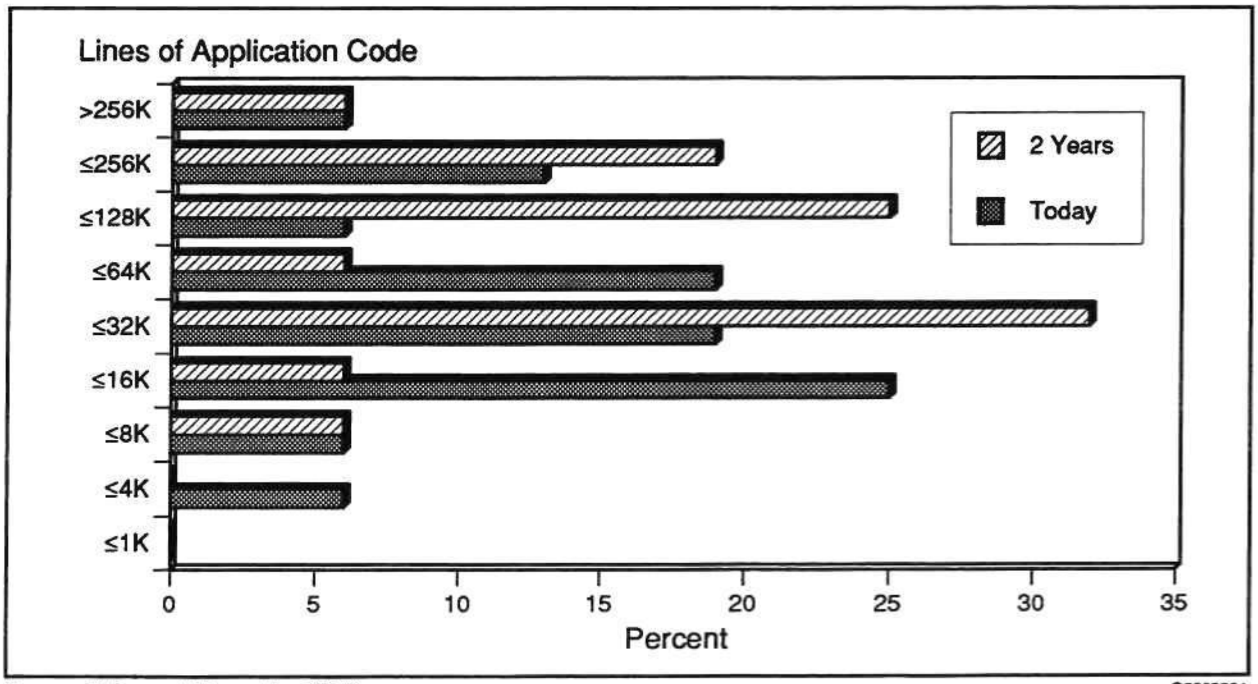
Figure 7-5
Lines of Application Software Written for the Application, 16 Bit



Source: Dataquest (December 1992) G2003263

Figure 7-6
Lines of Application Software Written for the Application, 32 Bit



Source: Dataquest (December 1992) G2003264

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

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

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

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

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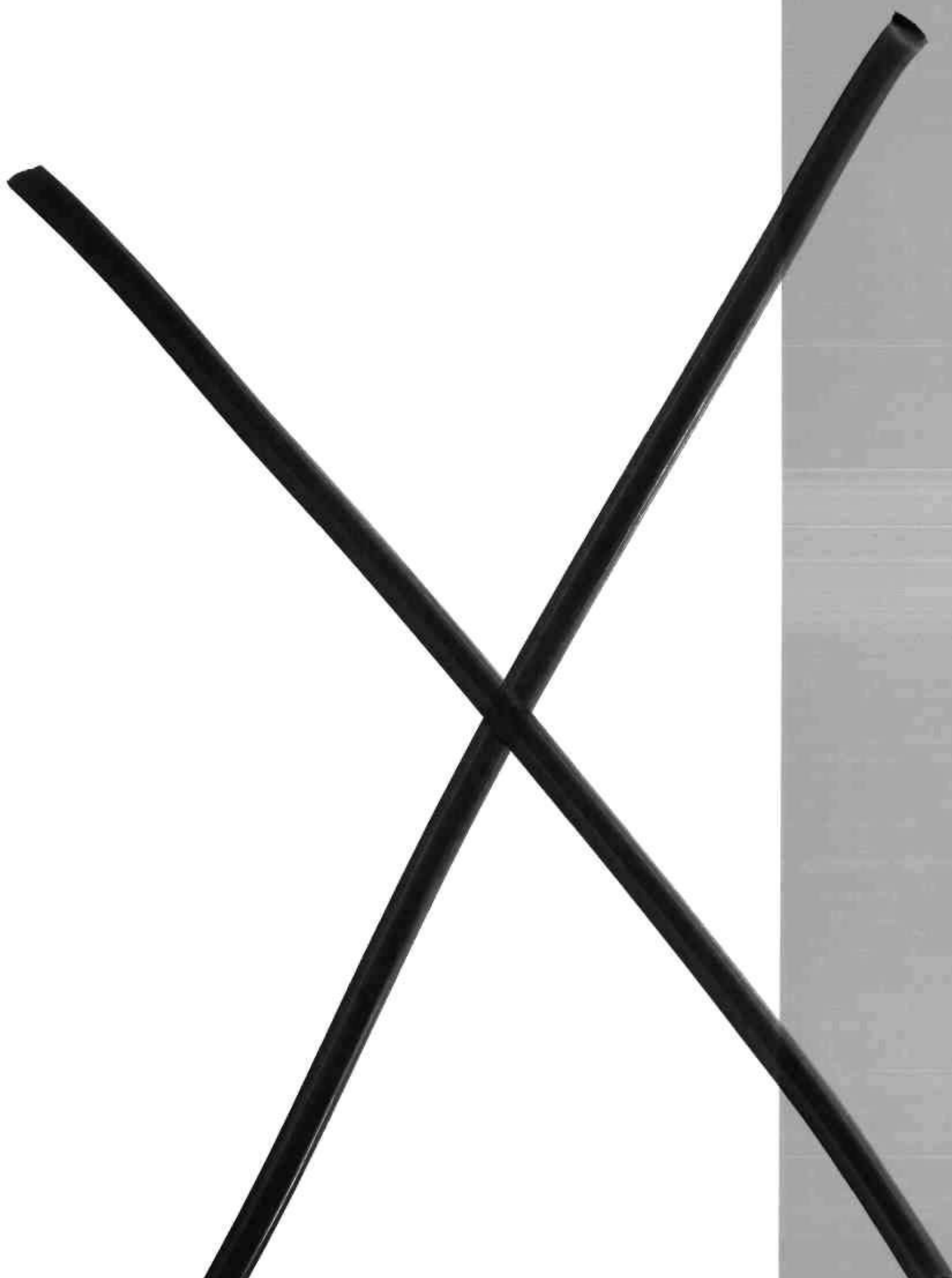

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Chapter 1
Executive Summary

Microcomponents is a large and fast-growing business, driven by the demand for greater performance, functional features, and user convenience of a wide array of electronic equipment. With more than $11.7 billion in 1991 revenue, microcomponents represents 20 percent of the total semiconductor business, which is estimated at nearly $60 billion. Furthermore, microcomponents is perhaps the segment most crucial to the semiconductor industry, driving the basic equipment architectures that in turn affect the types and quantities of other semiconductors consumed. This report details the trends in demand, industry competition, and product forecasts behind the development of this thriving business.

Major Findings

Major findings of this report are as follows:

- The microprocessor segment is dominated by the 80x86 family of microprocessors, which represents nearly 75 percent of current revenue. Direction for this family is largely dictated by Intel, which accounts for more than 80 percent of this revenue and has a completely dominant position within this line of products. A new genre of vendors is entering the mainstream competition for this business; their combined efforts will strengthen this family's position and in turn weaken Intel's dominance.

- Dataquest believes that 80x86 dominance will continue but will begin to diminish, reaching 65 percent of revenue by 1996 in an overall trend toward open-systems RISC (OSR) microprocessors. Market development for OSR microprocessors is enabled primarily by Microsoft and its Windows NT operating system, which effectively will produce a level playing field among microprocessor families. In another vein, this trend is driven by IBM and Apple, the world's largest personal computer companies, which are attempting to bring hardware differentiation and profit margins back to the mainstream computing market.

- Microprocessors designed for use in embedded applications are showing strong growth, with dramatic increases anticipated for sales into one of the most exciting new applications, hand-held electronic devices. This single application will have a pronounced effect on microprocessor technology, primarily driving the leading edge in integration level and power dissipation.

- Microprocessor (and microperipheral) revenue overwhelmingly is dominated by North American companies; Dataquest believes that this will continue throughout this forecast period.
- The microperipheral segment really represents a collection of interface functional areas that share a common demand factor, the growth of microprocessors, but have differing driving forces that shape their success and obsolescence. Dataquest believes that microperipherals in total will grow, but at a rate diminished by the integration of their functionality within the microprocessors they support.
- Dataquest believes that system core logic and math coprocessor micropериphals will be hardest hit by microprocessor integration, showing nearly flat growth and declining sales, respectively. On the other hand, graphics, communications, and mass storage controllers will flourish as system performance demand increases for these critical functions, which will remain outside the microprocessor.
- The microcontroller segment is not dominated by any single product family or architecture, but is largely controlled by the regional base of equipment production, which is primarily Japan for consumer goods. Dataquest believes that microcontroller products offer similar feature sets at different price/performance levels and that demand is driven more by the companies and their programs for customization, design support, and development tools than it is by product merits.
- Microcontroller revenue is dominated by Japanese companies selling the bulk of their products in Japan; Dataquest believes that this will continue throughout this forecast period but will be diminished substantially by the growth of Motorola in all regions of consumption.

Project analyst: Ken Lowe

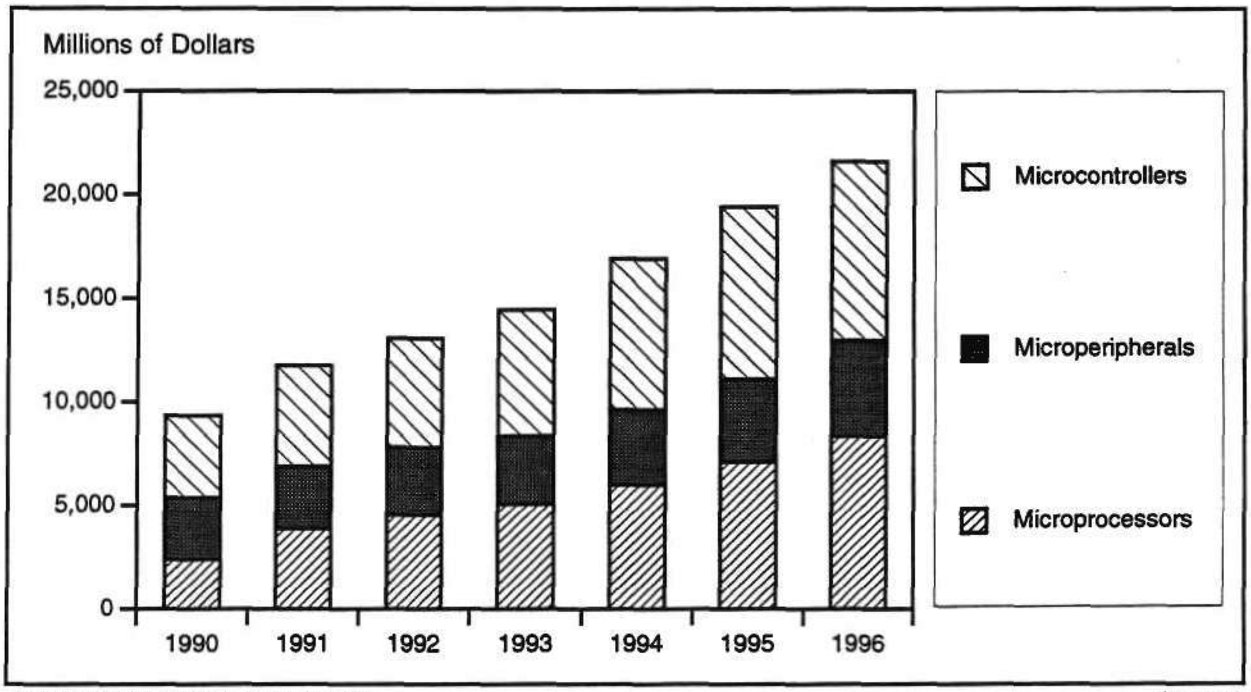
Chapter 2
Microcomponent Market Overview

Microcomponents represents a collection of highly intelligent digital logic ICs, manufactured primarily from MOS process technology, and used in nearly every type of electronic equipment. Though revenue from microcomponents predominantly results from their use in computer systems, revenue from noncomputer applications (called embedded applications) is increasing rapidly. This market and the industry that serves it are highly affected by developments in system software, the directions of which are discussed later in this chapter.

Market Size and Segmentation

As shown in Figure 2-1 and Table 2-1, microcomponents represent a large and growing market, forecast to grow from $11.7 billion in 1991 to more than $21.5 billion in 1996, nearly doubling its size in five

Figure 2-1
Microcomponent Industry Forecast



Source: Dataquest (December 1992)

G2002582

Table 2-1
Microcomponent Industry Forecast, All Segments
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996
Microprocessors	2,375	3,859	4,512	5,052	5,977	7,094	8,354
Microperipherals	2,986	3,020	3,293	3,306	3,652	4,005	4,614
Microcontrollers	3,959	4,855	5,244	6,090	7,291	8,307	8,624
Total	9,320	11,734	13,049	14,448	16,920	19,406	21,592

Source: Dataquest (December 1992)

years. Microcomponents comprise three major product segments, defined as follows:

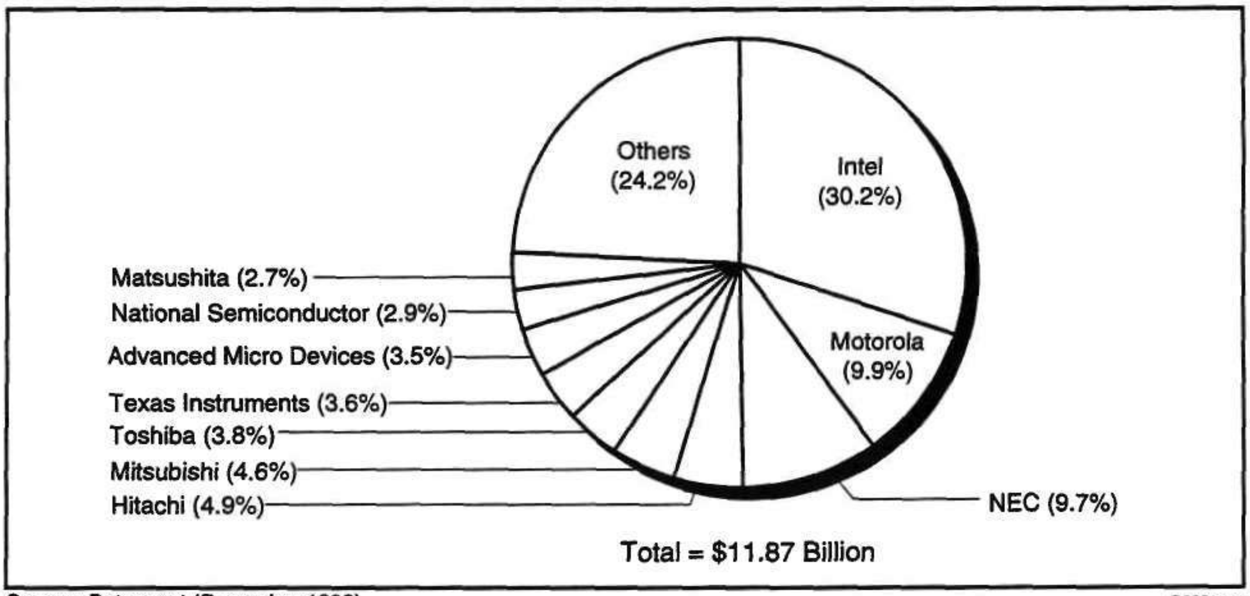
- Microprocessors: Single-chip devices with internal CPU circuits that can execute external instructions and perform control functions as programmed via software stored in external memory components. These devices typically include an instruction decoder, arithmetic logic unit, registers, and other logic to control execution.
- Microperipherals: Single or multichip devices used with microprocessors (or microcontrollers) to augment or enhance the CPU performance and perform the primary interface functions to external devices. These devices fall under distinctive categories of system core logic, math coprocessors, graphics/imaging controllers, communications controllers, and mass storage controllers, among others.
- Microcontrollers: Single-chip devices that perform system control functions within an overall electronic device without the need for other support circuits or external memory. These include the essential elements of a basic microprocessor, as well as extensive I/O functions, processing memory (RAM), and program store memory (ROM/EPROM). The revenue included in this category includes digital signal processing (DSP) devices unless otherwise stated.

Microprocessors, currently the second largest segment, will exhibit the highest overall growth over the forecast period, more than doubling sales and nearly taking over as the top segment. Microperipherals, the smallest segment, will show the slowest growth at slightly more than 50 percent. They will be negatively impacted by the integration of traditional microperipheral functions into microprocessors. Microcontrollers, the largest segment, will show strong growth after 1992. This segment has flattened somewhat because of recessionary conditions in Japan in markets where they are consumed. A complete analysis of the trends, competitive vendors, and forecast assumptions is covered in later chapters of this report.

Industry Competitive Structure

The microcomponent market is clearly led by Intel, which is the reigning king of microprocessors at 64 percent of revenue share (see Figure 2-2 and Table 2-2). Intel is ranked No. 1 in microperipherals, and fourth in overall microcontroller revenue. Motorola took second place and gained substantial revenue from all three segments; it was second in microprocessors, second in microcontrollers, and third in microperipherals. Third-place NEC held the leading position in microcontrollers, but with much less significant positions held in microprocessors (sixth) and microperipherals (fifth). The remainder of the top 10 vendors follow about this same pattern, with Hitachi, Mitsubishi, and Toshiba, and Matsushita gaining the primary revenue from microcontrollers, Texas Instruments from DSPs (part of microcontroller revenue), and AMD from microprocessors. National, at No. 9, is the exception and has a fully balanced revenue mix from all three subsegments.

Figure 2-2
1991 Top 10 Companies' Factory Revenue from Shipments of Microcomponent ICs to the World



Source: Dataquest (December 1992)

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Table 2-2
Top 50 Companies' Factory Revenue from Shipments of Microcomponent ICs to the World (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	2,726	3,578	31	30.2
2	3	Motorola	970	1,171	21	9.9
3	2	NEC	981	1,149	17	9.7
4	4	Hitachi	546	583	7	4.9
5	5	Mitsubishi	441	543	23	4.6
6	6	Toshiba	386	454	18	3.8
7	7	Texas Instruments	320	429	34	3.6
8	11	Advanced Micro Devices	218	416	91	3.5
9	8	National Semiconductor	309	341	10	2.9
10	9	Matsushita	250	321	28	2.7
11	12	Fujitsu	213	244	15	2.1
12	13	Philips	193	212	10	1.8
13	15	Western Digital	148	209	41	1.8
14	14	SGS-Thomson	175	167	-5	1.4
15	10	Chips & Technologies	240	165	-31	1.4
15	21	VLSI Technology	105	165	57	1.4
17	17	Cirrus Logic	129	151	17	1.3
18	16	Oki	131	137	5	1.2
19	18	Sharp	124	134	8	1.1
19	19	Siemens	116	134	16	1.1
21	23	LSI Logic	93	115	24	1.0
22	22	Zilog	100	110	10	.9

(Continued)

Table 2-2 (Continued)
Top 50 Companies' Factory Revenue from Shipments of Microcomponent ICs to the World
(Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
23	26	Sony	43	88	105	.7
24	24	Sanyo	71	69	-3	.6
25	20	Harris	110	65	-41	.5
26	29	United Microelectronics	39	62	59	.5
26	35	Ricoh	22	62	182	.5
28	42	Cypress Semiconductor	15	48	220	.4
29	NM	Dallas Semiconductor	0	41	NM	.3
30	27	Standard Microsystems	40	40	0	.3
31	25	Weitek	57	39	-32	.3
31	32	NCR	31	39	26	.3
33	31	Matra MHS	33	37	12	.3
34	33	ITT	28	35	25	.3
35	37	AT&T	21	33	57	.3
36	34	Performance Semiconductor	24	28	17	.2
37	35	Samsung	22	27	23	.2
38	40	Rohm	17	23	35	.2
39	27	Rockwell	40	20	-50	.2
39	38	Analog Devices	20	20	0	.2
39	38	Integrated Device Technology	20	20	0	.2
42	44	Seiko Epson	10	16	60	.1
43	41	Microchip Technology	16	15	-6	.1
44	NM	Winbond	0	14	NM	.1

(Continued)

Table 2-2 (Continued)
Top 50 Companies' Factory Revenue from Shipments of Microcomponent ICs to the World
(Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
45	44	TMS	10	12	20	.1
46	50	Goldstar	3	11	267	.1
47	NM	Hualon Microelectronic Corp.	0	9	NM	.1
48	30	Appian	38	8	-79	.1
49	47	TRW	6	7	17	.1
49	51	Waferscale Integration	2	7	250	.1
		All Others	41	44	7	.4
		North American Companies	5,851	7,349	26	61.9
		Japanese Companies	3,236	3,824	18	32.2
		European Companies	539	567	5	4.8
		Asia/Pacific Companies	67	127	90	1.1
		Total Market	9,693	11,867	22	100.0

NM = Not meaningful
Source: Dataquest (December 1992)

General Application Trends

Several conceptual directions have become more apparent in the computer system applications during the last year, and in turn are driving the shape of most future microcomponents. Some of the most significant trends are as follows:

- Virtualization: Using innovative techniques to maintain application software compatibility without native hardware instructions or I/O devices. This is being driven by the new genre of operating systems producing a gradual shift from a hardware- to software-based compatibility, supported by complementary technologies within microprocessors and microperipherals.
- Absorption: Using the increasing performance and bandwidth of the CPU to absorb more processing functions that would otherwise require intelligent microperipherals. This trend began with the integration of the math coprocessor. The next five years will see superscalar microprocessor performance increase to the level required to service audio (now using DSPs) and video (now using specialized compression chips) processing, to deliver multimedia computing at moderate costs.
- Standardization: Gaining widespread adoption of a consolidated list of interfaces and protocols. Standardization is being driven by the need for interoperability and cost-effectiveness. Among the standards are Ethernet, SCSI, and PCI, which have the most profound effect in networking, mass storage, and high-performance interface buses. This trend is a key enabler to further microprocessor integration.
- Integration: Moving complete system architectures down to the semiconductor level. Integration is being driven by the new classes of portable computing devices, which have limited real estate and power. This trend will carry over onto the desktop and eventually deliver the semicomputer era, where the semiconductor is the computer.

Operating System Directions

Dataquest believes that DOS/Windows/Windows NT will become the most dominant force in the desktop and portable computing markets, followed by the Mac/PowerOpen group. This in turn will eventually allow complete freedom of movement among different hardware architectures, with vendor differentiation focused on performance, packaging, and price.

Windows NT, Microsoft's next-generation operating system, will feature the Windows graphical user interface (GUI) and will provide uniform compatibility with DOS, Windows, and OS/2 applications. Windows NT is based on a completely new operating system kernel and will be one of the biggest factors in creating a level playing field among microprocessors competing with the 80x86. As a result, Dataquest predicts that the evolution of Windows NT will bring about architectural support for the following processors:

- 80x86: Support will begin when NT ships; will be standard with NT.

- MIPS: Support will begin when NT ships; will include the R4000 (and its variants).
- Alpha: Support will begin when NT ships; will be ported by Digital.
- PA-RISC: Support will begin early in 1994 (1 year after NT ships) as a Hewlett-Packard-initiated port.
- PowerPC: Support will begin late in 1994 as a Microsoft-initiated port.

PowerOpen, the first new operating system resulting from the IBM/ Apple alliance, will also play a key role in leveling the desktop, featuring the Macintosh user interface and compatibility with current MAC and AIX (IBM's version of UNIX) applications.

Computer Architecture Directions

From a hardware viewpoint, we have already seen breakdown of the barriers between what constitutes a PC versus a workstation. However, the trend toward GUI-based, multitasking operating systems will result in a uniform class of computers being marketed as desktop stations. At the same time, we will shift to more distinctive lines of segmentation by product form, separating out the fast-growing portable devices at the low end and the supercomputers and servers at the high end. The significance of these changes is the effect on market-targeting decisions for microcomponent vendors, opening up new opportunities and breaking down previously existing barriers.

Portable devices represent a distinct set of problems associated with delivering complete computers with low power, small size, and low weight. With these devices constantly moving up in performance and down in size, the entry barriers are becoming even greater. The most popular configuration today is the 5- to 6-pound notebook computers, which are taking over the initial surge started by the heavier laptop counterparts. For the portable segment, small size coupled with the movement to 3V power is the most pressing issue, driving downward to a handful of chips for a notebook and one or two chips for a hand-held. As the standards begin to coalesce and circuit density increases, integration down toward single-chip architectures begins to make more sense, containing all relevant I/O functions. As we reach this level of integration, we will see a reduction in the field of vendors capable of creating competitive offerings.

The increase in mainstream standardization is allowing more capabilities to be integrated without the risk of obsolescence. As vendors integrate more value-added microperipherals into a chip set (or single chip), both the average selling price and the barrier to entry for other vendors are increased, which further protects price erosion. An example would be graphics, which is quickly moving to accelerated architectures for the desktop. We will soon begin to see standardized video compression coprocessors appear as socketed options.

Chapter 3
Microprocessors

The microprocessor market is growing at an industry-leading pace and is setting the architectural trend for all forms of electronics. Currently at a $3.9 billion level, the microprocessor industry is forecast to more than double its size by 1996. Competition is becoming more intense at the strategic level between classes as well as at the tactical level within each class. Our analysis examines the current state of the microprocessor industry and its competitive positions, and provides a complete forecast of units, average selling price (ASP), and revenue, by processor class and product type.

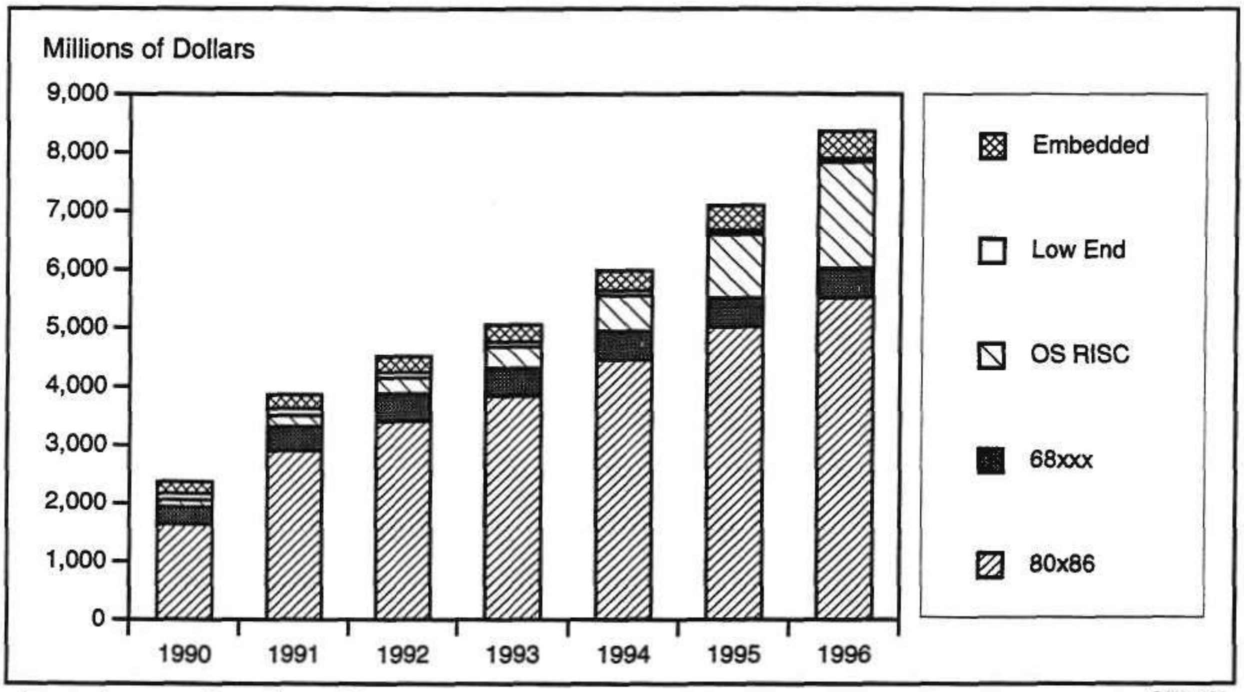
Microprocessor Segmentation

Dataquest segments the microprocessor market by processor class rather than by word length, which provides a more strategically sound model for analyzing market dynamics and competitive rivalry. These processor class segments include the following:

- x86: 80x86 family of processors
- 68K: 68xxx family of processors
- OSR: Open systems RISC processors
- LEA: Low-end architecture processors
- ESF: Embedded system focused processors

As shown in Figure 3-1 and Table 3-1, the x86 class clearly dominates the microprocessor revenue, driven primarily by the enormously successful IBM-compatible PCs. In spite of heavy competition from the OSR class, the x86 processors are forecast to remain dominant through this forecast period. At a faraway second place is the 68K class, primarily supported in volume by embedded applications. Its growth will slow to single digits during this forecast period. The OSR class of processors shows the highest growth rate and is shaping up to become the most vital competitor to the x86 class for computer system applications. LEA-class processors, the forerunners of today's advanced architectures, are nearing the decline stage and are becoming the only class to show decreasing revenue. ESF-class processors—designed to become the engines inside laser printers, X terminals, and many other embedded systems—will show strong growth in the latter half of this forecast period.

Figure 3-1
Total Microprocessor Revenue, by MPU Class



Source: Dataquest (December 1992)

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Table 3-1
Microprocessor Forecast, by MPU Class

MPU Class	1990	1991	1992	1993	1994	1995	1996
80x86							
Units (K)	43,320	51,810	55,597	58,187	61,402	66,932	71,047
ASP ($)	38	56	61	66	72	75	78
Revenue ($K)	1,637,195	2,904,130	3,410,247	3,836,239	4,450,766	5,013,885	5,516,760
68xxx							
Units (K)	14,430	18,450	24,050	27,790	28,988	29,584	28,782
ASP ($)	21	22	19	17	17	17	17
Revenue ($K)	298,360	408,930	467,560	476,986	485,660	494,844	501,494
OS RISC							
Units (K)	265	508	751	1,098	2,066	4,049	7,260
ASP ($)	454	383	362	329	299	269	249
Revenue ($K)	120,300	194,450	271,724	361,282	617,457	1,087,296	1,808,330
Low-End							
Units (K)	49,270	62,410	48,517	47,063	45,470	42,857	39,995
ASP ($)	2.27	1.90	1.91	1.85	1.78	1.73	1.67
Revenue ($K)	112,062	118,328	92,596	87,035	80,948	74,127	66,765
Proprietary							
Units (K)	3,890	4,660	6,234	7,590	9,919	13,792	16,353
ASP ($)	53	50	43	38	35	31	28
Revenue ($K)	206,800	232,750	269,450	290,439	342,633	423,843	460,253
All MPU							
Units (K)	111,175	137,838	135,149	141,728	147,846	157,215	163,437
ASP ($)	21	28	33	36	40	45	51
Revenue ($K)	2,374,717	3,858,588	4,511,577	5,051,980	5,977,464	7,093,995	8,353,601

Source: Dataquest (December 1992)

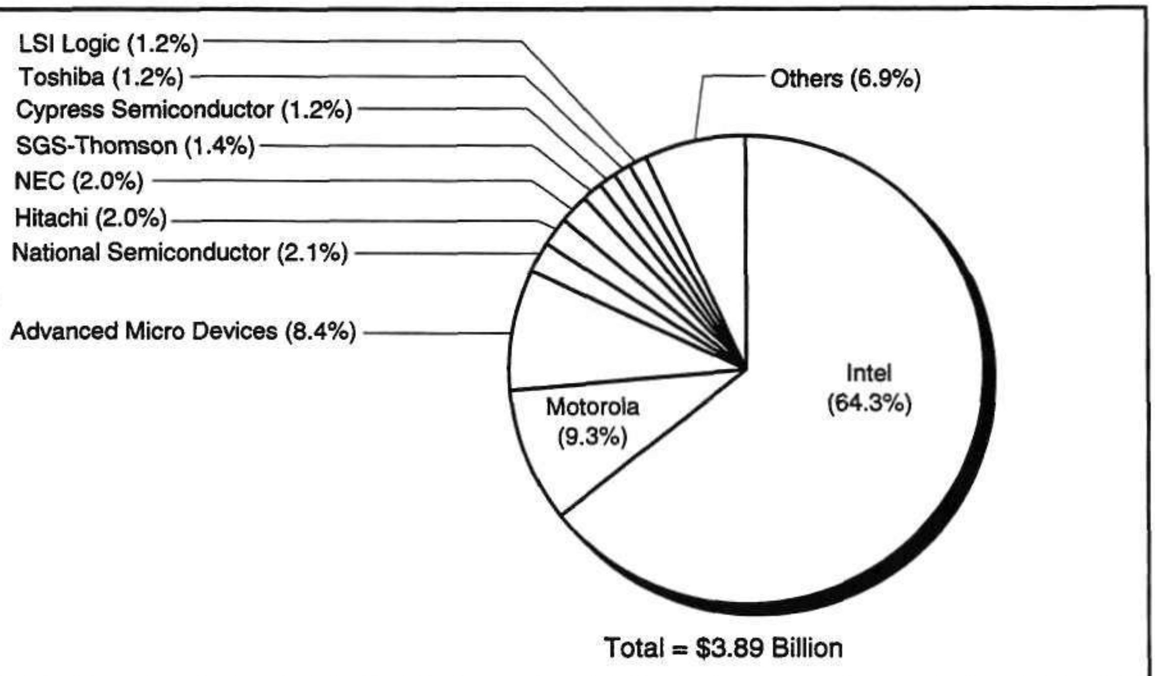
Industry Structure and Market Share

Market share distribution in revenue for 1991 draws a dramatic picture of this industry. Intel is the single dominant player, with 64 percent market share by revenue, generated primarily from the 386 product series (see Figure 3-2 and Table 3-2). This is the combined result of focusing on the highest-ASP microprocessor market, computer platforms, and controlling the highest-volume segment of this market, the x86 DOS PC.

On a revenue basis, both Motorola and Advanced Micro Devices (AMD) also have respectable shares at 9.3 percent and 8.4 percent respectively, though arrived at in the most opposite manner. Motorola invented the 68K product family and has slowly grown its revenue through a wide and varied set of applications. AMD introduced a replica of the Intel 386 microprocessor in 1991 and in just nine months grew its sales nearly 200 percent over last year.

The remaining vendors each have interesting histories that are relevant at the segmented level of discussion. However, there is an interesting contrast: If market share were based on unit volume, Zilog ($31 million revenue in 1991) would take the No. 1 spot with nearly 20 percent (because of the unceasing shipments of the Z80), followed closely by Intel with 18.6 percent and Motorola with 14.4 percent.

Figure 3-2
1991 Top 10 Companies' Microprocessor IC Market Share



Source: Dataquest (December 1992)

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Table 3-2
Top 30 Companies' Factory Revenue from Shipments of Microprocessor ICs to the World (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	1,826	2,504	37	64.3
2	2	Motorola	291	363	25	9.3
3	3	Advanced Micro Devices	110	327	197	8.4
4	6	National Semiconductor	66	81	23	2.1
5	4	Hitachi	72	76	6	2.0
5	4	NEC	72	76	6	2.0
7	7	SGS-Thomson	53	55	4	1.4
8	9	Toshiba	42	47	12	1.2
9	17	Cypress Semiconductor	13	46	254	1.2
10	10	LSI Logic	34	45	32	1.2
11	8	Harris	45	38	-16	1.0
12	11	Zilog	25	31	24	.8
13	12	Performance Semiconductor	24	28	17	.7
14	14	Siemens	20	21	5	.5
15	NM	Weitek	0	19	NM	.5
16	13	Mitsubishi	21	18	-14	.5
17	15	Fujitsu	19	16	-16	.4
18	17	Integrated Device Technology	13	14	8	.4
19	20	Philips	9	13	44	.3
19	16	Oki	16	13	-19	.3
21	19	Texas Instruments	10	12	20	.3
22	21	Matsushita	8	10	25	.3

(Continued)

Table 3-2 (Continued)
Top 30 Companies' Factory Revenue from Shipments of Microprocessor ICs to the World
(Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
23	22	Sharp	7	9	29	.2
24	24	TMS	5	7	40	.2
25	31	VLSI Technology	1	4	300	.1
25	27	Silicon Integrated Systems	3	4	33	.1
25	25	Ricoh	4	4	0	.1
28	27	Rockwell	3	3	0	.1
29	29	Hughes	2	2	0	.1
30	25	United Microelectronics	4	1	-75	*
30	31	TRW	1	1	0	*
30	31	NCR	1	1	0	*
30	29	Goldstar	2	1	-50	*
		All Others	9	3	-67	.1
		North American Companies	2,466	3,522	43	90.5
		Japanese Companies	261	269	3	6.9
		European Companies	95	96	1	2.5
		Asia/Pacific Companies	9	6	-33	.2
		Total Market	2,831	3,893	38	100.0

NM = Not meaningful
* = Calculated value is less than 0.1 percent.
Source: Dataquest (December 1992)

Each of the sections that follow provide a more detailed discussion by processor class, including market developments, competing vendors, and market forecast.

80x86 Family Microprocessors

The 80x86 processor class is defined as all upward-compatible versions of the 8086 microprocessor, regardless of word length, instruction extensions, or level of integration. The following subsegments and versions are broken out for discussion separately to more accurately depict the trends and rivalry within this class:

- 086 series: Includes the 8086, 8088, 16-bit V-series processors (V20/40 and V30/50), 80188, 80186, and new highly integrated versions.
- 286 series: Includes the 80286 alone.
- 386 series: Includes the 386SX, 386DX, 386SL, 376, the 32-bit V-series (for example, V60/70/80), and future integrated versions.
- 486 series: Includes the 486SX, 486DX, 486DX2, 486SL, and 486S16 versions, and future highly integrated versions.
- P5/Future series: Includes the P5 (expected to ship in the first quarter of 1993) and other Intel and non-Intel follow-on versions.

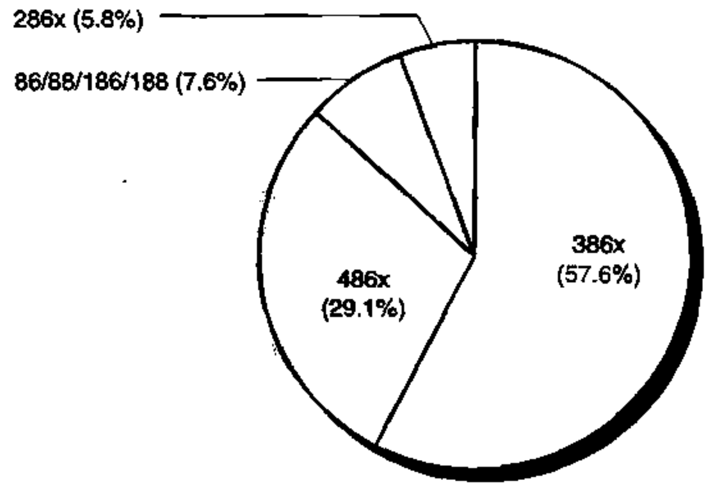
The original 8086 was introduced by Intel in 1978, had 29,000 transistors (then state of the art), ran at under 5 MHz, had a die size of 51,000 square mils, and initially sold for nearly $200 (now a $6 part). Now the P5 has 3.1 million transistors, runs up to 66 MHz, has a die size of 405,000 square mils, and will initially sell for nearly $1,000. What these parts have in common is the power of compatibility with more than 40,000 software applications, having been blessed by IBM's selection as the engine within its PC. Though embedded applications make up about 50 percent of 80x86 volumes, they are dominated by the lower-ASP 16-bit series. Figure 3-3 shows the distribution of revenue by product series as of the end of 1991.

As of the end of 1991, Intel and AMD were the only two vendors drawing substantial revenue from the 80x86 family. However, several vendors are lining up to take their shot.

The 80x86 vendor base was originally opened up through second-source licensing agreements with Intel. After growing critical mass in the market by using the early 8088 and 80286 processors, which were widely second-sourced, the scene changed. Intel introduced the 32-bit generation of 80x86 processors with the intent to grow its business around a family of single-sourced, upward-compatible processors that would eventually reach workstation performance. At press time (end of 1992), an estimated 90 percent of the 80x86 family revenue comes from the set of 32-bit versions (386 and 486 series).

The 086 series was the lifeblood of the early PC industry and is now moving quickly to an embedded-only application base. Current trends have the 8086 and 8088 heading downward, with their decline moderated by their portion of embedded designs as well as the V-series. The V-series, used by NEC in its line of Japanese PCs, is more stable and

Figure 3-3
1991 80x86 Market Share in Revenue, by Product Series



Source: Dataquest (December 1992) G2002586

shows a longer life because of different market conditions. On the other hand, the trend within the 186/188 versions is up, showing a renewed strength in industrial and office peripheral applications. Another positive trend is showing up in the use of single-chip PC components, such as Chips & Technologies' (C&T) new PC-chip product, which will also enhance this series' lifetime.

The 286 series, when introduced with the original IBM PC AT products, was thought to provide enough power for nearly any PC user. Now virtually obsolete for use in mainstream PCs, primarily because of the use of Windows, this series still sells into telecommunications, industrial, and other embedded applications.

The 386 series was introduced in 1985 and has become the dominant desktop PC microprocessor over the last two years. Essentially three mainstream versions are being shipped. The highest-selling version is the 386SX, a 16-bit output version that offers PC vendors the lowest-cost approach for a PC. The 386DX ships at about half the unit volume of the SX, and during the last half of 1992 has been dominated by AMD's 40-MHz version, for which prices have been severely dropped to stem the 486SX growth. Intel's proprietary 386SL has done well in garnering perhaps 40 percent of notebook volume.

The 486 series is becoming more convoluted with time, having originally begun as a full 32-bit processor (the 486DX) with integrated 8KB cache and floating point unit (FPU). The 486DX2 offers the same ingredients, with internal clock doubling, effectively increasing performance without affecting the system design, a well-accepted concept. The 486SX, which deletes the FPU, is now offered in many configurations, including the original Intel 486SX (now at 5V or 3V), the Cyrix (or TI) 486SLC (386SX pin-out), and 486DLC (386DX pin-out), both with only 1KB of cache. The recently announced 486SL is a full 486DX with the SL family bus control logic on-chip for low real-estate notebooks.

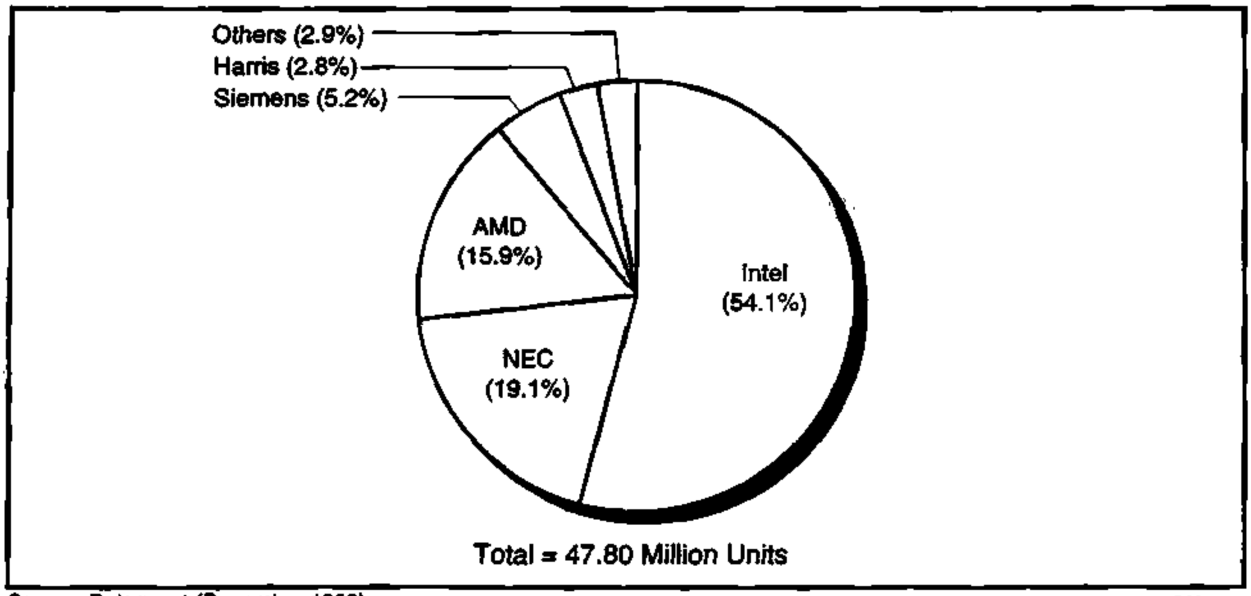
The P5/Future series of 80x86 processors includes the upcoming P5 (Pentium processor)—to be introduced in the first quarter of 1993—as well as other future processors consistent with this classification. This classification includes as a minimum the following:

- Full 486 instruction-set compatibility
- On-chip primary cache and FPU
- Superscalar, multi-issue architecture

Competitive Positions and Analysis

As of the end of 1991, this segment was dominated by Intel (see Figure 3-4 and Table 3-3), which still has more than half of the unit volume (but revenue in excess of 80 percent). Skipping to third place in unit volumes, AMD entered the market with the 386 in 1991 and was immediately successful, garnering more than a

Figure 3-4
1991 Top 5 Companies' 80x86 Microprocessor Market Share (Units)



Source: Dataquest (December 1992)
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Table 3-3
Each Company's Shipments of 80x86 Microprocessors to the World
(Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Intel	22,200	26,900	21	54.1
2	3	NEC	8,600	9,500	10	19.1
3	2	AMD	10,400	7,900	-24	15.9
4	4	Siemens	2,500	2,600	4	5.2
5	5	Harris	1,600	1,400	-13	2.8
6	5	Oki	1,600	920	-43	1.8
7	7	Fujitsu	820	480	-41	1.0
8	8	Sharp	40	43	8	.1
		Total 80x86 MPU	47,800	49,700	4	100.0

Columns may not add to totals shown due to rounding.
Source: Dataquest (December 1992)

quarter of a million dollars in revenue and positioning itself as a strong competitor. Second-ranked NEC markets the V-series 8086 equivalents (mostly consumed captively in its Japanese PC family) and is not viewed as a real threat to enter the lucrative 386/486 market. Similarly, neither Siemens nor Harris, longtime second sources of the 16-bit 80x86 series, are considered past and not future competitors. The new wave of small innovative vendors, in many cases teamed up with large established semiconductor houses, will create the mainstream rivalry. A brief discussion of this new wave of competition follows.

Intel's 80x86 road map calls for a dual focus on both desktops and portables, delivered in concert with its central strategy. It has long believed that its ultimate marketing edge is to drive up available transistor count through process and design technology and use that transistor count to do the following:

- Create leading-edge performance (desktop focus). This direction will result in introduction of the P5 during the first quarter of 1993, a 100-mips-class microprocessor with workstation-level floating point performance. Following this at 18- to 24-month intervals will be the P6 and P7, offering additional increases in performance level and multiprocessor support.
- Create leading-edge integration (portable focus). This direction has resulted in the 486SL, a 486 equivalent to the 386SL providing the ideal match for color notebooks. Following this will be the 386SC (single-chip) class of devices now being jointly developed with VLSI Technology.
- Continually decrease manufacturing costs. This direction will result in continued shrinkages of existing 486 and SL lines of products, reducing the die sizes and thus costs, enabling Intel to offer high-end (relative to competition) performance and integration at mainstream prices.
- Continually increase barriers to entry. This direction will result in limiting the available foundry capacity to the industry because of the level of design and process technology required to be performance- or cost-competitive, creating a strategic weakness for fabless vendors.

Intel is now complementing its technology edge with a three-pronged marketing strategy as a countermeasure to the insurgence of competition, as follows:

- Extensive litigation is used to slow down existing competitors, discourage potential new competitors, and create anxiety within the market over using potentially illegal competitive products.
- Combined advertising and corporate sales campaigns are used to drive the PC market transition into its second wave and to drive proprietary products (486 and SL versions) where end users gain superior features and upgradability.

- High-impact promotion and vendor-cooperative advertising is used to increase brand preference through aggressive advertising of the "Intel Inside" concept and its "Overdrive Processor" upgrade programs.

AMD entered the market in the second quarter of 1991 with exact copies (including microcode) of the 386DX and 386SX versions. IT's strategy has been to use its "licensed rights" to Intel's intellectual property to reverse-engineer fully compatible clones of Intel's products, including microcode, and offer higher-speed grades at the same price Intel offers the standard speed grades. This strategy paid off initially: AMD attained about 15 percent of the 386 market by the end of 1991 and about 35 percent by the end of the second quarter of 1992. Keeping the momentum going, in January 1992 the company preannounced plans for 486 clones to be sampled in the third quarter and shipped in the fourth quarter. However, these plans were destroyed in June 1992 when it lost in a court battle over intellectual property rights (the 287 microcode case). AMD will suffer a significant setback because it must now forward-engineer its 486 clones (unless the 287 decision is ruled not to apply to microprocessors). The result will be to move out until the second quarter of 1993 any real volume shipments and to take away AMD's "exact replica" advantage over other clones. AMD is expected to provide additional focus during 1993 on versions of 386 and 486 products for the portable market.

Cyrix entered the market in the second quarter of 1992 with a proprietary design representing a cross among the 486SX (instruction-set, cache) and 386SX and DX versions. Its strategy has been to forward-engineer its designs with 486 instruction-set compatibility and attack the installed base of 386 designs and units, offering to OEMs a pin-compatible option to upgrade their 386 system designs to 486s and to corporate end users the option to upgrade their installed 386s to 486s. Furthermore, it intends to do the same thing for the 486 installed base as it starts releasing upscaled versions of its product line in the coming months. Having recently won a court battle contesting its rights to use SGS-Thomson as its foundry, Cyrix is successfully growing its sales and will probably ship 300,000 or so units by the end of this year, representing a growing threat to Intel.

C&T entered the market in the fourth quarter of 1991 with a combination of exact clones and proprietary enhancements to the 386, as well as a single-chip PC based on an enhanced 8086 core. Having suffered severe technical problems in addition to poor financial health, it has announced its departure from the 386/486 clone race to pursue only integrated versions of the x86 family for hand-held and portable devices. In its current condition, it does not pose a real threat to Intel.

TI announced that it will enter the market in the fourth quarter of 1992 using the Cyrix design, with intentions of following up with more highly integrated versions using its wide array of technologies. Based on its manufacturing capabilities and widespread sales channels, TI presents a potential long-term threat to Intel. However, its limited microprocessor design expertise mitigates some of this threat.

Nexgen for years preannounced plans to enter the market, and now aims at a P5 competitive offering expected to be announced during the first quarter of 1993. Nexgen has a historic credibility problem to overcome in the industry and must align itself with an appropriate foundry for its parts.

Having acquired design house Meridian Technology during 1991, UMC is working on a clone of the 486SX expected to be introduced in the first quarter of 1993. With limited manufacturing muscle, a relatively low technology base, and limited sales channels (except in Asia/Pacific), UMC may have a difficult time sustaining growth in this ultimately competitive arena.

Other companies rumored to be working on 386/486 clone products include the following:

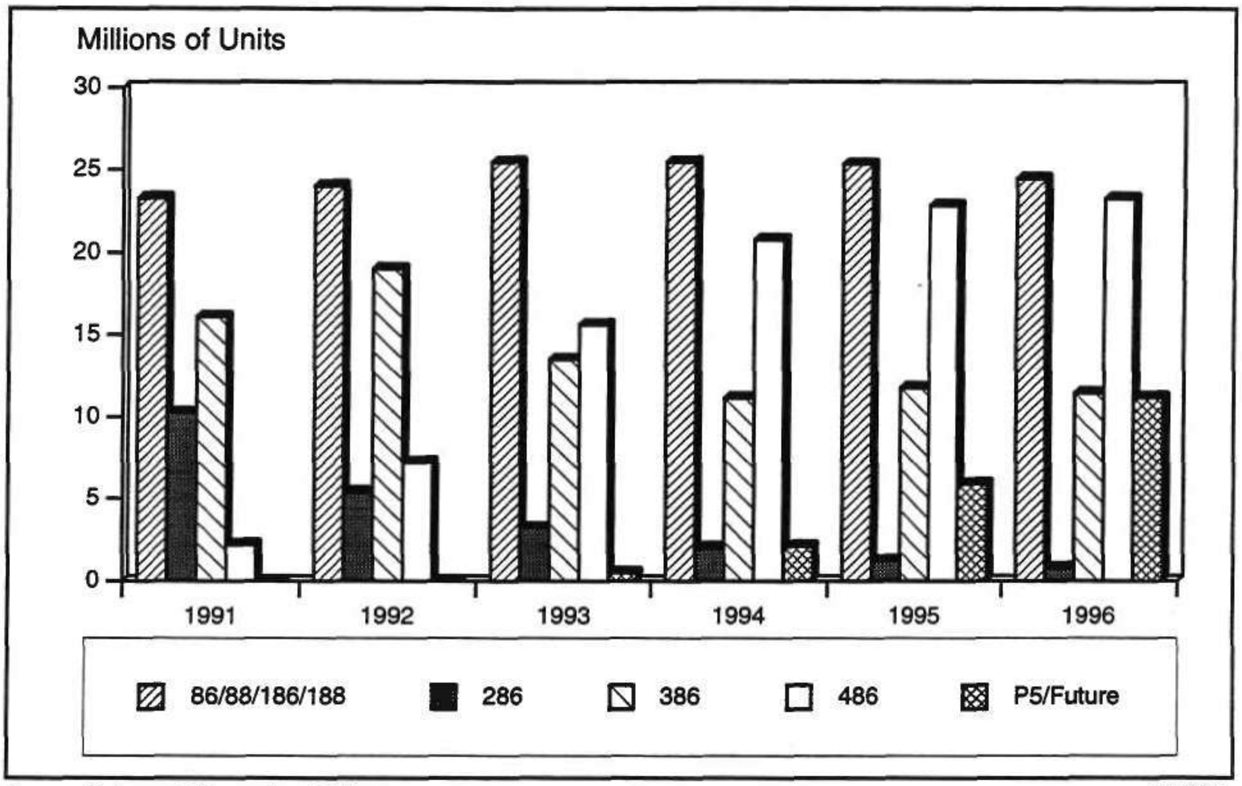
- VM Technology, a Japanese company reportedly with funding from Fujitsu, is working on 486-level products.
- Seiko-Epson is working on fully integrated versions of the 486, primarily for captive use.
- IIT, a competitor in the math coprocessor arena, is working on a 486-type product with ultrahigh floating point performance.

Forecast and Assumptions

It was clearly evident during 1991 that the future for 80x86 class of processors lay in the 32-bit versions, leaving the real battle among Intel, AMD, and other potential entrants. This entire family is being strengthened by competition, showing continued unit and revenue growth over the next five years (see Figures 3-5 through 3-7 and Table 3-4). Key assumptions relevant to this forecast are as follows:

- Unit volume in computer systems will show a steady increase in the next five years, showing some impact from the OSR (RISC) processors in the 1996 time frame.
- Unit volumes in embedded applications will remain relatively flat until 1995, when there will be an increase because of the growth of 80x86-based hand-held electronic devices.
- The 086 series will remain relatively flat during the next five years as the decline in 8086/88 (and V-series) shipments is offset by the increase in 80186/188 (and PC-Chip) shipments in the same time frame.
- The 286 series will decrease steadily over the next five years, supported only by its embedded applications base.
- The 386 series will peak this year and begin a slow decline over the next five years.

Figure 3-5
80x86 MPU Market Forecast, Units



Source: Dataquest (December 1992)
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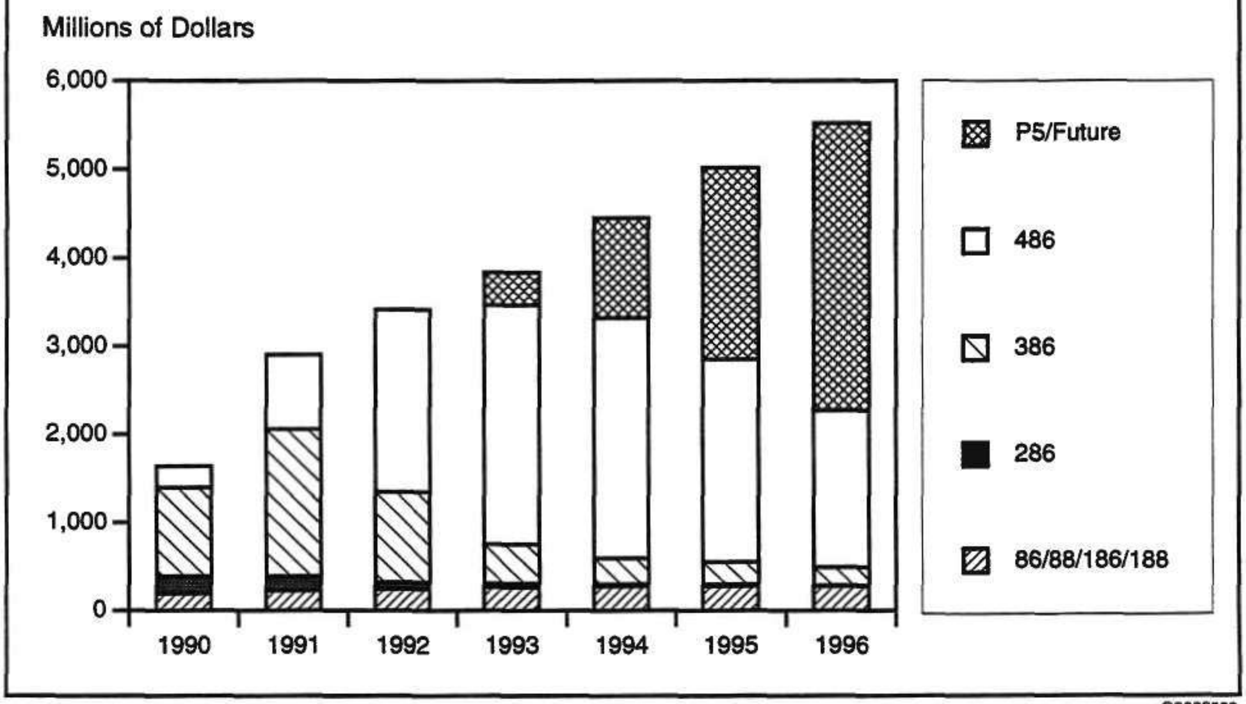
- The 386DX will drop off rapidly after this year, becoming obsolete because of low-cost 486SX-class products.
- The 386SX will drop off slowly over the next five years, surviving in low-end notebooks and entry-level systems with ASPs dropping to the mid-20s next year.
- The 386SL/SC versions will continue growth throughout this forecast and will become the 80x86 focal point for low-end notebook and hand-held designs.
- Intel will be successful in migrating PCs to the 486 series, which will propel it to dominance starting in 1993.
- The 486SX will continue its rapid growth through next year but will flatten out in 1994 and begin slowly moving down in 1995 as competition brings the 486DX downward in price and improved versions of the 486SL take over high-end portable demand.

Figure 3-6
80x86 MPU Market Forecast, Revenue



Source: Dataquest (December 1992)

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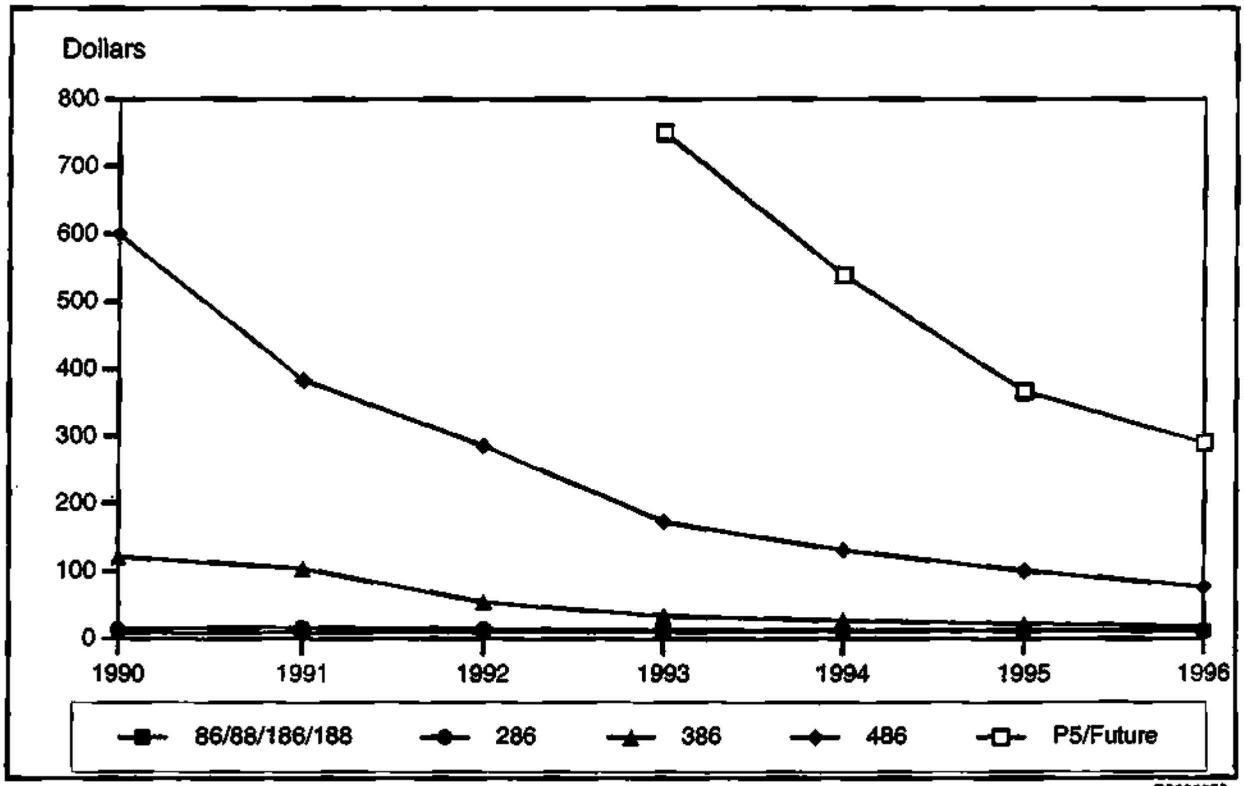
- The 486DX, led by the growth of the DX2 versions, will continue to grow throughout this forecast period, becoming the most widely cloned 80x86 version and representing the mainstream desktop until 1996.
- The 486SL/SC versions will show rapid growth during the forecast period, first taking the bulk of color notebooks, then moving down into the mainstream notebooks late in 1994.
- The P5 and future superscalar processors will take off starting in 1994 as software coalesces around the performance and multiprocessing capabilities offered and pricing drops to the upper end of mainstream levels.

Figure 3-7
80x86 MPU Market Forecast, ASP



Source: Dataquest (December 1992)

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Table 3-4
80x86 MPU Market Forecast

Processor	1990	1991	1992	1993	1994	1995	1996
8088x (Including V Series) (16/8-Bit)							
Units (K)	8,390	7,650	5,500	4,100	3,000	2,100	1,500
ASP ($)	6	6	6	6	6	6	6
Revenue ($K)	50,340	45,900	33,000	24,600	18,000	12,600	9,000
88SL/SC (Including 188) Integrated I/O							
Units (K)	2,470	3,610	4,693	5,632	6,195	6,504	6,830
(16/8-Bit)ASP ($)	12	12	11	11	10	10	9
Revenue ($K)	29,640	43,320	53,500	60,990	63,735	63,575	63,417
8086x (16/16-Bit)							
Units (K)	6,750	6,130	5,600	4,600	3,500	2,700	1,800
ASP ($)	7	7	7	7	7	7	7
Revenue ($K)	47,250	42,910	39,200	32,200	24,500	18,900	12,600
86SL/SC (Including 186) (16/16-Bit) Integrated I/O							
Units (K)	3,980	5,860	8,204	11,075	12,737	14,010	14,291
ASP ($)	15	15	14	13	13	13	13
Revenue ($K)	59,700	87,900	114,856	143,980	165,577	182,135	185,778
88/86 Subtotal							
Units (K)	21,590	23,250	23,997	25,407	25,431	25,315	24,420
ASP ($)	9	9	10	10	11	11	11
Revenue ($K)	186,930	220,030	240,556	261,770	271,812	277,210	270,794
286X (16/16-Bit)							
Units (K)	13,030	10,250	5,400	3,200	2,000	1,200	800
ASP ($)	16	16	14	13	13	13	13
Revenue ($K)	201,965	168,100	77,760	41,600	26,000	15,600	10,400

(Continued)

Table 3-4 (Continued)
80x86 MPU Market Forecast

Processor	1990	1991	1992	1993	1994	1995	1996
386SX (32/16-Bit)							
Units (K)	4,700	10,300	11,050	8,000	5,760	3,456	1,728
ASP ($)	69	68	43	26	21	17	13
Revenue ($K)	324,300	700,400	475,150	206,400	120,960	58,061	23,224
386SL/SC (32/16-Bit) Integrated I/O							
Units (K)	0	200	1,750	2,600	4,160	7,904	9,485
ASP ($)	0	130	68	39	29	23	19
Revenue ($K)	0	26,000	119,000	100,776	120,931	183,815	176,463
386DX (32/32-Bit)							
Units (K)	3,400	5,400	6,000	2,700	1,080	324	194
ASP ($)	185	165	65	39	29	25	21
Revenue ($K)	629,000	891,000	390,000	105,300	31,590	8,055	4,108
376/Miscellaneous (Miscellaneous 32-Bit)							
Units (K)	200	210	200	180	126	63	31
ASP ($)	275	260	234	211	190	171	154
Revenue ($K)	55,000	54,600	46,781	37,893	23,872	10,743	4,834
386 Subtotal							
Units (K)	8,300	16,110	19,000	13,480	11,126	11,747	11,439
ASP ($)	121	104	54	33	27	22	18
Revenue ($K)	1,008,300	1,672,000	1,030,931	450,369	297,354	260,674	208,630
486SX (32/32-Bit)							
Units (K)	0	400	2,900	6,300	7,245	6,158	4,619
ASP ($)	0	220	130	75	60	48	38
Revenue ($K)	0	88,000	377,000	472,500	434,700	295,596	177,358

(Continued)

Table 3-4 (Continued)
80x86 MPU Market Forecast

Processor	1990	1991	1992	1993	1994	1995	1996
486SL/SC (32/32-Bit) Integrated I/O							
Units (K)	0	0	100	1,200	2,160	3,024	3,629
ASP ($)	0	0	250	175	140	112	90
Revenue ($K)	0	0	25,000	210,000	302,400	338,688	325,140
486DX (32/32-Bit) Integrated FPU							
Units (K)	400	1,800	4,200	8,100	11,340	13,608	14,969
ASP ($)	600	420	395	250	175	123	86
Revenue ($K)	240,000	756,000	1,659,000	2,025,000	1,984,500	1,666,980	1,283,575
486 Subtotal							
Units (K)	400	2,200	7,200	15,600	20,745	22,790	23,216
ASP ($)	600	384	286	174	131	101	77
Revenue ($K)	240,000	844,000	2,061,000	2,707,500	2,721,600	2,301,264	1,786,073
P5/Future (32/64- and 32/32-Bit)							
Units (K)	0	0	0	500	2,100	5,880	11,172
ASP ($)	0	0	0	750	540	367	290
Revenue ($K)	0	0	0	375,000	1,134,000	2,159,136	3,240,863
All 80X86							
Units (K)	43,320	51,810	55,597	58,187	61,402	66,932	71,047
ASP ($)	38	56	61	66	72	75	78
Revenue ($K)	1,637,195	2,904,130	3,410,247	3,836,239	4,450,766	5,013,885	5,516,760

Source: Dataquest (December 1992)

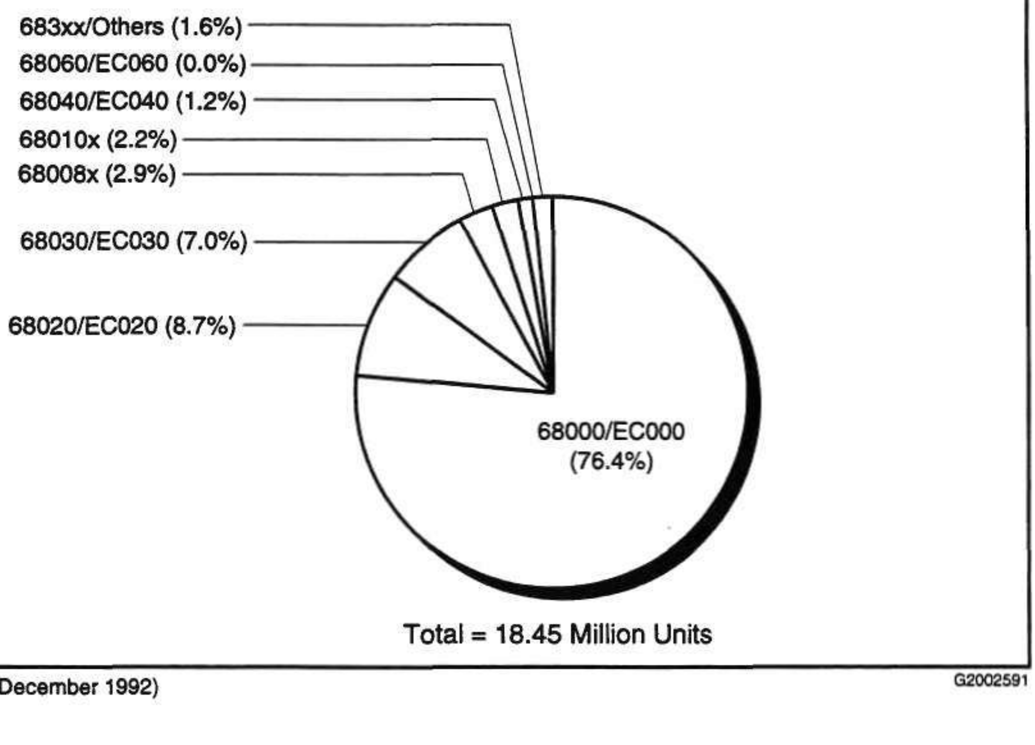
68K Family Microprocessors

The 68xxx processor class is defined as all upward-compatible versions of the 68000 microprocessor, regardless of word length, instruction extensions, or level of integration. The following are also broken out as subsegments to enable a more focused analysis of market trends and competitive positions (note that each of these series, except 68008/010, includes the 0xx devices and the ECxx devices):

- 68000 series (32/16-bit device, 000 and EC00 versions)
- 68008 series (32/8-bit device)
- 68010 series (32/16-bit device)
- 68020 series (32/32-bit device, 020 and EC020 versions)
- 68030 series (32/32-bit device, 030 and EC030 versions)
- 68040 series (32/32-bit device, 040, EC040, and LC040 versions)
- 68060 series (32/32-bit device: available 1994)
- 683xx series (various application-specific devices)

As shown in Figure 3-8, the 68000 accounts for the bulk of the current volume. However, the fastest growing segment is the 683xx series. As of the end of 1991, Motorola maintained nearly 85 percent of the 68K market volume. Furthermore, the 15 percent volume shared with other

Figure 3-8
1991 68xxx Market Share in Unit Shipments, by Series



Source: Dataquest (December 1992)

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vendors is only in the 32/16-bit segment (the only licensed parts), leaving all the high-ASP, high-margin parts to Motorola.

The original 68000 was introduced in 1979 with a 32-bit architecture, using 68,000 transistors, and only 68,200 square mils. Since then, the 68K family has found its way into a wide variety of systems and embedded applications. It became the processor of choice for Apple's Macintosh and Commodore's Amiga. It became the first processor of choice for the leading workstation vendors, Sun and Apollo. It became the processor of choice for the leading laser printer vendors, HP and Apple. It became the first processor of choice for several vendors of X Window terminals, including market leader NCD. Current status and trends by series are detailed in the following paragraphs.

The 68000 series continues to exhibit growth, more than 12 years after its introduction. It is the leading-volume microprocessor to date used in laser printer applications, having been the first choice by both HP and Apple. It continues to gain new volume design wins, including the Sega-Genesis game, which will account for more than 7 million units next year. It offers a well-designed instruction set and a very low entry cost. It also is offered by the highest-quality semiconductor vendor, Motorola, and is second-sourced by four others.

The 68008, with its 8-bit external data bus, is on its way down, partially made obsolete by the new 68EC000, which can manage either 8- or 16-bit external operations. Motorola expects to see sales at zero in the 1994 time frame.

The 68010 is also dropping off, though not as sharply as the 68008. As with the 68008, Motorola would like to see designs transition to other parts (68EC00 or EC020) within the next year.

The combined total of all high-end 68K processors (68020/030/040) grew by 68 percent last year to more than 4 million units. Most of the unit volume for these versions came from platform sales, most notably the Macintosh. All individual processors in this group experienced growth during 1991.

The 68020's growth has flattened in the last two years as a result of a crossover effect between falling computer sales and rising embedded sales. The future of this series is in the EC020 version, which is slated to become the next high-volume member of the 68K family, eventually displacing the 68000 series.

The 68030 continues to grow, with Apple having moved nearly its entire Macintosh line up to the 68030 as the demand for performance continues to grow. Though a number of embedded designs are beginning to adopt the 030, it is far and away the highest-volume 68K series for computer applications.

The 68040 began shipping last year, though much later than originally anticipated, moving just more than 200,000 units in its first year. In addition, in January 1992 Motorola released a 33-MHz version of the

68040, turning in nearly 29-mips performance. A second new part based on the 68040 was also introduced in 1991. The 68LC040 series is a lower-cost version of the 68040 actually targeted toward low-cost PCs (including portables) and OS-related embedded applications such as communications controllers and X terminals. This part is identical to the 68040, except that it removes the FPU (like a 486SX) and adds low-power buffers, lowering its price to $185 for a 25-MHz, 22-mips processor.

The 68060 series is a superscalar RISC-like implementation of the 68K architecture, planned for introduction in the first quarter of 1994. It uses a four-stage instruction pipeline with internal Harvard architecture, branch cache, and external system bus interface compatible with the 68040. Targeted at the desktop and high-end embedded marketplace, this 2.8-million transistor chip is implemented in a 3.3V process and designed to operate up to 66 MHz.

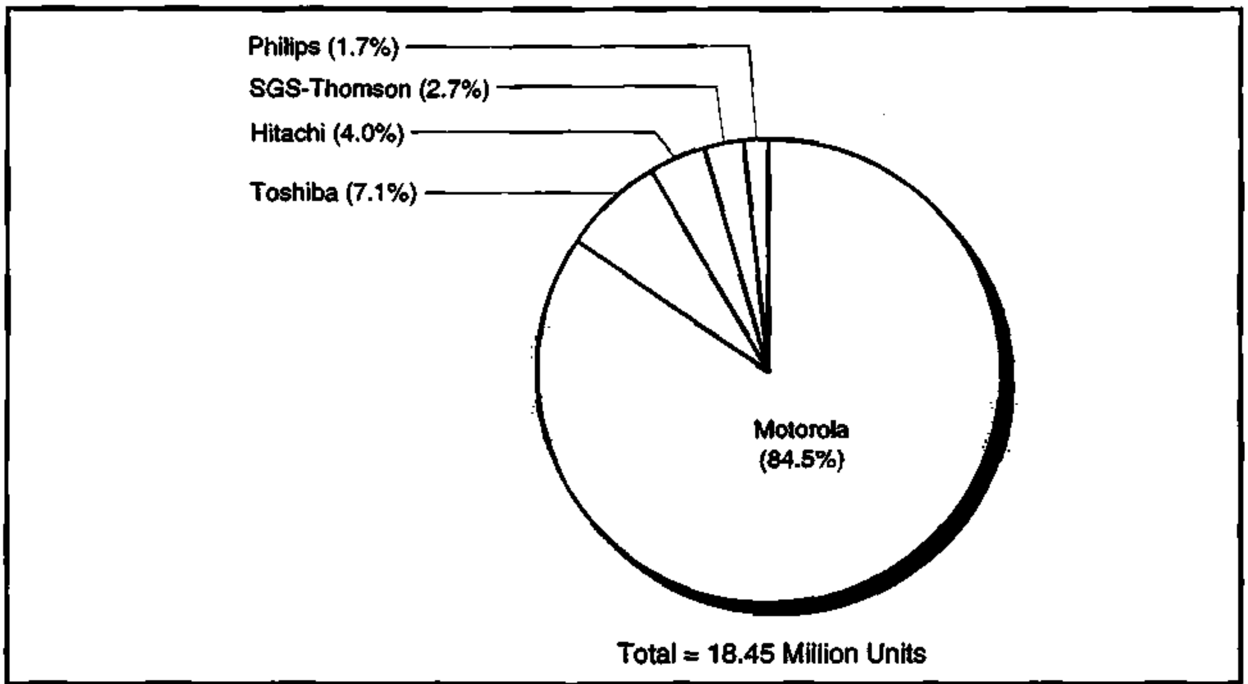
The 683xxx series has been in production for some time, and is marketed as a microcontroller, but at this time is basically a microprocessor with integrated I/O (no internal EPROM). This series takes a different course toward functional integration and low cost. Each 68300 is a virtual system on a chip, combining a 68xxx processor core, an intermodule bus, and peripheral modules such as memories, timers, and I/O circuits (in fact, future versions may be complete microcontrollers). These also are fully static parts, enabling standby modes and lower power consumption, making them attractive for products such as hand-held instruments.

Competitive Positions and Analysis

As shown in Figure 3-9 and Table 3-5, Motorola has more than 80 percent of this processor series (and 100 percent of the others). Other than Toshiba, which doubled its sales of 68000 parts in 1991, unit volumes for all other vendors are decreasing. It is noteworthy that each of these other vendors has other, more highly visible processors that their marketing programs are focused on.

As part of its strategy to deliver a range of highly integrated embedded control devices, Motorola plans to offer products from $1 and 100-mips within five years. Motorola is expected to remain the dominant vendor in the 68K family as well as a strong force in the overall microprocessor market.

Figure 3-9
1991 Top 5 Companies' 68xxx Microprocessor Market Share



Source: Dataquest (December 1992)
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Table 3-5
Each Company's Shipments of 68xxx Microprocessors to the World
(Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Motorola	11,700	15,590	52	84.5
2	4	Toshiba	720	1,310	108	7.1
3	3	Hitachi	960	738	-13	4.0
4	5	SGS-Thomson	570	498	-2	2.7
5	2	Philips	1,200	314	-70	1.7
		Total 68xxx MPU	15,200	18,450	38	100.0

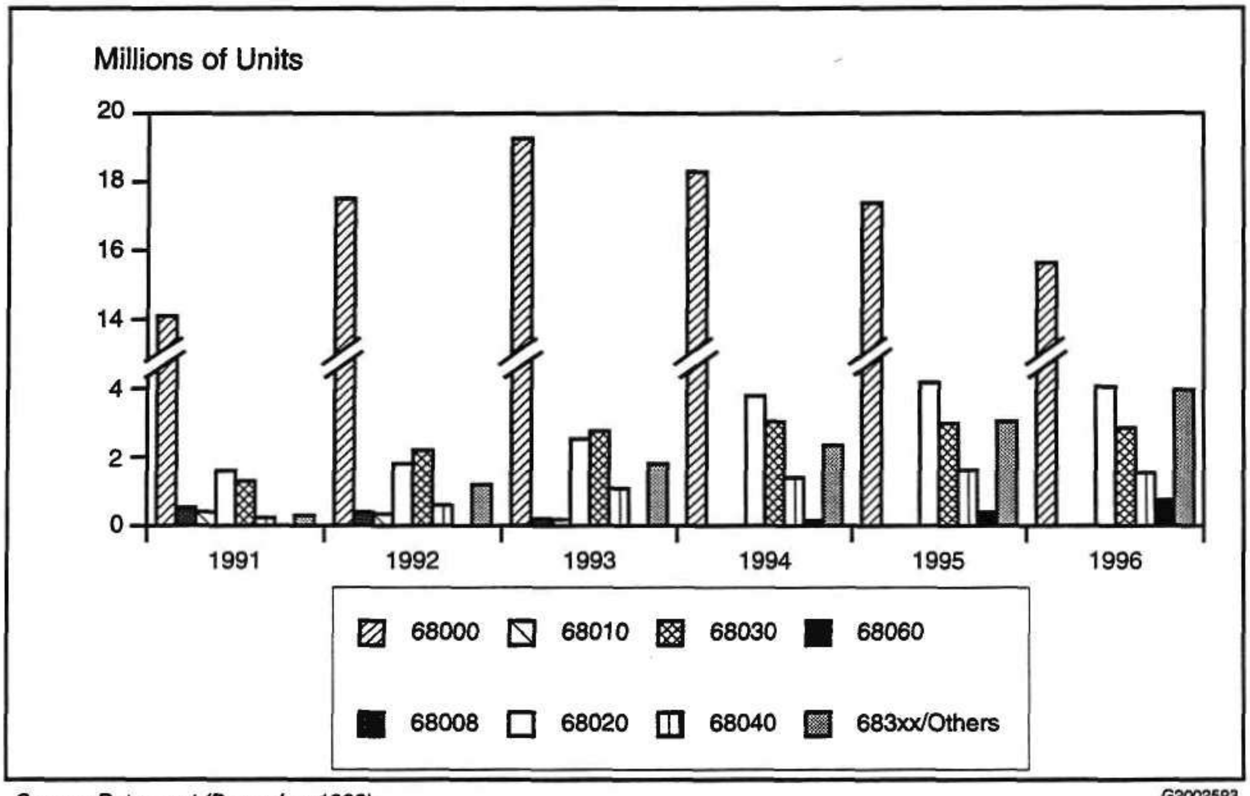
Columns may not add to totals shown due to rounding.
Source: Dataquest (December 1992)

Forecast and Assumptions

The 68K family has had a history of taking leadership positions within many high-growth markets and will be a leader in the increased consumerization of advanced technology. As shown in Figures 3-10 through 3-12 and Table 3-6, the 68K family will continue slow growth over the next five years, based on the following assumptions:

- Motorola and the 68K family will maintain a strong position in embedded applications, which will account for an increasing percentage of total unit volume (more than 95 percent in 1996).
- Computer-based applications will drop off as Apple turns on the PowerPC family, though the Macintosh is assumed to remain partially 68K-based and about 35 percent in volume by 1996.
- ASPs will decline slightly as the shift from computers to embedded decreases the volume of high-ASP parts.

Figure 3-10
68xxx MPU Market Forecast, Units



Source: Dataquest (December 1992)

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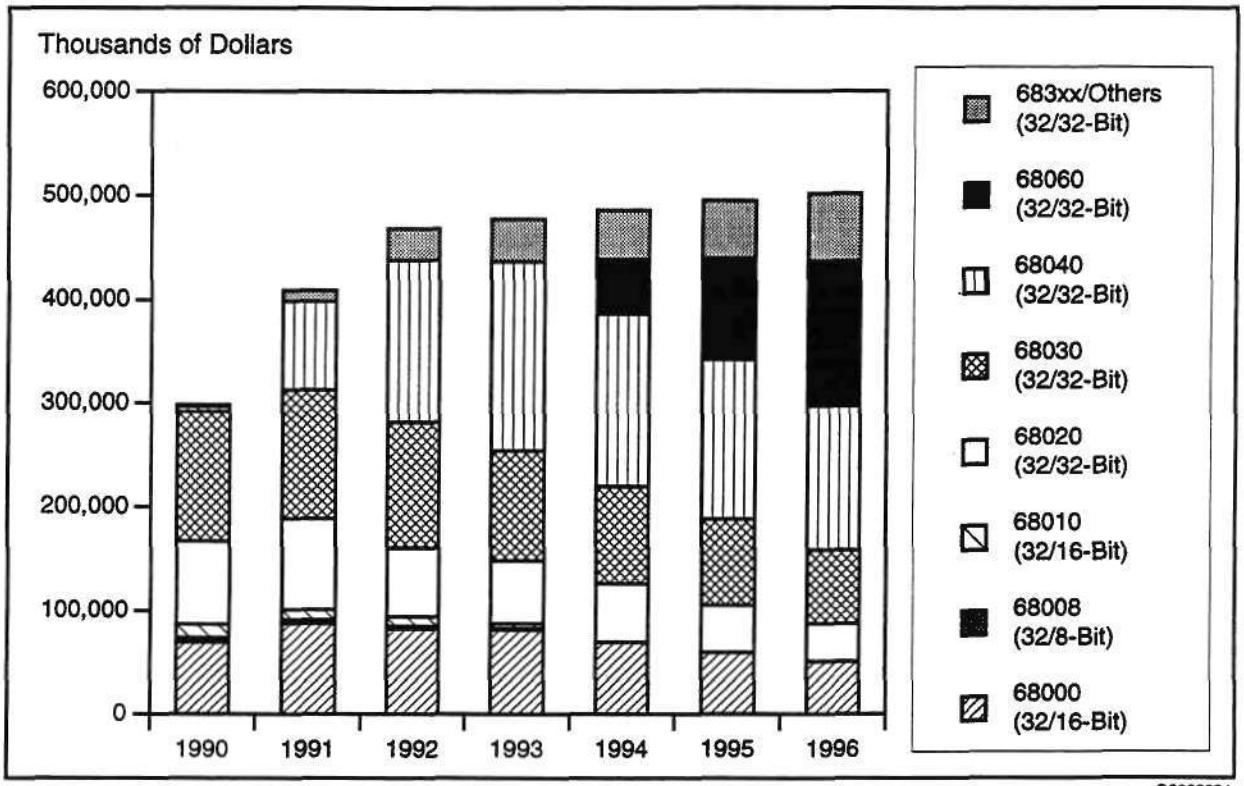
Figure 3-11
68xxx MPU Market Forecast, Revenue



Source: Dataquest (December 1992)

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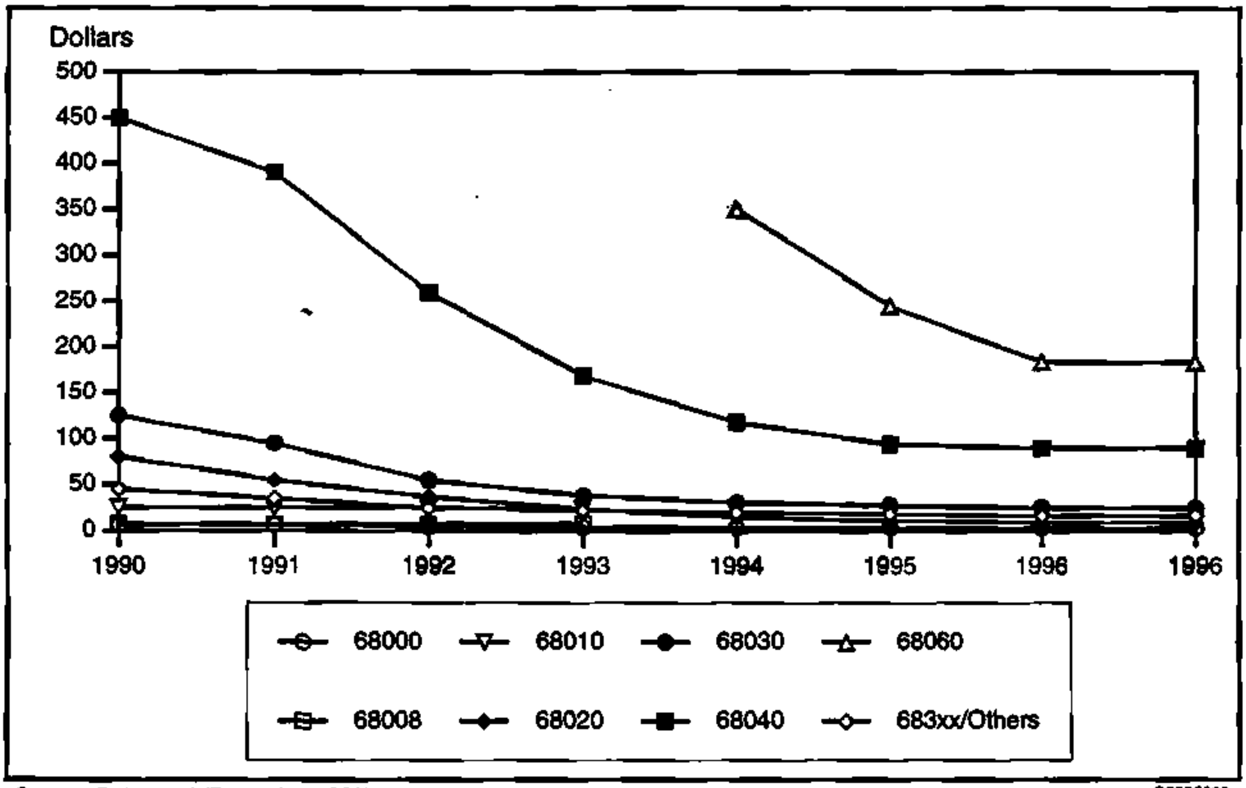
Figure 3-12
68xxx MPU Market Forecast, ASP



Source: Dataquest (December 1992)

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Table 3-6
68xxx MPU Market Forecast

MPU Class	1990	1991	1992	1993	1994	1995	1996
68000/EC000 (32/16-Bit)							
Units (K)	11,200	14,100	17,500	19,250	18,288	17,373	15,636
ASP ($)	6	6	5	4	4	3	3
Revenue ($K)	69,440	87,420	82,250	81,428	69,621	59,526	50,894
68008X (32/8-Bit)							
Units (K)	660	530	400	210	0	0	0
ASP ($)	7	7	7	7	0	0	0
Revenue ($K)	4,620	3,710	2,960	1,551	0	0	0
68010x (32/16-Bit)							
Units (K)	520	400	350	180	0	0	0
ASP ($)	25	25	25	25	0	0	0
Revenue ($K)	13,000	10,000	8,750	4,506	0	0	0
68020/EC020 (32/32-Bit)							
Units (K)	1,000	1,600	1,800	2,520	3,780	4,164	4,044
ASP ($)	80	55	37	24	15	11	9
Revenue ($K)	80,000	88,000	66,600	60,606	56,700	45,800	36,398
68030/EC030 (32/32-Bit)							
Units (K)	1,000	1,300	2,200	2,750	3,025	2,986	2,844
ASP ($)	125	95	55	39	31	28	25
Revenue ($K)	125,000	123,500	121,000	105,875	93,170	82,763	70,956
68040/EC040/LC040 (32/32-Bit)							
Units (K)	10	220	600	1,080	1,406	1,620	1,543
ASP ($)	450	390	260	169	118	95	90
Revenue ($K)	4,500	85,800	156,000	182,520	166,285	153,315	138,731

(Continued)

Table 3-6 (Continued)
68xxx MPU Market Forecast

MPU Class	1990	1991	1992	1993	1994	1995	1996
68060/EC060 (32/32-Bit) 2.5-Mil							
Units (K)	0	0	0	0	150	400	760
ASP ($)	0	0	0	0	350	245	184
Revenue ($K)	0	0	0	0	52,500	98,000	139,650
683XX/Others (32/32-Bit) (Including 683xx)							
Units (K)	40	300	1,200	1,800	2,340	3,042	3,955
ASP ($)	45	35	25	23	20	18	16
Revenue ($K)	1,800	10,500	30,000	40,500	47,385	55,440	64,865
68K Total							
Units (K)	14,430	18,450	24,050	27,790	28,988	29,584	28,782
ASP ($)	21	22	19	17	17	17	17
Revenue ($K)	298,360	408,930	467,560	476,986	485,660	494,844	501,494

Source: Dataquest (December 1992)

Open Systems RISC Microprocessors

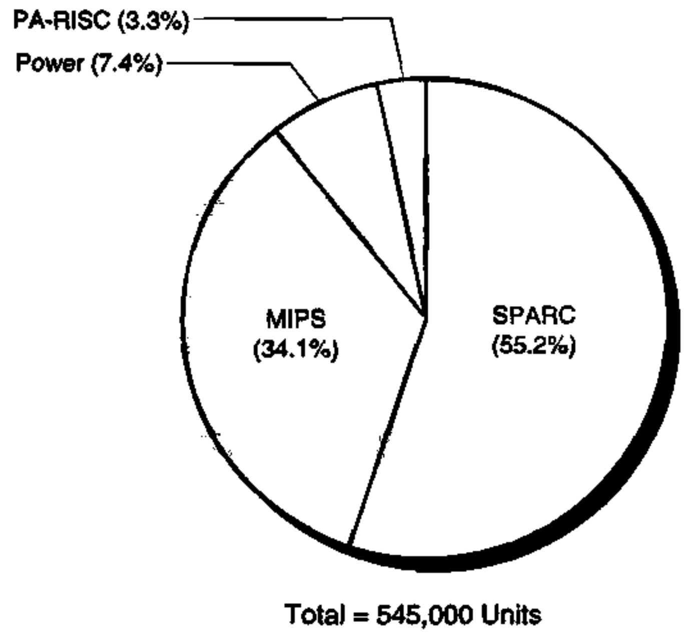
Open systems RISC (OSR) processors in total accounted for more than 500,000 units in 1991. Though statistically insignificant in volume, this class is setting the pace for competition in the computer systems market. This class is defined as RISC-based microprocessors, focused primarily on computing platforms (workstation and PC, among others). It is backed (or implicitly backed) by some form of open systems consortium, which makes it a candidate for mainstream adoption. Based on this definition, we have included the following families:

- SPARC family
- MIPS family
- PA-RISC family
- PowerPC family
- Alpha family

Each segment really stands for a major industry alliance aimed at the future mainstream desktop. Each alliance includes a standardized microprocessor architecture (instruction-set level), operating system strategy, multiple sources of chips, and one or more top systems vendors. Interestingly, each also has its own exclusive list of chip vendors, with the exception of LSI Logic, which participates in both MIPS and SPARC families.

The SPARC family accounts for more than half the total unit volume, having started its industry movement earlier than the others (see Figure 3-13). MIPS processors represent about one-third of the total, though many of these are used for embedded applications. The PowerPC and PA-RISC families together account for less than 15 percent of the total volume and are being captively consumed by IBM and HP, respectively. The Alpha processor will just begin sample shipments in 1992 of less than 10,000 units (about 1,000 units to vendors outside of Digital Equipment Corporation).

Figure 3-13
1991 Open Systems RISC MPU Market Share



Source: Dataquest (December 1992)

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SPARC Family

SPARC microprocessors are expected to grow only slightly this year because they are still primarily being tied to the growth of Sun Microsystems. This is a result of SPARC's primary driving force becoming its primary weakness. Sun is a dominant player in the workstation market whose continued growth directly results in increased sales of SPARC chips. Though Sun's stated strategy is to allow SPARC clone vendors to become a significant part of the market, its aggressive marketing, pricing, and channel dominance has prevented such developments. We expect this trend to continue for SPARC, growing only around Sun's business and the Solaris operating system. This situation is further compounded by the proprietary nature of the individual SPARC products, with no second sourcing and thus no ability to realize direct price competition or availability protection (imagine being in an allocation problem with a device that Sun is using).

MIPS Family

The market for MIPS processors grew by 142 percent during 1991, on top of the dramatic momentum picked up through the formation of the Advanced Computing Environment (ACE) initiative. Though the MIPS processor movement was primarily focused on developing platform sales, the failed ACE initiative pushed most of the burden to the embedded applications, which accounted for about 40 percent of the 1991 volume. Furthermore, two-thirds of the platform units are shipped to just two customers, with Silicon

Graphics picking up the entire focus as Digital begins to transition its workstation line to the Alpha processor. An amazing number of significant announcements affected the MIPS camp in 1992, including the following:

- The withdrawal of Compaq and Zenith from the ACE initiative
- The acquisition of MIPS Computer by Silicon Graphics
- The loss of Digital as a long-term supporter and customer of the MIPS processors
- The shipment of the R4000, one of the fastest integer-performance single-chip microprocessors to date
- The announcement of the R4400, a successor to the R4000 with 32KB of cache, internal speeds of 150 MHz, and estimated performance of 113 SPECmarks

PowerPC Family

The PowerPC family, the primary processor for the PowerOpen Computing Environment formed by the IBM/Apple/Motorola relationship, represents an outgrowth of IBM's RS/6000 POWER architecture. This new family is being jointly developed and separately manufactured by IBM and Motorola. Plans call for initial models designed to service the entire platform market for workstations, PCs, notebooks, and servers. Sporting a tuned instruction set, driven by optimizing compiler considerations, the first single-chip version to ship (in 1993) will be the 601, a slight performance improvement to the existing multichip version. In 1991, IBM shipped about 40,000 units for its own captive use. Moreover, starting in 1994, this new architecture, supported by a new advanced architecture, will be offered on the merchant market in the following versions:

- 603: Optimized for power/performance and targeted at the notebook and entry systems, selling at about $100.
- 604: Optimized for performance/price and targeted at power-user ($2,500) desktops, selling at about $400.
- 620: Maximized for all-out performance in multiprocessing systems and servers.

PA-RISC Family

The Precision Architecture RISC (PA-RISC) microprocessor was developed by HP; early versions have shipped since 1987. Using new advanced VLSI technology announced by HP in 1989 enabled the company to significantly increase performance of systems based on the PA-RISC. This new generation of PA-RISC first appeared in April 1991 in the HP 700 series of workstations, delivering the fastest benchmarks to date: 66 MHz, 77 mips, and 76 SPECmarks.

A lower-speed version of the PA-RISC processor running at 35 MHz was introduced in January 1992, offering workstations at 35 mips for less than $5,000. A high-performance version, the model 7100, was introduced recently with performance in the 120-SPECmark range. The PA-RISC architecture will continue to be extended upward and downward as HP prepares it for entry-level systems (for running Windows NT) and embedded applications.

Alpha Family

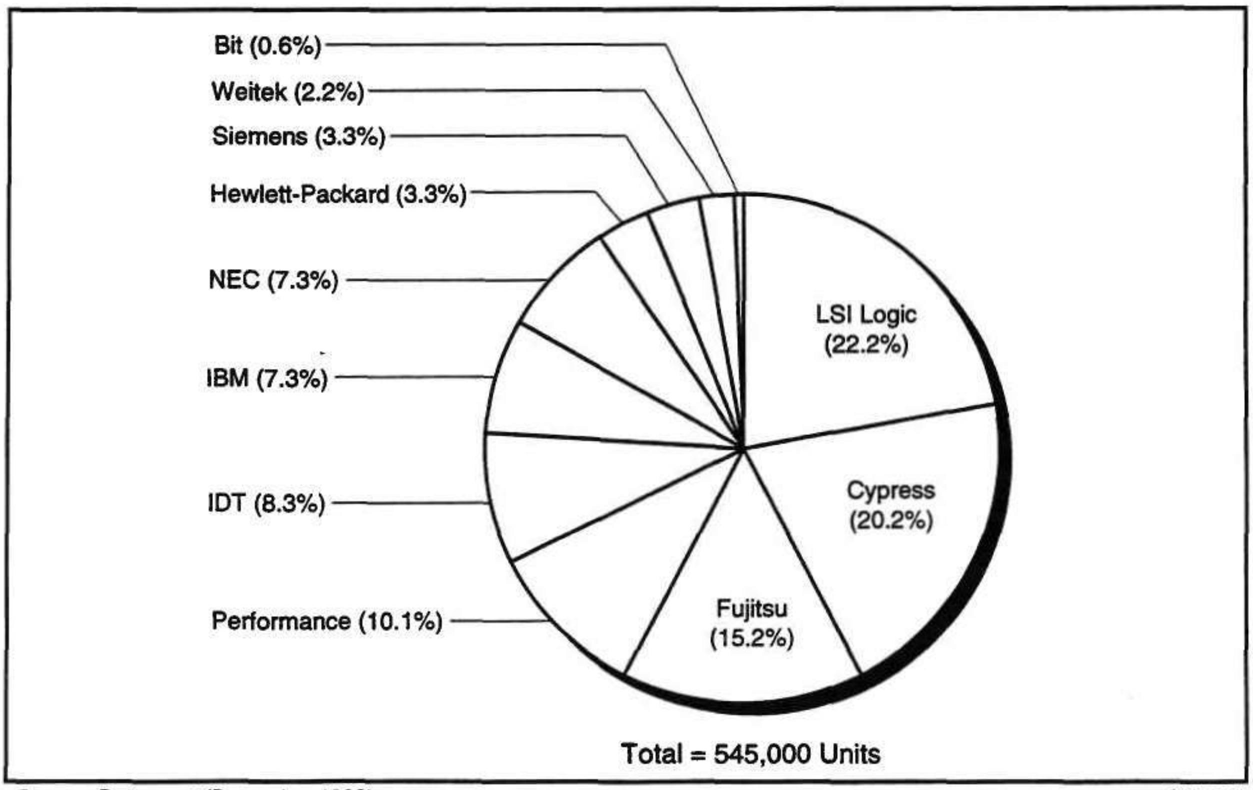
The Alpha microprocessor was developed by Digital notably in response to the lack of dramatic performance increases expected from the MIPS processor camp. Using expertise built up by generations of uVAX chip design, Alpha represents the most recent RISC architecture, devoid of most of the early architectural mistakes made with the other RISC families. Digital maintained a relatively low level of promotion for Alpha during most of 1992. Then, in the fourth quarter, it began exposing the chip and systems in nearly every event available. Alpha's key strengths include its high performance level (greater than 100 SPECmarks at 133 to 150 MHz), support from Windows NT, and Digital's sales channel strength. Digital plans to ship three versions by the end of 1993, as follows:

- 21064: High performance with 120-plus SPECmarks at a target price of $800.
- 21066: Price/performance versions with 80-plus SPECmarks at a target price of $400.
- 21068: Low-end version with about 40 SPECmarks and at a target price of less than $100.

Competitive Positions and Analysis

As shown in Figure 3-14 and Table 3-7, the OSR processor segment is controlled by a moderate number of vendors, all focused on one

Figure 3-14
1991 Top 11 Companies' Open Systems RISC Microprocessor Market Share



Source: Dataquest (December 1992)

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Table 3-7
Each Company's Shipments of Open Systems RISC Microprocessors to the World (Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	LSI Logic	103	121	17	22.2
2	4	Cypress	25	110	340	20.2
3	2	Fujitsu	45	83	84	15.2
4	3	Performance	33	55	67	10.1
5	5	IDT	20	45	125	8.3
6	6	IBM (Captive currently)	15	40	167	7.3
6	8	NEC	5	40	700	7.3
8	7	Hewlett-Packard (Captive currently)	6	18	200	3.3
8	NM	Siemens	0	18	NM	3.3
10	NM	Weitek	0	12	NM	2.2
11	8	Bit	5	3	-40	.6
		Total Open Systems RISC MPU	257	545	112	100.0

NM = Not meaningful
Columns may not add to totals shown due to rounding.
Source: Dataquest (December 1992)

architecture (with the exception of LSI). Therefore, the following discussion focuses on the competition for the two current volume architectures, SPARC and MIPS.

Regarding SPARC competition, both Cypress and Fujitsu experienced exceptional growth in 1991. Both offer integrated IU/FPU chips. These market share gains were made at the expense of LSI Logic, which was singularly dominant in 1990 and seems to have lost this position forever.

Fujitsu's sales were boosted by Sun's introduction of the SPARC-Station IPX and ELC and furthered by the beginning of its embedded sales with its SPARC-Lite series. Cypress also picked up a larger portion of Sun's business, including its 600 series SPARC-Servers as well as other accounts such as Solborne. Taking the limelight in 1992, TI attacked at both the high and low ends with the SuperSPARC (Viking) and the MicroSPARC (Tsunami), respectively. SuperSPARC has been a technical failure this year, yielding volume parts only at 33 MHz, far less than the expected 50 MHz, thereby hurting high-end performance. Furthermore, though MicroSPARC was a well-designed piece of hardware, its volume will depend on factors such as mainstream operating system support and volume clone vendors, which we do not believe will happen.

As of the end of 1991, seven vendors signed up as MIPS processor manufacturers (including Sony). Performance Semiconductor and Integrated Device Technologies (IDT) were able to maintain their No. 1 and 2 positions, respectively, in 1991. Performance sells the majority of its units to Digital, which has led to its downfall this year because shipments have leveled off and are beginning to head downward as Digital moves the Alpha architecture. IDT has the most balanced position, selling chips to workstation vendors and embedded applications, and is expected to take the No. 2 position in 1992. NEC came on strong in 1991; its strength has continued throughout this year and the company is expected to become the No. 1 vendor by the end of 1992. LSI Logic continues its loss of market share (as it also did in the SPARC processor market), but introduced a well-positioned integrated chip for X Window terminals in 1991. Siemens, at No. 5, showed healthy growth in its first year of shipping. Finally, there was the entry of Toshiba, which focused on being a major supplier of ACE/ARC systems before that focus went sour.

The PowerPC family is being jointly developed and separately manufactured by IBM and Motorola. In 1991, IBM shipped about 40,000 units for its own captive use. We expect that, starting in 1993, the new chips will be offered by both vendors. To date, the only chip production has been IBM and the only outside merchant chip source announced is Motorola (though the agreement between them calls for chip vendors to be added).

The PA-RISC microprocessor was developed by HP, with early versions having shipped since 1987. The PA-RISC camp now includes

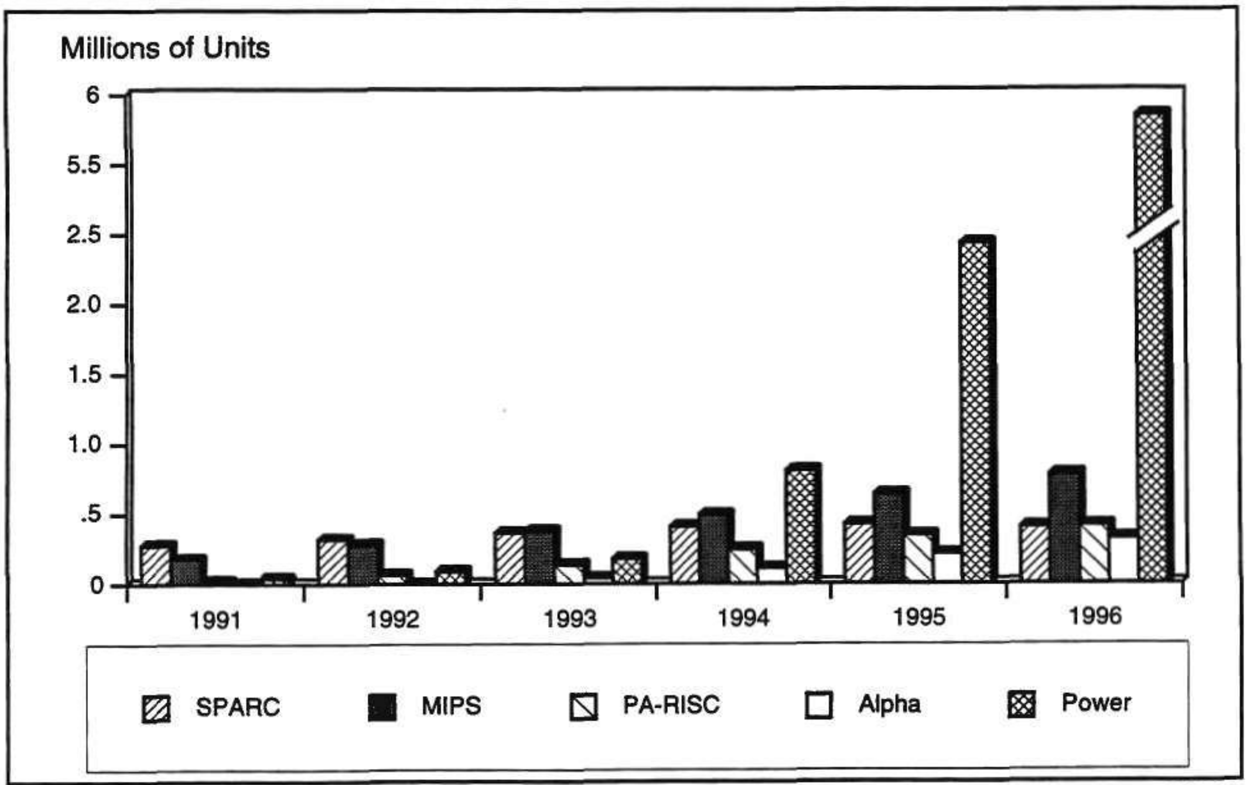
Hitachi, Samsung—both planning to ship PA-RISC chips and system products—and Winbond, which will focus on embedded applications. In 1991, HP produced about 18,000 units for its own captive consumption, with three times that volume expected for this year.

The Alpha microprocessor was developed by Digital notably in response to the lack of dramatic performance increases expected from the MIPS processor camp. It will begin to ship units this year (less than 10,000) and expects to add two or more outside vendors during early 1993.

Forecast and Assumptions

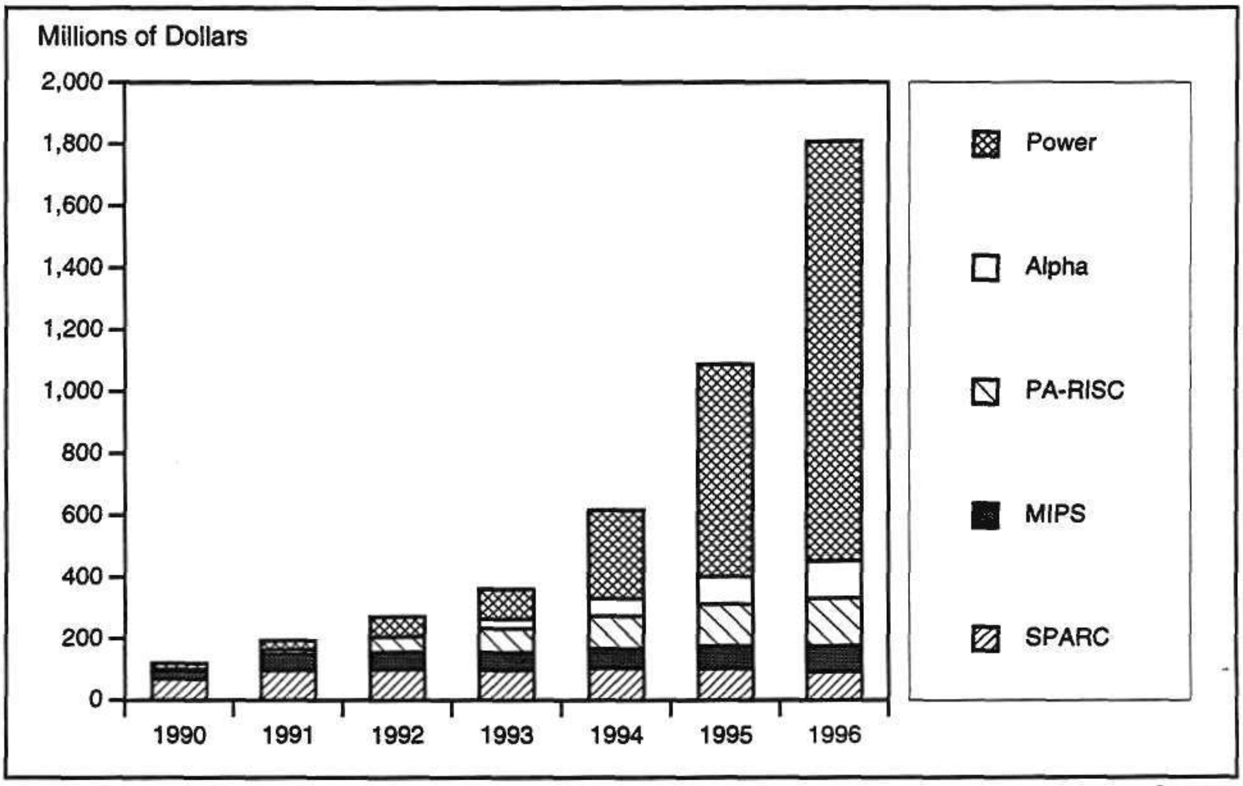
The platform RISC class of microprocessors represents a dichotomy: It has the lowest unit volume of all classes but the most industry heavyweights, and highest R&D investment, of all other classes. There is no doubt that the unit volumes as a whole will continue to grow substantially during the next 10 years, perhaps capturing 35 percent of the platform processor market by the year 2000, as earlier projected by Dataquest. Figures 3-15 through 3-17 and

Figure 3-15
Open Systems RISC MPU Market Forecast, Units



Source: Dataquest (December 1992)

Figure 3-16
Open Systems RISC MPU Market Forecast, Revenue



Source: Dataquest (December 1992)

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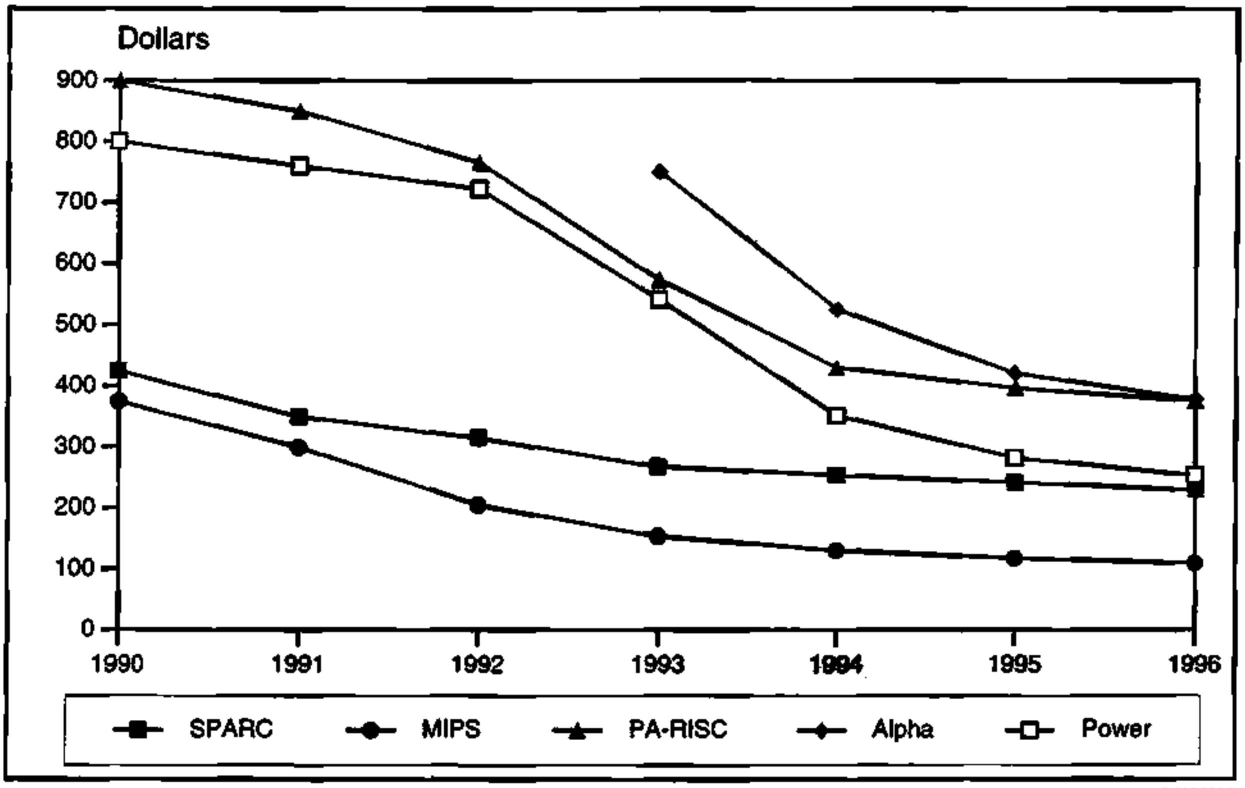
Table 3-8 show the forecasts by product family. Key assumptions are as follows:

- All of these processor families, with the exception of the PowerPC, will experience low to moderate revenue growth for differing reasons over the next five years, but will not achieve dramatic volume growth because of the lack of support by mainstream PC volume vendors.
- SPARC family processors will continue mild unit growth, peaking in 1995 as a result of a Sun-only computer market, Solaris as the only operating system, and no real volume-embedded applications. ASPs will drive toward low in the $200 range to reach the price targets that Sun will go after.
- MIPS family processors will show reasonable growth during this forecast period, primarily driven by embedded applications, and additionally supported by continued growth of Silicon Graphics and a small number of volume system vendors marketing it with Windows NT. ASPs will drive toward low in the $100 range because of the embedded focus.
- PA-RISC family processors will grow strongly during this period, starting from a small captive base, because of the strength of HP

Figure 3-17
Open Systems RISC MPU Market Forecast, ASP



Source: Dataquest (December 1992)

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in workstations, the performance leadership of the PA-RISC architecture, and our anticipation of Windows NT support by 1994. ASPs will drive toward high in the $300 range as a result of their primary success in power-user desktops and servers.

- Alpha family processors will also grow strongly during this period, starting from a zero base, because of the systems sales channel strength of Digital, the support of Windows NT, and attainment of a small number of volume system vendors during the late-1993 time frame. ASPs will drive toward high in the $300 range as a result of their primary success in power-user desktops and servers.

- PowerPC family processors will exhibit dramatic growth starting in 1994, because of combining the two most powerful microprocessor suppliers outside of Intel (Motorola and IBM), combining the two highest-volume PC suppliers, and adding a complete set of operating system support including Macintosh, PowerOpen, Taligent, and our assumption of Windows NT (ported by Microsoft) in late 1994. ASPs will drive toward the middle of the $200 range because of their success in the midrange desktops (equivalent to last year's 386DX and next year's 486DX prices).

Table 3-8
Open Systems RISC MPU Market Forecast

Processor	1990	1991	1992	1993	1994	1995	1996
SPARC (32/32-Bit)							
Units (K)	160	275	316	364	407	424	402
ASP ($)	425	350	315	268	254	242	230
Revenue ($K)	68,000	96,250	99,619	97,377	103,609	102,366	92,385
MIPS (32/32-Bit)							
Units (K)	76	175	280	378	491	639	779
ASP ($)	375	300	205	154	131	118	109
Revenue ($K)	28,500	52,500	57,400	58,118	64,220	75,137	85,251
PA-RISC (32/16-Bit)							
Units (K)	6	18	65	137	246	344	413
ASP ($)	900	850	765	574	430	396	376
Revenue ($K)	5,400	15,300	49,725	78,317	105,728	136,177	155,242
Alpha (32/32-Bit)							
Units (K)	0	0	0	40	112	213	319
ASP ($)	0	0	0	750	525	420	378
Revenue ($K)	0	0	0	30,000	58,800	89,376	120,658
Power (32/32-Bit)							
Units (K)	23	40	90	180	810	2,430	5,346
ASP ($)	800	760	722	542	352	282	253
Revenue ($K)	18,400	30,400	64,980	97,470	285,100	684,239	1,354,794
OSR Total							
Units (K)	265	508	751	1,098	2,066	4,049	7,260
ASP ($)	454	383	362	329	299	269	249
Revenue ($K)	120,300	194,450	271,724	361,282	617,457	1,087,296	1,808,330

Source: Dataquest (December 1992)

Low-End Architecture Microprocessors

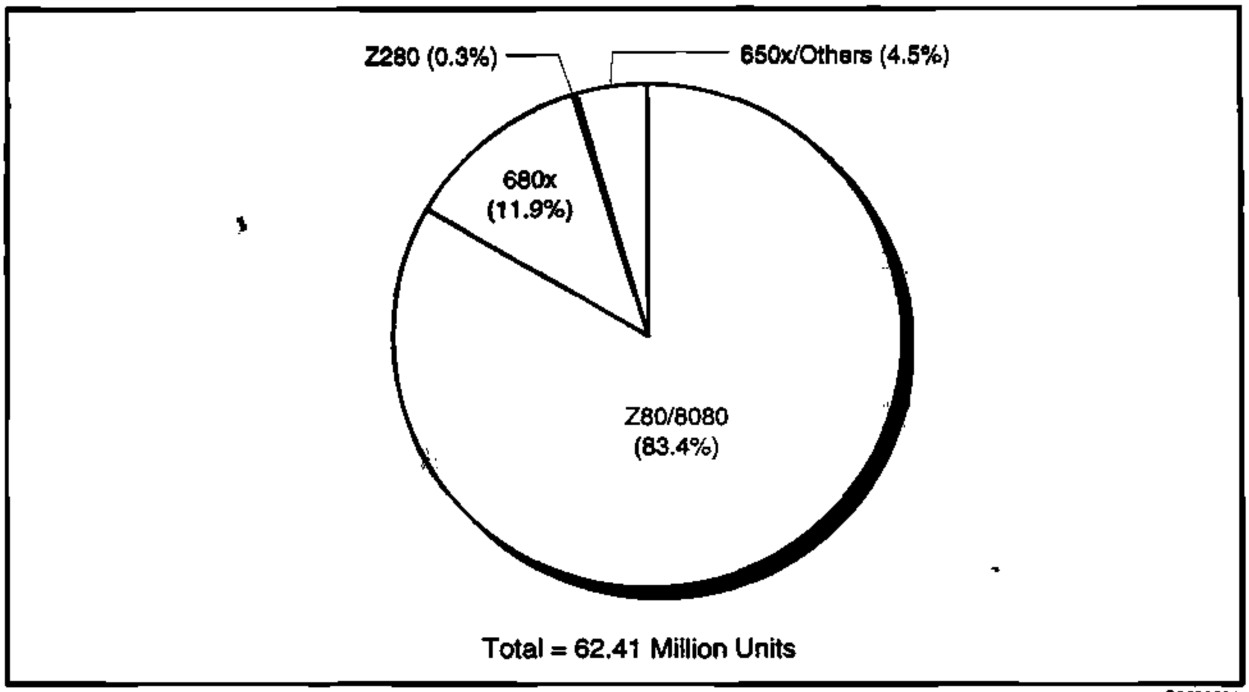
The low-end architecture class of processors is actually a collection of the first real microprocessors to hit the market and gain widespread use. Included are the following families:

- Z80 family: Includes the Z80, 8085, and 8080.
- 680x family: Includes 6800/02/08/09 and equivalents.
- 6502 family: Includes 6502, 65SC816/802 and equivalents.

These processors became the basis of many new products, including the early high-volume PCs such as the Apple IIs, Commodore 64s, and Radio Shack TRS-80s; the modern instrumentation such as function generators, logic analyzers, and medical diagnostic equipment; and the new era of industrial control designs such as modern traffic lights and manufacturing process controls. In addition, the 8-bit processors are the architectural basis for some of the most successful lines of microcontrollers in use today.

This entire class and each family in it grew through 1991, reaching nearly 63 million units (see Figure 3-18). All vendors involved in this class essentially compete in only one family, with the exception of Hitachi and SGS-Thomson. Furthermore, because the Z80 family is so dominant in volume, this subsegment is the real focus of our analysis.

Figure 3-18
1991 Shipments of Low-End Microprocessors, by Series



Source: Dataquest (December 1992)

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The actual microprocessor credited with starting the microprocessor revolution, the 8080, in fact no longer ships. But its code lives on compatibly in its direct successor, the 8085, and in the eminently more successful Z80. In the case of the Z80, volume continues to grow, having broken through 50 million units in 1991. The 8085 on the other hand is close to the end of its long life and has a decreasing unit volume, accounting for just more than 5 million of the 53 million total.

Though you will not find Radio Shack shipping any more TRS-80s, the bulk of Z80 applications are hidden in many obscure places that just continue to live. These volumes are being actively supported through the availability of Z80 cores and enhanced versions, such as the Z180.

Motorola first introduced the 6800 in 1974; it has since become the foundation for one of the broadest groups of microcomponent products. Among its derivative members (not all totally code-compatible) are the 6802/08/09 microprocessors represented here and the 6805 and 6801/HC11 microcontroller families. In fact, the combined 1991 unit volume for these derivative members is much more than 200 million units. The 6800 is well past its prime and is not recommended for new designs. For new designs, Motorola steers designers to either the embedded versions of its 68K family, which can be reasonably cost-effective with much more power, or its microcontroller products, which are more cost-effective.

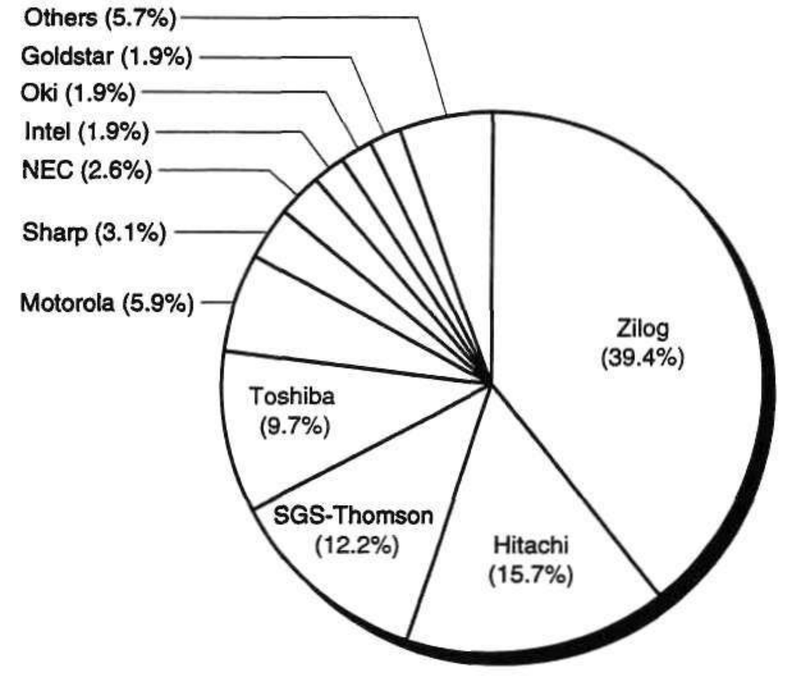
It seems certain that the 6502 family is near the end (slightly less than 2 million units for a low-priced, low-growth component). However, with nearly 1 million units a year being consumed between Commodore and Apple, one could imagine a slow death over the next three or four years.

Competitive Positions and Analysis

This segment is dominated by Zilog, with nearly 40 percent of the volume and one of the highest growth rates, 29 percent (see Figure 3-19 and Table 3-9). Also turning in respectable volumes with positive (or zero) growth rates are the next three vendors, Hitachi, SGS-Thomson, and Toshiba. The remaining vendors represent little significant consequence to rivalry within this segment.

Zilog, the inventor of the Z80, has been regaining market share in the last two years, having grown back to nearly 50 percent market share in 1991. The other active player to also grow its Z80 volumes in 1991 was Hitachi, which is ranked second. Both Zilog and Hitachi are involved in growing their Z80 business, having jointly developed the more integrated CMOS Z180 (Hitachi 64180), in addition to Zilog's Z280. Volumes for the remaining vendors were essentially down or flat, indicating a decreasing interest in this low margin product.

Figure 3-19
1991 Top 10 Companies' Low-End Microprocessor Market Share (Units)



Source: Dataquest (December 1992)

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Until last year, Motorola dominated the 680x volumes with more than 50 percent market share. However, because of its focus on other areas, its 680x volumes have dropped and SGS-Thomson absorbed the lost share. Hitachi, another 680x vendor, seems to place little emphasis on this family, as do the other minor shareholders in this field.

Table 3-9
Top 20 Companies' Shipments of Low-End Microprocessors to the World (Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Zilog	19,800	25,500	29	39.4
2	2	Hitachi	8,200	10,200	24	15.7
3	3	SGS-Thomson	7,900	7,900	0	12.2
4	4	Toshiba	5,700	6,300	11	9.7
5	5	Motorola	3,900	3,800	-3	5.9
6	7	Sharp	2,500	2,000	-20	3.1
7	6	NEC	2,600	1,700	-35	2.6
8	8	Intel	1,700	1,200	-29	1.9
8	9	Oki	1,600	1,200	-25	1.9
8	NM	Goldstar	NA	1,200	NM	1.9
11	12	Rockwell	600	620	3	1.0
12	11	National	650	550	-15	.8
13	15	Mitsubishi	420	380	-10	.6
13	NM	NCR	NA	380	NM	.6
15	13	Siemens	490	350	-29	.5
15	14	AMD	480	350	-27	.5
17	NM	UMC	NA	300	NM	.5
18	17	Harris	270	280	4	.4
19	10	CA Micro Devices	710	270	-62	.4
20	16	Fujitsu	300	200	-33	.3
		All Others	120	90	-25	.1
		Total Low-End MPU	57,900	64,800	12	100.0

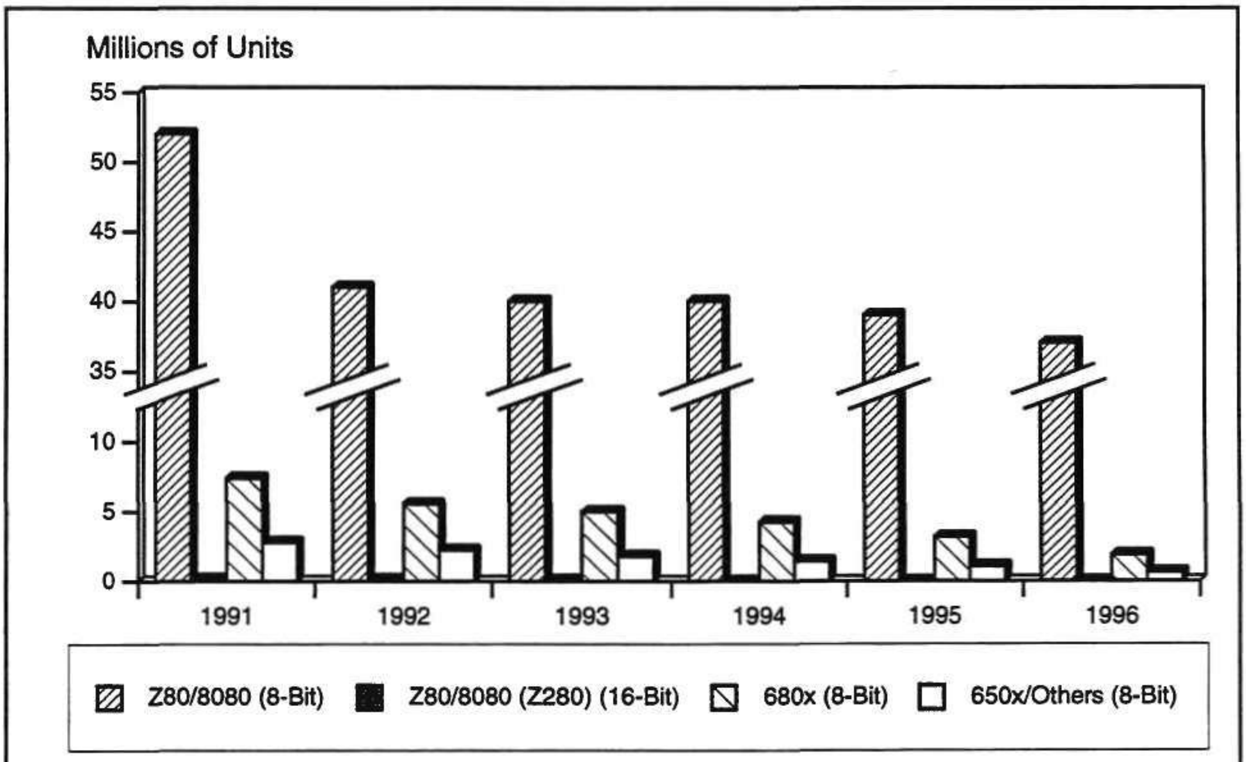
NA = Not available
NM = Not meaningful
Columns may not add to totals shown due to rounding.
Low-end MPUs consist of the Z80/8080, 680x, and 6502 families.
Source: Dataquest (December 1992)

Forecast and Assumptions

Low-end architecture processors combine the highest unit volumes with the lowest ongoing R&D investment. Dataquest predicts that revenue as well as unit volumes will begin to fall off in 1992 and continue a gradual decline over the next few years (see Figures 3-20 through 3-22 and Table 3-10). Key assumptions relating to this forecast are as follows:

- ASPs have experienced the bulk of their erosion and will decline only slightly during the next few years.
- These processors have been kept alive by the obscurity of their applications, most of which are not high-technology goods that do not get redesigned often.
- Most new designs will either migrate to the more robust embedded 16 or 32-bit architectures (which can work with 8-bit external words) or the more integrated microcontrollers.
- The longest living of these dinosaurs will definitely be the Z80, with its exceptional volumes and reasonably active development and support efforts.
- The 68xx and 6502 will begin to fall off dramatically by the 1995 time frame, when even the most stodgy applications will have to be redesigned.

Figure 3-20
Low-End MPU Market Forecast, Units



Source: Dataquest (December 1992)

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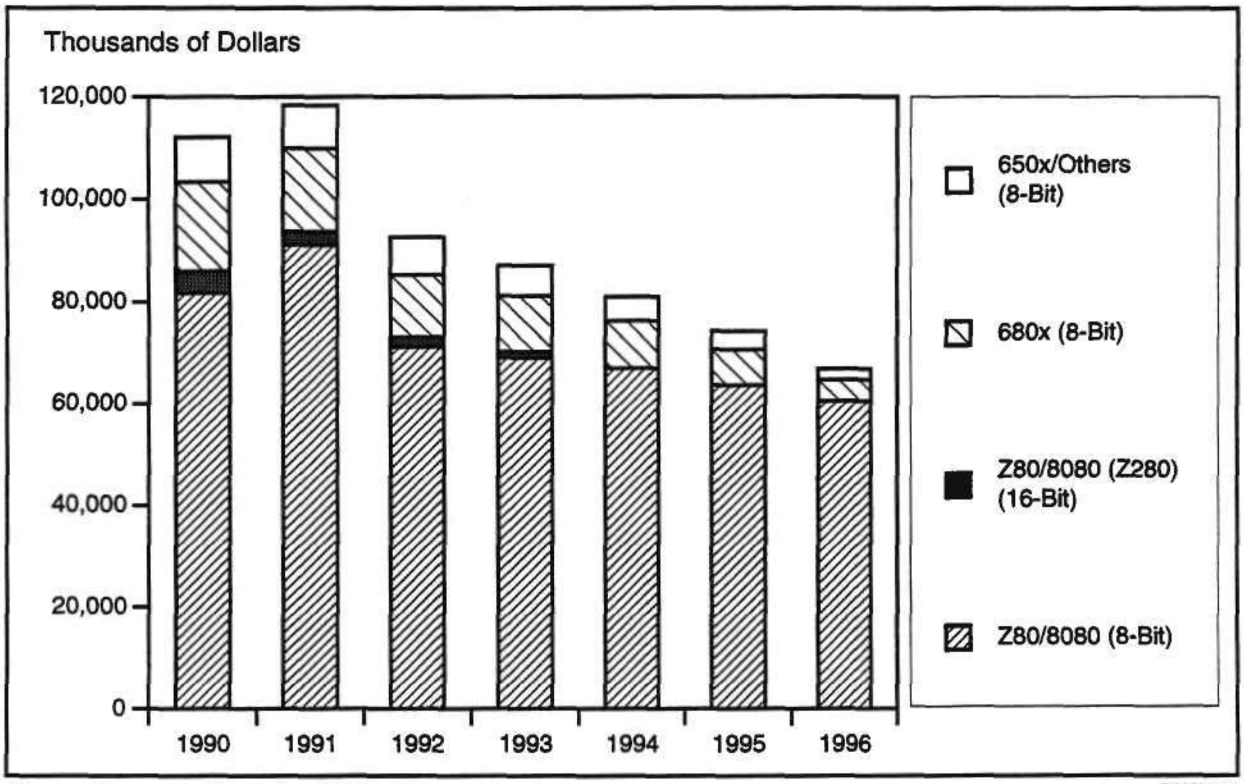
Figure 3-21
Low-End MPU Market Forecast, Revenue



Source: Dataquest (December 1992)

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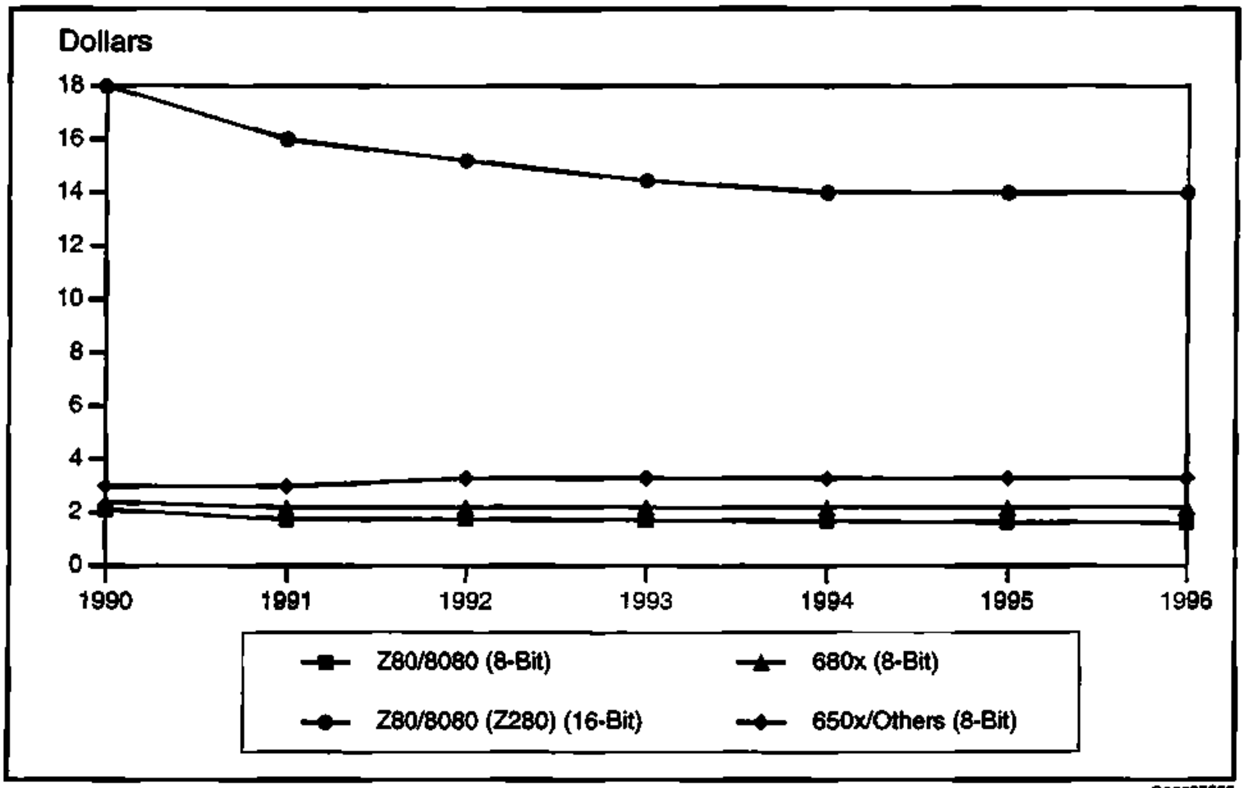
Figure 3-22
Low-End MPU Market Forecast, ASP



Source: Dataquest (December 1992)

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Table 3-10
Low-End MPU Market Forecast

Processor	1990	1991	1992	1993	1994	1995	1996
Z80/8080 (8-Bit)							
Units (K)	38,900	52,050	40,599	40,193	39,791	38,597	37,439
ASP ($)	2.10	1.75	1.75	1.72	1.68	1.65	1.61
Revenue ($K)	81,690	91,088	71,048	68,931	66,877	63,573	60,433
Z80/8080 (Z280) (16-Bit)							
Units (K)	240	160	128	83	0	0	0
ASP ($)	18	16	15	14	0	0	0
Revenue ($K)	4,320	2,560	1,946	1,201	0	0	0
680X (8-Bit)							
Units (K)	7,230	7,400	5,550	4,995	4,246	3,184	1,911
ASP ($)	2	2	2	2	2	2	2
Revenue ($K)	17,352	16,280	12,210	10,989	9,341	7,005	4,203
650X/Others (8-Bit)							
Units (K)	2,900	2,800	2,240	1,792	1,434	1,075	645
ASP ($)	3	3	3	3	3	3	3
Revenue ($K)	8,700	8,400	7,392	5,914	4,731	3,548	2,129
Total							
Units (K)	49,270	62,410	48,517	47,063	45,470	42,857	39,995
ASP ($)	2	2	2	2	2	2	2
Revenue ($K)	112,062	118,328	92,596	87,035	80,948	74,127	66,765

Source: Dataquest (December 1992)

Embedded System Focused Microprocessors

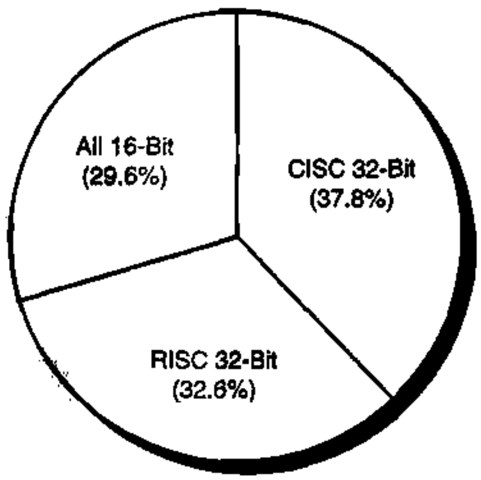
Perhaps the least understood of the microprocessor classes, the embedded system focused microprocessors accounted for a respectable $230 million in revenue for 1991. Though paling in comparison to the size of the x86 segment or the growth rate of the OSR segment, this class will set the pace for some exciting market segments.

This class is defined as the collection of 16- and 32-bit microprocessors created for (or now primary selling into) embedded system applications. These applications include such areas as data processing peripherals, telecommunications systems, and hand-held electronic devices (personal digital assistants, or PDAs, and personal communicators). At this time, Dataquest divides this class into the following subsegments and specific products:

- 16-bit processors: Includes the Z8000 and various other less significant processors.
- CISC 32-bit processors: Represents the past generation of 32-bit devices, including the 32xxx and various others.
- RISC 32-bit processors: The new generation of 32-bit devices including the i960, 29K, ARM, and Hobbit.

Current revenue is divided relatively evenly among the three subsegments (see Figure 3-23). In contrast to this situation, the RISC 32-bit subsegment will account for the overwhelming majority by the 1996 time frame.

Figure 3-23
1991 Proprietary MPU Revenue, by Subsegment



Source: Dataquest (December 1992)

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Significant Product Applications

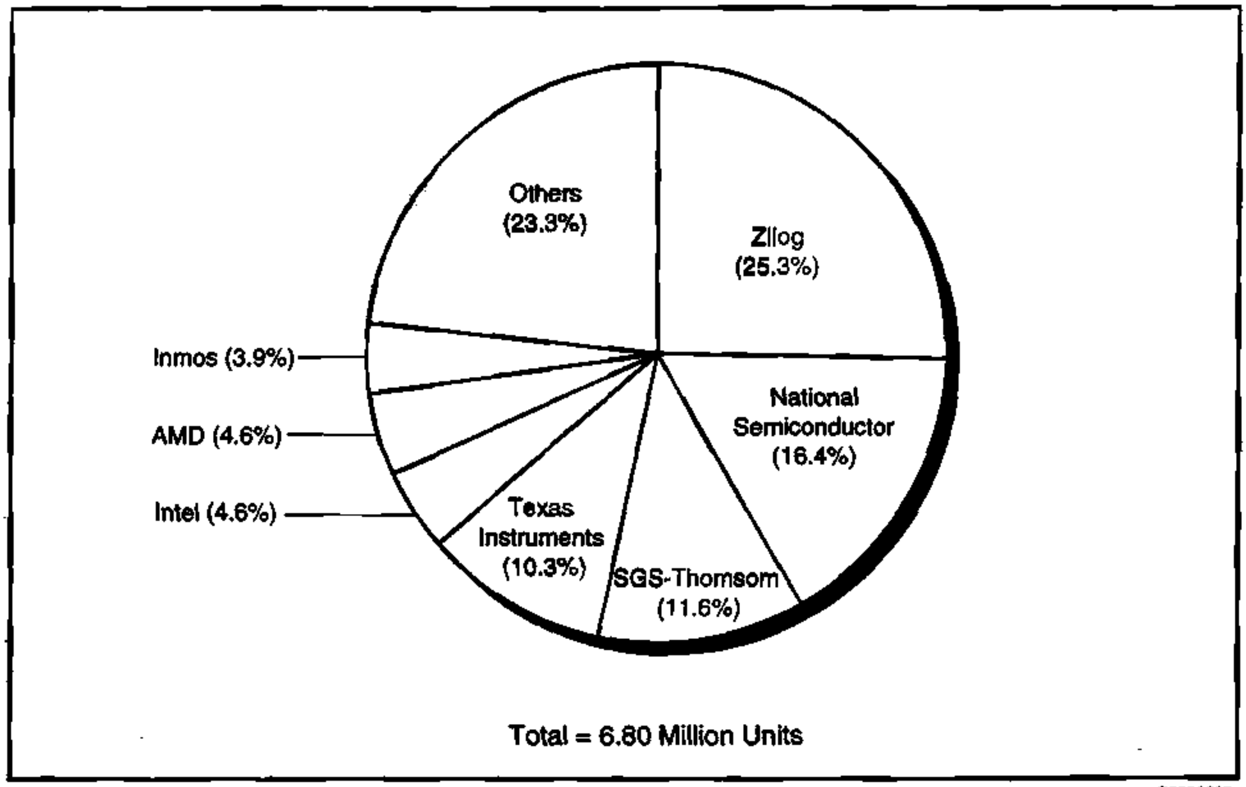
The most significant products and their primary applications are as follows:

- Z8000: A 16-bit CISC microprocessor invented by Zilog and second-sourced by SGS-Thomson and Sharp, it accounted for about 2 million units last year. It has found most acceptance in real-time control applications, largely military and industrial.
- 32xxx: A 32-bit CISC microprocessor (offered with both 32- and 16-bit I/O versions) invented and sole-sourced by National, it accounted for about 1.1 million units last year. It has been most successful in office peripherals such as laser printers and facsimile machines.
- Transputer: A 32-bit RISC microprocessor invented and sole-sourced by Inmos, a division of SGS-Thomson, it accounted for 260,000 units last year. It has made its success primarily in Europe, with specific victories in telecommunications equipment where multiprocessing is a big plus.
- i960: A 32-bit RISC microprocessor invented and sole-sourced by Intel. It began its early growth through a variety of applications, gaining the most ground in intelligent network equipment (now far surpassed by laser printer volumes) such as bridges and routers, which accounted for about 200,000 units in 1991.
- 29K: A 32-bit RISC microprocessor invented and sole-sourced by AMD, which drew in about 225,000 units in 1991. Its application base includes more than 350 design wins in laser printers, networking, communications controllers, and industrial systems. As with the i960, its most substantial wins were in laser printers (accounting for about 550,000 units this year), which include Apple and HP (LaserJet IIIsi).
- Hobbit: A 32-bit RISC microprocessor invented by AT&T and soon to be second-sourced by NEC. It is aimed at a new class of devices called personal communicators, a combination of palmtop pen computer and cellular telecommunicator. The Hobbit is designed to provide high performance (with full 32-bit addressability), low power consumption, and the ability to integrate leading-edge communications functions on one chip.
- ARM: A 32-bit RISC microprocessor invented by Acorn Computers and commercialized through a joint development by Apple, VLSI Technology, and Acorn, the ARM processor has found early applications in home computers and drawing accelerators but is now the main focus of development for Apple and Sharp's new line of PDAs.

Competitive Positions and Analysis

Based on unit shipments, today's field of competitors is dominated by companies delivering CISC technology-based processors (see Figure 3-24 and Table 3-11). In the leading position, representing the Z8000 product, is Zilog, a company known for delivering high

Figure 3-24
1991 Top 7 Companies' Embedded Microprocessor Market Share (Units)



Source: Dataquest (December 1992)

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volumes of microprocessors (the Z80 in particular). It produced 1.7 million units in 1991. Next is National Semiconductor, with 1.1 million units of its 32xxx series. SGS-Thomson, which also markets the Z8000 as well as its own Transputer (Inmos Division), turned in a respectable 780,000 units for 11.6 percent market share in 1991. All three of these segment-leading companies are experiencing relatively flat sales growth because of the age of these architectures, compared to the new wave of competition hitting the market, which is described in the following section.

Intel hit pay dirt this year with the i960 because it sold its soul to win the contract of the year, HP's new LaserJet IV, which will replace the current generation and account for much more than 1 million units in 1993. This deal reputedly included a relatively profitless unit price on top of issuing HP some limited manufacturing rights. Though it will gain the economics of high volume, Intel will have to improve the i960's cost structure before it will be poised to go after a wider range of price-critical performance-oriented designs. Also under Intel is the i860, a 50,000-units-per-year processor that seems to be going nowhere fast.

Table 3-11
Each Company's Shipments of Proprietary/Miscellaneous Microprocessors to the World (Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	3	Zilog	930	1,700	83	25.3
2	1	National	1,000	1,100	10	16.4
3	5	SGS-Thomson	620	780	26	11.6
4	1	Harris	1,000	750	-25	11.2
5	4	Texas Instruments	860	690	-20	10.3
6	9	Intel	110	310	182	4.6
6	10	AMD	100	310	210	4.6
8	7	Inmos	240	260	8	3.9
9	6	Matsushita	320	220	-31	3.3
9	11	Hitachi	99	220	122	3.3
11	8	Hughes	180	150	-17	2.2
12	14	Motorola	62	85	37	1.3
13	13	VLSI Technology	71	70	-1	1.0
14	16	Performance	22	24	9	.4
15	17	Mitsubishi	8	20	150	.3
16	15	Sharp	54	10	-81	.1
16	18	Fujitsu	6	10	67	.1
18	12	Toshiba	74	4	-95	.1
		Total Proprietary/ Miscellaneous MPU	5,800	6,800	17	100.0

Columns may not add to totals shown due to rounding.
Source: Dataquest (December 1992)

Meanwhile, AMD continues to sustain its high growth rate with the 29K family, which launched itself to an estimated 750,000 units this year. This year also saw the introduction of the Am29200, a completely integrated processor subsystem that has set the new standard for embedded processors. The 29200 includes the 29K core, DRAM/ROM controller, programmable DMA, 16 programmable I/O channels, 8 interrupts, serial port, parallel port, and a host of internal controls, including a wait-state generator, 24-bit timer/counter, and a high-speed serializer/deserializer (for laser printer interfaces).

AT&T Microelectronics has been developing its technology base to deliver a complete line of components for mobile computing and communications applications. Its latest venture is its Personal Communication Systems business unit, centered around the Hobbit processor. Its current set of alliances includes NEC (which will second-source the Hobbit), Toshiba, and EO (which will provide the PenPoint operating system).

SGS-Thomson, through its Inmos Division, manufactures one of the first embedded RISC processors, the Transputer. A good technical design incorporating multiprocessing capabilities, the Transputer gained reasonable strength in the European market, especially in telecommunications equipment. However, insufficient promotion has caused this product to stagnate over the last two years, allowing larger industry vendors to catch up. Based on current events, this will ultimately lead to a gradual decline in Transputer sales in three to five years because of encroachment by newer, better-integrated, better-supported processors. SGS-Thomson also ships the Z8000, another processor that will run into difficult competition in the next few years.

The combined marketing power, manufacturing strength, and development skills of Apple and Sharp set on top of the custom IC development skills of VLSI represents the set of strengths that VLSI Technology will use to successfully deliver its ARM processor. Originally designed by Acorn Computers, the continuation of the ARM processor was spun off into an independent company called Advanced Risc Machines Ltd. under joint funding from Apple and VLSI Technology. Now the focus is on delivering complete handheld PDAs, as Apple calls them, requiring a great deal of software and product design (interface circuits and packaging) to start producing these devices in the millions.

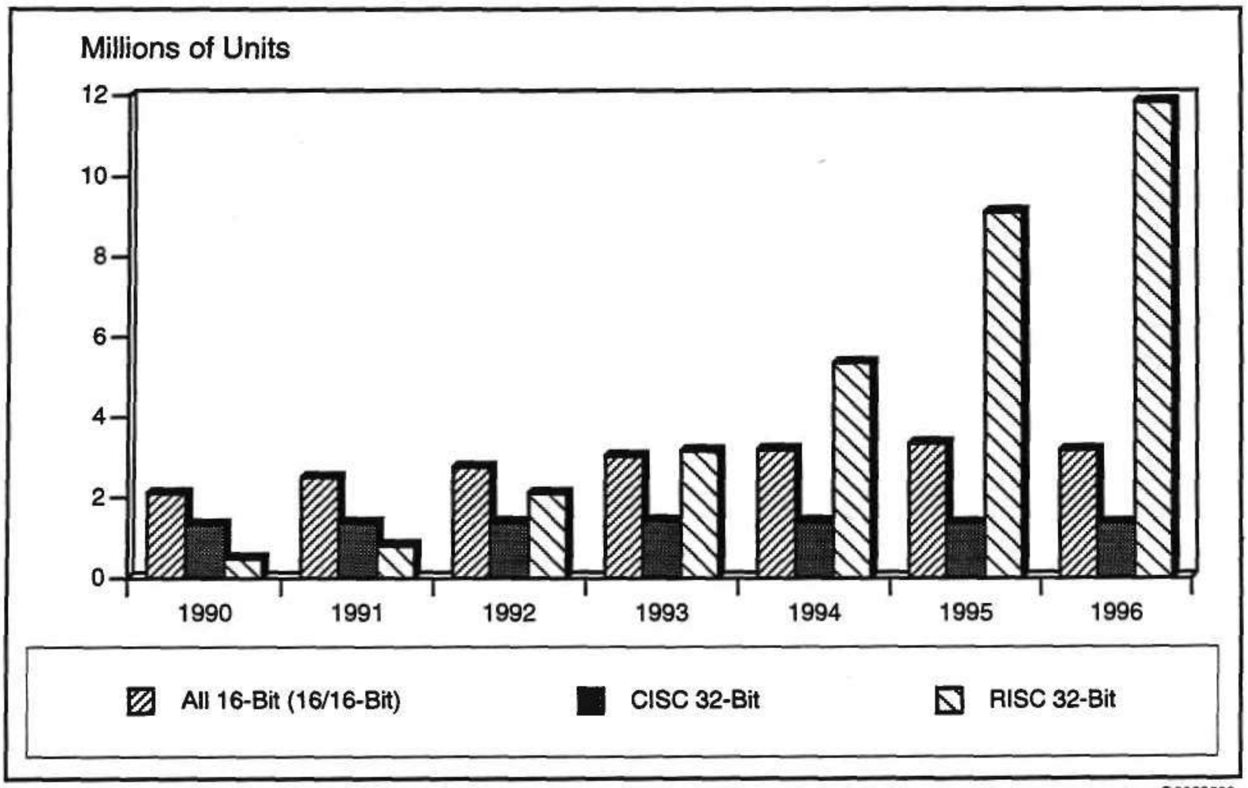
Additional vendors worth mentioning include Motorola and TI. Motorola is represented in this segment by its 88K RISC microprocessor, an advanced high-performance architecture that unfortunately will miss the high-performance computing market (except for Data General) as they had originally planned. It does however have a shot at a second wind through automotive engine control applications. TI is represented in this segment by its 340xx CISC microprocessors designed primarily for graphics applications. Actually, the 340xx was quite advanced for its time, but because of some errors in marketing decisions, it never hit the big time and is now sliding fast into the background.

Forecast and Assumptions

This entire class is forecast to show strong revenue growth over the next five years, more than doubling sales by 1996 (see Figures 3-25 through 3-27 and Table 3-12). The RISC 32-bit portion will represent the majority of future growth and volume, eclipsing the other sub-segments by 1996. Key assumptions for this forecast include the following:

- Volume will continue to grow through 1994, primarily from the increase in office automation applications, primarily laser printers, and led by the i960 and 29K.
- Volume growth will increase dramatically in 1995 and 1996 because of the explosive growth in hand-held electronic devices, led by the ARM and Hobbit processors.
- ASPs will drop off consistently throughout this period as the product mix moves down first from high-volume laser printer applications and then from the low-cost hand-held devices.

Figure 3-25
Embedded MPU Market Forecast, Units



Source: Dataquest (December 1992)

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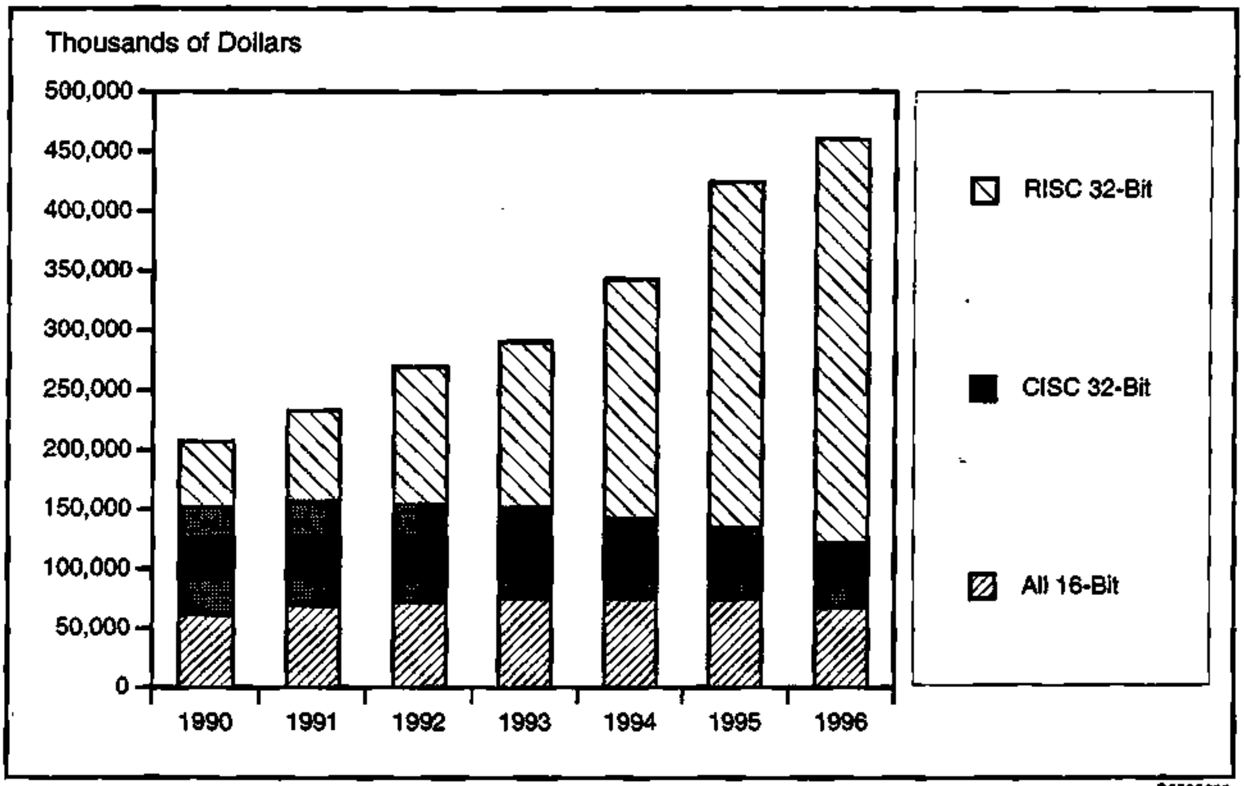
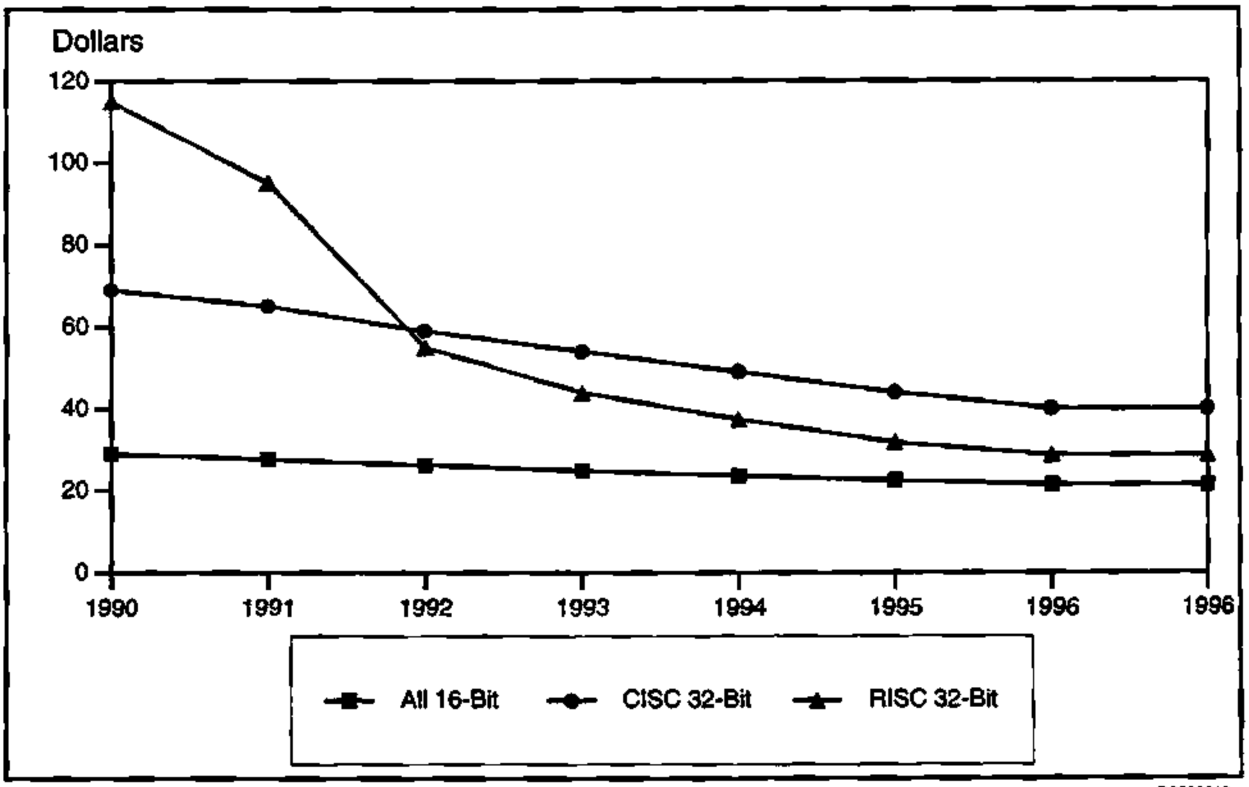
Figure 3-26
Proprietary MPU Market Forecast, Revenue



Source: Dataquest (December 1992)

Figure 3-27
Proprietary MPU Market Forecast, ASP



Source: Dataquest (December 1992)

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Table 3-12
Proprietary MPU Market Forecast

Processor	1990	1991	1992	1993	1994	1995	1996
All 16/16-Bit (16/16-Bit)							
Units (K)	2,100	2,500	2,750	3,025	3,176	3,335	3,168
ASP ($)	29	28	26	25	24	22	21
Revenue ($K)	60,900	68,875	71,974	75,213	75,025	74,838	67,541
CISC 32/32-Bit							
Units (K)	1,310	1,360	1,384	1,415	1,387	1,353	1,351
ASP ($)	69	65	59	54	49	44	40
Revenue ($K)	90,700	87,875	81,976	76,625	67,330	59,605	54,114
RISC 32/32-Bit							
Units (K)	480	800	2,100	3,150	5,355	9,104	11,835
ASP ($)	115	95	55	44	37	32	29
Revenue ($K)	55,200	76,000	115,500	138,600	200,277	289,400	338,598
Proprietary Total							
Units (K)	3,890	4,660	6,234	7,590	9,919	13,792	16,353
ASP ($)	53	50	43	38	35	31	28
Revenue ($K)	206,800	232,750	269,450	290,439	342,633	423,843	460,253

Source: Dataquest (December 1992)

Chapter 4
Microperipheral Market Segment

The majority of microperipheral applications naturally lie in computer systems matched up with microprocessors that power the system. However, this situation is changing. As more and more communications and consumer equipment become "computerized," microperipherals will play an increasing role outside of mainstream computers. An example is hand-held electronic devices (HEDs), an application segment representing a conglomeration of personal communicators, palmtop computers, and other portable accessories.

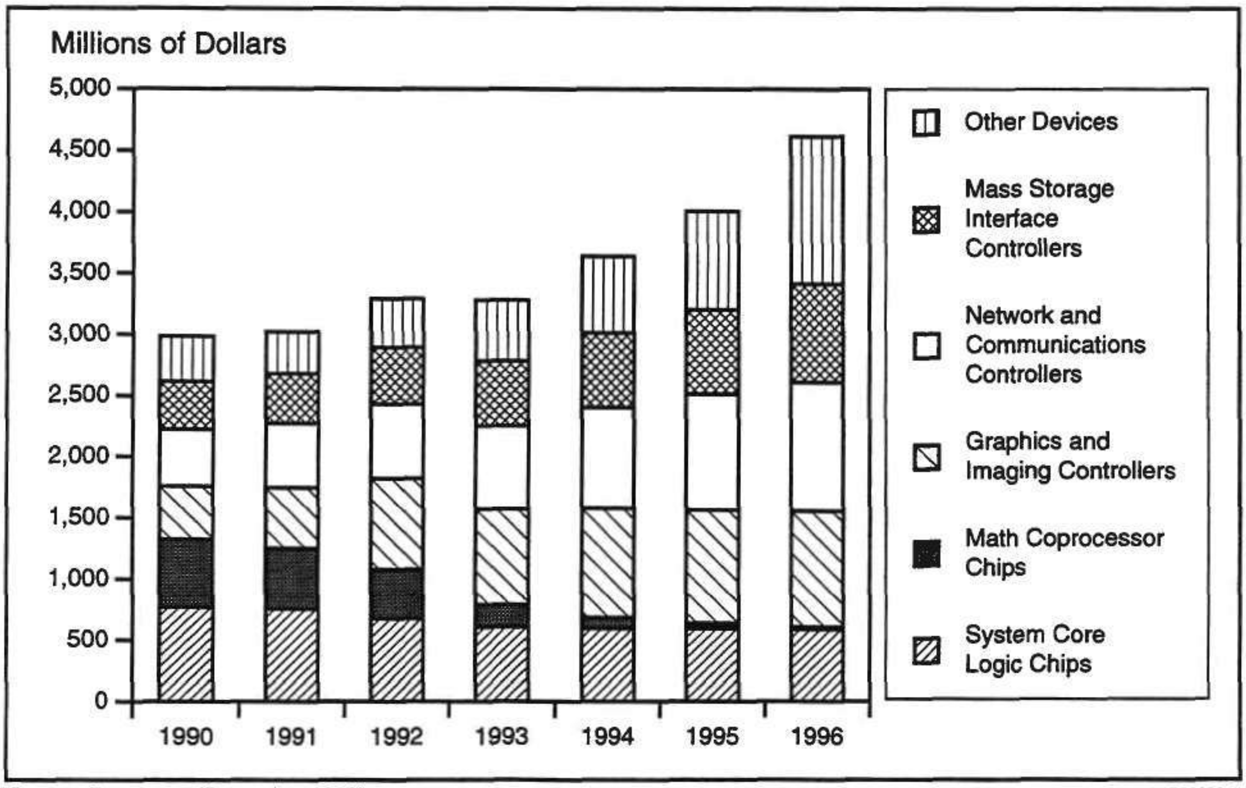
Dataquest defines microperipherals as logic devices used with microprocessors (or microcontrollers in minor cases) to implement the bulk of the direct CPU interface functions in both host systems and embedded devices. Many functional solutions within each subsegment are implemented as a set of multiple devices or a chip set, and many use ASIC methodologies to develop these merchant chips. Microperipheral products are further divided into the following subsegments:

- System core logic chip sets: Devices dedicated to a particular microprocessor interface that perform some basic interface functions such as memory management, DRAM control, cache control, bus interface controllers, DMA controllers, and interrupt controllers.
- Math coprocessors: Devices that interface directly to a particular microprocessor and perform floating point calculations (also referred to as floating point units).
- Graphics and imaging controllers: Devices that typically interface to some form of system bus to interpret, control, and display the visual output of systems (computer-generated graphics, live video, and other images), including PC graphics chips, image processors, and video codecs.
- Communications controllers: Devices that control, format, and perform handshaking for the transmission and reception of information between systems or intelligent devices, which includes network controllers, modems, serial UARTs, and other communications interfaces.
- Mass storage controllers: Devices used to control data storage into and retrieval from all forms of mass storage media (magnetic, optical, and others), which includes controllers used within host computers (host-side) and within mass storage drives (device-side).

- Other microperipherals: Devices used to input or output information through other forms, including audio input and output controllers, keyboard controllers, pen-input controllers, parallel port controllers, and various miscellaneous devices.

Microperipherals are projected to grow moderately from slightly more than $3 billion in 1991 to nearly $5 billion in 1996 (see Figure 4-1 and Table 4-1). Though the largest subsegment today is system core logic, it is projected to decline slightly over the next five years primarily because of portable systems using highly integrated processors. Math coprocessors, devices whose time has come and gone because of the new age of integrated microprocessors, will fall off sharply over the next three years. Driven by the increasing importance of graphical user interfaces (GUIs) and multimedia, graphics and imaging controllers will grow handsomely over the next several years. Communications controllers, led by network interface devices, will exhibit strong growth as connectivity becomes pervasive. Mass storage controllers, used in every host system and nearly all types of storage drives, will double in revenue by 1996. Finally, the other microperipherals used to interface some of today's "nontypical" input/output devices will reach $1.2 billion by 1996, driven primarily by audio controllers, one of the fastest growing areas.

Figure 4-1
Total Microperipheral Revenue, by Subsegment



Source: Dataquest (December 1992)

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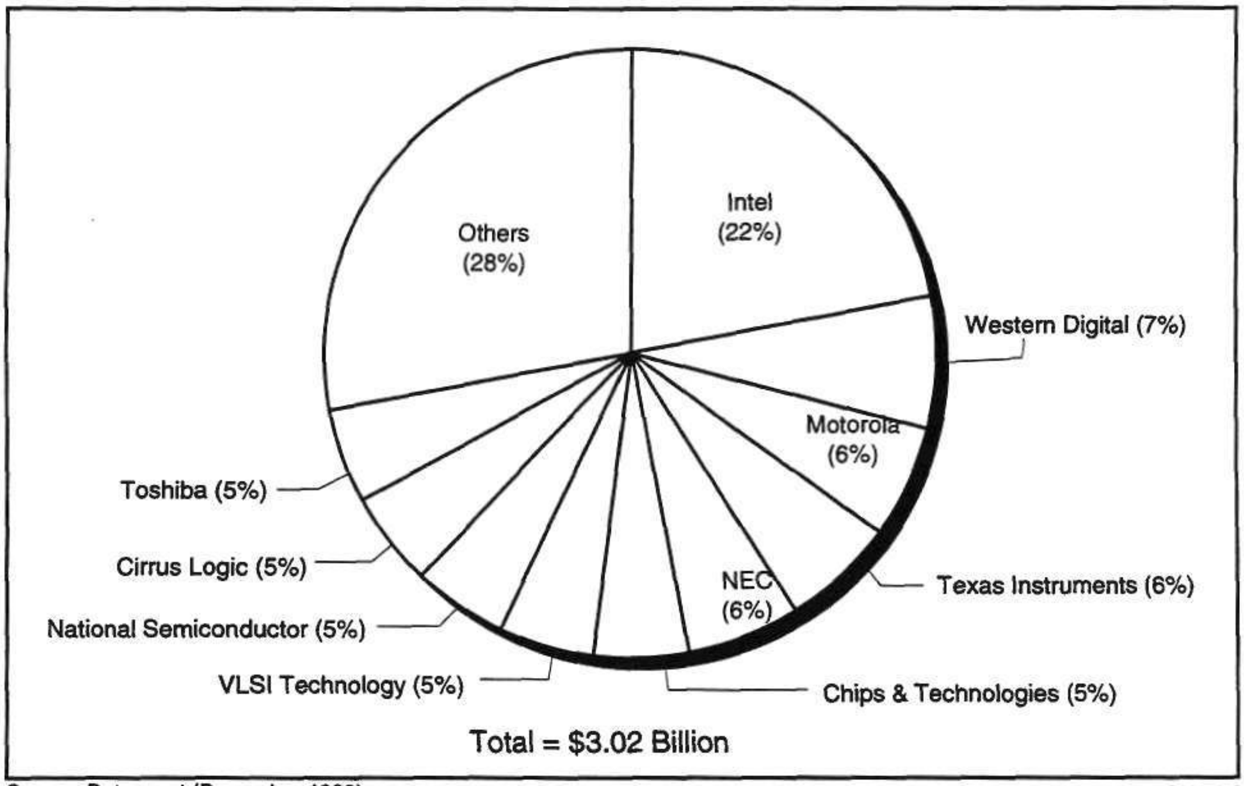
Table 4-1
Microperipheral Forecast, by Subsegment

Device Type	1990	1991	1992	1993	1994	1995	1996
System Core Logic Chips							
Units (K)	19,920	22,616	23,509	23,929	24,484	25,940	29,295
ASP ($)	39	33	29	26	25	23	20
Revenue ($K) −4	769,460	756,932	675,176	629,042	605,770	592,746	588,141
Math Coprocessor Chips							
Units (K)	6,259	6,028	5,766	3,867	2,268	1,115	609
ASP ($)	89	82	70	49	41	41	37
Revenue ($K) - decline	558,054	496,917	403,993	188,280	94,094	45,457	22,703
Graphics and Imaging Controllers							
Units (K)	19,609	22,128	28,722	31,235	34,437	35,482	37,991
ASP ($)	22	22	26	25	26	26	25
Revenue ($K) 14	430,432	491,850	743,558	779,750	889,826	927,154	944,045
Networks Communications Controllers							
Units (K)	45,500	56,901	68,736	82,084	97,107	113,502	129,343
ASP ($)	10	9	9	8	9	8	8
Revenue ($K) 15	465,500	527,101	608,029	679,031	825,638	948,598	1,053,516
Mass Storage Interface Controllers							
Units (K)	60,893	65,629	75,891	88,922	105,339	122,859	145,469
ASP ($)	6	6	6	6	6	6	6
Revenue ($K) 12%	393,029	407,239	462,505	530,104	611,977	691,159	805,676
Other Devices							
Units (K)	370,000	340,000	400,000	500,000	625,000	800,000	1,200,000
ASP ($)	1	1	1	1	1	1	1
Revenue ($K)	370,000	340,000	400,000	500,000	625,000	800,000	1,200,000
MPR Total							
Units (K)	522,180	513,302	602,623	730,038	888,635	1,098,899	1,542,708
ASP ($)	5.72	5.88	5.46	4.53	4.11	3.64	2.99
Revenue ($K)	2,986,475	3,020,039	3,293,261	3,306,207	3,652,305	4,005,114	4,614,082

Source: Dataquest (December 1992)

Though much of the available volume for microperipherals is driven by common sets of applications, their penetration ratios, demand factors, and industry participants are more disparate than homogeneous. Figure 4-2 and Table 4-2 show market share distribution (top 10 vendors) of total revenue in microperipherals, each vendor participating in one or many unrelated subsegments. Therefore, the market trends and analysis relevant to each individual subsegment—except other microperipherals—will be presented in the sections that follow. A detailed analysis of other microperipherals will appear in a subsequent report on audio and other new input devices.

Figure 4-2
1991 Top 10 Companies' Microperipheral IC Market Share



Source: Dataquest (December 1992)

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Table 4-2
Top 10 Companies' Factory Revenue from Shipments of Microperipheral ICs to the World (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	544	650	19	22
2	6	Western Digital	148	209	41	7
3	4	Motorola	167	194	16	6
3	9	Texas Instruments	130	194	49	6
5	3	NEC	176	192	9	6
6	2	Chips & Technologies	240	165	-31	5
7	11	VLSI Technology	104	161	55	5
8	5	National Semiconductor	150	153	2	5
9	10	Cirrus Logic	129	151	17	5
10	7	Toshiba	144	149	3	5
		All Others	993	802	1	28
		North American Companies	2,049	2,260	10	70.2
		Japanese Companies	700	747	7	23.2
		European Companies	135	109	-19	3.4
		Asia/Pacific Companies	41	103	151	3.2
		Total Market	2,925	3,020	10	100.0

Source: Dataquest (December 1992)

System Core Logic Chip Sets

At a 1991 revenue of more than $750 million, this is the largest subsegment of microperipherals and represents the conduit between the microprocessor and all the other electronic devices. This includes both single and multichip chip sets as well as discrete devices supporting the following functions:

- Cache controllers
- Memory management units
- DRAM controllers
- Bus interface controllers
- DMA controllers
- Interrupt controllers

Demand for core logic is linked directly to that of microprocessors, and especially those used in computer applications. Core logic chips are divided into two subsegments, 80x86 PC core logic and other core logic. The 80x86 PC segment is overwhelmingly dominant for several reasons, as follows:

- Computer system unit volumes are dominated by 80x86 PCs.
- Most 80x86 PCs are designed using merchant core logic.
- Motorola has never developed an integrated line of core logic for the 68K microprocessor family, which is primarily used in computer systems by Apple and Commodore with their own ASICs.
- Most RISC-based systems use custom ASICs for system core logic.
- Most embedded applications use either ASICs (for high volume) or discrete/PLD-based designs (for low volume).

Most people consider core logic chip sets to be synonymous with the 80x86 PC core logic subsegment. This subsegment can be further broken down by bus type, by processor type, and by platform type (that is, desktop versus portable). Dataquest uses bus type as the primary segmentation boundary because this is the most crucial strategic decision outside of platform type (we expect to add platform type as a segment basis during 1993). Bus type segments include only system interface buses and do not include expansion "ports." Support for the PCMCIA expansion port is projected to grow rapidly during the next five years, penetrating more than 80 percent of all systems by 1996.

Current trends within the x86 PC core logic are as follows:

- 486s are ramping fast, with 486SX and DX2s leading growth.
- P5 is around the corner, presenting a new challenge with 64-bit bus and much higher speeds.
- ISA is the dominant system bus, with local bus support becoming critical. EISA is relegated to servers and high-end systems.

- Local bus support currently favors Video Electronics Standards Association (VESA) VL bus, with PCI expected to take over within 12 months.
- Cache controllers are becoming a critical performance element, used by almost all 386DX and 486DX systems.
- The Intel SL product line is taking a healthy portion of notebook volume; this will increase with the introduction of the 486SL, which does not require a core logic chip set (it includes all the memory, bus, and power control logic required to build a notebook computer).

Competing with a relatively homogeneous set of products, the industry has seen continued price erosion throughout the past two years as more vendors use price to attract customers. Certain features, however, still allow premium prices to be obtained. Cache is considered a must (by market perception) in those systems where it is common. In many 486 applications, bus operations can be dominated by writes instead of reads, based on the efficient use of the internal cache. This makes features such as byte gathering write-buffering and secondary caches even more important to system performance. In addition, the following factors influence pricing:

- Flexibility of designs is becoming critical to OEMs as the breadth of microprocessor choices expands.
- Performance in the Windows environment is the most crucial benchmark.
- System price/performance continues to be the bottom line, with price outweighing performance.

Bus Wars: The Continuing Saga

Until recently, the debate over bus standards was centered around the traditional system expansion buses, Industry Standard Architecture (ISA), Extended Industry Standard Architecture (EISA), and Microchannel Architecture (MCA). For years, it was predicted that EISA and MCA would grow substantially, overtaking the obsolete ISA bus. However, this theory was all but abandoned during the last year because the local bus phenomenon has hit, giving rise to a higher-performance, more cost-effective method of interfacing to other microperipherals.

The local bus movement was driven by the need for high-performance peripherals, primarily graphics controllers, to gain higher bandwidth communication with the CPU. In order to achieve higher performance, vendors began to connect graphics chips directly to the CPU data and address buses with discrete arbitration logic. Because this led to various ad hoc approaches to the problem, it created a standards problem, which led to two separate movements, each with a slightly different set of objectives.

Representing the interests of the graphic chip and board vendors, VESA set up a committee to develop a standard local bus interface, primarily for the 486 processor. This resulted in the VL bus specification, first published in mid-1992 and then fully ratified as a standard in the fall. Representing the interests of the 80x86-based system business, Intel embarked on creating a local bus standard that would be processor-independent and peripheral-efficient. This resulted in the Peripheral Component Interconnect (PCI) bus, also announced in mid-1992. A comparison of these two buses is further accentuated by the following factors:

- The VL bus has a higher potential peak bandwidth because it shares the same data/address buses. However, this prevents concurrent bus operation of processor and peripherals, which is allowed by the PCI bus.
- The PCI bus uses a multiplexed data/address bus scheme that reduces the number of peripheral connections to 45 pins, compared to more than 100 for the VL bus, which represents a large cost advantage for most microperipheral components.
- The VL bus initially had the advantage of a connector specification to allow for add-in cards. However, PCI now offers a connector specification (October 1992) that is more space-efficient on the motherboard than the VL bus.
- The VL bus is a relatively minor change to the direct 486 local bus interface being used already, and as such begins with much greater component availability than the PCI bus and will be the tactical winner in early volume during 1993.
- The PCI bus is considered to be a superior specification by most system manufacturers and is becoming the strategic development focus for most microperipherals. It will become the dominant volume leader in the future, eventually making the VL bus approach obsolete.
- The PCI bus will also be used by other processors (including Digital Equipment Corporation's Alpha chip) to tap into the variety of 80x86 peripherals.

As a result of the onset of local buses, most importantly the PCI bus, standard expansion buses used to segment core logic chip sets will become further fragmented into the following subsegments and versions. Note that this segmentation denotes only support of system-level buses and does not preclude addition of expansion ports such as PCMCIA.

- ISA-bus chip sets include (both AT and older XT) designs with:
  - ISA (or PC XT) bus support
  - ISA and VL bus support
  - ISA and PCI bus support

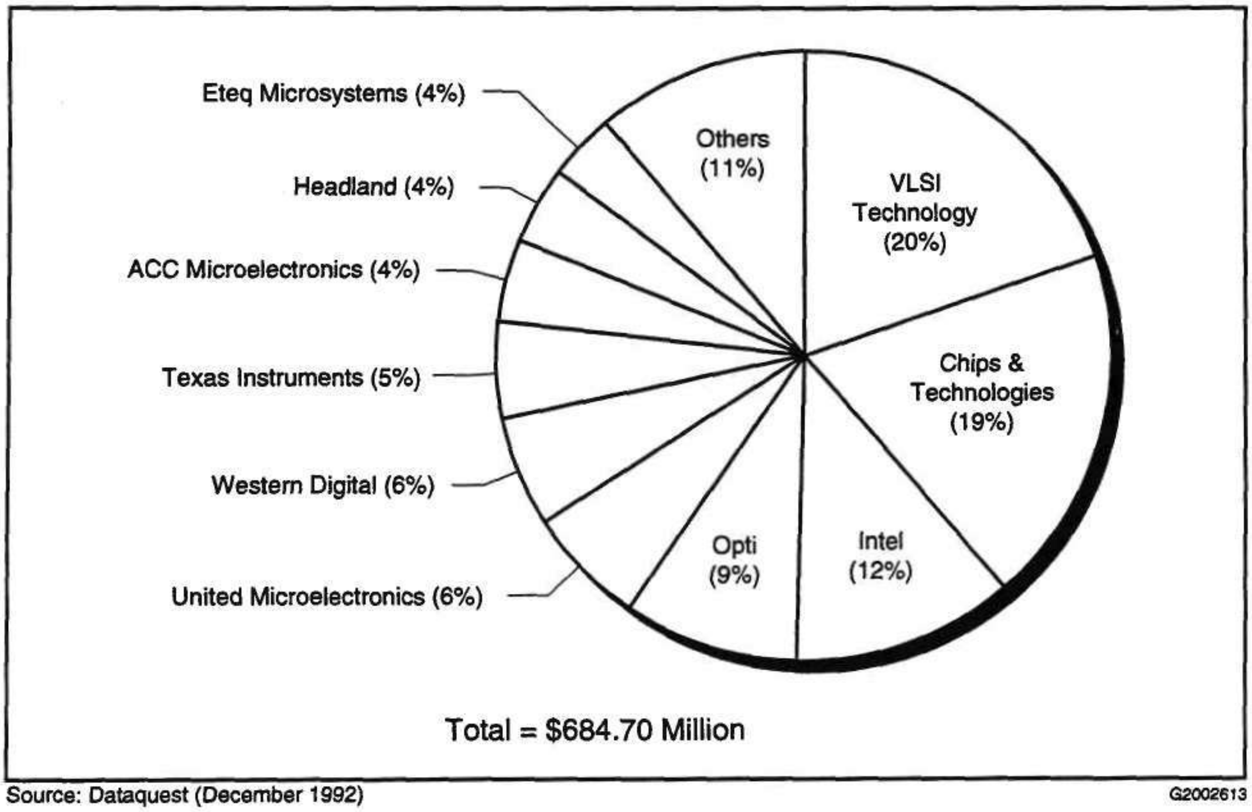
- EISA-bus chip sets include designs with (note that EISA with VL bus chip sets are not expected to be significant if introduced):
    - EISA-only bus support
    - EISA and PCI bus support
- MCA-bus chip sets include any chip set supporting the MCA bus.
- PCI-bus chip sets include chip sets that only support the PCI bus without provision for any other expansion bus (which will be supplanted by support for PCMCIA ports).

Outside of popular 80x86 PC core logic segment, the trend is moving toward integrated chip sets for RISC processors. Most notable is the introduction of several devices for the SPARC processor, as well as the chip set introduced by MIPS for its own processors. Though these devices are offered at a relatively high price tag, we expect this trend to continue, with more aggressively priced products appearing for the PowerPC architecture in anticipation of its high growth.

Competitive Positions and Analysis

The 80x86 PC core logic subsegment is home for a large number of significant vendors (see Figure 4-3 and Table 4-3). However, three

Figure 4-3
1991 Top 10 Companies' 80x86 Core Logic Chip Set Market Share



Source: Dataquest (December 1992)

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Table 4-3
1991 Core Logic Chip Set Market Share

1991 Rank	Vendor	Revenue ($K)	Share (%)	Shipments (K)	Share (%)	ASP ($)
80x86 Core Logic Chip Sets: All Segments						
Worldwide Market Share by Vendor: 1991						
1	VLSI Technology	135,000	20	4,637	22	29
2	Chips & Technologies	130,000	19	4,160	20	31
3	Intel	80,000	12	475	2	168
4	Opti	63,000	9	2,280	11	28
5	United Microelectronics	43,000	6	1,370	7	31
6	Western Digital	40,000	6	1,349	7	30
7	Texas Instruments	35,000	5	1,260	6	28
8	ACC Microelectronics	30,000	4	1,023	5	29
9	Headland	28,000	4	890	4	31
10	Eteq Microsystems	24,000	4	625	3	38
	Others	76,700	11	2,657	13	29
	Total	684,700	100	20,726	100	33
80x86 Core Logic Chip Sets: ISA Segment (Including XT)						
Worldwide Market Share, by Vendor: 1991						
1	VLSI Technology	135,000	22	4,637	23	29
2	Chips & Technologies	126,000	21	4,120	20	31
3	Opti	63,000	10	2,280	11	28
4	United Microelectronics	43,000	7	1,370	7	31
5	Western Digital	40,000	7	1,349	7	30
6	Texas Instruments	35,000	6	1,260	6	28
7	ACC Microelectronics	30,000	5	1,023	5	29
8	Headland	28,000	5	890	4	31
9	Eteq Microsystems	24,000	4	625	3	38
10	Intel	2,000	0	45	0	44
	Others	76,000	13	2,650	13	29
	Total	602,000	100	20,249	100	30

(Continued)

Table 4-3 (Continued)
1991 Core Logic Chip Set Market Share

1991 Rank	Vendor	Revenue ($K)	Share (%)	Shipments (K)	Share (%)	ASP ($)
80x86 Core Logic Chip Sets: EISA Segment Worldwide Market Share, by Vendor: 1991						
1	Intel	70,000	100	375	99	187
	Others	200	0	2	1	100
	Total	70,200	100	377	100	186
80x86 Core Logic Chip Sets: MCA Segment Worldwide Market Share, by Vendor: 1991						
1	Intel	8,000	11	55	15	145
2	Chips & Technologies	4,000	6	40	11	100
	Others	500	1	5	1	100
	Total	12,500	18	100	27	125

Source: Dataquest (December 1992)

companies typify the current dynamics of this fast-moving segment of microperipherals. In the No. 1 position with a low growth rate is VLSI Technology, the current leader in 16-bit PC systems (386SX and 286). In the No. 4 position with the highest growth rate is Opti, the current leader in 32-bit PC systems (486 and 386DX). Chips & Technologies, steadily losing market share because its product line failed to keep up with the changes taking place, is in second place. Also noteworthy in any 80x86 context is Intel, in third place, which until the last 12 months was the only merchant vendor of EISA bus chip sets and created the early de facto standards in interrupt controller and cache controller chips. Already insignificant and dying is the MCA bus chip sets, the stillborn child of IBM, whose merchant versions by Intel and Chips & Technologies never took off. The following paragraphs offer brief synopses of the positions and products for each leading vendor.

No. 1-ranked VLSI Technology represents 20 percent of the market revenue and 22 percent of the unit volume. With its primary emphasis as a company on PC products, it offers the broadest line of chip sets for both desktop and notebook systems (having formed the Portable Systems Division in mid-1992). On top of its size and product breadth, VLSI gained further by forming a strategic partnership with Intel to develop integrated 386 processor/chip set products for the hand-held market. This will also result in an advantageous position for VLSI in the mainstream notebook market, being one step ahead in integration technology. VLSI's product line includes the following:

- For desktops:
  - VL82C311 (SCAMP), a single-chip ISA controller for low-cost 386SX-based systems.
  - VL82C486, a single-chip (without cache) ISA controller optimized for 486-based systems.
  - VL82C425, a second-level cache controller for use with the VL82C486 chip.
  - VL82C480, a single-chip (with cache) ISA controller designed for 486-based systems.
  - VL82C106, a combination I/O chip solution that supports two serial ports, parallel port, keyboard, mouse, and real-time clock.
  - VL82C113A, a combination I/O chip optimized for use with the VL82C486 and C311 system controllers.
- For notebooks:
  - KODIAK, a low-power chip set for 486 and 386DX systems comprising a system controller, power management unit, and bus-expanding controller.
  - SCAMP II, a two-chip set for 386SX-, Am386-, and Cx486SLC-based systems, including system management interrupt.
  - SCAMP Notebook, a three-chip set (including the SCAMP-LT single chip controller) for 386SX- and 286-based systems

As is widely known, Chips & Technologies started the PC core logic chip set business in the mid-1980s. It was the first to introduce chips for the early 286- and 386-based clone PCs and has remained focused on desktop solutions. Its product line includes a wide range of ISA-compatible chip sets for 386SX, 386DX, and 486 processors, as well as an MCA-compatible chip set. Though ranked second in overall core logic chip sales, Chips & Technologies has been steadily losing market share (down from 40 percent in 1988) over the last three years. This is a direct result of its "bet your company" focus on entering the 386 processor business, a move that has placed it in severe financial difficulties. The highlight within the last 12 months was introduction of WINCHIPS, a high-performance desktop ISA chip set offering modularity (one- to three-chip solutions), VL bus support, and low-TTL-part count. Unfortunately, PC systems designed around Chips & Technologies' older products are becoming obsolete and the WIN-CHIPS product has yet to gain significant design wins, placing the company in jeopardy.

Intel has had mixed successes in its chip set product endeavors ranging from its de facto standards in cache controllers (82385), interrupt controllers (8259A), and EISA chip sets to its de facto failures in MCA and ISA chip sets. Though its primary goal in chip sets is to enable 80x86 processor growth, Intel always looms in the distance as the most dangerous threat to the entire chip set business. This year Intel hit with two big introductions that will affect the development paths of all other companies, as follows:

- Advanced Programmable Interrupt Controller (APIC) architecture, which is optimized for multiprocessor systems running multitasking operating systems. The first version was introduced in October; the 82489DX can work alongside the standard 8259A, improves interrupt response, and allows hardware priority tuning with dynamic interrupt distribution.
- The Peripheral Component Interconnect (PCI) bus standard and the industry's first combination ISA/PCI chip set (November 1992). The 82420 PCI chip set was optimized for 486-based designs and includes the 82424TX cache DRAM controller (CDC), the 82423TX data path unit (multiplexer/demultiplexer), and the 82378IB system I/O component (DMA, IDE, arbitration, and ISA bus interface). These chips will be sold both as a complete chip set as well as separately.

Opti (Santa Clara, California) was founded in 1989 and is the fastest-growing company of the major PC logic chip set companies. As a noted spin-off from Chips & Technologies, this start-up has grown to the point of eclipsing the company from which its founders came slightly more than three years. This growth has not come without pain, however, because Opti has been facing a lawsuit filed by Chips & Technologies claiming patent infringement, trade secret violations, and false advertising. Ironically, the two companies have just settled these claims, with Opti acknowledging the validity of the patent infringement and agreeing to pay Chips & Technologies an undisclosed sum in exchange for continuing to ship product. Ranked a distant third in 1991, it will most likely be the No. 2 player in 1992 (ahead of Chips & Technologies), reaching about $100 million in revenue by the end of this year. Focusing on high-end 32-bit solutions, Opti is the leader in chip sets for 486-based systems, a lead that we expect it to retain for the immediate future. New products introduced during 1992 include the following:

- 82C291 (May 1992): An ISA chip set for 33/40-MHz versions of the Am386SX and Cyrix 486SLC processors featuring write-back cache and priced at $18 (10,000 quantity).
- 82C498 (May 1992): A universal 32-bit ISA chip set with write-back cache that supports all versions of 386DX, 486SX, and 486DX/DX2 ranging to 50 MHz.
- DNXB (September 1992): A two-device chip set including power management for high-end notebook computers using 386, 486SX/DX, or 486DLC processors.
- EISA 486AWB: An EISA chip set optimized for 486DX2 processor systems featuring Opti's exclusive new Adaptive Write-back cache architecture, which reportedly improves performance by 10 percent.

United Microelectronics Corporation (UMC) is located in Taiwan and has been focused on PC core logic chip sets for the last four years. Beyond its simple location advantage for acquiring its share of Asia/Pacific business, its offerings are positioned correctly for the Taiwan market: an adequate feature set with the lowest possible price. Though its chip set products are not a force outside of the Asia/Pacific region, it is focusing on another development that could open up its potential: a 486SX clone being developed by Meridian, a U.S. design company acquired by UMC. If successful, this could propel UMC into a unique position of offering package deals with both processors and chip sets.

Western Digital (WD), weighing in at 6 percent market share, has been relatively quiet this year, with the exception of its efforts in 3V logic. Working together with AMD, WD became part of the 3V reference designs being put together for use in low-voltage notebook designs. In addition, WD has been active in pursuit of a relationship with Cyrix, most notably for the use of its 486DLC parts for an upgrade offering to the existing 386DX installed base. Though no external hints of activity exist, it would not be surprising to see WD enter the market with an integrated chip set strategy, offering core logic, graphics, and mass storage interfaces woven together in an aggressively priced chip set.

It would seem that Texas Instruments historically simply has entered the market too late with each generation, missing the advantages of early design wins and premium prices. Being the leader in 8088/86-based PC XT system chip sets does not support the image of leading-edge technology. Another example is its untimely introduction of an EISA chip set after the market decided that EISA is primarily for servers and will be relegated to some 5 percent of the overall volume. However, the technology TI has developed should not be discounted; TI represents an impending threat by integrating core logic with its newly acquired Cyrix 486 technology. This threat is most prominent for the notebook market, where its low-end 486 processors parts are well matched and integration can effectively reduce valuable real estate and power.

ACC Microelectronics, which was established in Santa Clara in 1987 to focus on core logic solutions for both notebook and desktop systems, made it to seventh place in 1991. Its most novel product has been the ACC2046 (introduced in February 1991), a single-chip solution for both desktops and notebooks using 486 and 386DX processors. Its line includes single-chip controllers for 286, 386SX, 386DX, and 486 systems up to 50 MHz. Its strategy continues to be focused on using its wide core logic library to develop timely single-chip solutions for mainstream PC systems. Its most recent introduction was the ACC2168 single-chip, 32-bit controller (208-pin package), which is similar to the 2046 but with local bus support and without the power-saving features.

Headland Technology began as a separate company, became a division of LSI Logic, and has now been absorbed as an internal product line. Over the last two years, its core logic products have been focused on the notebook/laptop markets. The company garnered the eighth place for 1991. In January 1992, it introduced new solutions for both notebook and desktop PCs. The HT22LV is its new notebook chip set, which offers a single-chip 386SX solution featuring power-saving features and operation down to 2.7V. The HTK340 was designed for 486-based desktop systems, with byte gathering write buffers providing optimized performance especially beneficial to the 486DX2 clock-doubled processors. Though its parent, LSI Logic, continues to experience organizational and financial difficulties, Headland has the potential for immediate growth.

Eteq was founded in 1989 to develop and market high-performance PC logic chip sets for desktop systems. It soon introduced one of the first interchangeable 386/486 chip sets (named Cougar) capable of running at 40 MHz. Later in 1991, it introduced the Bengal 386/486 chip set with write-back cache and the Panda 386SX chip set with support for 33-MHz clock speed. All of its chip sets support only the ISA bus. Though only ninth in overall ranking, it was one of the top players in 486-based systems in 1991, a position of strength because the 486 has taken off in volumes.

Of the 20 additional PC core logic system vendors, a few stand out as noteworthy in their potential. Symphony Labs (located in California's Silicon Valley) is focused on developing flexible PC core logic chip sets. Symphony showed significant growth over the 12 months based on its Haydn 3 chip set (including cache controller) that works with all 386/486 processors up to 50 MHz. In addition, Symphony's new products include one of the first (non-Intel) EISA chip sets (November 1991), and Haydn II (August 1992), one of the first chip sets to support the VL-bus standard. Oak Technology, a leading vendor of low-end PC graphics chips ventured into the core logic business this last year with two new ISA bus offerings for 386SX-based systems, one each for desktop and notebook systems (OTI-020 and OTI-040 Oaknote). It also announced one of the first chip sets to support the 33-MHz version of AMD's 386SX.

Outside of PC core logic, there have been several significant announcements, which indicates an impending trend toward industry support on non-x86 processors. Most significant were those directed toward the SPARC architecture, as follows:

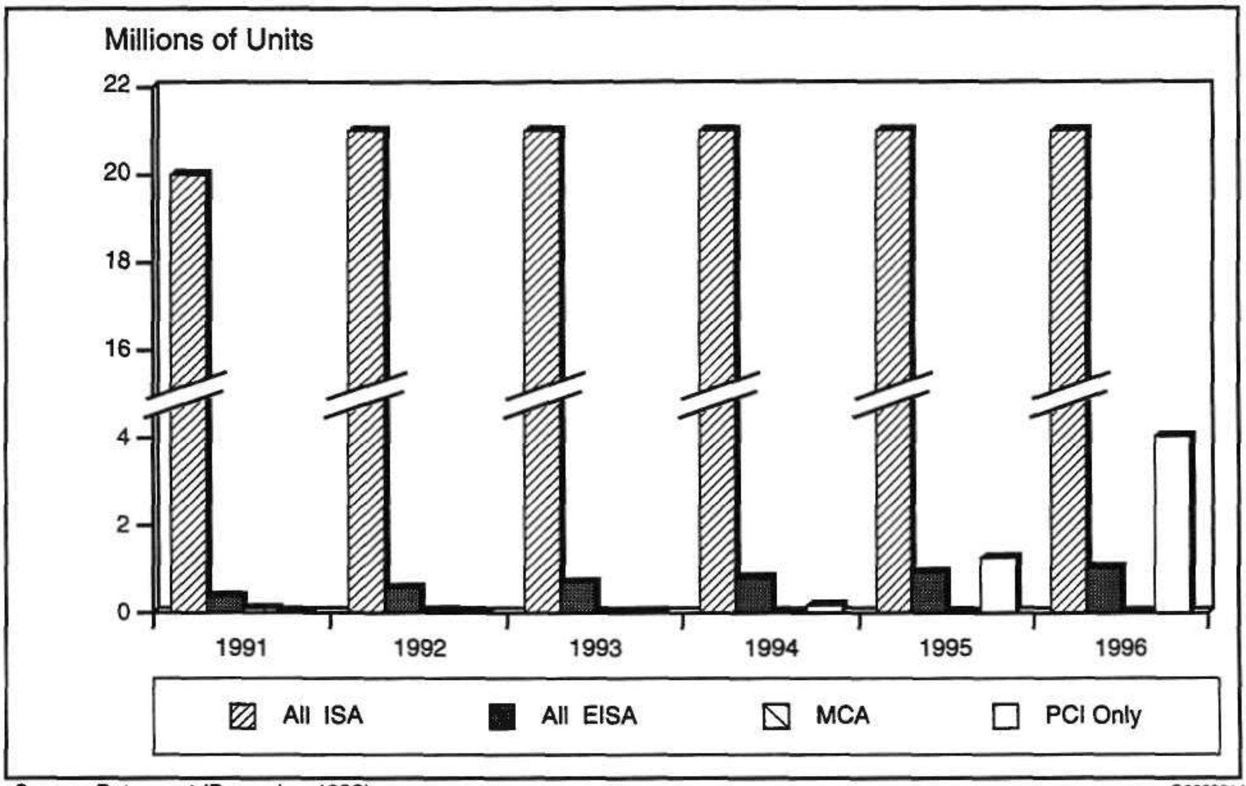
- Tera Microsystems, founded in 1989 to develop core logic for RISC processors, offers a product called microCORE that integrates cache, memory management, I/O control, DRAM control, and certain peripheral functions. Late last year, Tera licensed and began marketing Sun's 40-MHz SPARC chip set and SPARCstation 2 board design to SPARC clone makers.
- NCR announced a highly integrated two-chip SBus I/O chip set under an agreement with Sun. The Master I/O device (NCR89C100) is an Sbus master that includes an Ethernet core, small computer systems interface (SCSI) core, parallel port, DMA controller, and interrupt controller. The Slave I/O device (NCR89C105) integrates all the 8-bit system I/O functions including dual serial ports, floppy disk controller, and an Sbus interface for byte-wide peripherals.
- LSI Logic announced an all-surface-mount 40-MHz Mbus chip set (SparKit-40/Mbus) that includes the L64831 floating point unit, the L64815 SPARC memory management/cache/tag unit, the L64850 SPARC DRAM controller, the L64851 SPARC Mbus to standard I/O interface, the L64852 SPARC Mbus to Sbus interface, the L64853 enhanced Sbus DMA, and the L64855 Sbus graphics controller. This seven-device chip set began shipping in July 1992 and is offered at a lofty $629 (100-unit) price tag.
- Cypress introduced a new timing control unit for stretching clocks in a SPARC system to simplify the wait-state logic and a new DRAM controller (not bound to the SPARC processor) that maximizes memory performance in multiprocessing systems.

Forecast and Assumptions

Core logic chip set demand is directly tied to the processors they are designed to work in and to the type of system architecture they support. Thus, the PC core logic chip sets evaluated herein are driven by the unit volumes of 80x86 processors used in PCs, which represents both a large and growing opportunity. Chip set revenue will continue to decline mildly because of ASP declines outstripping unit growth (see Figures 4-4 through 4-6 and Table 4-4). The key driving forces and relevant assumptions affecting PC core logic chip sets are as follows:

- Overall volume will increase only slightly throughout the forecast period as much of the growth in portable systems moves to integrated architectures such as the SL.

Figure 4-4
80x86 PC Core Logic Chip Set Market Forecast, Units



Source: Dataquest (December 1992)

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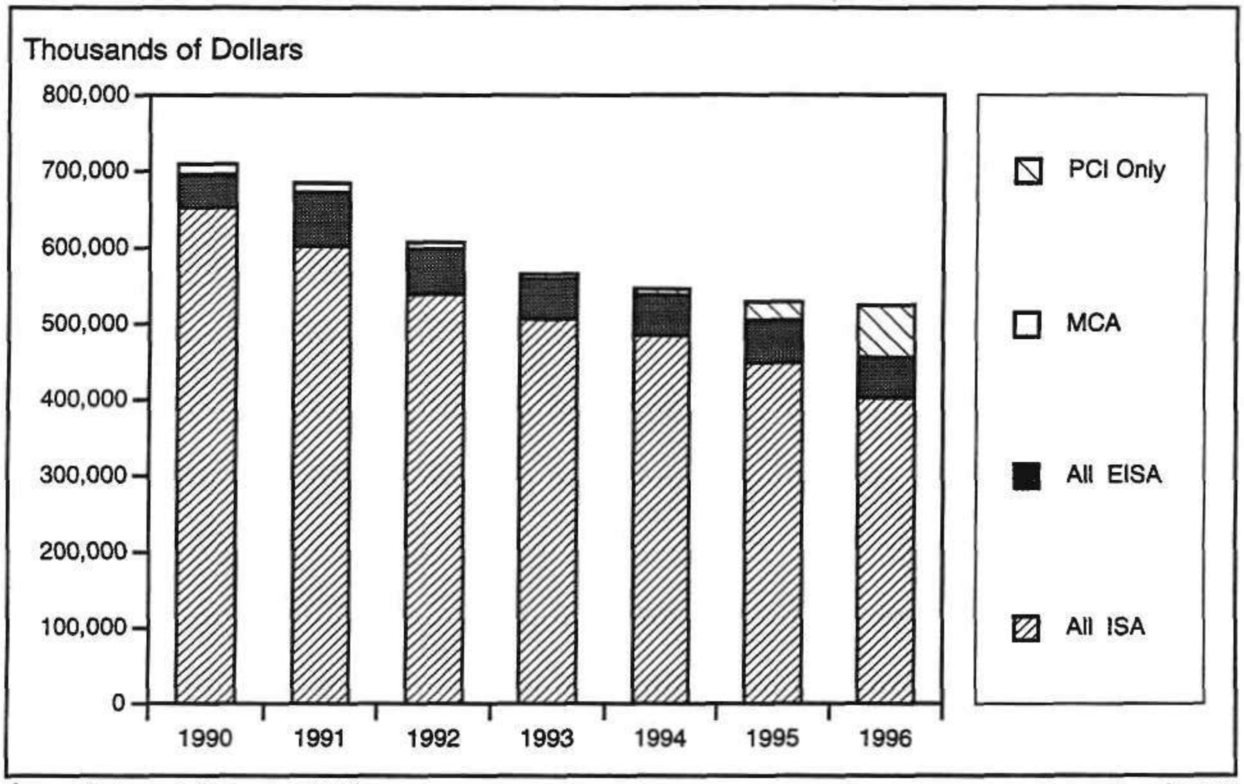
- Overall ASPs will decline gradually as 32-bit architectures continue to move to single-chip versions and competition stays intense.
- 80x86 PCs will continue to grow throughout this forecast period, becoming overwhelmingly dominated by pure 32-bit (32-bit internal and external) in 1993, led by the Intel 486 and compatible clones.
- Many older 80x86 processors will quickly move into obsolescence for computer applications, thus eliminating the chip set requirement for the 8088/86 by 1993, the 286 by 1994, and the 386DX by 1995.
- The 386SX-class processors (386 CPU with 16-bit external bus) will remain active throughout the forecast period; however, use beyond 1993 will be primarily in high-integration forms such as the 386SL not requiring a standard chip set as we define it.
- Local bus architectures will become ubiquitous during 1993, which will stem the growth of the high-performance expansion buses, EISA and MCA.

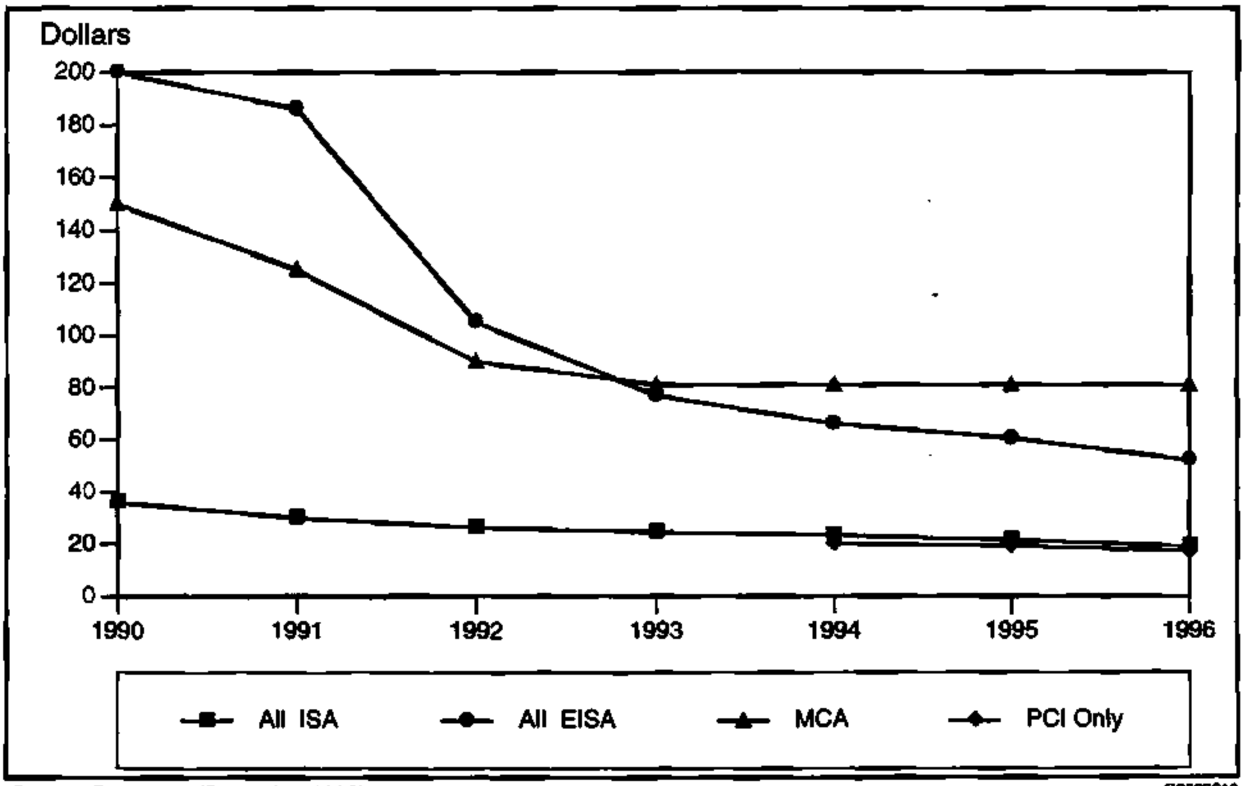
Figure 4-5
80x86 PC Core Logic Chip Set Market Forecast, Revenue



Source: Dataquest (December 1992) G2002615

- The VL bus, expected to be implemented in volume only along with ISA chip sets, will be the dominant local bus standard initially by winning the bulk of new system designs from the second half of 1992 through the first half of 1993 because of widespread availability of parts. However, the VL bus will peak early with 27 percent of the market in 1993 and drop off slowly thereafter, becoming all but obsolete by 1996.
- The PCI bus, driven by a superior technical specification, the marketing strength of Intel, and the support of key OEM vendors, will take the bulk of design wins beyond the first half of 1993 and will grow from 9 percent penetration in 1993 to more than 90 percent penetration in 1996.
- The Intel PI bus used on the SL family of processors is not explicitly forecast here because it comes with the SL processors and thus does not represent a chip set opportunity; furthermore, it will go away in the 1994 time frame as Intel moves all processors to the PCI bus standard.

Figure 4-6
80x86 PC Core Logic Chip Set Market Forecast, ASP



Source: Dataquest (December 1992) G2002616

- MCA chip sets in the merchant market essentially will become obsolete by the end of 1993.
- EISA chip sets will remain in use for servers and vertical-focused systems and will primarily be used along with PCI local bus support starting in 1994.
- Starting in 1994, we will see the growth of a new architecture for both desktop and portable systems, with PCI as the only system peripheral bus and PCMCIA as an external expansion port.

Table 4-4
80x86 PC Core Logic Chip Set Market Forecast

Product	1990	1991	1992	1993	1994	1995	1996
ISA							
Units (K)	18,110	20,239	19,121	13,111	6,754	2,158	492
ASP ($)	36	30	26	22	21	19	17
Revenue ($K)	651,960	602,110	497,140	289,747	141,797	40,771	8,375
ISA/PCI							
Units (K)	0	0	0	1,898	8,953	16,340	19,130
ASP ($)	0	0	0	40	26	22	19
Revenue ($K)	0	0	0	75,935	232,787	359,484	363,465
ISA/VL							
Units (K)	0	0	1,480	5,807	5,267	2,614	1,838
ASP ($)	0	0	29	24	21	19	17
Revenue ($K)	0	0	42,327	141,169	110,582	49,392	31,255
All ISA							
Units (K)	18,110	20,239	20,601	20,816	20,974	21,112	21,460
ASP ($)	36	30	26	24	23	21	19
Revenue ($K)	651,960	602,110	539,466	506,851	485,167	449,647	403,095
EISA							
Units (K)	220	377	568	564	386	329	0
ASP ($)	200	186	105	75	68	64	58
Revenue ($K)	44,000	70,122	59,630	42,307	26,061	21,069	0
EISA/PCI							
Units (K)	0	0	0	130	427	600	1,033
ASP ($)	0	0	0	85	65	59	52
Revenue ($K)	0	0	0	11,066	27,772	35,124	53,717

(Continued)

Table 4-4 (Continued)
80x86 PC Core Logic Chip Set Market Forecast

Product	1990	1991	1992	1993	1994	1995	1996
All EISA							
Units (K)	220	377	568	694	813	929	1,033
ASP ($)	200	186	105	77	66	60	52
Revenue ($K)	44,000	70,122	59,630	53,373	53,833	56,193	53,717
MCA							
Units (K)	90	100	60	25	0	0	0
ASP ($)	150	125	90	81	81	81	81
Revenue ($K)	13,500	12,500	5,400	2,025	0	0	0
PCI Only							
Units (K)	0	0	0	0	183	1,260	4,031
ASP ($)	0	0	0	0	20	19	17
Revenue ($K)	0	0	0	0	3,651	23,945	68,526
Total							
Units (K)	18,420	20,716	21,229	21,535	21,970	23,301	26,524
ASP ($)	39	33	28	26	25	23	20
Revenue ($K)	709,460	684,732	604,496	562,249	542,651	529,785	525,338

Source: Dataquest (December 1992)

Math Coprocessor Subsegment

Math coprocessors are fast becoming a product of the past as high-performance microprocessors with a built-in floating point unit (FPU) become more mainstream. Providing acceleration for floating point calculations, math coprocesssors used to be demanded for a select set of technical (CAD, visualization), business (spreadsheets, among others) and embedded (motion control) applications. The most critical of these is technical applications, where workstations have flourished and offer much higher floating point performance than is available on a PC. To model these demand trends and competitive movements, we will look at two subsegments, 80x87-compatible (PC math coprocessors) and "other" math coprocessors.

80x87 Math Coprocessors

The 80x87 math coprocessor subsegment includes products for essentially every generation of Intel 80x86 processor introduced and now has an installed base of about 12 million units. These coprocessors have been sold through two separate channels, direct to system OEMs for configuring high-performance systems, and at the retail level for users later upgrading their own systems. Traditionally, the market has been evenly split between these two channels. However, during the last 12 months the OEM market has all but disappeared as system manufacturers have switched to Intel 486DX-based systems to fulfill high-performance system demand. The retail channel is also weakening at an increasing pace because of the ramp-up of 486 systems, the age of the 386 installed base, and the introduction of Intel's Overdrive Processor line.

The 80x87 segment specifically includes the following products, which support their respective 80x86 microprocessor counterpart:

- 8087 and 80187, which work with the 8086/88 and 80186/188, respectively.
- 80287, which works with the 80286.
- 387, which represents two versions: the 387SX, which works with the 80386SX, and the 387DX, which works with the 386DX.
- 487, which works with the 486SX.

The 80x87 market was comparatively slow to develop, representing less than $60 million in revenue by 1985. The 8087s sold only moderately into early PCs because of limited applications requiring floating point calculations (PC-based CAD did not take off until the 80286-based IBM PC AT was introduced). However, these first-generation 80x87 math coprocessors continue to sell several hundred thousand units per year for embedded applications.

The market for PC math coprocessors really hit its growth during the second half of the 1980s as Intel's second generation, the 80287, took off. Selling initially at retail shelves for more than $300, the 80287 was purchased by a large percentage of PC AT-compatible users working with CAD applications. As the 80386-based PCs became the natural replacement for high-performance PC applications, this demand began to feather over to the 80387, which became the highest single revenue-producing math coprocessor in history. Unfortunately, it also became the last—introduction of the 80486(DX) in 1989 signaled the eventual end of the PC math coprocessor business. As its last effort in the 387 series, Intel introduced two new products in the first half of 1992 to strengthen upgrade demand. RapidCAD is an integrated 386/387 chip (a 486DX without cache) designed to capture the remaining high-performance 386DX upgrades. However, it is finding this a small market. 387Mobile, a low-power math coprocessor for all 386SL and SX portable computer systems, reportedly is ramping well.

Intel's 486DX offers a truly premium solution for PC users with floating point-intensive applications. Not only did the 486DX incorporate an internal FPU, but it also increased its performance substantially. This created a wide separation between the performance of 486DX-based systems and 386/387-based systems, stemming demand for 387s. Keeping with tradition, Intel introduced its latest (and last) math coprocessor in 1991, the 487, to go along with the 486SX (a 486 without an internal FPU). However, based on the momentum of the 486DX, price erosion expected from upcoming competition, and Intel's new upgrade strategy, the 487 is fated to become a stillborn product.

Other Math Coprocessors Subsegment

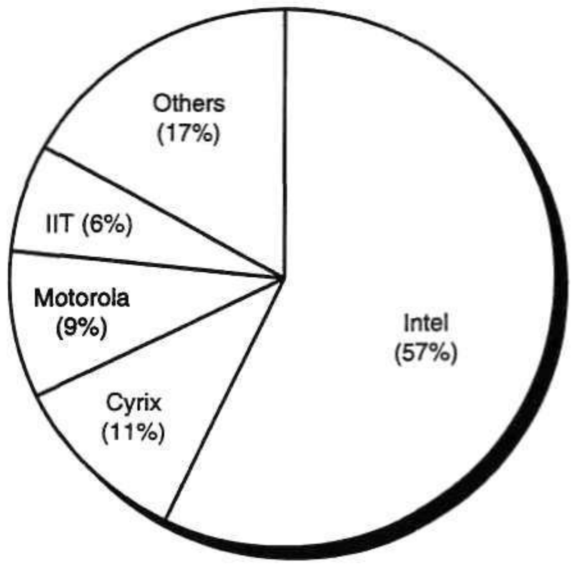
The "other" subsegment is a collection of the math coprocessors offered for use with other families of microprocessors. The largest of these is the 6888x series supporting the 68K family. The 68K series math coprocessors traditionally were dominated by sales into 68K-based workstations (68020 and 68030) and Apple Macintoshes. However, the 68040 (like the 486DX) incorporates an internal FPU and has taken over the high-performance demand for the Macintosh. At the same time, most workstations have moved over to RISC-based processors, where the generation of separate FPU components is also disappearing.

SPARC-compatible math coprocessors represented a growing arena until 1992, when integrated versions (Integer and FPU units) have become prolific. MIPS-compatible math coprocessors are still widely used with the R3000 series. However, the R4000 is projected to take over the bulk of MIPS-compatible systems by the end of 1993, severely stemming this growth. Likewise, the HP PA-RISC 7100, the IBM PowerPC 601, and the Digital Alpha 21064 represent the beginning of single-chip integrated processors (with FPU) for their respective families.

Competitive Positions and Analysis

The competitive field was dominated in 1991 by Intel, which dominated the 80x87 segment (see Figure 4-7 and Table 4-5). Motorola also captured a reasonable share, which is significant because of its monopoly on the 68K family of math coprocessors. Cyrix and IIT achieved respectable sales levels in 1991 because they successfully

Figure 4-7
1991 Top 4 Companies' Math Coprocessor Market Share



Source: Dataquest (December 1992)

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established competitive products and channels for their 80387 compatibles.

Texas Instruments, Weitek, IDT, LSI Logic, and Performance Semiconductor all had minor revenue resulting from their sales into the SPARC- and MIPS-compatible markets.

The 80x87-compatible market is completely dominated by Intel, which has 74 percent of the revenue. The originator of the 80x86 and 80x87 series, Intel has had the incumbent position of dominance that other vendors must attack. These attacks began back in the mid-1980s when Weitek introduced a faster math coprocessor for 80386 systems that required a slightly different socket and drivers to operate. Soon after, AMD entered the market with a 80287-compatible, using exact Intel microcode. This precipitated the recent string of legal actions between the two companies.

The real skirmishes began in 1989 when a new set of vendors appeared with 80387-compatibles, most notably Cyrix and IIT. The new vendors brought slightly higher performance and lower prices to the market in exchange for the guaranteed compatibility that comes with the Intel brand. After two years, channels were set up, accounts were established, and the products were proven to be compatible. Cyrix set up wide distribution channels in the United

Table 4-5
1991 Math Coprocessor Market Share

1991 Rank	Vendor	Revenue ($K)	Share (%)	Shipments (K)	Share (%)
Math Coprocessors: All Segments					
Worldwide Market Share by Vendor: 1991					
1	Intel	284,000	57	3,600	60
2	Cyrix	53,000	11	525	9
3	Motorola	44,000	9	1,025	17
4	IIT	32,000	6	300	5
	Others	84,000	17	575	10
	Total	497,000	100	6,025	100
Math Coprocessors: 80x87 Segment					
Worldwide Market Share by Vendor: 1991					
1	Intel	284,000	74	3,600	79
2	Cyrix	53,000	14	525	11
3	IIT	32,000	8	300	7
	Others	14,000	4	150	3
	Total	383,000	100	4,575	100
Math Coprocessors: Others Segment					
Worldwide Market Share, by Vendor: 1991					
1	Motorola	44,000	39	1,025	71
	Others	70,000	61	425	29
	Total	114,000	100	1,450	100

Source: Dataquest (December 1992)

States and has led some of the price decreases in the past two years, including its most recent offerings of $40 math coprocessors bundled with its 486DLC microprocessors. IIT gained a stronger presence in Europe and has been more focused on developing derivative products, leveraging its expertise in high-performance floating point design. Other 80x87 vendors include Weitek, whose high-performance math coprocessors dropped way off during the latter half of 1991 because of the 486DX. ULSI has had little success with its low-priced offerings, and Chips & Technologies entered the market too late (fourth quarter of 1991) for any major impact.

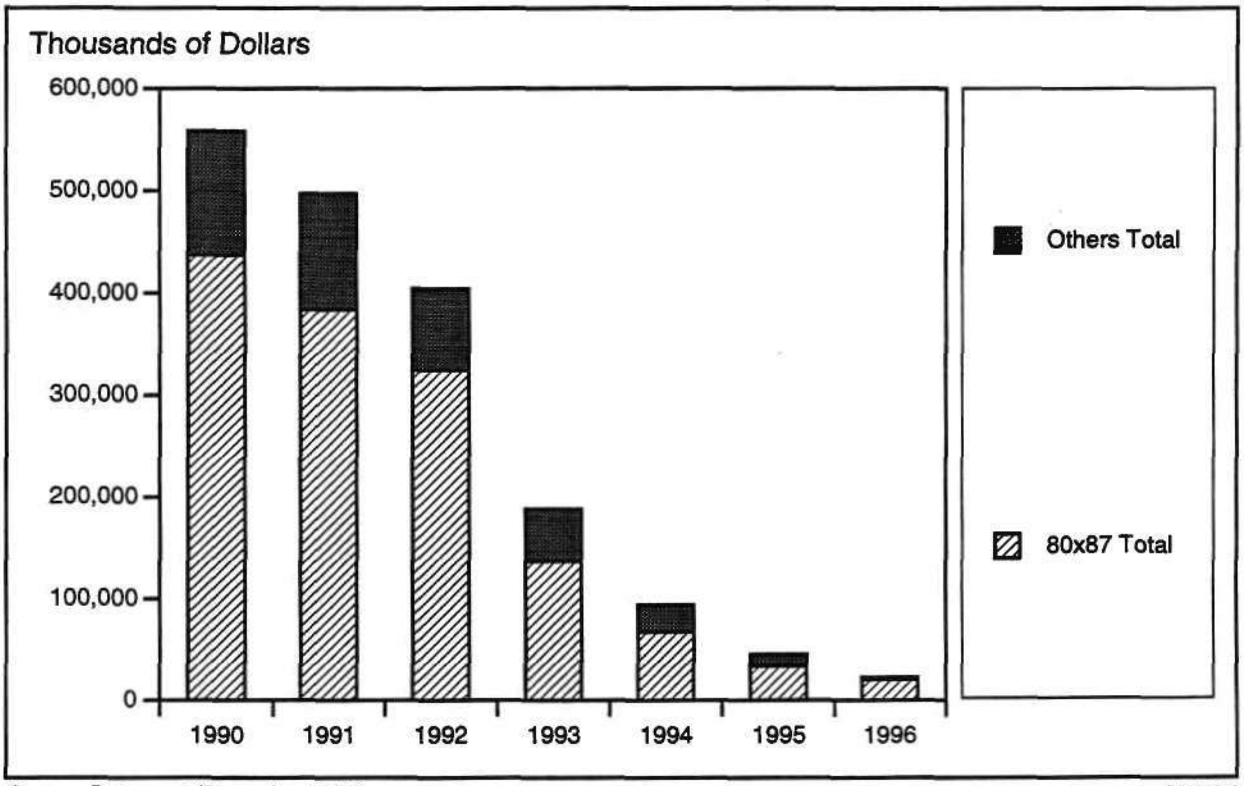
Unfortunately, the math coprocessor market opportunity has now been abridged as Intel moves the 486 family into the mainstream with a new upgrade strategy. Intel's strategy for retail business is to replace the existing math coprocessor upgrade demand with a new scheme of complete processor upgrades or what it calls "Overdrive Processors." The strategy calls for OEMs to include a special socket in their 486 and higher systems designed to accept an Overdrive Processor. End users can then purchase an Overdrive Processor at retail stores that is simply the next level of performance above their existing system's microprocessor. Therefore, the 486DX2 (in a special pin-out) becomes the Overdrive Processor for 486SX and 486DX systems, and the P5 (again in a special 32-bit pin-out) becomes the Overdrive Processor for 486DX2 systems. This scheme became possible through Intel's clock-doubling technology and the 486's on-chip cache, where processor performance can be increased regardless of the external system interfaces.

Forecast and Assumptions

The entire math coprocessor market is projected to decrease rapidly over the next five years as all new-generation microprocessors include an FPU on-chip. The 80x87-compatibles will continue to represent the bulk of the market (see Figure 4-8 and Table 4-6). Competition that became widespread between 1988 and 1991 resulted in continual price erosion offset by increasing volume until the end of 1991. Price erosion in the last two years has taken the form of a large annual step function downward, occurring each June and affecting the entire market. At midyear 1992, retail 387 prices dropped from the $150 to $200 range to the $75 to $100 range. The retail upgrade market is expected to splinter into two parts, a low-level residual demand for math coprocessors from the installed base of systems, and a new demand for higher-performance microprocessors (Intel's Overdrive Processors) that will use internal clock doubling, larger caches, and multi-issue architectures to offer socket-compatible upgrades. This new demand will stem the growth of math coprocessor revenue in exchange for microprocessor revenue. The following detailed assumptions affect this forecast:

- Volume for the 8087 series is projected to fall off in proportion to the 8088/86 microprocessors, while the 80187 is projected to maintain its volume because of the growth of 80186/188 applications. Because these primarily are sold directly to manufacturers, pricing is expected to remain relatively constant for both.

Figure 4-8
80x87 and Others Math Coprocessor Market Forecast



Source: Dataquest (December 1992)

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- 80287 volumes are already low and will continue to slide downward, held up by a few miscellaneous embedded applications. Pricing has been dropping over the last two years and is likely to continue, proportional to the 80387 series.
- The 80387-compatible series reached its volume peak in 1991 and has just gotten its last breath of mature life as it rapidly descends toward a residual demand level. One exception could be the MobileMath product, whose volumes are likely to stay low but steady for the next few years. Pricing for all products will continue to move downward, attempting to achieve maximum penetration into the large 386 installed base.
- The 80487-compatible series will be a stillborn product, with its only success coming from the Japanese market where the 486DX is more than three times the price of the 486SX (because of import regulations), making it more cost-effective to purchase 486SX systems, then upgrade with the 487. Pricing will track the decreases in 486DX prices (because the 487 is simply a repackaging of the 486DX) but will not affect overall volumes. Any natural growth that would have propelled the 487 will be funneled into the Overdrive Processors from Intel.

Table 4-6
Math Coprocessor Market Forecast

Product	1990	1991	1992	1993	1994	1995	1996
8087/187							
Units (K)	1,113	930	825	747	497	376	244
ASP ($)	55	50	50	50	50	50	50
Revenue ($K)	61,204	46,500	41,246	37,328	24,846	18,806	12,210
80287							
Units (K)	1,324	595	270	90	46	24	0
ASP ($)	65	50	40	35	35	35	35
Revenue ($K)	86,050	29,725	10,800	3,136	1,610	840	0
80387							
Units (K)	2,319	3,041	3,250	2,040	1,171	466	272
ASP ($)	125	100	75	45	35	30	30
Revenue ($K)	289,875	304,122	243,750	91,806	40,998	13,973	8,171
80487							
Units (K)	0	8	114	18	0	0	0
ASP ($)	0	350	250	250	250	250	250
Revenue ($K)	0	2,772	28,420	4,583	0	0	0
80x87							
Units (K)	4,756	4,574	4,459	2,895	1,714	866	517
TotalASP ($)	92	84	73	47	39	39	39
Revenue ($K)	437,130	383,119	324,215	136,853	67,454	33,620	20,381
6888x							
Units (K)	1,195	1,004	907	660	393	169	93
ASP ($)	45	40	35	30	27	25	25
Revenue ($K)	53,753	40,148	31,750	19,808	10,610	4,217	2,322

(Continued)

Table 4-6 (Continued)
Math Coprocessor Market Forecast

Product	1990	1991	1992	1993	1994	1995	1996
OS RISC							
Units (K)	198	331	300	232	96	46	0
ASP ($)	200	150	110	88	79	71	64
Revenue ($K)	39,672	49,650	33,027	20,420	7,580	3,245	0
Miscellaneous							
Units (K)	110	120	100	80	65	35	0
ASP ($)	250	200	150	140	130	125	125
Revenue ($K)	27,500	24,000	15,000	11,200	8,450	4,375	0
Others							
Units (K)	1,503	1,455	1,307	972	554	249	93
Total ASP ($)	80	78	61	53	48	47	25
Revenue ($K)	120,925	113,798	79,777	51,427	26,639	11,837	2,322
All							
Units (K)	6,259	6,028	5,766	3,867	2,268	1,115	609
Total ASP ($)	89	82	70	49	41	41	37
Revenue ($K)	558,054	496,917	403,993	188,280	94,094	45,457	22,703

Source: Dataquest (December 1992)

- The 68K series of math coprocessors has already begun to tail off and will continue to gradually decrease in both unit volume and revenue, buoyed by various embedded applications.
- Math coprocessors for RISC-based processor families will begin to drop off dramatically in 1993 as the new generation of integrated processors becomes mainstream.
- All other math coprocessors will remain inconsequential to the overall revenue of this segment.

Graphics and Imaging Controllers

Graphics and imaging controllers include a variety of products: PC graphics controllers (for example, VGA chips), CRT controllers, imaging controllers, and video compression/decompression (codec) controllers. The following market analysis will focus on PC graphics controllers, the dominant subsegment of graphics and imaging.

PC Graphics Controllers

The features important for mainstream PC graphics have undergone an evolution during the life cycle of each new graphics standard. In prioritized order, these features include standards compatibility, display modes (resolution and color), and graphics performance. When VGA was first introduced, compatibility was most important and all other features were subordinate. Soon compatibility became widespread and support for higher resolution and improved color display modes became critical. Finally, graphics performance has become the key differentiator, especially under the Windows environment, as measured by Winbench and other benchmarking programs. This cycle will end up repeating itself as we head into the next generation of mainstream graphics centered around intelligent graphics standards.

Our new segmentation divides the world of PC graphics into two basic types of display outputs—CRT and flat-panel—as well as into three subsegments—nonintelligent, fixed-function, and programmable—according to the type of architecture used. In addition, the two primary subsegments, nonintelligent and fixed-function, have two significant standards within each. These segments and standards are described in the following sections.

Nonintelligent Standard Controllers

Nonintelligent standard controllers are the traditional low-end PC graphics where architectures are based on previous IBM PC graphics standards (without hardware graphics acceleration or drawing assistance). These include VGA (super VGA) and low end (other bit-mapped controllers, that is, EGA, CGA, MDA, and HGC). These controllers also typically are accessed as a screen bit-map, with no graphics drawing, bit-blting, or processing. However, they may support local bus interfacing and many display modes beyond the standards. Though they typically use DRAM display memory, VRAM VGA controllers have been sold by multiple manufacturers.

These controllers began their use when the IBM PC was first introduced in 1981 with MDA and later CGA, providing 80 x 25 character text and primitive graphics. IBM has since introduced a new-generation bit-mapped graphics standard every three years, with EGA in 1984 and VGA in 1987. However in 1990, XGA was introduced, the first (real) intelligent graphics standard by IBM. It has signaled a new direction in mainstream PC graphics. Demand for these bit-mapped standard controllers will come primarily for chip sales to motherboard vendors as they continue to serve the truly low-end desktop DOS user segment as well as the fast-growing notebook PCs.

Fixed-Function Controllers

Fixed-function controllers are taken from a portion of the traditional high-end PC graphics and feature a fixed set of graphics acceleration functions (with bit-blt as a minimum). This includes accelerated VGA (denoted as AcVGA, which includes 8514A-type controllers) and XGA, the last IBM standard introduced in late 1990. These controllers typically have some fixed combination of graphics blting, drawing, and processing functions, and use either DRAM or VRAM display memory, with DRAM becoming the most common.

This type of controller began its use on the PC many years ago in the form of proprietary line-drawing engines and blt-engines, among others, for low-volume, high-end applications. With IBM's introduction of the 8514A in 1987, they began to take off in more moderate volume, gaining momentum from clone industry support. They have only recently (last two years) been sold in any substantial volume on the PC. These controllers will form the basis for the next-generation graphics standards, following the lead set by IBM with the XGA and alternative Windows Graphics Accelerators, both positioned to serve the fast-growing power-user market of Windows users. Fixed-function controllers will far outsell programmable processor controllers because of their sufficiently high performance under Windows, much greater availability (3:1 vendor ratio), and a lower cost of implementation.

Programmable/Other Controllers

The remaining portion of PC graphics controllers achieve graphics acceleration through a fully programmable processor dedicated as a PC graphics controller (that is, not a full microprocessor used in graphics applications). Though the TI-340xx family typifies this use, it is not at all dedicated as a PC graphics controller, so like many others it is accounted for under microprocessors. These controllers have not entered the mainstream and are not expected to play a significant role until late 1994, when integrated graphics and video decompression controllers are introduced at realistic price points.

CRT Graphics Controllers

The CRT graphics controller market declined slightly last year as price erosion exceeded the growth in unit volumes. This year, however, will be a different story as the impact of the new GUI accelerator graphics chips is felt, stemming the drop in ASPs and fueling a shift to a higher level of performance (and price range).

Previous generations of VGA and superVGA products had plummeted from their beginning $30 range to their current $15 range. Now the accelerated graphics controllers are shifting the market back upward to begin the next $30-to-$15 price erosion cycle. As the market shifts to the GUI accelerators, several new players have taken the opportunity to enter the game during the last 12 to 18 months including Weitek, S3, NCR, ATI, Avance Logic, and IIT.

Flat-Panel Controllers

Driven by the booming notebook market, flat-panel graphics controllers are still in their high-growth phase, with relatively few competitors and relatively high entry costs, compared to the desktop. Minimum features required for a flat-panel controller beyond its desktop counterparts include: LCD panel support for a wide variety of panels; high integration including RAMDAC; and low power consumption including support for both 3V and 5V versions. Though the industry still has only three significant players—Cirrus, Chips & Technologies, and Western Digital—its growth and margins are attractive targets. During the last year, we have seen new entries by the following vendors (with rumors spreading about at least two others):

- SMOS (November 92) with a palmtop VGA controller chip.
- Oak Technology with a flat-panel VGA controller with its OakNote chip set.
- Trident (January 92) with a local bus-capable notebook VGA controller.

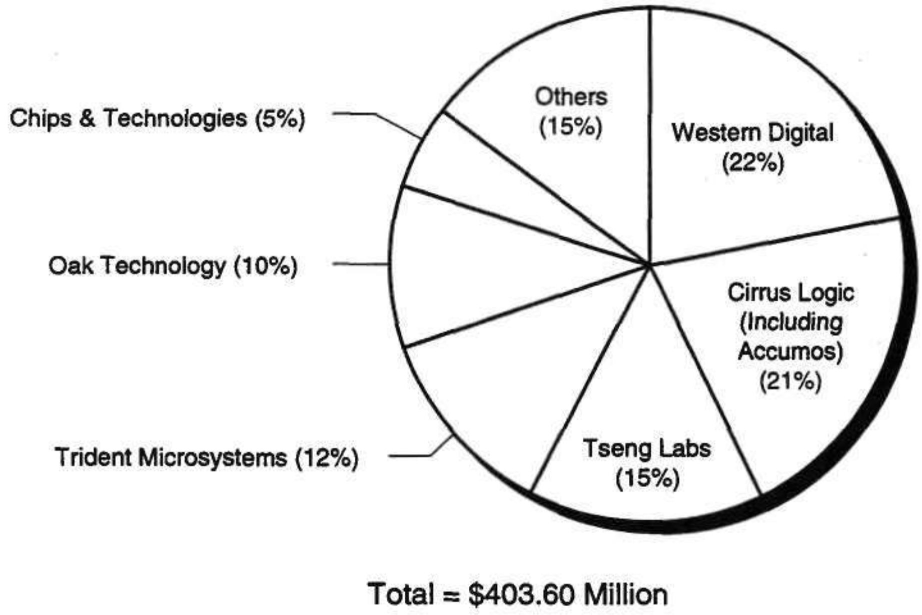
Flat-panel VGA support seems like a simple task, but it involves several areas of expertise that either take years to develop or dollars (license or royalty) to acquire. These features include basic driver output technology, color-mapping algorithms, frame acceleration (for dual-scan panels), and simultaneous CRT and flat-panel display (Cirrus' SimulSCAN). Today's drivers also must support a growing number of panels, including the following:

- Monochrome STN: The first level of technology, requiring support for both single-scan and dual-scan capability.
- Color STN: Similar in technology to monochrome STN (with dual-scan coming), primarily supporting a 16-bit interface but with some panels still using 4- and 8-bit interfaces.
- Color TFT: A large step upward in sophistication and a wider variety of versions beyond the common 9-bit (512-color) interface.

Competitive Positions and Analysis

The PC graphics chip arena is brimming with competition. Several new vendors have entered to take advantage of the emerging growth segments, flat-panel VGA controllers and accelerated VGA controllers. This market segment had six substantial players as of the end of 1991, most of which have products within each market segment (see Figure 4-9 and Table 4-7). The following paragraphs provide a brief description of each player's products and positioning.

Figure 4-9
1991 Top 6 Companies' PC Graphics Controller Market Share



Source: Dataquest (December 1992)

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Ranking as a top competitor for every area of graphics and imaging products, Cirrus Logic offers one of the strongest portfolio of products in the graphics and imaging area. Cirrus acquired Acumos in April 1992 and is expected to benefit by taking over the No. 1 position this year, with an estimated $95 million in graphics revenue. Cirrus develops microperipheral products for the user interface, mass storage, and communications segments of the PC market. Its strategy for user interface products is to develop (or acquire) leading-edge technology targeted for value-added applications within all forms of graphics, video, and audio areas. Following this strategy, Cirrus has positioned itself with good product depth in every segment.

Flat-panel graphics is Cirrus' strongest area, dominating the market with an estimated 56 percent share (1991 revenue) being used in more than 50 percent of LCD notebook designs worldwide. Offering the broadest LCD VGA controller product line, Cirrus introduced the following products in 1992:

- CL-GD6412 (February 1992): LCD VGA controller offering the first mixed-voltage (JEDEC LVCMOS 3.3V or 5V standards) operation for notebooks.
- CL-GD6225 (August 1992): LCD VGA controller with windows acceleration.

Table 4-7
1991 PC Graphics Controller Market Share

1991 Rank	Vendor	Revenue ($K)	Share (%)	Shipments (K)	Share (%)	ASP ($ Est.)
PC Graphics Controller Market						
Market Share, by Vendor: 1991						
1	Western Digital	90,400	22	4,000	19	22.60
2	Cirrus Logic (Including Accumos)	85,600	21	3,600	17	23.78
3	Tseng Labs	59,000	15	2,900	13	20.34
4	Trident Microsystems	50,000	12	3,500	16	14.29
5	Oak Technology	42,000	10	3,900	18	10.77
6	Chips & Technologies	21,600	5	1,000	5	21.60
	Others	55,000	14	2,700	13	20.37
	Total	403,600	100	21,600	100	18.69
PC Graphics Controller Market: General/CRT Segment						
Market Share, by Vendor: 1991						
1	Western Digital	60,000	20	3,200	17	18.75
2	Tseng Labs	59,000	20	2,900	16	20.34
3	Trident Microsystems	50,000	17	3,500	19	14.29
4	Oak Technology	42,000	14	3,900	21	10.77
5	Cirrus Logic (Including Accumos)	28,000	9	1,800	10	15.56
6	Chips & Technologies	11,000	4	600	3	18.33
	Others	50,000	17	2,500	14	20.00
	Total	300,000	100	18,400	100	16.30

(Continued)

Table 4-7 (Continued)
1991 PC Graphics Controller Market Share

1991 Rank	Vendor	Revenue ($K)	Share (%)	Shipments (K)	Share (%)	ASP ($ Est.)
PC Graphics Controller Market: Flat-Panel Segment						
Market Share, by Vendor: 1991						
1	Cirrus Logic (Including Accumos)	57,600	56	1,800	56	32.00
2	Western Digital	30,400	29	800	25	38.00
3	Chips & Technologies	10,600	10	400	13	26.50
	Others	5,000	5	200	6	25.00
	Total	103,600	100	3,200	100	32.38

Source: Dataquest (December 1992)

- CL-GD6205 (August 1992): Single DRAM LCD VGA controller (two-chip solution).
- CL-GD6440 (November 1992): LCD VGA controller offering 32-bit local bus operation and support for all types of color and monochrome LCD flat panels.
- We expect its next product (first half of 1993) to be the first LCD controller to include bit-blt acceleration for Windows.

Aided by the acquisition of Acumos, Cirrus was the No. 5 player (1991 revenue) in desktop graphics and is heavily focused on improving this area of products. Its major announcement in 1992 was rollout of its TrueColor VGA family in June, comprising the following four highly integrated products (including palette DAC, clock synthesizer, and hardware cursor):

- CL-GD5420: Entry-level superVGA controller ($17 at 1,000 quantity) with 256-color DAC.
- CL-GD5422: Multimode true-color VGA controller ($21.50 at 1,000 quantity) with multimode-palette DAC.
- CL-GD5424: Local bus true-color VGA controller ($23.00 at 1,000 quantity) with multimode-palette DAC.
- CL-GD5426: Accelerated local bus true-color VGA controller with bit-blt, raster operations, and local bus support.

Multimedia and video products have also begun to take off this year, resulting primarily from acquisition of Pixel Semiconductor in 1991. Focused on multistream real-time video architectures, Cirrus and Pixel introduced two major products in August this year, as follows:

- CL-PX2070: A programmable digital video processor that captures, stores, processes, and routes multiple streams of full-motion video.
- CL-PX2080: A MediaDAC that digitally mixes and simultaneously displays graphics with multiple independent streams of live video.

Though Western Digital was still ranked as the No. 1 vendor of PC graphics controllers in 1991, its overall market share shrunk dramatically to 22 percent in 1991. Until the end of 1991, its graphics controller product line had fallen behind and its captive Paradise adapter board line had been made obsolete. However, it has been on a recovery path during the last 12 months, introducing one of the first successful accelerated VGA controllers, the 90C31, late last year. The 90C31 offered aggressive price/performance with 1024 x 768 x 256 resolution, hardware bit-blt, line drawing, hardware cursor support, and a wide variety of memory organizations. Its major flaw is the omission of local bus support (we anticipate a new announcement shortly), a must for gaining design wins today. WD is also second ranked in flat-panel graphics controllers and has just announced (November 1992) one of the first accelerated VGA flat-panel controllers featuring local bus support (Intel's SL family PI bus, 386 or 486 versions) and integrated RAMDAC and video clock generator. In addition to its graphics controller developments, WD reintroduced the Paradise adapter card line (in April 1992) after pulling out one-and-a-half years earlier.

Tseng Labs was founded in 1983 and had remained entirely focused on graphics and video chips for the PC industry. Tseng's strong growth really took off with the introduction of the ET4000/A (1989). Until this year, the ET4000/AX was the graphics controller to beat on the desktop, offering leading-edge performance along with the right resolutions and feature set. Multiple revisions have been used to keep the ET4000 current, resulting in well more than 8 million units shipped since its introduction. Nearly a year after rumors began, Tseng has just announced (September 1992) its ET4000/W32, a Windows accelerator VGA controller with local bus (VL-compatible) support, bit-blt, and secondary hardware window support for low-cost implementation of video windowing on a PC. Though Tseng holds a strong market position, including recent design wins at both IBM and Compaq, it must quickly get back on the leading edge in order to maintain momentum. The W32, selling in the low $20s (in high volume), may be the right price/performance point for the upcoming generation of systems.

Trident Microsystems has continued to experience strong growth for several years and is estimated to be the volume leader (in unit shipments) at this time. Since incorporating in 1987, Trident's revenue (fiscal year ending in June) has grown from $1.3 million (FY1987) to $67 million (FY1992). This growth came to fruition this year, with Trident receiving a $7.5 million capital investment from TA Associates in January in preparation for its initial public offering in October. Trident has remained focused on producing PC graphics chips for board- and system-level customers. Trident largely is successful because it serves the growing Asia/Pacific market (a controlling share in Hong Kong) and offers chips with adequate performance at low to medium prices surrounded by turnkey board design kits. This year saw a spate of introductions from Trident. as follows:

- TVGA9000 (January 1992): Low-cost desktop VGA controller designed for connection to the ISA bus.
- TLCD9100 (January 1992): Flat-panel VGA controller supporting LCD output and local bus interfacing.
- TVGA8900CX (March 1992): A desktop VGA controller that incorporates local bus support; VideoView video processing chip set for scalable motion video from PAL or NTSC input.
- TVGA8900CL (November 1992): A performance upgrade (2.5X) to its predecessor, the TVGA8900C desktop VGA controller (Trident's highest-volume part), which supports 1024 x 768 at 256 colors.

Chips & Technologies has been losing market share in nearly every area of business for the past three years. This year, however, its graphics product line will be the diamond in the rough, showing exceptional growth during the second half of the year. With most of its market perception based on its failed 386 CPU products and poor financial condition, its nearly doubled graphics revenue seems insignificant to most observers. While it still tries to find the right formula for desktop/CRT graphics chips, its new Wingine chip has remained at the starting blocks (except for the major win at Epson). However, its notebook VGA chips gained some significant design wins this year and will move it to second place in the flat-panel controller subsegment. Product announcements during the last year included the following:

- 65520 midrange Vampire family (January 1992): VGA notebook controller offering a full range of resolution, 3.3V and 5V operation, and support for all buses (PI, ISA, MCA, and local bus 386/486).
- 64200 Wingine (May 1992): Desktop VGA solution utilizing a unique direct memory bus architecture (similar to local bus) where the CPU writes directly to the VRAM video memory and the controller resides on the ISA bus connected to the serial output from the VRAM.
- 82C481 (August 1992): Graphics Accelerator offering 16-, 24- and 32-bit color support with full acceleration features (including bit-blt, line draw, and poly fill) for use along with the Wingine VGA chip.
- 65510 (September 1992): Subnotebook VGA controller offering low power consumption, low real estate, and monochrome flat-panel-only support for less than $20.
- 65530 (September 1992): Flat-panel GUI accelerator for high-performance notebooks is a single-chip controller supporting almost all color and mono panels and simultaneous CRT/flat-panel scanning.

Oak Technology shot through the roof last year with nearly 4 million units shipped, primarily low-cost VGA controllers sold into Taiwan. Though it introduced several new products this year, its momentum has dropped somewhat and we expect its unit volumes to be lower this year. Part of its momentum loss was likely because it split its focus into other product areas including core logic chips and mass storage chips. In January 1992 it introduced the OTI-087, a local bus VGA controller supporting 24-bit color, hardware cursor, and other performance enhancements.

After entering the market in May of 1991, Weitek shot too low, then too high. It hopes the third time is the charm. Its first product, the W5086, only supported 16 colors at 1024 x 768, which was too low for this generation of accelerated VGA controllers. This drove it to make a judicious decision to enter the retail graphics board market to move its chips and create an image. Earlier this year it entered into an alliance with VLSI technology to jointly develop user interface processors working with VLSI local bus core logic, followed by an alliance with Sierra to jointly develop integrated graphics controllers with RAMDAC. July 1992 saw introduction of the Power 9000, a standalone high-performance 1280 x 1024 x 256-color controller using its 8720 graphics engine core, VRAM memory, and sporting a $70 price tag (1,000 quantity) without VGA compatibility. Finally in September, it landed back on earth with the W5286 single chip accelerated VGA controller, using DRAM or VRAM, and listed at a cool $20 (5,000 quantity).

ATI Technologies began business as purely an add-in graphics card manufacturer and soon after began developing its own graphics chips to ship with its board-level products. With revenue in excess of $200 million and 350 employees, it ships more than 1.5 million graphics cards per year, far and away the leader in the retail market. In 1991 it began shipping quantities of its graphics chips on the merchant market. Its real push began with introduction of the 68800 accelerated VGA graphics chip, which offers multiple bus support (ISA, EISA, MCA, local bus), high resolution (to 1280 x 1024 x 256 colors), and DRAM or VRAM memory support. Its strategy to sell chips only to system manufacturers explains the high $79 price (1,000 quantity) that probably scares away most board companies. With one of the most complete software packages including drivers and fonts, this is a company worth watching for growth in the accelerated VGA market.

S3 was founded in 1989 by former Chips & Technologies cofounders Dado Banatao and Ron Yara, with the aid of more than $16 million in venture financing. After abandoning its original goal of producing a complete line of systems and peripheral logic chips based on an advanced interconnect scheme similar to the local bus concept, they focused on graphics chips. With graphics as its lifeblood, S3 has shot up to become one of the strongest forces in the graphics chip business. It will have more than $28 million in revenue in 1992. Its first product, the 86C911, represents the integration of a high-performance 8514-like core with a VGA graphics core. Using VRAM display memory, this yielded the fastest Windows accelerator chip on the market at the time and achieved more than 60 add-in board design wins. This established its image in the market as the performance leader, and in June and July of this year it went on to introduce two new DRAM-based products to go after the mainstream systems market, and a new level of high-performance VRAM product, as follows:

- 86C801: A DRAM-based VGA accelerator with ISA interface.
- 86C805: A DRAM-based VGA accelerator (same as 801) with local bus or EISA support.
- 86C924: An 86C911 pin-compatible part with 24-bit color and local bus support.
- 86C928: An ultrahigh-performance VRAM-based accelerator with local bus support.

Vendors included under the "other" category include NCR Microelectronics, Integrated Information Technologies (IIT), SMOS Systems, Headland, SGS-Thomson, and Avance Logic described.

NCR Microelectronics made its graphics debut in February 1992 with the introduction of its NCR77C22E+, a surprisingly competitive accelerated VGA controller. This controller offers bit-blt support, local bus interfacing, and 1024 x 768 x 256 color resolution, with prices starting at $25 (1,000 quantity). NCR has been a strong vendor of ASIC products and services, which it balances against standard merchant ASSP products, led by SCSI, Ethernet, and now graphics. It intends to continue introducing leading-edge graphics controllers and looks to become a strong competitor.

IIT entered the market this year with a pair of offerings aimed at using XGA compatibility as a key differentiating feature. IIT had an advantage in delivering the XGA-compatible architecture because it was one of the few companies that cloned the 8514A architecture and then integrated VGA. IIT is the first company outside of SGS-Thomson (which simply licensed the XGA architecture from IBM) to offer an enhanced XGA-compatible graphics controller. Named the AGX-014 (ISA version) and 015 (VL-bus version), these controllers are priced at $37 and $46 (1,000 quantity), respectively, and feature the following:

- Full XGA compatibility
- Hardware acceleration including bit-blt and line drawing
- Hardware cursor (64 x 64 x 2)
- Resolutions to 1280 x 1024
- Support for 24-bit color

SMOS Systems (a Seiko-Epson subsidiary) announced its first foray into the graphics chip business in November 1992 with an LCD VGA controller aimed at the hand-held and subnotebook markets. Offered in both 3V (SPC8107) and 5V (SPC8105) versions, these chips support both ISA/PI bus interfaces, provide a two-chip solution (using a 256Kx16 DRAM), and are aggressively priced at $15 and $13 (25,000 quantity), respectively.

Avance Logic popped on the scene in 1992, started by a few ex-Trident people and funded by a deep-pocketed conglomerate from the Asia/Pacific region. It entered the market with a new GUI accelerated VGA chip set that includes the ALG101 graphics controller chip, the ALG1101 XGA-compatible RAMDAC (64K colors), and the ALG3102 clock generator chip sold as a package for $46 at 1,000 quantity.

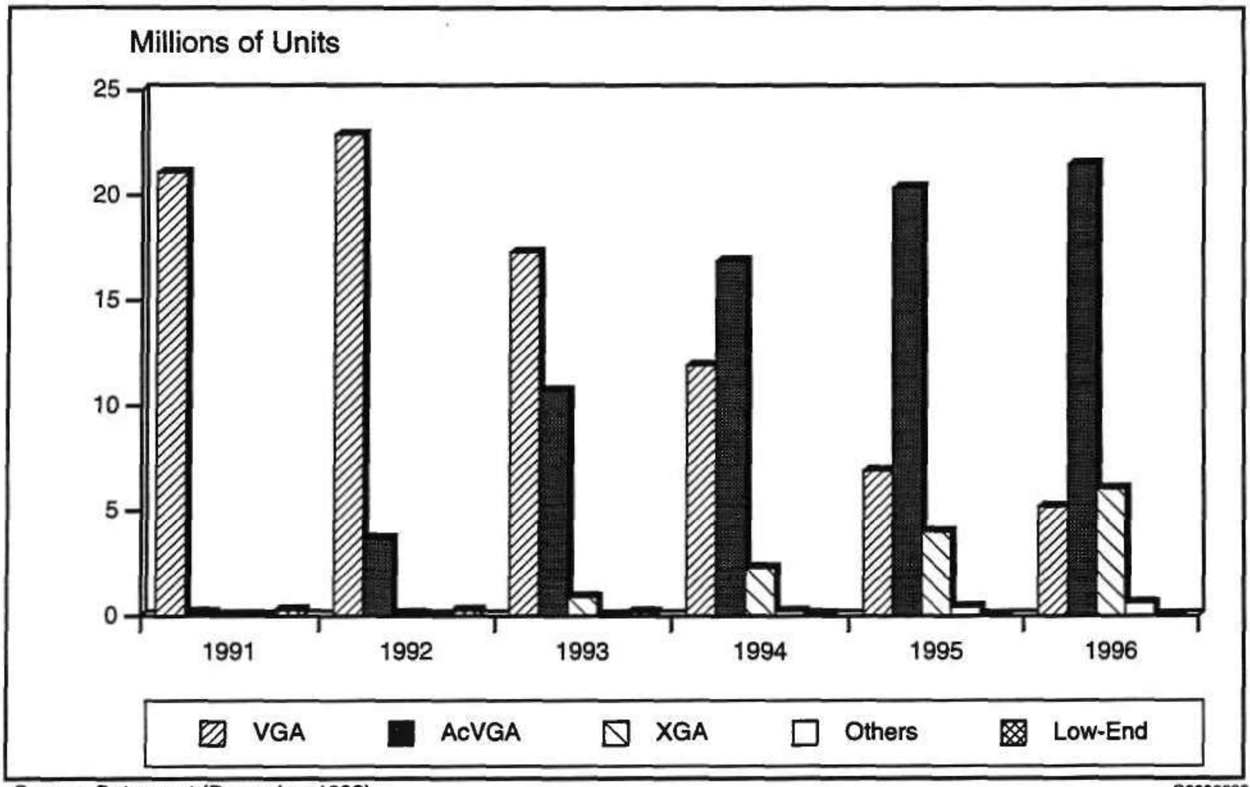
Headland Technology has drifted in and out of the mainstream graphics chip market over the last several years, focusing more or less on boards versus chips, depending on who was calling the shots. It seems that the company has made the decision to focus on graphics chips, as signified by announcement in August that the Video 7 brand and associated product line was sold to Computer Visualization (a new venture sprung from Spea Software). On the chip side, Headland's big introduction was the HT216 and 216-32 products announced in the second and third quarters, respectively. These are local bus VGA chips with wide resolution support, ISA and local bus support, respectively, and certain hardware assistance, including cursor store and color expansion.

SGS-Thomson continues to generate more noise than volume with its licensed IBM XGA offerings. However, the next 12 months could change things because new announcements from IBM are around the corner and could deliver the right architecture at the right time and the right price (though we expect this movement to be 12 months away).

Forecast and Assumptions

Graphics controllers are in a high-growth phase, with revenue expected to approach $1 billion by 1996 as a result of increased importance on the visual interface (see Figures 4-10 through 4-12 and Table 4-8). Demand is driven by the 80x86 PC market, which

Figure 4-10
Graphic Chip Market Forecast, Units



Source: Dataquest (December 1992)
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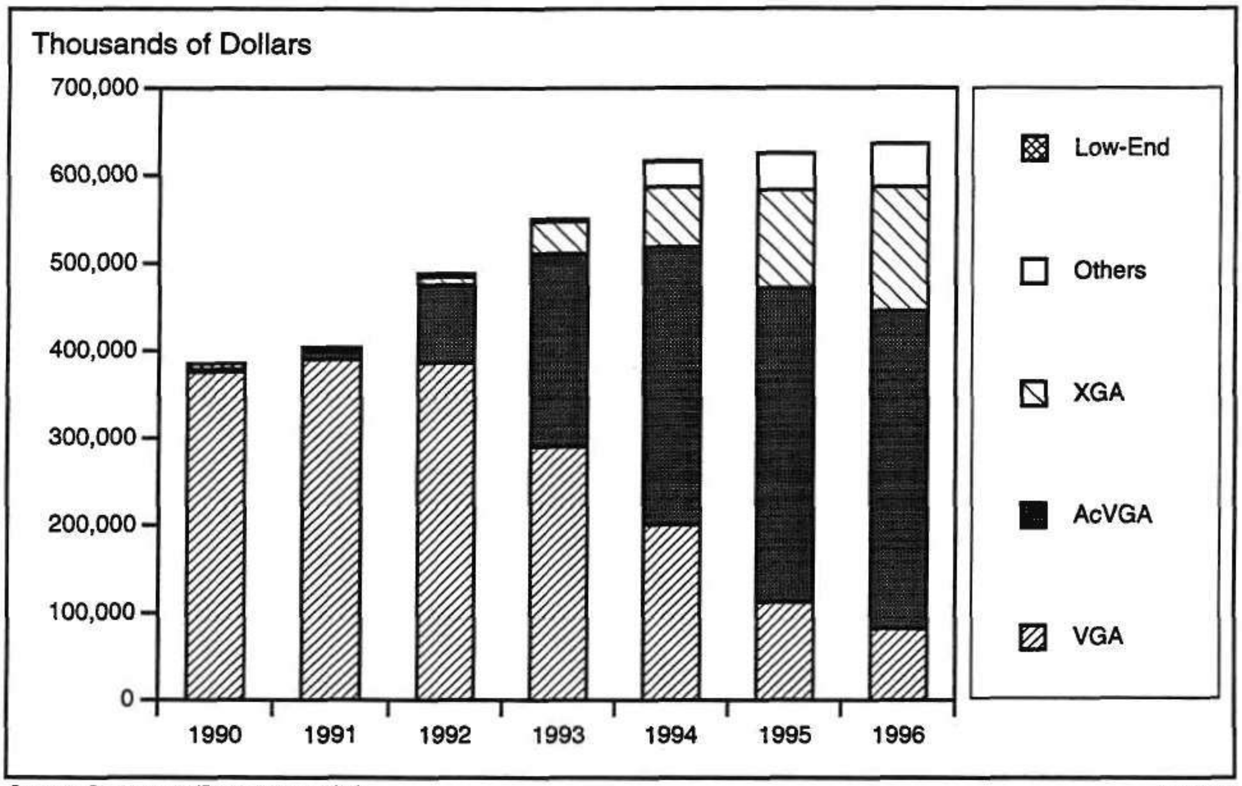
Figure 4-11
Graphic Chip Market Forecast, Revenue



Source: Dataquest (December 1992)

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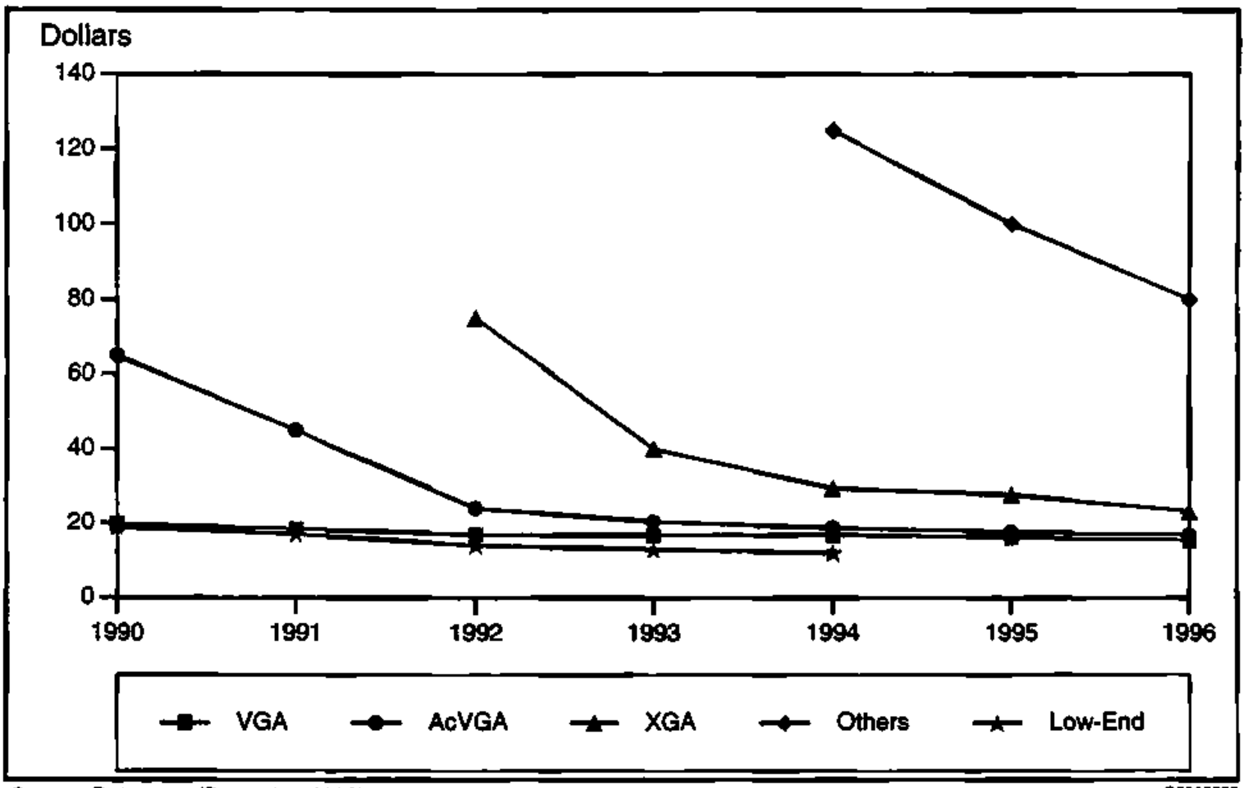
is affected by numerous factors. The primary factors affecting graphics growth are as follows:

- The application environment for PC users continues to move rapidly to Windows, creating a "software standard" that decreases the need for drivers (though they remain a key requirement).
- XGA-compatible controllers will continue to grow throughout the forecast period and will represent a significant but in no way dominant standard within PC graphics.
- Dramatic growth will continue within the portable PC market, specifically notebooks and laptops, which will drive flat-panel sales for the next several years.
- The basic PC engine will continue to become more powerful each year and will eventually present a threat of integration for graphics and decompression-processing functions.
- Resolution is being driven toward 1024 x 768 for mainstream use, which will in turn drive demand for greater performance and fuel the growth of the fixed-function controllers, AcVGA and XGA, which together will become dominant by 1993 for CRT and by 1995 for flat panel.

Figure 4-12
Graphic Chip Market Forecast, ASP



Source: Dataquest (December 1992)

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- Digital video technology will slowly start to find its way into more systems in the 1994 to 1995 time frame, which in turn will drive graphics controllers that accommodate motion video, with compression being the key enabler.
- The industry will begin moving more toward built-in motherboard graphics in both low-end (because of price) and high-end (because of performance attributed to wide, high-speed local-bus interface) systems.

Table 4-8
Graphic Chip Market Forecast, by Application

	1990	1991	1992	1993	1994	1995	1996
CRT/General Controllers							
Units (K)							
VGA	17,550	18,228	18,779	11,373	6,146	3,140	2,057
AcVGA	59	200	3,733	10,464	14,341	14,443	13,784
XGA	0	0	113	910	2,049	2,930	4,115
Others	0	0	0	0	228	419	617
Low-End	0	0	0	0	0	0	0
Total	17,609	18,428	22,626	22,747	22,763	20,931	20,573
ASP ($)							
VGA	18.00	16.00	14.00	12.00	11.00	10.50	10.00
AcVGA	65.00	45.00	24.00	20.00	17.00	15.00	14.00
XGA	95.00	95.00	75.00	40.00	28.00	25.00	20.00
Others	0	0	0	0	125.00	100.00	80.00
Low-End	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Average	18.16	16.31	15.96	16.80	17.45	17.43	16.78
Revenue ($K)							
VGA	315,897	291,650	262,911	136,481	67,607	32,967	20,573
AcVGA	3,835	9,000	89,598	209,271	243,795	216,638	192,975
XGA	0	0	8,485	36,395	57,364	73,259	82,292
Others	0	0	0	0	28,454	41,862	49,375
Low-End	0	0	0	0	0	0	0
Total	319,732	300,650	360,993	382,146	397,220	364,727	345,215

(Continued)

Table 4-8 (Continued)
Graphic Chip Market Forecast, by Application

	1990	1991	1992	1993	1994	1995	1996
Flat-Panel Controllers							
Units (K)							
VGA	1,500	2,900	4,126	5,937	5,814	3,793	3,241
AcVGA	0	0	0	322	2,645	5,961	7,778
XGA	0	0	0	0	265	1,084	1,944
Others	0	0	0	0	0	0	0
Low-End	300	300	270	189	95	0	0
Total	1,800	3,200	4,396	6,448	8,818	10,838	12,963
ASP ($)							
VGA	40.00	34.00	30.00	26.00	23.00	21.00	19.00
AcVGA	0	0	45.00	35.00	28.00	24.00	22.00
XGA	0	0	95.00	65.00	40.00	35.00	30.00
Others	0	0	0	0	0	0	0
Low-End	19.00	17.00	14.00	13.00	12.00	12.00	12.00
Average	36.50	32.41	29.02	26.07	24.89	24.05	22.45
Revenue ($K)							
VGA	60,000	98,600	123,785	154,362	133,713	79,657	61,573
AcVGA	0	0	0	11,285	74,072	143,058	171,108
XGA	0	0	0	0	10,582	37,932	58,332
Others	0	0	0	0	0	0	0
Low-End	5,700	5,100	3,780	2,457	1,134	0	0
Total	65,700	103,700	127,565	168,104	219,501	260,647	291,013

(Continued)

Table 4-8 (Continued)
Graphic Chip Market Forecast, by Application

	1990	1991	1992	1993	1994	1995	1996
Merchant Market Graphics Chips							
Totals, By Segment							
All Controllers							
Unit Shipments (K)							
VGA	19,050	21,128	22,905	17,310	11,960	6,933	5,298
AcVGA	59	200	3,733	10,786	16,986	20,403	21,562
XGA	0	0	113	910	2,313	4,014	6,059
Others	0	0	0	0	228	419	617
Low-End	300	300	270	189	95	0	0
Total	19,409	21,628	27,022	29,195	31,581	31,769	33,536
ASP ($)							
VGA	19.73	18.47	16.88	16.80	16.83	16.24	15.51
AcVGA	65.00	45.00	24.00	20.45	18.71	17.63	16.89
XGA	0	0	75.00	40.00	29.37	27.70	23.21
Others	0	0	0	0	125.00	100.00	80.00
Low-End	19.00	17.00	14.00	13.00	12.00	0	0
Average	19.86	18.70	18.08	18.85	19.53	19.69	18.97
Total Revenue ($K)							
VGA	375,897	390,250	386,695	290,843	201,320	112,624	82,146
AcVGA	3,835	9,000	89,598	220,555	317,867	359,696	364,083
XGA	0	0	8,485	36,395	67,945	111,191	140,624
Others	0	0	0	0	28,454	41,862	49,375
Low-End	5,700	5,100	3,780	2,457	1,134	0	0
Total	385,432	404,350	488,558	550,250	616,721	625,373	636,228
Other Graphics and Imaging Products							

(Continued)

Table 4-8 (Continued)
Graphic Chip Market Forecast, by Application

	1990	1991	1992	1993	1994	1995	1996
Units (K)	200	500	1,700	2,040	2,856	3,713	4,455
ASP ($)	225.00	175.00	150.00	112.50	95.63	81.28	69.09
Revenue ($K)	45,000	87,500	255,000	229,500	273,105	301,781	307,817
Total Graphics and Imaging							
Units (K)	19,609	22,128	28,722	31,235	34,437	35,482	37,991
ASP ($)	21.95	22.23	25.89	24.96	25.84	26.13	24.85
Revenue ($K)	430,432	491,850	743,558	779,750	889,826	927,154	944,045

Source: Dataquest (December 1992)

Communications Controllers

Communications controllers are divided between local area network (LAN) controllers and other communications controllers. LAN controllers are the focus of this analysis and include the communications standards designed to bring connectivity between computers and network resources, which includes Ethernet, Token-Ring, and other access methods. Other communications controllers include a variety of devices such as modems, ISDN interfaces, UARTs, and miscellaneous controllers.

Network controllers come in several flavors, with two major standards competing for dominance. They will be used in four major application segments, with various technical, marketing, and environmental factors affecting them. Unlike with most other computing features, the selection of a network interface is a centralized decision that is simply implemented at each desktop.

Dataquest defines a network controller as an integrated chip or chip set that provides all the media access control functions. This does not include transceiver chips, which are sold separately. For the purposes of analysis and forecasting, we have created three general categories of network controller, based on the media access method: Ethernet, Token-Ring, and others.

Ethernet controllers were first introduced in 1982 by AMD as a result of a joint technology pact with Digital Equipment Corporation. They have evolved to highly integrated chips that support the standard IEEE 802.3 interface specification. These controllers can be subcategorized into low-end and high-end chips, which correspond to 8/16-bit and 32-bit host interfaces, respectively. Because both generally support the full 10-Mbps Ethernet standard, the primary difference is in the system bus bandwidth consumed in supporting the transmission of information. Thus we find the 32-bit chips commonly used in workstations and servers and the 8/16 bit chips dominant for PC add-in cards. The leading vendors of Ethernet controller chips are National Semiconductor, AMD, Intel, and Fujitsu.

Token-Ring controllers were first developed by IBM and were further enhanced through joint development with Texas Instruments. They are also highly integrated chips supporting the standard IEEE 802.5 interface specification, but with a major twist. In order to be reliable, these controllers must also be compatible with the IBM implementation. At the time of this writing, the only verified sources are IBM (primarily captive), TI (cooperatively developed with IBM), and National (licensed from IBM). Token-Ring controllers and their transceivers can support either 4 Mbps or 16 Mbps, representing a slightly higher bandwidth capability than Ethernet.

The "other" category includes several standards and proprietary interfaces not considered as serious contenders for the mainstream standard race, including the following:

- AppleTalk: Apple interface standard built into all Macintosh computers except the high-end systems (Quadra), which have Ethernet.
- Arcnet: Supported by Standard Microsystems and represents a substantial number of installed systems.
- Fiber-distributed data interface (FDDI): Includes copper and twisted-pair versions and is on its way to becoming a standard. Because FDDI offers both high bandwidth and determinism (a token-passing scheme), it is being considered for all types of high-performance applications such as LAN backbones or dedicated workstation networks.

What is Dataquest's position regarding physical layer (cabling) methods? Dataquest concurs that unshielded twisted-pair (UTP) is becoming largely dominant because of lower costs with maintained bandwidths. Furthermore, widespread adoption of twisted-pair allows fully integrated single-chip network controllers, which decreases the cost and real-estate requirements, factors that are both crucial to moving onto PC motherboards.

Application Markets

The complexion of network controller applications will change quite dramatically during the next four to five years as complete office connectivity becomes a reality. In order to effectively study the driving forces and estimate market potential, we have segmented the network controller market into four primary applications:

- Desktop PCs
- Portables
- Workstations
- Network resources

The network controller market (in units) to date has been dominated by sales into desktop PC applications. The potential for each application segment is based on each application's total unit shipment forecast multiplied by the estimated network penetration. Network penetration is defined as the percentage of total units shipped that result in a network controller shipment, either built-in or optional add-in card.

Desktop PCs

Desktop PCs include all types of PCs (IBM-compatible and Apple, among others) and represent the use of network controller chips built directly on motherboards or as add-in cards. Though the forecast growth of desktop PCs is not extremely high through 1996, network penetration will increase dramatically. This is a direct result of the coming trend of standard built-in connectivity (network-ready) in the 80x86 PC arena being driven by the cost/benefit advantages of built-in network support. This evolutionary trend is quite similar to that of the graphics controller market in the late 1980s.

To date, most network controllers used in desktop PC applications have been sold as optional third-party add-in cards. The major exception to this is Apple, where AppleTalk has been included with every Macintosh since 1987. By connection standards, the desktop PC is currently 54 percent Ethernet, 23 percent Token-Ring, and 23 percent other (which is dominated by AppleTalk and Arcnet). Though current mainstream desktop PC end-user needs are relatively simple, nonperformance-critical, and cost-sensitive, this may change as multimedia applications take off.

Portable PCs

Portables includes all types of portable computers (laptops and hand-held, among others) and represents network controllers built directly on motherboards, as add-in cards (including tiny PCMCIA cards), or in docking stations. Portable computers are forecast to grow substantially during the next five years. Network penetration is also forecast to grow to about 35 percent by 1996, resulting in a total of 8 million units. This penetration will be driven by both PCMCIA-based network cards as well as the use of notebooks as a primary computer. The standards and driving forces for portables are expected to follow that of desktop PCs, with the addition of wireless connections that will become important in the 1994 to 1995 time frame.

Workstations

The workstation category includes technical workstations, X Window terminals, and other high-end systems and represents network controllers built directly on motherboards or as add-in cards. Workstations and X terminals are forecast to grow dramatically during this time frame. Assuming that network penetration remains at nearly 100 percent, this translates into direct unit growth to about 5 million units by 1996. This segment is almost exclusively standardized on Ethernet. However, Token-Ring is common as an optional installation and FDDI is expected to grow heavily.

Network Resources

Network resources include dedicated servers, hubs and repeaters, internetwork equipment (bridges and routers, among others), and network peripherals (printers, scanners, fax machines, and multimedia devices). Because these devices are services for networks, their growth is driven by the overall growth in networking nodes and the topology of networks. Network peripherals is anticipated to be one of the largest growth subsegments. We expect to see network interfaces as a standard feature on $1,000 laser printers as the cost to add them drops below $20. The standards mix within these devices is expected to track that of the overall network trends.

Moving toward Standardization

Within most companies, the choice of networking standard has been affected by political factors as much as technical factors. In some cases, it was driven by the dominance of mainframe and minicomputer vendors (primarily IBM and Digital) within the customer's environment, providing central network management to gain control of MIS decisions. In other cases, it was driven by the ease of a built-in connection method, such as AppleTalk for Macintoshes. The result has generally been a heterogeneous computing environment with multiple connectivity standards. These multiple standards are then bridged to form one integral network, often limited by its weakest link, and typically fraught with problems.

Our outlook is toward more uniformity in networking and a consolidation among standards. Based on the current needs of the mass market and industry momentum, Ethernet is expected to become integrated into 80x86 PCs in a similar fashion as the evolution of VGA graphics into 80x86 PCs during the last four years. The driving forces behind Ethernet becoming the dominant standard include the following:

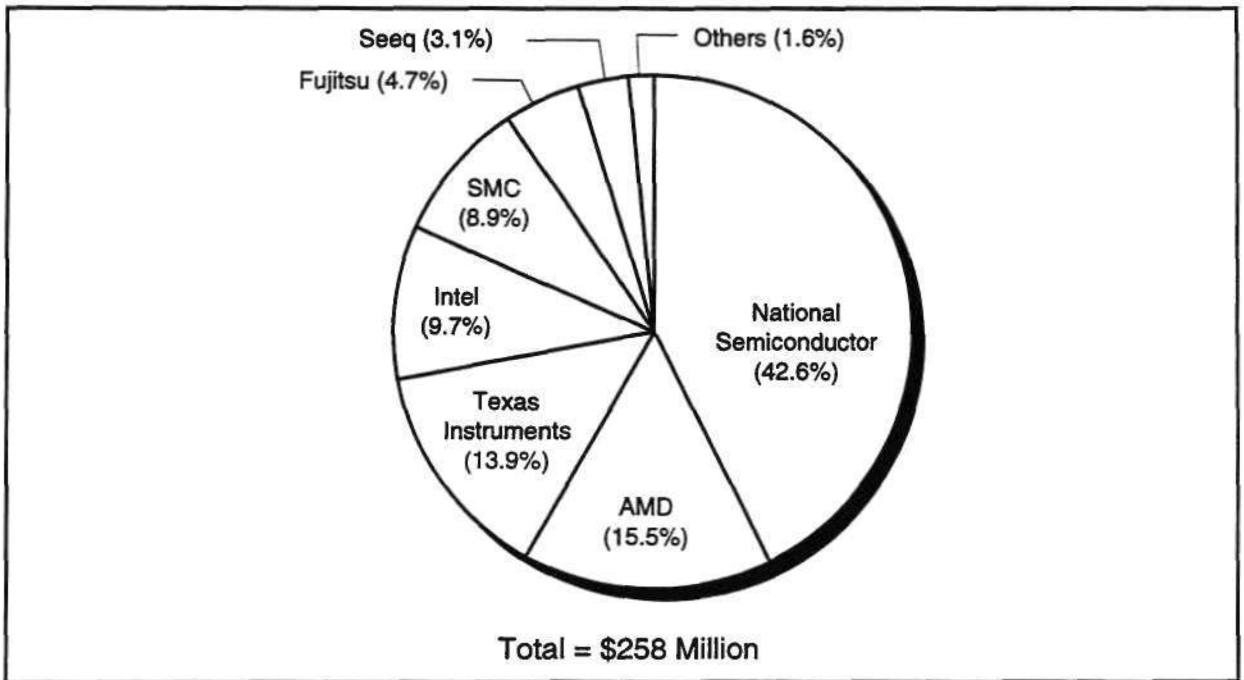
- Ethernet is the most-prolific, lowest-risk standard covering the largest quantity of installed networks.
- The driver support required is minimal where all the top chip suppliers support the primary network operating systems.
- The cost of embedding Ethernet with a twisted-pair interface is less $25; the size is less than 5 square inches.
- There is substantial growth in adoption of Ethernet as the mainstream 80x86 PC connectivity standard, including built-in motherboard use.
- The bulk of Token-Ring business is still captive (IBM), lessening the available merchant market. IBM does not have a sufficient share of the PC market to force Token-Ring as a connectivity standard.
- Most companies will prefer to consolidate the number of different networks used within their environment.
- Ethernet provides a satisfactory solution for mainstream connectivity at half the cost of Token-Ring solutions.
- Workstations will remain primarily Ethernet, except for a minor portion of Token-Ring and a growing portion of FDDI being used in performance-critical situations.
- Apple will move to Ethernet as a replacement standard for AppleTalk on Macintoshes intended for the office.

Competitive Positions and Analysis

From a chip supply viewpoint, Ethernet is supported by the largest number of vendors with much lower cost solutions than Token-Ring (see Figure 4-13 and Table 4-9). Perhaps even more significant than unit differences is the difference in merchant chip revenue—more than $200 million for Ethernet controllers and less than $40 million for Token-Ring controllers in 1991. This is because the large portion of Token-Ring shipments have been captive; IBM owned nearly 75 percent of the Token-Ring adapter market in 1991 and produces its own chips. The following paragraphs provide an overview of the merchant chip vendors involved.

National Semiconductor was by far the largest merchant vendor of network controllers and has expanded its offerings to one of the broadest product lines available. It is the dominant vendor of controller chips for PC add-in network cards, driving its position as the overwhelming leader in Ethernet unit volumes as well as revenue. It led the industry in integration, being the first vendor to offer an integrated single-chip Ethernet solution (St-NIC). In a joint development agreement established with IBM, it just introduced the first single-chip integrated Token-Ring chip with IBM compatibility. National also offers a two-chip FDDI solution with an integrated transceiver for twisted-pair. National has already stated its intention to offer asynchronous transfer mode-based products as a LAN solution. As part of the driving force to Ethernet on motherboard, National recently announced its AT/LANTIC single-chip controller with ISA bus interface and software configuration.

Figure 4-13
1991 Top 7 Companies' LAN Chip Market Share



Source: Dataquest (December 1992) G2002623

Table 4-9
LAN Chip Market Share

1991 Rank	Vendor	Revenue ($M)	Share (%)	Shipments (K)	Share (%)
Network Controller Market: All Segments					
Market Share, by Vendor: 1991					
1	National Semiconductor	110	43	3,500	51
2	AMD	40	16	900	13
3	Texas Instruments	36	14	600	9
4	Intel	25	10	550	8
5	SMC	23	9	700	10
6	Fujitsu	12	5	400	6
7	Seeq	8	3	150	2
	Others	4	2	120	2
	Total	258	100	6,920	100
Network Controller Market: Ethernet Segment					
Market Share, by Vendor: 1991					
1	National Semiconductor	110	52	3,500	58
2	AMD	40	19	900	15
3	Intel	25	12	550	9
4	SMC (ex W/D)	15	7	500	8
5	Fujitsu	12	6	400	7
6	Seeq	8	4	150	2
	Others	2	1	50	1
	Total	212	100	6,050	100

(Continued)

Table 4-9 (Continued)
LAN Chip Market Share

1991 Rank	Vendor	Revenue ($M)	Share (%)	Shipments (K)	Share (%)
Network Controller Market: Token-Ring					
Market Share, by Vendor: 1991					
1	Texas Instruments	36	100	600	100
2	National (Entered in 1992)	0	0	0	0
3	C & T (No Shipments in 1991)	0	0	0	0
4	IBM (All Captive in 1991)	0	0	0	0
	Others	0	0	0	0
	Total	36	100	600	100
Network Controller Market: Others Segment					
Market Share, by Vendor: 1991					
1	SMC (Arcnet)	8	80	200	74
	Others	2	20	70	26
	Total	10	100	270	100

Source: Dataquest (December 1992)

AMD is the next largest vendor, with about 16 percent of market revenue in 1991. AMD has been one of the strongest vendors in the high-performance Ethernet market with its Lance and Iliac chips, controlling more than 80 percent of the workstation market. Though not expected to offer a Token-Ring solution, it is also making a play to capture the FDDI market as it develops. Its most recent product introduction was the Am79C960 PCnet ISA device, designed for use on PC motherboards. This new product offers an Ethernet solution that can be implemented for less than $25, including bus master architecture and no local buffer memories.

Until this year, Texas Instruments was the single-volume vendor of merchant Token-Ring controllers, achieving $36 million in revenue in 1991. Its TMS380 series of Token-Ring chip sets has been the de facto standard used by PC add-in board vendors and workstations manufacturers and was the first to offer 16-Mbps-level support. This year, TI took a major step forward and introduced a new dual-protocol chip, the TMS380C26, servicing interfaces to either Token-Ring or Ethernet networks.

Intel, present in nearly every segment of microperipherals, is the fourth largest vendor of network controllers and is growing fast. Having focused on high-end PCs and servers with its 82596, Intel has augmented its growth through its captive business with the Intel Lan Adapter product line sold at retail. However, growth is likely to come from its new integrated Ethernet controller designed as a PC motherboard solution. To date, Intel has only offered Ethernet network chips, but it rounds out its communications product line by being one of the top vendors of integrated fax/modem chips.

Standard Microsystems grew its network controller business with a low-cost, proprietary network solution called Arcnet. Then, in late 1990, it expanded its product line by acquiring the Ethernet controller line from Western Digital. This year it took a further step and offers a Token-Ring solution it claims was completely developed internally.

Fujitsu Microelectronics' APD division is based in San Jose, California and is focused on LAN controllers and RISC processors (SPARC-compatibles). Its LAN offerings are focused on low-cost Ethernet solutions, with some of its transceiver technology jointly developed with Level One. Attempting to gain volume sales into the PC market, Fujitsu has introduced integrated Ethernet controllers as well as an Ethernet PCMCIA card for the portable market.

Several other vendors offer significant LAN controller solutions that have not achieved dramatic market shares. Seeq has been active for many years in the network controller business, focused on advanced Ethernet controllers, mainly for high-end applications. Chips & Technologies entered the market in late 1991 with a dual-protocol Token-Ring/Ethernet chip set that never took off and is now offering a low-end Ethernet chip set to go after the PC motherboard business. NCR has been a low-level participant in the Ethernet controller market and became more active this year with the acquisition of marketing rights to a line of products developed by Winbond, a Taiwanese semiconductor company.

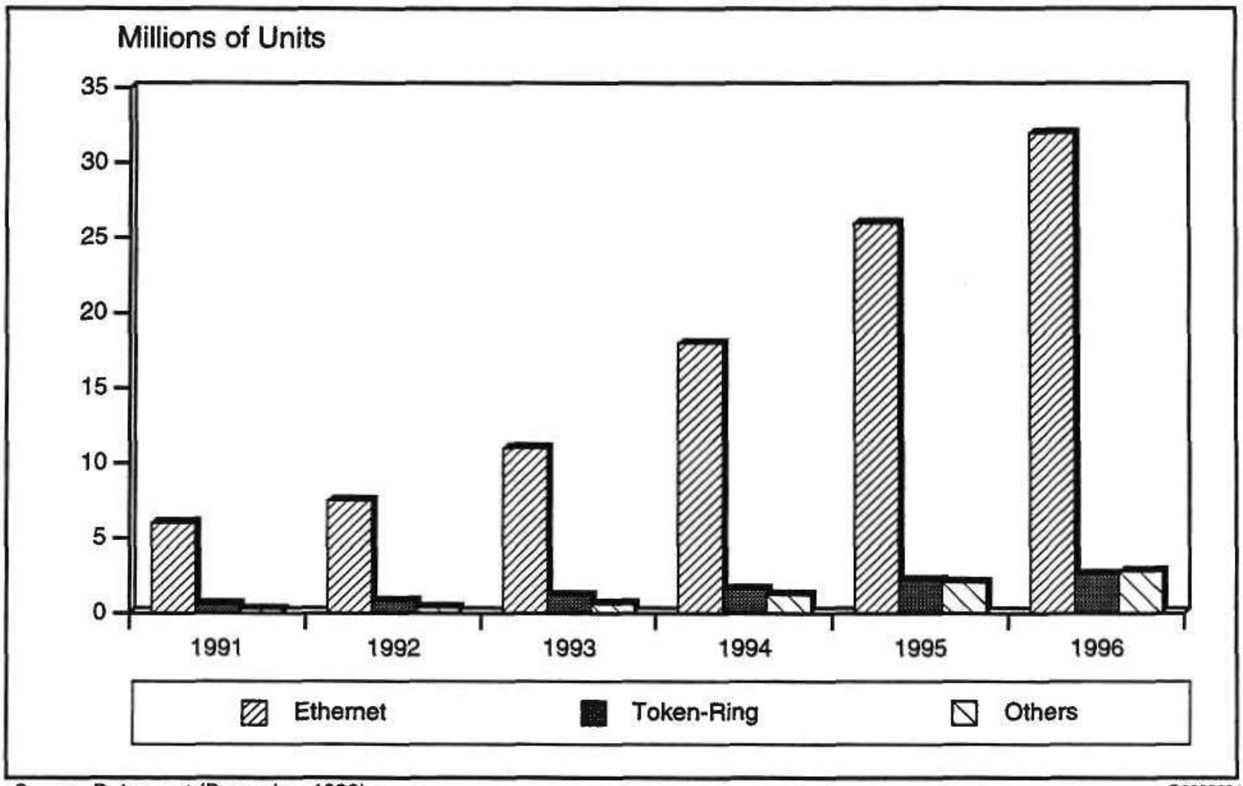
Forecast and Assumptions

As a result of this analysis, Dataquest is forecasting the network controller merchant chip market to more than double in size over the next five years. Figures 4-14 through 4-16 and Table 4-10 summarize this growth, depicting the growth from about $257 million in 1991 to $678 million in 1995. Because of the decreasing ASPs for controller chips, compound revenue growth is about half that of shipment growth, which is shown to grow from just under 7 million units in 1991 to more than 37 million units by 1996.

Dataquest has made the following observations:

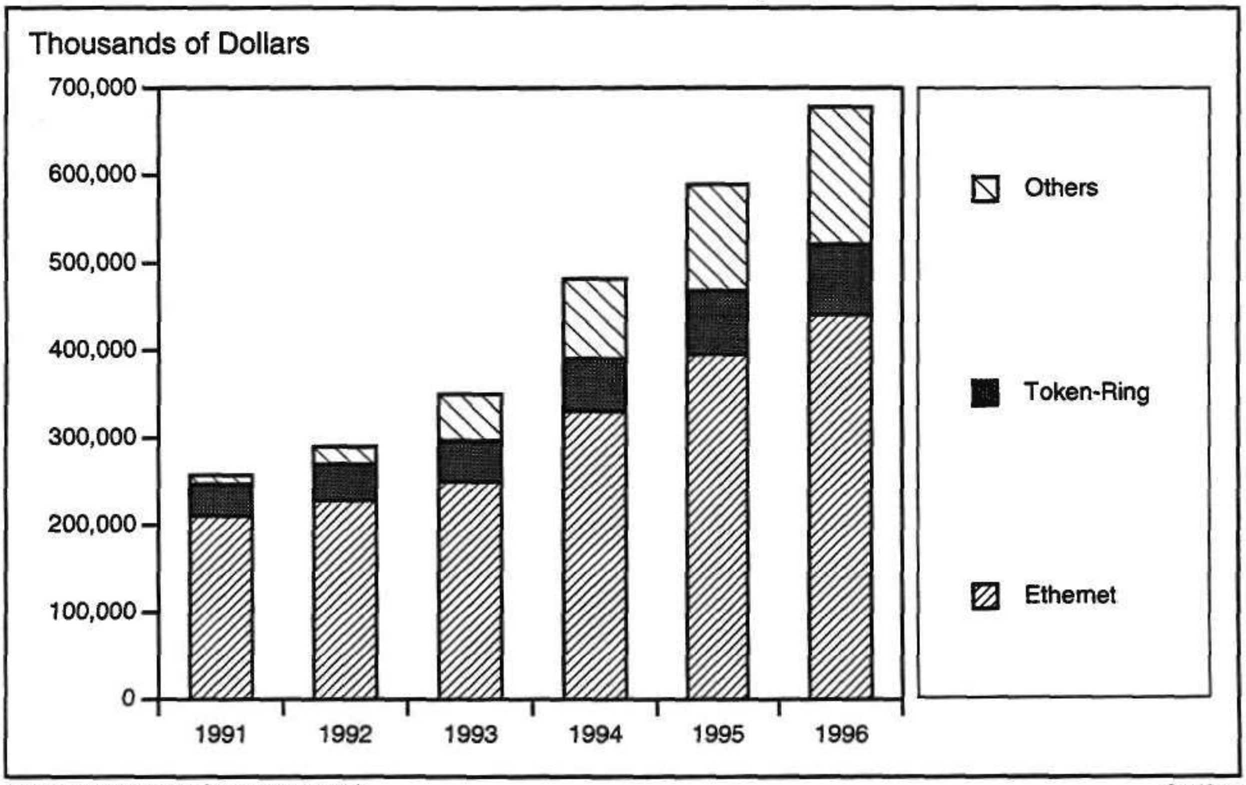
- The trend toward motherboard network solutions in 80x86 PCs will drive network penetration in desktop PCs from 48 percent in 1991 to 85 percent in 1996, which yields 21.9 million units.

Figure 4-14
Network Chip Market Forecast, Units



Source: Dataquest (December 1992)
G2002624

Figure 4-15
Network Chip Market Forecast, Revenue

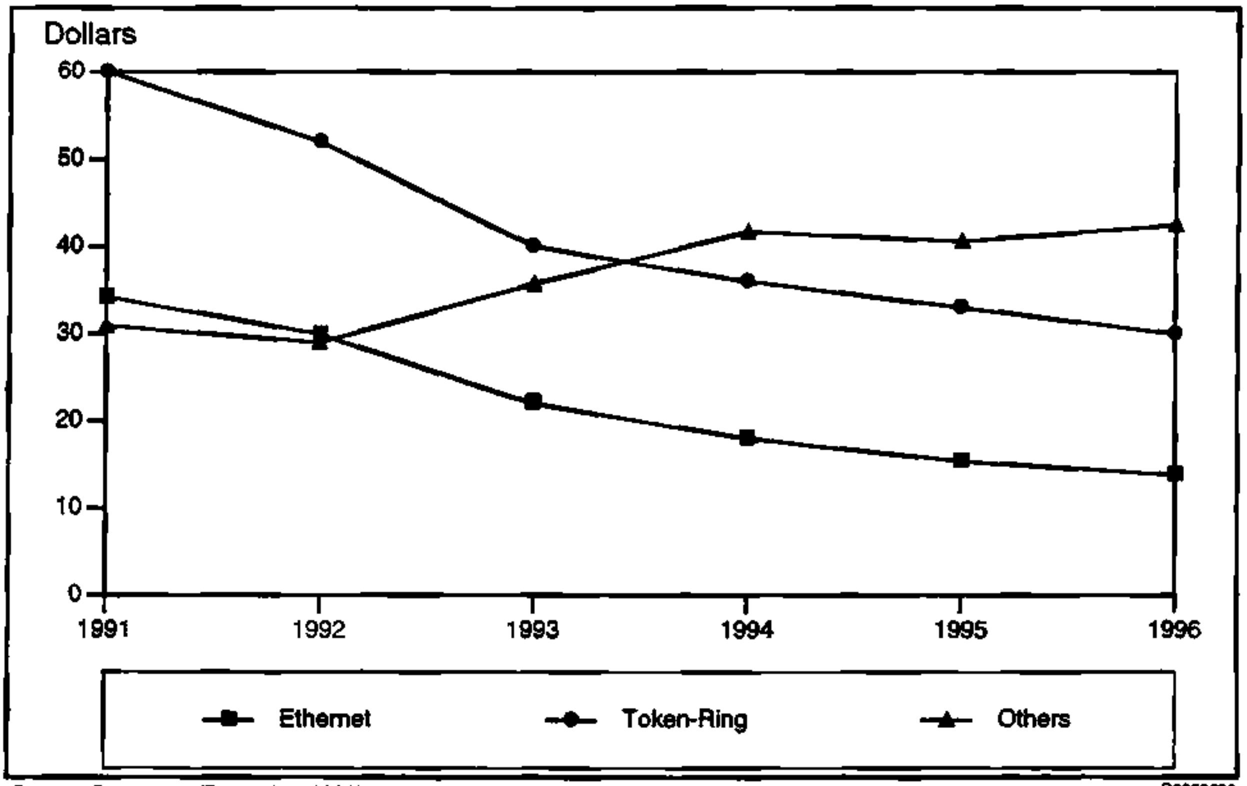


Source: Dataquest (December 1992)

G2002625

- Ethernet, driven by the desire for homogeneous networks and the movement toward network-ready 80x86 PCs, will become the dominant standard for mainstream connectivity, accounting for 77 percent of all nodes in 1996.
- Token-Ring will remain a sizable standard but will slowly decay as a percentage of shipments, being relegated to networks where IBM dominates or systems offering dual protocols.
- Dual-protocol controllers will be too costly to build onto motherboards (except workstations) or to replace standalone Ethernet controllers, but will be attractive to replace Token-Ring adapters.
- FDDI (part of "other") will begin to gain a foothold in the market beginning in 1993, when technology will be proven, costs will be lower, and demands large enough to profitably market products. FDDI will continue to become the high-end standard where high bandwidth and/or determinism are essential.

Figure 4-16
Network Chip Market Forecast, ASP



Source: Dataquest (December 1992)
G2002626

- All other standards (AppleTalk and Arcnet, among others) will decay to minor proportions by 1996 (each less than 5 percent).
- ASPs of Ethernet controllers will drop dramatically over the next two years as a result of focus on PC motherboard designs, which will drive the overall ASP of network controllers.
- The modem/other segment of the communications controller market will continue to grow, doubling in size over five years.

Table 4-10
Network Chip Market Forecast

	1990*	1991	1992	1993	1994	1995	1996
Unit Shipments, by Segment (K)							
Ethernet		6,020	7,540	11,260	18,304	25,708	31,929
Token-Ring		608	800	1,194	1,671	2,218	2,678
Others		273	395	629	1,232	2,087	2,896
Total Shipments		6,901	8,736	13,084	21,207	30,012	37,504
Revenue, by Segment ($K)							
Ethernet		210,199	228,142	249,229	330,476	395,288	441,026
Token-Ring		36,479	41,624	47,770	60,155	73,198	80,343
Others		10,423	20,262	52,902	91,067	120,694	156,555
Total Revenue ($K)		257,101	290,029	349,901	481,698	589,180	677,924
ASP, by Segment ($)							
Ethernet		34	30	22	18	15	14
Token-Ring		60	52	40	36	33	30
Others		31	29	36	42	41	42
	1990*	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
Communications Controllers Market Forecast: 1992							
Network Controllers							
Units (K)	5,500	6,901	8,736	13,084	21,207	30,012	37,504
ASP ($)	41.00	37.25	33.20	26.74	22.71	19.63	18.08
Revenue ($K)	225,500	257,101	290,029	349,901	481,698	589,180	677,924
Modems/Others							
Units (K)	40,000	50,000	60,000	69,000	75,900	83,490	91,839
ASP ($)	6	5	5	5	5	4	4
Revenue ($K)	240,000	270,000	318,000	329,130	343,941	359,418	375,592
Total							
Units (K)	45,500	56,901	68,736	82,084	97,107	113,502	129,343
ASP ($)	10	9	9	8	9	8	8
Revenue ($K)	465,500	527,101	608,029	679,031	825,638	948,598	1,053,516

*1990 figures estimated from different sources.
Source: Dataquest (December 1992)

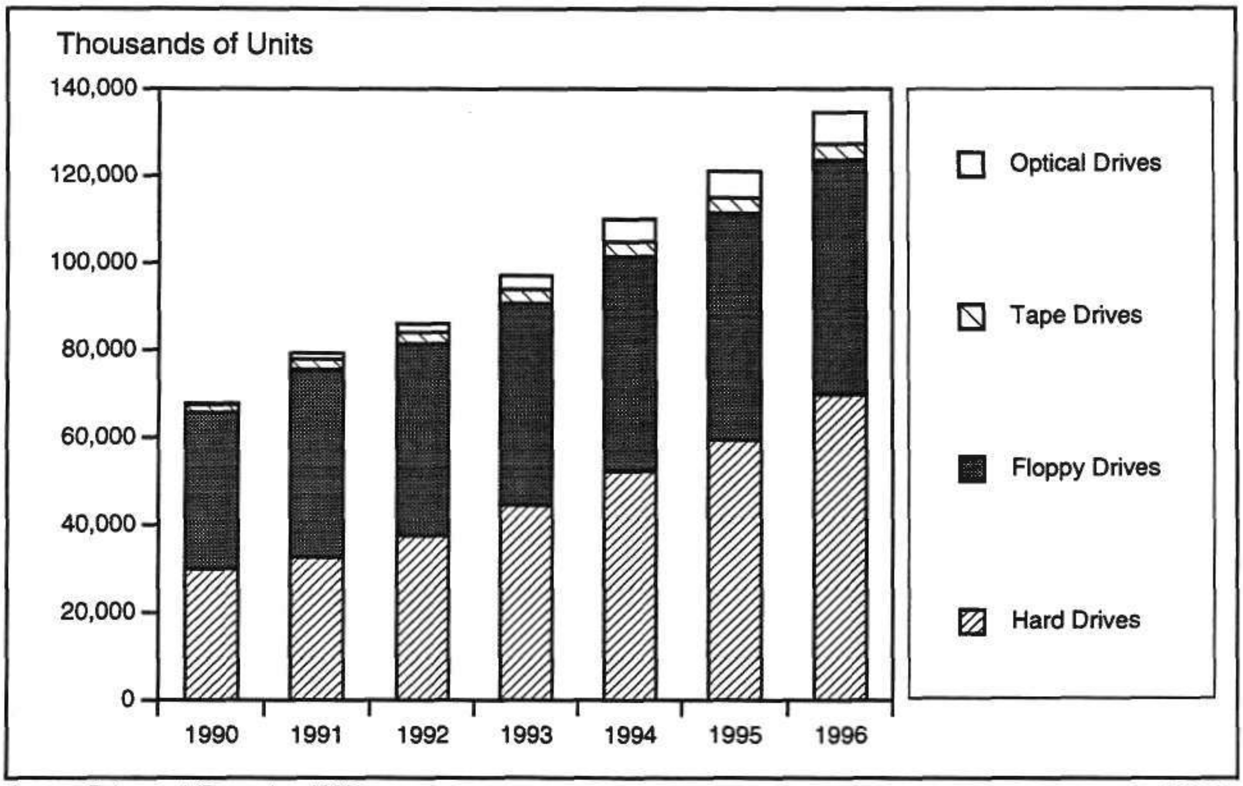
Mass Storage Controllers

Mass storage controllers have become a sizable segment of microperipherals, accounting for more than $400 million dollars in 1991. Two primary markets exist for mass storage controller chips, the device-side or peripherals (also called target systems) such as hard disk drives, CD-ROMs, and scanners, among others, and the host-side (also called host/initiator systems) such as PCs and workstations. The device-side market is dominated by hard disk drives, which in turn is dominated by seven large companies: Conner Peripherals, Seagate Technology, Maxtor, HP, IBM, Quantum, and Micropolis. The host-side market is dominated by the 80x86 PCs, the Macintosh platform, and to a lesser extent technical workstations.

Device-Side Applications

Mass storage controller applications can be segmented by mass storage device types, each of which requires a controller on the device and one within the host system as well. All of the basic mass storage drive market shows continued growth over the forecast period (see Figure 4-17), and each basic type of storage device has its own host interface standards that it adheres to. The major exception to this is the SCSI interface, which is becoming a pervasive standard across all segments, requiring only a single host

Figure 4-17
Mass Storage Market Forecast, Shipments



Source: Dataquest (December 1992)

G2002627

controller (which accommodates up to eight devices). The basic mass storage device segments and their standards are as follows (battles among differing standards is most pronounced within the hard disk drive segment, which will be analyzed in further detail in the sections that follow):

- Hard disk drives: Controller standards are divided between integrated device electronics (IDE) (which is used with the bulk of IBM-compatible PCs), SCSI (used on all types of platforms), and a small portion of "other" (mainly the electronic storage device interface, or ESDI).
- Floppy disk drives: The de facto controller standard is the old NEC 765-based interface (5-1/4-inch and 3-1/2-inch devices), except for high-density floppies (Bournolli, Insite) that use SCSI.
- Tape drives: These are dominated by 1/4-inch cartridges and use a mixture of floppy-disk controllers, QIC-02 interfaces, SCSI, and others.
- Optical drives: These are dominated by CD-ROMs; almost all devices including WORM drives and jukeboxes use SCSI as the interface standard.

Hard disk drive electronics can be divided into three essential blocks: the digital control block, the motor drive circuits, and the read/write circuits. Industry efforts are under way to develop highly integrated components for each area to lower total cost, reduce real estate, and improve features. Though additional efforts are under way to utilize DSPs in place of many analog components, the greatest focus is on the digital controller block, which comprises the microcontroller (commonly Motorola's 68HC11, Intel's 8051/80196, National's HPC+, and Zilog's Z8), the host interface controller, data buffer memory, and drive interface logic.

The host interface controller is the focal point of competition between the two primary competing standards, IDE and SCSI. SCSI is a universal peripheral interface standard encompassing all forms of mass storage devices as well as peripherals and as such is covered under a separate section. On the other hand, IDE is used exclusively for hard disk drives, specifically for the 80x86-compatible PC systems. Its use was first popularized by Cirrus and Conner and became the de facto PC standard hard disk interface for both desktop and portables. As a standard, it is used only internal to the host PC system, supports only hard disk drives (only two per controller with maximum of 512MB each), and allows transfer rates up to 8 MB/sec. Its host-side control comes built-in with most modern core-logic PC chip sets and with the Intel SL microprocessor architecture. For these applications it offers adequate performance and the lowest cost approach for both host-side and drive-side implementations, which to date have maintained momentum against the encroachment of SCSI drives.

In addition to the standards competition, efforts are under way to integrate the complete digital control block into one or two components. However, integrating the microcontroller would affect the firmware used and would pose a barrier to entry within many accounts. Dataquest expects to see several types of integrated products introduced in 1993 based on the starting point for a given vendor. Thus this represents both an opportunity for controller vendors to integrate surrounding functions on-chip, as well as a threat from microcontroller vendors that will integrate the host interface on chip. Furthermore, we expect to see new entrants appear with novel approaches that take advantage of the opportunity to gain new design wins as the industry transitions.

Host-Side Applications

The standard being employed for the hard disk mass storage controller devices (host interfaces) depends on the target platform, which fall into the following situations:

- Desktop 80x86 PCs: Dominated by IDE (greater than 95 percent by volume) because of historical usage and economics (IDE comes built-in with most PC core logic chip sets); SCSI (primarily used for greater than 200MB drives) is beginning to gain momentum, driven by the use of high-speed/high-capacity drives, CD-ROMs, and key vendors (such as IBM's use within the PS/2 family).
- Portable 80x86 PCs: Like their desktop counterparts, these are almost all IDE because of the same historical and economic reasons in addition to power dissipation (SCSI requires terminations: 48 milliamps on 18 signals). However, SCSI is starting to be used for docking station connection or for support of multiple device types. For some devices, the PCMCIA standard is even being considered for use.
- Macintosh PCs: Apple was one of the early adopters of the SCSI standard (in 1984) and now uses SCSI as the primary device interface in all of its Macintosh models, including the Powerbook series of portables.
- Workstations: Nearly all vendors of technical workstations (including Sun, IBM, HP, and Digital) have standardized on the use of SCSI as the standard mass storage device interface.
- Midrange and others: Because many of the major workstation vendors are also dominant vendors of midrange systems (IBM, HP, and Digital, among others), it is not surprising that the SCSI standard dominates here for some 75 to 80 percent of the unit volume.

SCSI Standard Overview

SCSI is a fast, intelligent, multitasking I/O channel that can connect multiple peripheral devices to a host computer. SCSI was not necessary until the advent of high-performance workstations and PCs using multiple types of mass storage and peripheral devices such as high-capacity rigid drives, CD-ROM drives, and tape units. The SCSI approach has been around since the early 1980s, developed by Shugart Associates (initially called SASI) and then NCR until it was assigned an ANSI name (SCSI) and working group in 1982. It allows up to eight peripherals to be connected simultaneously, thus enabling systems to consolidate all mass storage and peripheral devices onto one bus. The range of SCSI transfer rates exceeds that of standard serial, parallel, or IDE buses so that newer high-capacity disks and high-bandwidth peripherals may be used. Thus far, because SCSI is not a universal standard within operating systems, drivers must be installed for its use.

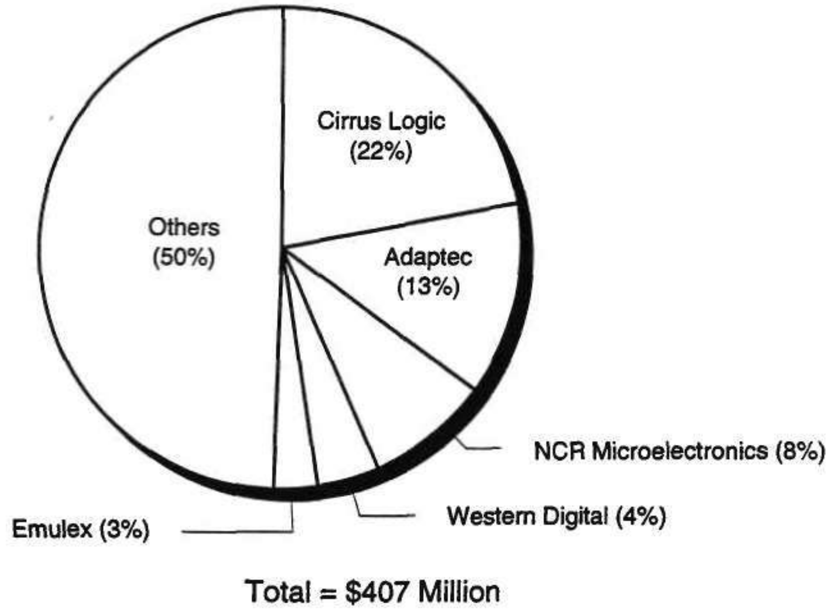
The first commercial SCSI protocol chip was introduced in 1983 (NCR 5385), which began a long series of industry products. Momentum picked up in 1984 when Apple adopted the SCSI approach for the Macintosh. However, it was not until 1986 that ANSI formally approved the SCSI standard (now SCSI-1). Formal approval for the second-generation standard (SCSI-2) began in 1989 with its formal adoption due anytime (end of year 1992). Meanwhile, work has already begun for a third-generation standard (SCSI-3). The basic features of each generation are as follows:

- SCSI-1: Offers 8-bit interface bus, 5- to 10-MB/sec (asynchronous versus synchronous) transfer rates, and features a relatively robust command set primarily focused on mass storage devices. SCSI-1 costs nearly the same as the IDE approach, has sufficient performance for nearly all but fast hard disks, and is the current standard employed by the Macintosh.
- SCSI-2: Offers 8-bit or 16-bit (wide) interface buses, 5- to 40-MB/sec transfer rates, and features an expanded command set (including command queuing) aimed at accommodating full support of CD-ROM, scanners, communications devices, and others. SCSI-2 costs slightly more to implement than SCSI-1 ($5 range), is required for high-performance hard disks, offers the widest device type support (all DAT, most optical, arrays, and scanners), and is standard now on most workstations.
- SCSI-3: Offers a new 16-bit cable option (P cable), transfer rates in excess of current standards, and features a new SCSI interlocked protocol (SIP) option as well as the ability to support dual-porting. SCSI-3 features have begun to appear in new products and are expected to take shape in the form of a fiber-optic interface to eliminate transmission length problems.

Competitive Positions and Analysis

The market share distribution presented in Figure 4-18 and Table 4-11, as well as the competitive discussions, reflect only the detailed vendor data for the SCSI and IDE subsegments. Based solely on these subsegments, the competitive field was dominated in 1991 by Cirrus Logic, turning in a combined total of $90 million primarily because of revenue from the IDE subsegment. All other major vendors—Adaptec, NCR, Western Digital, and Emulex—gained their positions primarily from SCSI revenue. Each vendor and its position is described in the following paragraphs.

Figure 4-18
1991 Top 5 Companies' Mass Storage Market Share



Source: Dataquest (December 1992) G2002628

Cirrus is the largest overall vendor in mass storage controllers, with a total 1991 revenue base of $172 million. Mass storage controllers represent more than 60 percent.

Cirrus was the first company to develop high-integration mass storage controllers to enable disk drive electronics to be placed directly onto the hard drive. As a result, it became the leading supplier of the IDE standard. It also has a secondary but growing position in SCSI controllers and acquired Crystal Semiconductor last year to gain access to mixed-signal technology for use in disk analog integration. Major customers for Cirrus include Conner Peripherals (30 percent of its 1991 revenue), Maxtor (new MXT-54 3 1/2-inch drive), HP (the new 1.3-inch drive uses a custom Cirrus chip), Seagate, and NEC.

Adaptec is a broad line supplier of SCSI and other peripheral control products for OEM and peripheral manufacturers. Key historical milestones include the first programmable controller chip (1983), the first multitasking AT-to-SCSI host adapter (1987), and the first single-chip disk controller (1989). It is the dominant vendor of SCSI PC host adapters (but not host controllers) and SCSI development systems including software tools. Major customers for Adaptec include HP, Digital, Conner Peripherals, Seagate, Maxtor, Hitachi, Quantum, Grid, and Apple (printers). Adaptec has been active in

Table 4-11
Mass Storage Market Share Forecast

1991 Rank	Vendor	Revenue ($K)	Share (%)	Shipments (K)	Share (%)	ASP ($ Est.)
Mass Storage Controllers: All Segments						
Market Share, by Vendor: 1991						
1	Cirrus Logic	90,000	22	11,500	18	7.83
2	Adaptec	52,000	22	6,300	10	8.25
3	NCR Microelectronics	34,000	8	3,700	6	9.19
4	Western Digital	17,000	4	1,900	3	8.95
5	Emulex	12,000	3	1,300	2	9.23
	Others	202,000	50	40,700	62	4.96
	Total	407,000	100	65,400	100	6.22
Mass Storage Controllers: SCSI Segment						
Market Share, by Vendor: 1991						
1	NCR	34,000	26	3,700	25	9.19
2	Adaptec	27,000	21	3,100	21	8.71
3	Cirrus Logic	19,000	15	2,100	14	9.05
4	Western Digital	17,000	13	1,900	13	8.95
5	Emulex	12,000	9	1,300	9	9.23
	Others	20,000	16	2,800	19	7.14
	Total	129,000	100	14,900	100	8.66
Mass Storage Controllers: IDE Segment						
Market Share, by Vendor: 1991						
1	Cirrus Logic (Including Accumos)	71,000	49	9,400	48	7.55
2	Adaptec	25,000	17	3,200	16	7.81
	Others	50,000	34	7,000	36	7.14
	Total	146,000	100	19,600	100	7.45

Source: Dataquest (December 1992)

SCSI development over the last 12 months, which included the following key events:

- In late 1991, Adaptec introduced a SCSI printer controller that allows high-speed transfers (full pages in 1.2 seconds) and entered into an agreement with Apple to design a laser printer controller for the Personal Laserwriter NTR (March).
- It won a SCSI host adapter order with Sanyo for a pen-based computer (April).
- It began codevelopment with IBM for incorporating SCSI as a direct access storage device (DASD) within OS/2 (January).
- It announced its new design toolkit for SCSI software development (January).
- It announced the availability of embedded drivers within SCO UNIX 4.0 (January).

NCR was one of the early pioneers of SCSI technology and had a pivotal role in establishing the SCSI standard. NCR continued its efforts and introduced the first commercial chip product compatible with the SCSI standard. Now, NCR manufactures one of the broadest SCSI product lines including chips, boards, and system-level products. The NCR 53C7X0 family of chips is generally acknowledged to be the highest-performance host chip because of its 2-mips processor on chip, which minimizes host interrupts. NCR continues to invest heavily in SCSI technology development for both standalone SCSI controllers and integrated Core Logic. Major customers for NCR include Apple, Sun, Seagate, and Conner. Among other developments, NCR announced a strategic marketing arrangement with Corel Systems to exclusively use NCR products in its CorelSCSI kits.

Western Digital is a medium-size, vertically integrated company with a captive hard disk drive business. It manufactures a limited line of hard disk controller chips with an external focus on SCSI chips, the bulk of which are consumed by IBM for its disk drive manufacturing. It is also a leading vendor of floppy disk controller chips.

Emulex is a small manufacturer of high-performance storage and networking products with special emphasis on Digital-compatible products and high-end drives. Its mass storage products are focused on SCSI host-side applications at both chip and board levels. It reputedly receives some of its host-side SCSI chips from NCR.

Fujitsu has a small SCSI product offering that has had limited market success to date. Its primary usage has been in SPARC-compatible systems that use the Fujitsu SPARC processors. It has been strengthening its line, having added in late 1991 the 8660X series with a small MPU on-chip (similar to the NCR 53C7X0).

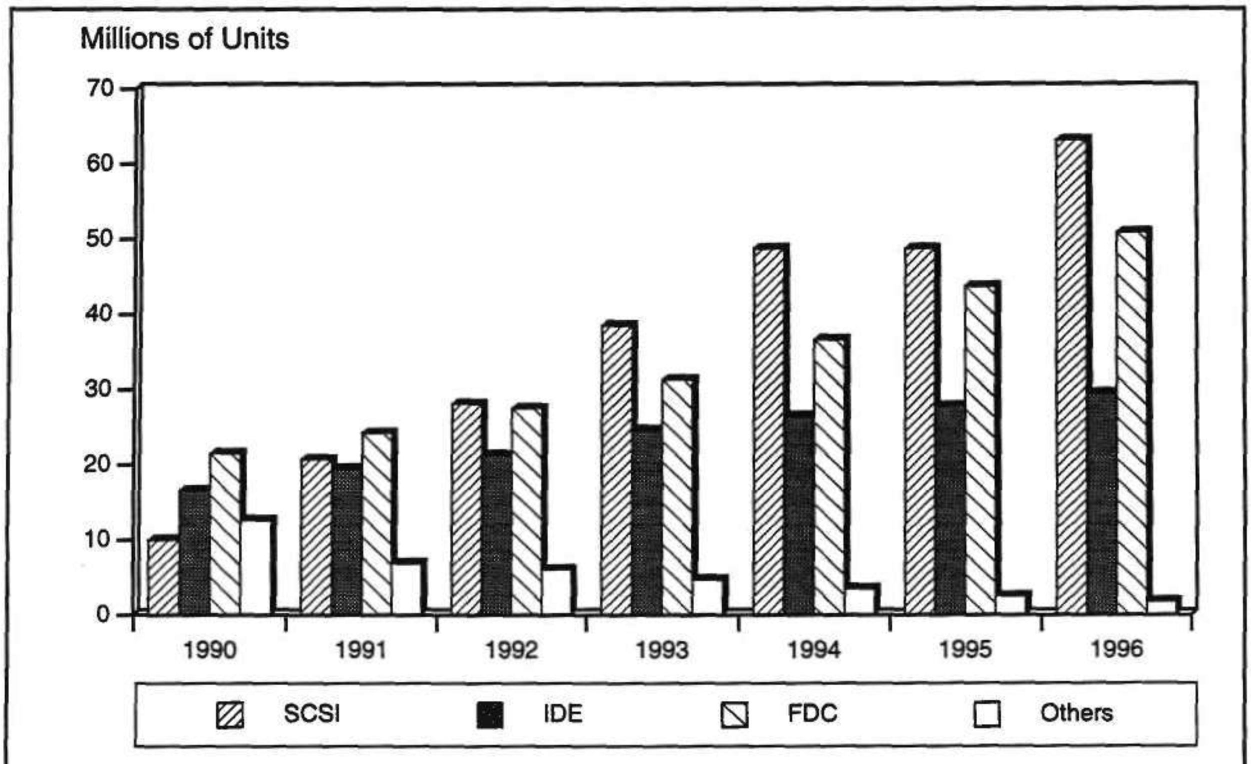
NEC was the largest semiconductor company in the world in 1991 and has a broad overall line of mass storage controllers. It is a small player in both floppy disk controller chips and SCSI controller chips. NEC developed the uPD765 FDC, the industry-standard LSI floppy disk controller (FDC) chip that contains the circuits for interfacing a host system to four floppy drives and supports either FM or MFM formats. NEC is strong in the Japanese market and relatively weak in the U.S. market.

Three additional vendors are noteworthy for their potential to affect the host-side mass storage controller market. Intel offers a selection of mass storage chip sets, including the 8272A and 82077 (introduced in 1990 FDCs) and the 82064, an older PC AT hard disk controller compatible with the WD2010. Chips & Technologies offers a fair selection of floppy and hard disk controllers, primarily for the host-side and with limited market success. AMD offers some SCSI controllers that it licenses from both NCR and Western Digital, also with limited market success.

Forecast and Assumptions

The mass storage controller market is projected to maintain strong growth over the forecast period, almost doubling by 1996 (see Figures 4-19 through 4-21 and Table 4-12). Driven by relentless

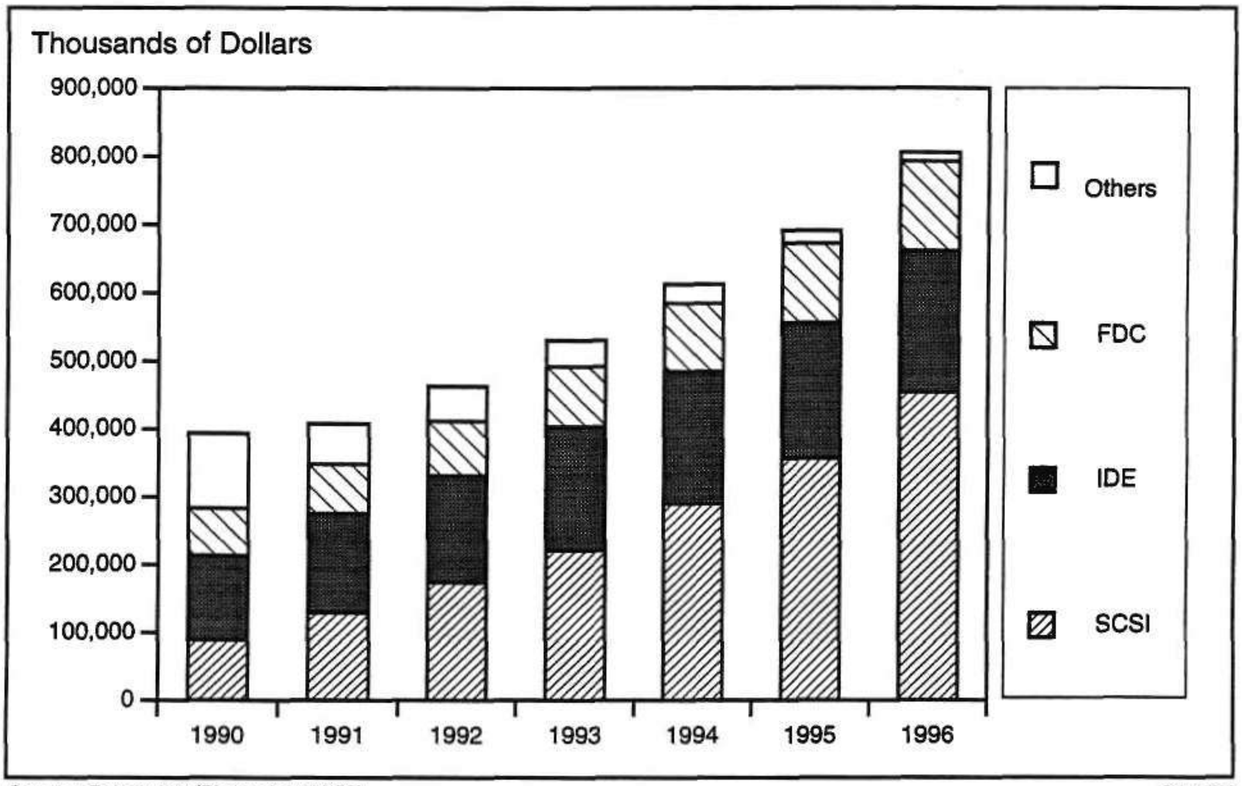
Figure 4-19
Mass Storage Controller Market Forecast, Units



Source: Dataquest (December 1992)

G2002629

Figure 4-20
Mass Storage Controller Market Forecast, Revenue



Source: Dataquest (December 1992)

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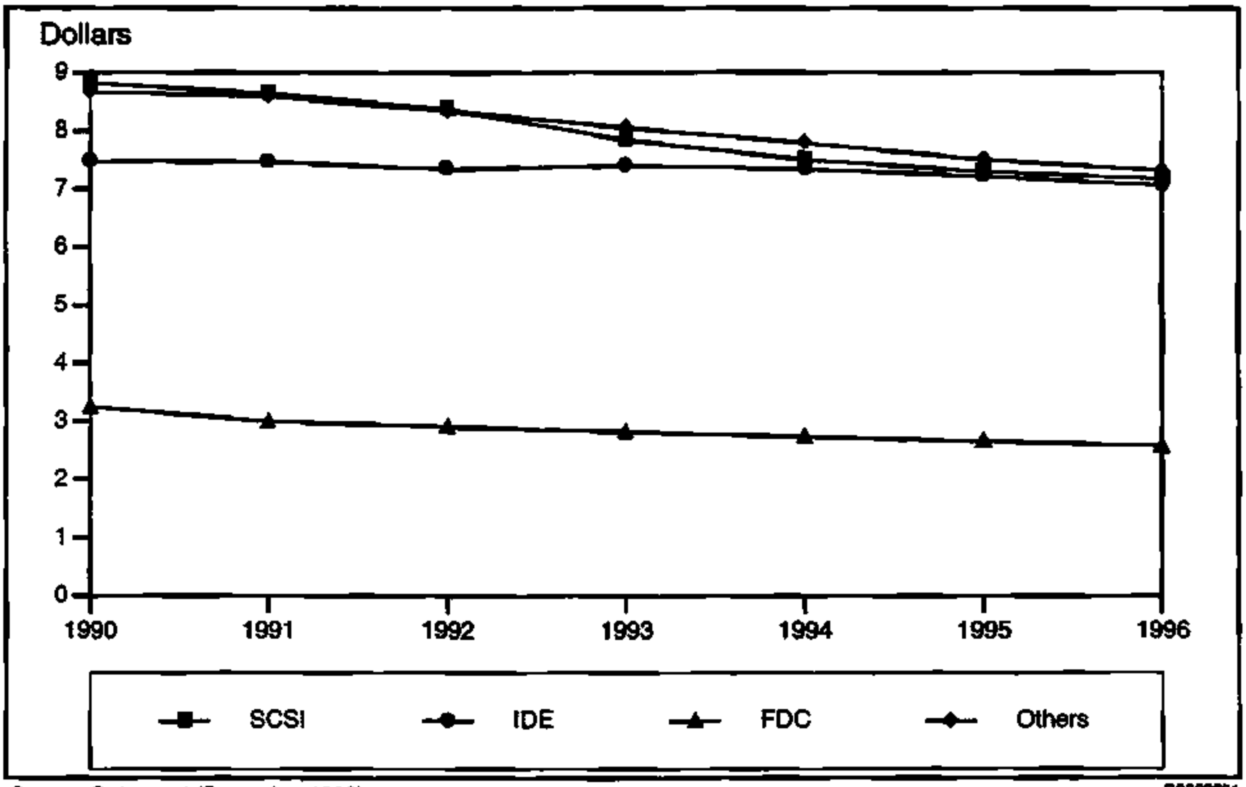
demand forecast for all forms of mass storage devices used in PCs and workstations, mass storage controller demand is subject to the following key assumptions:

- Unit volumes driven by mass storage devices as well as host systems (PCs and workstations) face several threats to the continuance of growth, but are also subject to the vagaries of forecasting and may not achieve the growth forecast for them.
- Integration of the mass storage controller function within the microcontroller, DSP, or other integrated subsystem chip will not have a major impact in the next three years.
- The use of flash memory-based solid-state disks (now being worked on by Intel and Conner) will severely impact the demand for mass storage in hand-held devices and will begin to have an impact on floppy sales in the 1995 time frame.
- Overall, SCSI controllers will become the leading subsegment in revenue in 1992 and the leading subsegment in unit volumes in 1994, driven by the following:
  - Hard disk drives, where SCSI will continue to gain market share, driven by the movement to higher-capacity drives (more than 200MB), overtaking unit dominance to IDE in 1996.

Figure 4-21
Mass Storage Controller Market Forecast, ASP



Source: Dataquest (December 1992)

G2002631

- Optical drives, where SCSI will remain the overwhelming dominant standard, becoming 100 percent by 1996.
- Tape drives, where SCSI will continue to grow, becoming the dominant standard interface starting in 1995.

- For floppy drives, the standard FDC interface will remain overwhelmingly dominant throughout the forecast period, with SCSI at about 2 percent in 1996.
- 80x86 PCs (both desktop and portable) will drive most of the unit growth for host-side controllers during the forecast period, which will be driven to adopt SCSI (on the desktop) by the use of CD-ROMs for software distribution and multimedia applications.
- Controller prices will drop only slightly overall as increased functionality is incorporated and higher-priced mass storage device-side controllers become greater than 50 percent of the mix (currently host-side controllers dominate in unit volumes).

Table 4-12
Mass Storage Controller Market Forecast

Controller Segments	1990	1991	1992	1993	1994	1995	1996
All Controllers							
Device-Side							
Units (K)	26,350	29,945	35,692	44,225	54,349	62,927	75,112
ASP ($)	9.09	8.79	8.54	8.18	8.00	7.86	7.76
Revenue ($K)	239,638	263,217	304,785	361,890	434,532	494,890	583,041
Host-Side							
Units (K)	34,543	35,684	40,199	44,697	50,989	59,932	70,356
ASP ($)	4.44	4.04	3.92	3.76	3.48	3.27	3.16
Revenue ($K)	153,391	144,022	157,721	168,215	177,445	196,268	222,636
All Types							
Units (K)	60,893	328,855	380,684	450,820	539,878	617,757	728,517
ASP ($)	6.45	1.24	1.21	1.18	1.13	1.12	1.11
Revenue ($K)	393,029	407,239	462,505	530,104	611,977	691,159	805,676
All Types							
SCSI							
Units (K)	10,074	14,906	20,782	28,144	38,586	48,809	63,220
ASP ($)	8.82	8.64	8.37	7.84	7.50	7.29	7.17
Revenue ($K)	88,858	128,845	173,969	220,716	289,280	355,605	453,029
IDE							
Units (K)	16,641	19,588	21,389	24,649	26,571	27,801	29,507
ASP ($)	7.48	7.47	7.34	7.40	7.33	7.21	7.05
Revenue ($K)	124,439	146,301	156,946	182,476	194,773	200,416	208,149
FDC							
Units (K)	21,509	24,217	27,552	31,365	36,637	43,708	50,920
ASP ($)	3.25	3.00	2.91	2.82	2.74	2.66	2.58
Revenue ($K)	69,904	72,651	80,176	88,534	100,312	116,082	131,180

(Continued)

Table 4-12 (Continued)
Mass Storage Controller Market Forecast

Controller Segments	1990	1991	1992	1993	1994	1995	1996
Others							
Units (K)	12,669	6,918	6,168	4,764	3,545	2,541	1,822
ASP ($)	8.67	8.59	8.34	8.06	7.79	7.50	7.31
Revenue ($K)	109,828	59,442	51,414	38,378	27,612	19,055	13,317
Total							
Units (K)	60,893	65,629	75,891	88,922	105,339	122,859	145,469
ASP ($)	6.45	6.21	6.09	5.96	5.81	5.63	5.54
Revenue ($K)	393,029	407,239	462,505	530,104	611,977	691,159	805,676

Source: Dataquest (December 1992)

Chapter 5
Microcontrollers

Market Development and Trends

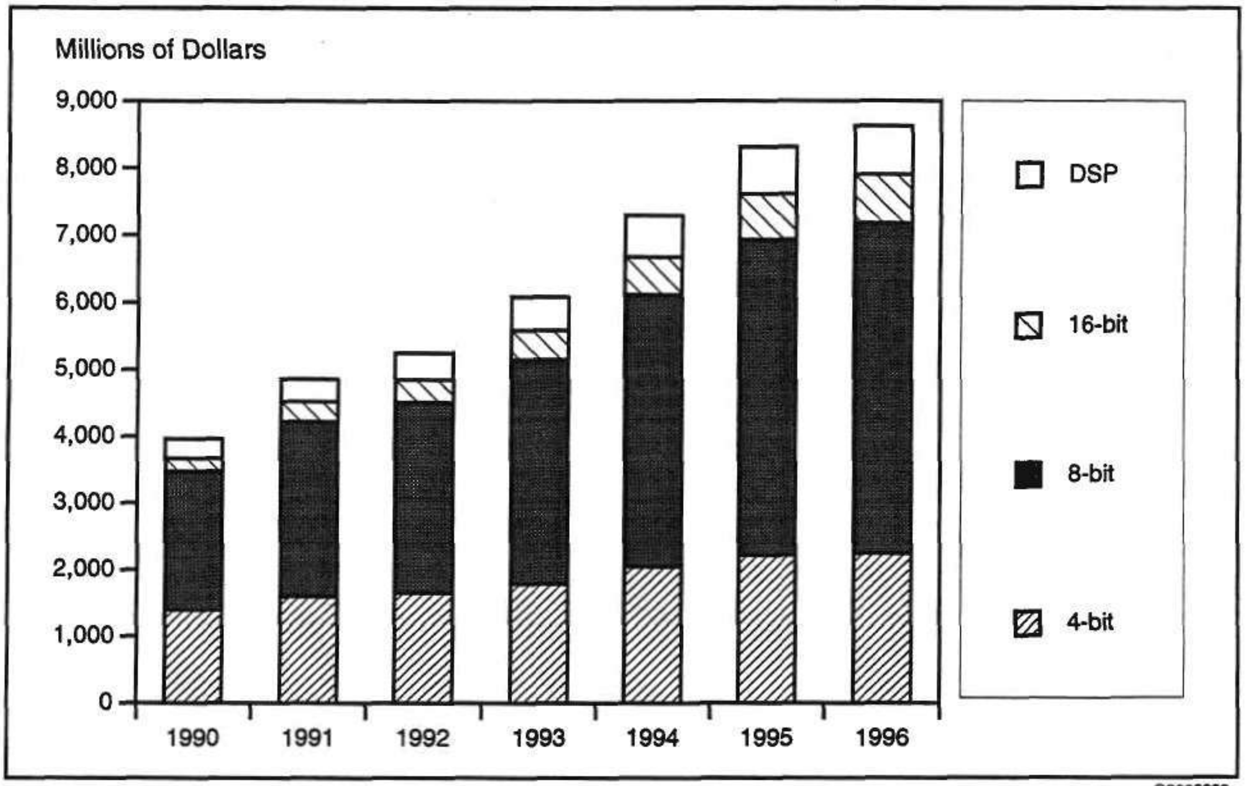
Microcontrollers are ubiquitous in their usage, providing the hidden control behind nearly every individual appliance, instrument, and piece of entertainment equipment we use. They are in cars, cameras, televisions, telephones, disk drives, logic analyzers, copiers, and the card readers used in automated teller machines. As the sophistication of these applications grows, microcontrollers must keep pace by expanding their functional features, increasing performance to manage the additional features, and providing easier methods of programming to reduce development time per function.

As shown in Figure 5-1 and Table 5-1, total revenue for microcontrollers (including digital signal processors, or DSPs) will continue to grow handsomely throughout the next five years, achieving a compound annual growth rate (CAGR) of more than 12 percent. Demand for microcontrollers is tied directly to equipment production and is most dominated by consumer, telecommunications, automotive, and data processing applications, all of which are forecast to achieve strong growth beyond 1992. In some cases, added equipment features have spawned the use of multiple microcontrollers to distribute decision-making and control.

Few threats exist for the mainstream microcontroller market, which offers the most cost- and space-effective method of implementing electronic equipment control (without data processing).

On the other hand, there is an increasing clash with microprocessors designed for embedded uses that integrate most of the I/O and control features but leave out the memory. This clash has existed for a number of years with the Z80, which still sells at nearly 50 million units per year and is growing. However, the most serious long-term threat is at the high end, where pricing, real estate, and code size allow embedded microprocessors to compete head-on for many socket opportunities. One example of this is the automotive power train, which shows signs of converting to a single high-performance 32-bit processor (Ford initially chose the custom version of the 88K) supported by a distributed network of low-performance 8-bit units.

Figure 5-1
MOS Microcontroller Revenue, by Segment



Source: Dataquest (December 1992)

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Product Structure and Segmentation Basis

For formal segmentation of microcontrollers, Dataquest maintains the traditional splits on the basis of word width (external data path), as follows:

- 4-bit microcontrollers: The most homogeneous of the three segments, these are all low-performance, have small on-chip memory, typically contain application-specific I/O features, and are dominated (more than 90 percent) by Japanese vendors.
- 8-bit microcontrollers: The most varied of the three segments, these range from the low-performance 68HC05 series to the-high performance H8 series, offer a wide range of memory sizes and types, and are offered by nearly every vendor.
- 16-bit-plus microcontrollers: The highest performance level in microcontrollers, these are only offered by a select number of vendors and are the primary focus of integration with high-performance subsystems such as DSP units and others.

Table 5-1
Revenue from MOS Microcontroller ICs Shipped to the World, 1990-1996
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total MOS Microcontroller Revenue	3,959	4,855	5,244	6,090	7,291	8,307	8,624	12.2
Growth Rate (%)	19.0	22.7	8.0	16.1	19.7	13.9	3.8	
Percent of Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
4-Bit Revenue	1,394	1,598	1,654	1,787	2,048	2,222	2,247	7.1
Growth Rate (%)		14.6	3.6	8.0	14.7	8.5	1.1	
Percent of Total	35.2	32.9	31.5	29.3	28.1	26.7	26.1	
8-Bit Revenue	2,079	2,618	2,854	3,363	4,074	4,712	4,927	13.5
Growth Rate (%)		25.9	9.0	17.8	21.2	15.6	4.6	
Percent of Total	52.5	53.9	54.4	55.2	55.9	56.7	57.1	
16-Bit Revenue	194	303	337	439	557	670	725	19.1
Growth Rate (%)		56.2	11.3	30.3	26.8	20.3	8.2	
Percent of Total	4.9	6.2	6.4	7.2	7.6	8.1	8.4	
DSP Revenue	291	337	398	501	611	703	725	16.6
Growth Rate (%)		15.8	18.0	26.0	22.0	15.0	3.1	
Percent of Total	7.4	6.9	7.6	8.2	8.4	8.5	8.4	

Columns may not add to totals shown due to rounding.
Source: Dataquest (December 1992)

This split facilitates analysis of the product mix based on the forces that drive the use of greater word widths, which include the following:

- The need for higher I/O bandwidth
- The need for quality HLL compilers (difficult on 4-bit)
- The need for higher on-chip performance

The nature of microcontrollers and their customized use defies explicit segmentation, except on a rudimentary basis. Outside of the two widespread families, 80xx and 68xx, most internal CPU architectures are proprietary to each vendor. They also contain a set of features too numerous to track by individual variation, including an unlimited mixture of the following:

- CPU types
- Nonvolatile memory size and types (ROM, EPROM, EEPROM, and flash)
- RAM sizes (normally static RAM)
- Internal control subsystems (for example, watchdog timers and counters)
- Data converters (D/A and A/D)
- Specialized drivers/outputs (for example, LCD drivers)
- Specialized receivers/inputs

In many respects, the factors influencing demand and market momentum are associated more with companies and their programs rather than products and their features. Thus, within each category are many variants in hardware features, software support, customization programs, and company relationship, among others. An alternate method of product segmentation, which addresses the issue of architectural compatibility, the primary segmentation in microprocessors, is to divide microcontrollers between proprietary and licensed microcontrollers, as follows:

- Proprietary microcontrollers: The collection of unrelated vendor-specific product families that includes nearly all the 4-bit and 16-bit units and the majority of 8-bit units sold by Japanese companies.
- Licensed microcontrollers: Includes the two major 8-bit families—the 68xx family now dominated in volume by their inventor, Motorola, and the 80xx family, led in volume by their inventor, Intel—and other minor licensed families.

The proprietary versions, which include the high-volume 4-bit units, dominate with nearly 70 percent of the unit volumes. The licensed versions are interesting in that they provide a certain degree of development compatibility within a wide range of primarily 8-bit devices. A result of the way the microcontroller industry developed, the 68xx family and the 80xx family of microcontrollers still sell in large and growing volumes. Though the 8048/49 series is not code-compatible with the 8051/52 series, and the 68xx series is not fully compatible up and down the scale, the assembly language, programming tools, and development equipment is nearly the same within each family.

In addition to these differences, many versions of these families are single-vendor components, like proprietary parts in many ways.

Yet another way to examine the product mix is on a nonsegmented top selling basis. Table 5-2 lists the top 10 products on a vendor-specific, unit volume basis. Though this list is dominated by 4-bit products, the top product is an 8-bit unit, Motorola's 68HC05, marketed under its CSIC program. Also interesting is the fact that Motorola, which appears twice on the list, is the only non-Japanese vendor listed. This list includes only vendor-specific quantities, even though the industry aggregate volumes of the 8051/31 family would place it fourth on the list with 62.5 million units.

Motorola's CSIC Program

Several years ago, Motorola quietly began using a new methodology of matching specific microcontrollers to customer requirements. This methodology was called customer-specific integrated circuit (CSIC) microcontrollers and was designed to provide the lowest-cost method to deliver microcontrollers meeting exact customer requirements. CSIC program development was driven by the lack of broad-based success with microcontroller core-based ASICs, which differ to the customer as follows:

- ASIC
  - Results in customized device
  - Requires NRE or amortized NRE
  - Proprietary design
  - Customer does front-end design
  - Automated layout
- CSIC
  - Results in customized device
  - Normally no NRE charges
  - Nonproprietary design
  - Motorola does design
  - Hand-packed layout

The problems traditionally occurring in ASIC microcontrollers include errors introduced by the customer (usually a system engineer) doing IC design, the large die size (and thus cost)

Table 5-2
Top 10 Product Shipments of Microcontrollers to the World
(Thousands of Units)

1991 Rank	1990 Rank	Product	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	3	68HC05	Motorola	73,600	131,900	79	8.4
2	1	uPD75X	NEC	101,000	106,000	5	6.8
3	2	SM Series	Sharp	98,500	95,200	-3	6.1
4	4	HMCS-400	Hitachi	54,400	61,500	13	3.9
5	5	MN1500	Matsushita	53,500	57,800	8	3.7
6	7	TLCS-47	Toshiba	45,000	50,000	11	3.2
7	6	LC57/58XX	Sanyo	45,700	45,600	-0	2.9
8	8	uPD78XX	NEC	39,000	44,800	15	2.9
9	11	68HC11	Motorola	27,700	40,500	46	2.6
10	9	M5046X/56X	Mitsubishi	31,200	33,800	8	2.2
		All Others		797,300	896,200	12	57.3
		Total MCU		1,366,900	1,563,300	14	100.0

Note: Columns may not add to totals shown due to rounding.
Source: Dataquest (December 1992)

produced by using automated routing, and steep upfront engineering costs (NRE) in some cases. Because most customized microcontrollers were primarily 4-bit units offered by Japanese vendors, Motorola chose to implement the CSIC methodology around its low-cost 68HC05 architecture. As a result, the 68HC05 now offers more than 100 different CSIC derivatives, some of which are used by more than 10 customers (as a result of common application needs) and in 1991 became the single highest volume product series with nearly 132 million units. It is still growing. This program has worked so well that Motorola has become one of the primary forces in migrating 4-bit designs to 8-bit designs by consolidating more functional circuits into the microcontroller and improving the cost-performance of the solution.

Major Technology Trends

Evolution of technology used within microcontrollers seems to move at a snail's pace, in contrast to microprocessors that use innovative techniques to double performance every 18 months or so. The same word widths, performance levels, relative on-chip memory sizes, and I/O features have existed for years. However, the major technology trends (outside of process technology) affect the ease with which these products are used and not their performance levels. These trends include the following:

- Continued increase in the use of high-level language programming, which today is dominated by C and is moving more and more to C++.
- The use of fuzzy logic programming, a technique of modeling inputs and outputs to replace lookup-table approaches to reduce memory and increase performance.
- Increased use of one-time-programmable (OTP) and flash memory technologies to enable field programmability either at the customer site or as updates to the customer.

In process technology, microcontrollers are no different from other MOS digital circuits, showing a steady trend toward the conversion from NMOS from CMOS (see Table 5-3). As of the end of 1991, CMOS represented about 80 percent of the microcontroller volume, up from 75 percent the year before. Process technology also varies on a regional basis, with CMOS representing more than 90 percent of Japanese vendor shipments versus only 35 percent of European vendor shipments. Vendors using primarily CMOS indicates a strategy of investing in new lines and processes to shrink die sizes as a cost-reduction technique, most typical for high volumes. Vendors using a high percentage of NMOS shipments indicates a strategy of leveraging existing capital equipment to reduce the overhead cost component, most typical for low or declining volumes.

Table 5-3
Shipments of All Microcontrollers by Process Technology to the World (Thousands of Units)

Process Technology	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
NMOS/PMOS	338,400	311,400	-8	19.9
North American Companies	128,500	108,700	-15	7.0
Japanese Companies	150,900	149,100	-1	9.5
European Companies	59,000	53,600	-9	3.4
CMOS	1,028,500	1,251,900	22	80.1
North American Companies	176,700	255,400	45	16.3
Japanese Companies	832,900	950,900	14	60.8
European Companies	18,900	28,700	52	1.8
Asia-Pacific Companies	NA	16,900	NM	1.1
Total MCU	1,366,900	1,563,300	14	100.0
North American Companies	305,200	364,100	19	23.3
Japanese Companies	983,800	1,100,000	12	70.4
European Companies	77,900	82,300	6	5.3
Asia-Pacific Companies	NA	16,900	NM	1.1

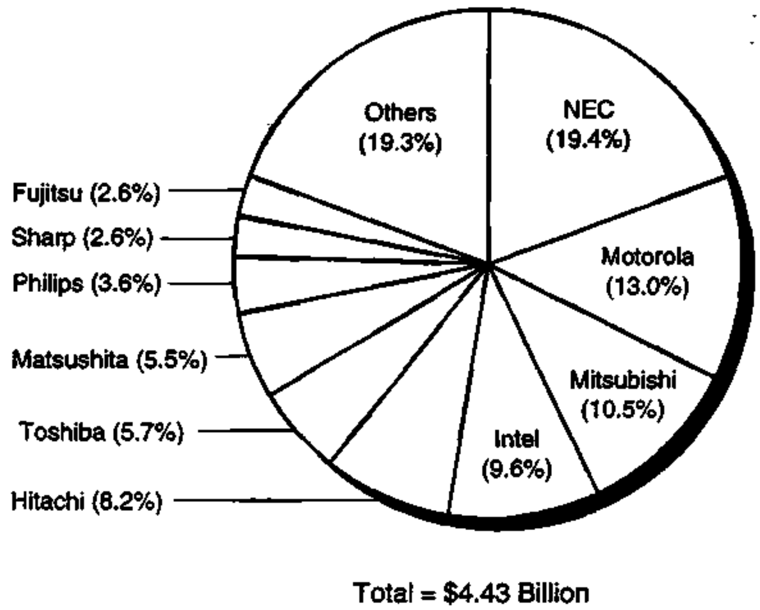
NM = Not meaningful
NA = Not available
Note: Columns may not add to totals shown due to rounding.
Source: Dataquest (December 1992)

Competitive Positions and Analysis

From a worldwide perspective, microcontroller revenue and volumes are fragmented among more than 30 different companies, with a relatively smooth gradient of decreasing market share from the first to the last vendor (see Figure 5-2 and Table 5-4). On a revenue basis, the top 10 vendors maintained their ranking, except Fujitsu, which displaced National. The top 10 are dominated by Japanese vendors, who own 7 of the top 10 positions, though the vast majority of their revenue comes from Japan, a relatively protected domestic business. The market status of these vendors is summarized as follows:

- NEC has a strong No. 1 position (with nearly 50 percent more revenue than No. 2-ranked Motorola) and perhaps the most balanced portfolio of products, which gain strong revenue contributions from all product segments. It has a reasonable mix of revenue from each of the three regions outside of Japan.
- Motorola establishes an equally strong No. 2 position, excelling in 8-bit microcontrollers, the only product segment it serves (outside of its 32-bit 683xx line of microprocessors being marketed as microcontrollers). It has the strongest regional balance of business, ranking No. 1 in Europe, Asia/Pacific, North America (essentially tied), and is the only non-Japanese vendor on the top 10 list for Japan.
- No. 3-ranked Mitsubishi offers strong competition with 4-bit and low-end 8-bit devices primarily in the Japan and Asia/Pacific regions, where it is the second largest player.
- Intel is in fourth place and is the single dominant vendor of 16-bit microcontrollers, complemented by the uncharacteristic line of commodity 8-bit 80xx series devices.
- Ranked fifth and sixth, respectively, Hitachi and Toshiba have the strongest regional mix of all Japanese vendors, exporting from 30 to 50 percent of their microcontrollers to all three other regions.
- The remaining three Japanese vendors, Matsushita, Sharp, and Fujitsu, are entirely focused on sales in Japan, accounting for 80 to 90 percent of their revenue.
- Philips is No. 8 and is the single European vendor on the list. Its revenue primarily comes from 8-bit microcontrollers (mainly from acquisition of Signetics).

Figure 5-2
1991 Top 10 Companies' Microcontroller Market Share



Source: Dataquest (December 1992) G2002633

Regional Nature of Microcontroller Industry

More than for any other type of microcomponent, competition for microcontroller business is regionalized in nature. Almost every company (with the exception of Motorola) does the vast majority of its business in the region it originates from, and almost every region is dominated by domestic vendors. This is driven by several reasons, including the following:

- Many consumer goods use captive microcontrollers (that is, Philips' televisions using their own microcontrollers, among others), which primarily affects Japan and Europe.
- Having a local R&D headquarters is a significant advantage, especially if the use of customized versions is involved.
- Many countries and Japan in particular are still protected with a set of entry barriers, including strong national loyalty/favoritism, and cultural issues.

This situation of regional dominance is most severe in Japan, where only 8 percent of the market is penetrated by non-Japanese companies (that is, Japanese companies hold 92 percent of the Japanese market). By the same token, Japanese companies, because of their product lines and style of business, have had only limited success outside of Japan. Furthermore, because Japan represents nearly 50 percent of the total consumption of microcontrollers, Japanese

Table 5-4
Top 30 Companies' Factory Revenue from Shipments of Microcontroller ICs to the World (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	NEC	714	860	20	19.4
2	2	Motorola	486	574	18	13.0
3	3	Mitsubishi	363	463	28	10.5
4	4	Intel	356	424	19	9.6
5	5	Hitachi	337	364	8	8.2
6	6	Toshiba	197	251	27	5.7
7	7	Matsushita	182	243	34	5.5
8	8	Philips	125	159	27	3.6
9	9	Sharp	111	117	5	2.6
9	11	Fujitsu	92	117	27	2.6
11	10	National Semiconductor	93	107	15	2.4
12	13	Siemens	78	94	21	2.1
13	12	Oki	82	93	13	2.1
14	17	Sony	38	81	113	1.8
15	14	Texas Instruments	70	80	14	1.8
16	16	SGS-Thomson	69	67	-3	1.5
17	14	Sanyo	70	65	-7	1.5
18	22	Ricoh	17	57	235	1.3
19	18	Matra MHS	33	37	12	.8
20	19	ITT	28	35	25	.8
21	22	Zilog	17	21	24	.5
22	26	Rohm	13	19	46	.4
23	26	Samsung	13	17	31	.4

(Continued)

Table 5-4 (Continued)
Top 30 Companies' Factory Revenue from Shipments of Microcontroller ICs to the World
(Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
24	28	Seiko Epson	10	16	60	.4
25	20	Harris	25	14	-44	.3
25	21	Advanced Micro Devices	21	14	-33	.3
25	24	Microchip Technology	15	14	-7	.3
28	25	Rockwell	14	9	-36	.2
29	NM	Dallas Semiconductor	0	7	NM	.2
30	NM	GEC Plessey	0	5	NM	.1
		All Others	24	3	-88	.1
		North American Companies	1,141	1,301	14	29.4
		Japanese Companies	2,226	2,746	23	62.0
		European Companies	309	362	17	8.2
		Asia/Pacific Companies	17	18	6	.4
		Total Market	3,693	4,427	20	100.0

NM = Not meaningful
Source: Dataquest (December 1992)

vendors appear to dominate the worldwide market, with 62 percent of the market and 7 of the top 10 ranked positions (by revenue).

Table 5-5 helps demonstrate a more normalized perspective on the true strengths of the competitive field; it shows the differences between the regional supply base, inclusive and exclusive of revenue from a competitor's own region (that is, exclusive means subtracting Intel's revenue from North America and NEC's revenue from Japan, among others). If the regional component is removed, North American and Japanese companies essentially share the lead in microcontrollers, with European vendors having a diminished portion. Furthermore, Motorola becomes substantially dominant at 22 percent, with NEC and Intel following at about the same level. As we move to more open global competition, this may become a leading indicator of the competitive positioning.

Table 5-5
1991 Worldwide Microcontroller Market Share, Including and Excluding Region of Origin

Rank	Vendor	Revenue ($M)	Percentage
Including Region of Origin			
1	NEC	860	19
2	Motorola	574	13
3	Mitsubishi	463	10
4	Intel	424	10
5	Hitachi	364	8
	Total	4,427	100
Excluding Region of Origin			
1	Motorola	364	22
2	NEC	223	14
3	Intel	210	13
4	Toshiba	124	8
5	Mitsubishi	117	7
	Total	1,631	100

Source: Dataquest (December 1992)

4-Bit Microcontrollers

The primary driving force behind 4-bit microcontrollers is the consumer market, followed at a distance by automotive and other applications. Consumer applications represent the vast bulk of 4-bit unit volumes and encompass a wide variety of equipment including appliances and entertainment equipment, most of which is dominated by Japanese manufacturers using Japanese microcontrollers (often captive to the manufacturer). Also important are automotive applications, primarily the more ancillary functions such as key-lock mechanisms and stereo control. Though 1992 has been an off year in these applications because of recessionary economics, this segment will continue to grow over the next several years.

The 4-bit microcontroller segment is perhaps the easiest to characterize because it has few standards to base its products on. Products in this segment are typified by the following types of features:

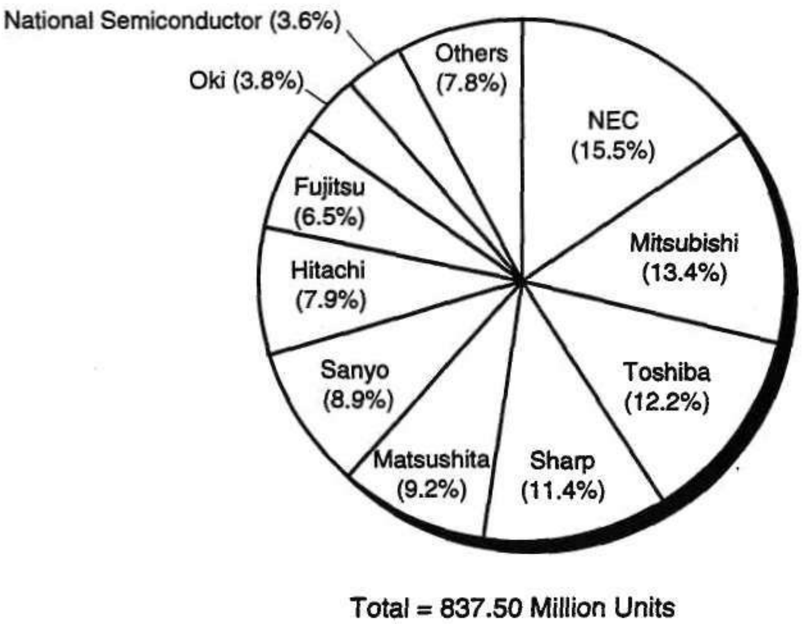
- CPU performance is relatively low and can control only a limited number of on-chip features.
- Code size is the smallest and is still heavily dependent on assembly.
- ROM is almost always on-chip and in the 1KB to 4KB range.
- RAM is almost always on-chip and in the 64- to 256-byte range.
- I/O features range from a simple 4-bit serial port to a full complement of A/D channels and LCD drivers.

Price is the most important element for the 4-bit microcontroller market. Average selling prices have been gradually decreasing, reaching $1.76 in 1991. A large percentage of 4-bit units are sold well below $1.00, however, and represent the lowest-cost microcontrollers. The closest competition to this range of low-cost 4-bit devices is Motorola's 68HC05, which also sells at less than $1.00, depending on functions. Furthermore, Motorola is attempting to change the cost metrics by using its CSIC program and creating customized versions that absorb outlying circuits, and by offering the lowest solution cost rather than the lowest device cost.

Competitive Positions and Analysis

As was previously pointed out, the competition for 4-bit microcontrollers comes almost entirely from the Japanese vendor base (see Figure 5-3 and Table 5-6). With 4-bit units representing more than 50 percent of the total microcontroller unit volume, the top vendors in this segment—NEC, Mitsubishi, and Toshiba—dominate the overall microcontroller unit volumes (ranking 1, 2, and 4, respectively). Furthermore, nearly every vendor in this segment has a fair level of captive internal consumption in consumer and other goods, contributing to the overall entry barrier.

Figure 5-3
1991 4-Bit Worldwide Microcontroller Market Share



Source: Dataquest (December 1992) G2002634

Though 1991 showed only marginal unit growth for most vendors, including NEC, Toshiba, Sharp (slight decline), Sanyo, Hitachi, Fujitsu, and Oki Semiconductor, National Semiconductor, the single non-Japanese vendor, is showing major signs of weakness in this segment. It had an 18 percent decline in 4-bit unit sales. One notable exception to this trend is second-ranked Mitsubishi, which had a 22 percent growth in 1991, perhaps because of its increasing business in the Asia/Pacific region. Looking ahead, 1992 is shaping up to be an even more difficult year and may show decreased unit shipments for many vendors in this field.

Table 5-6
Each Company's Shipments of 4-Bit Microcontrollers to the World (Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	NEC	126,800	129,700	2	15.5
2	4	Mitsubishi	91,900	111,900	22	13.4
3	3	Toshiba	95,600	102,200	7	12.2
4	2	Sharp	98,500	95,200	-3	11.4
5	6	Matsushita	67,500	76,700	14	9.2
6	5	Sanyo	74,100	74,600	1	8.9
7	7	Hitachi	63,000	66,100	5	7.9
8	8	Fujitsu	54,300	54,100	-0	6.5
9	10	Oki	30,200	32,100	6	3.8
10	9	National	36,500	30,000	-18	3.6
11	11	Sony	25,700	29,200	14	3.5
12	NM	Samsung	NA	16,500	NM	2.0
13	12	Texas Instruments	7,300	10,000	37	1.2
14	13	SGS-Thomson	5,900	4,700	-20	.6
15	14	Seiko	2,400	4,100	71	.5
16	NM	Goldstar	NA	400	NM	*
17	15	Rockwell	97	34	-65	*
		Total 4-Bit MCU	779,800	837,500	7	100.0

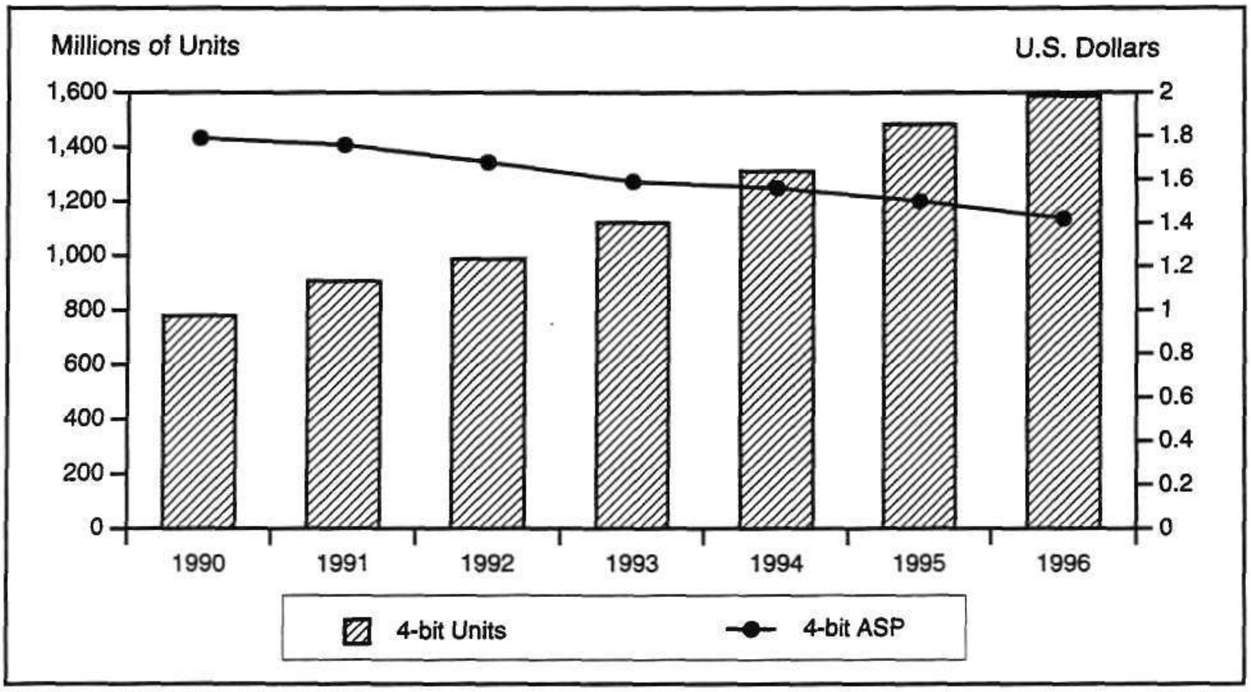
NA = Not available
NM = Not meaningful
* = Calculated value is less than 0.1 percent.
Note: Columns may not add to totals shown due to rounding.
Source: Dataquest (December 1992)

Forecast and Assumptions

As shown in Figure 5-4 and Table 5-7, 4-bit microcontrollers are forecast to show continued, albeit mild growth, over the next five years. The key assumptions driving this forecast are as follows:

- Because of the severe current economic slump in Japan, which is heavily tied to consumer equipment production, revenue growth in 1992 will slow to a mere 3.6 percent overall.
- As the Japanese and worldwide economies improve, starting in 1993, growth will rebound somewhat, reaching a 7.1 percent CAGR for the forecast period.
- Unit volumes will continue to climb out of the 1992 recession, reaching their peak growth rate in 1994, then declining again as the impact of low-end 8-bit microcontrollers begins to be felt. Dataquest predicts that 8-bit unit volumes will finally overtake 4-bit unit volumes in 1996.
- ASPs will continue on a slight decline simply because of the minor decreases in manufacturing costs as well as competitive pressures from customized 8-bit devices.

Figure 5-4
4-Bit MOS Worldwide Microcontroller ASP and Shipments



Source: Dataquest (December 1992)

G2002635

Table 5-7
4-Bit MOS Microcontroller ASP and Shipments (Millions of Units) to the World

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
4-Bit Units	779	906	988	1,121	1,311	1,482	1,586	11.8
Growth Rate (%)		16.3	9.0	13.5	17.0	13.0	7.0	
Percent of Total	56.0	53.4	52.4	51.0	49.7	48.5	47.8	

DSP units are excluded from this table.
Columns may not add to totals shown due to rounding.
Source: Dataquest (December 1992)

8-Bit Microcontrollers

Demand for 8-bit microcontrollers, which represent the widest variety of applications and features offered, is spread out among almost all application areas including consumer (cameras and VCRs, among others), telecommunications (featured handsets, among others), data processing (disk drives), automotive (environmental controls, among others), and others. Because of this range of applications, consumption is spread out over all regions. With 1991 revenue of $2.6 billion, this segment provides nearly 54 percent of the total for the microcontroller industry.

The 8-bit microcontroller segment is either simple or difficult to characterize, depending on the purposes of analysis. To examine the dynamics of licensing and the advantages of multiple sources and direct price competition, we could subsegment the 8-bit market into the following major families, which are quantified in Figure 5-5 and Table 5-8:

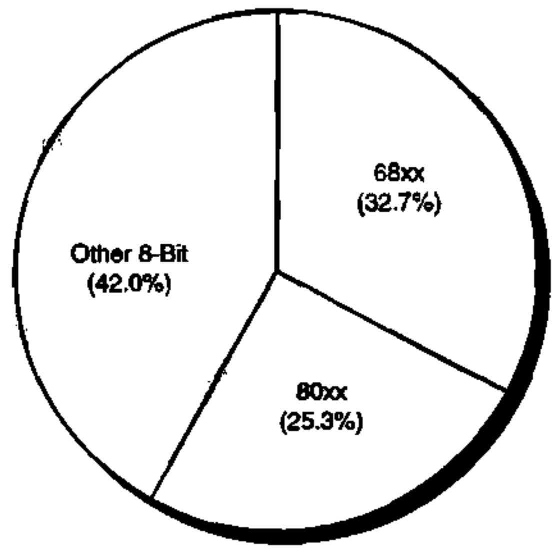
- 68xx family: Originated by and licensed from Motorola; came from the 6800 microprocessor into the upscaled 6801/HC11 architecture and the 6805/HC05 downscaled architecture.
- 80xx family: Originated by and licensed from Intel; really represents two primary series, the low-end 8048/49 series that is nearing the end of its useful life, and the high-end 8051/52 series, each of which contains a number of versions.
- Proprietary: The collection of vendor-specific architectures that offer a competitive set of features to the two licensed families, but without the advantages of second-sourcing and commodity price competition.

Beyond these categories, products in this segment are typified by the following unlimited variety of features:

- CPU performance ranges from low to medium-high (two to eight times the 4-bit devices).
- Code size is moderate and is heavily dependent on quality compilers.
- ROM is typically in the 1KB to 4KB range.
- RAM is typically in the 128- to 512-byte range.
- I/O features range all over the spectrum.

Pricing is a crucial element at the low end of the 8-bit line, where the Motorola 68HC05 competes on cost with the mainstream 4-bit microcontrollers. It becomes less crucial in the upper ranges of 8-bit devices. ASPs for 8-bit microcontrollers have decreased gradually because of two offsetting factors: the increasing volumes of high-end 8-bit devices, and the aggressive pricing of low-end 8-bit devices. During the last two years, overall prices decreased only slightly from $3.53 in 1990 to $3.48 in 1991.

Figure 5-5
1991 Worldwide Shipments of Licensed versus Proprietary 8-Bit Microcontrollers



Source: Dataquest (December 1992)
G2002636

Table 5-8
Shipments of Licensed versus Proprietary 8-Bit Microcontrollers to the World
(Thousands of Units)

Processor Class	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
Licensed vs. Proprietary 8-Bit Microcontrollers				
80xx	169,600	175,200	3.3	25.3
68xx	186,800	226,900	21.5	32.7
Other 8-Bit	213,500	291,600	36.6	42.0
Total 8-Bit MCU	569,900	693,700	21.7	100.0

NA = Not available
NM = Not meaningful
*Calculated value is less than 0.1 percent.
Note: Columns may not add to totals shown due to rounding.
Source: Dataquest (December 1992)

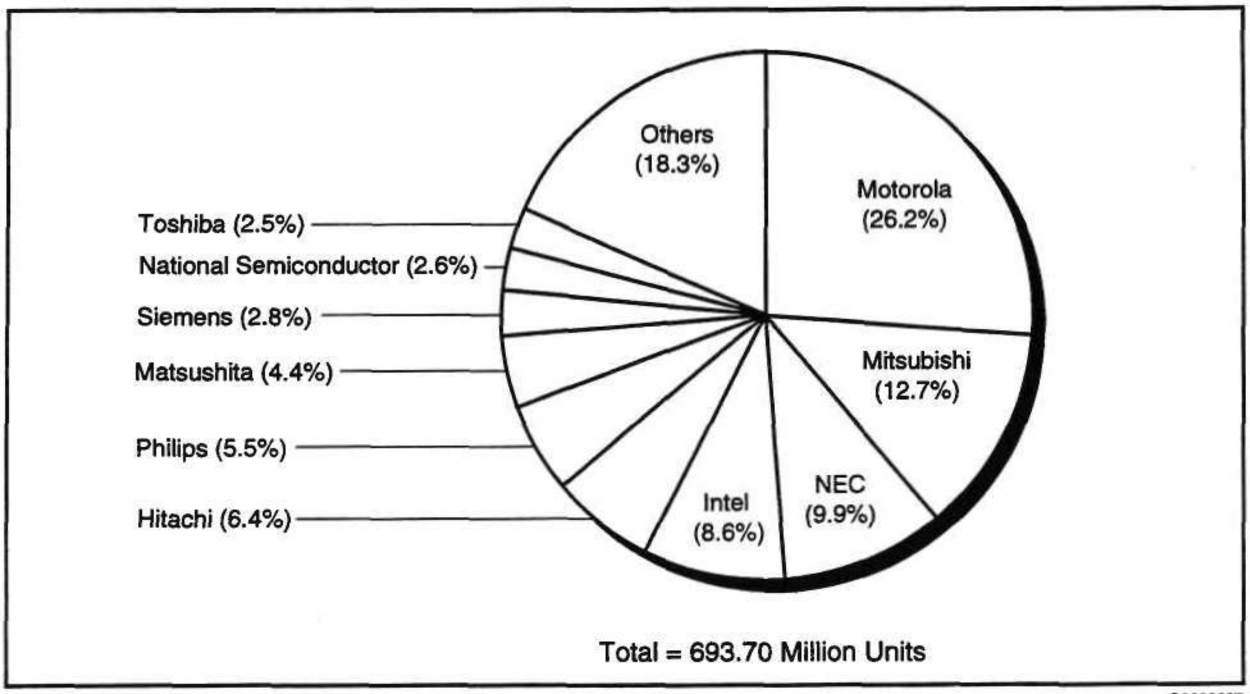
Competitive Positions and Analysis

The vendor base for 8-bit microcontrollers is the most uniformly spread of all segments, showing participation in the top 10 list (see Figure 5-6 and Table 5-9) from three North American vendors, five Japanese vendors, and two European vendors. Motorola has a commanding lead and one of the highest growth rates, built up around its diverse 68xx product family. Motorola balances its sales between the 68HC05 series and the 68HC11 series, which provide good examples of low-end and high-end 8-bit competition, respectively, in the market today.

The 68HC05 is the highest-volume microcontroller, sold into cameras, toys, cellular phones, pagers, and automobiles, among others. It competes with the 8048 series on the high end (mainly in North America) and with the 4-bit controllers on the low end. The 68HC11 is also one of the top 10 microcontrollers (having just shipped the 100 millionth unit this year) selling into disk drives, automotive, and high-end communications applications, competing against the 8051 and other proprietary 8-bit processors.

Mitsubishi also turned in a high 32 percent growth rate, moving a great deal of relatively medium-range 8-bit devices. NEC is doing well with its uPD78xx family, having recently expanded its K2 series for real-time embedded control applications. Intel remains focused on the 8051/52 series for servicing 8-bit applications,

Figure 5-6
1991 Top 10 Companies' 8-Bit Microcontroller Market Share



Source: Dataquest (December 1992)

G2002637

Table 5-9
Each Company's Shipments of 8-Bit Microcontrollers to the World
(Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Motorola	134,800	181,800	35	26.2
2	2	Mitsubishi	66,900	88,400	32	12.7
3	3	NEC	59,500	68,900	16	9.9
4	4	Intel	58,300	59,700	2	8.6
5	5	Hitachi	46,500	44,300	-5	6.4
6	6	Philips	35,700	38,400	8	5.5
7	7	Matsushita	17,000	30,400	79	4.4
8	9	Siemens	16,400	19,500	19	2.8
9	8	National	16,700	18,200	9	2.6
10	13	Toshiba	12,200	17,500	43	2.5
11	10	Texas Instruments	14,600	17,000	16	2.5
12	16	Sony	9,000	16,700	86	2.4
13	11	Sharp	12,600	16,000	27	2.3
14	12	Oki	12,400	13,300	7	1.9
15	15	Zilog	10,300	11,900	16	1.7
16	20	Microchip Technology	5,700	10,500	84	1.5
17	14	SGS-Thomson	10,800	10,100	-6	1.5
18	16	Matra MHS	9,000	9,600	7	1.4
19	18	Fujitsu	7,900	8,500	8	1.2
20	23	Sanyo	1,400	7,000	400	1.0
21	19	AMD	7,300	3,900	-47	.6
22	21	Rockwell	2,800	1,000	-64	.1

(Continued)

Table 5-9 (Continued)
Each Company's Shipments of 8-Bit Microcontrollers to the World
(Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
23	22	Harris	1,500	900	-40	.1
24	25	Seiko	100	220	120	*
25	24	NCR	480	0	-100	*
		Total 8-Bit MCU	569,900	693,700	22	100.0

* = Calculated value is less than 0.1 percent.
Note: Columns may not add to totals shown due to rounding.
Source: Dataquest (December 1992)

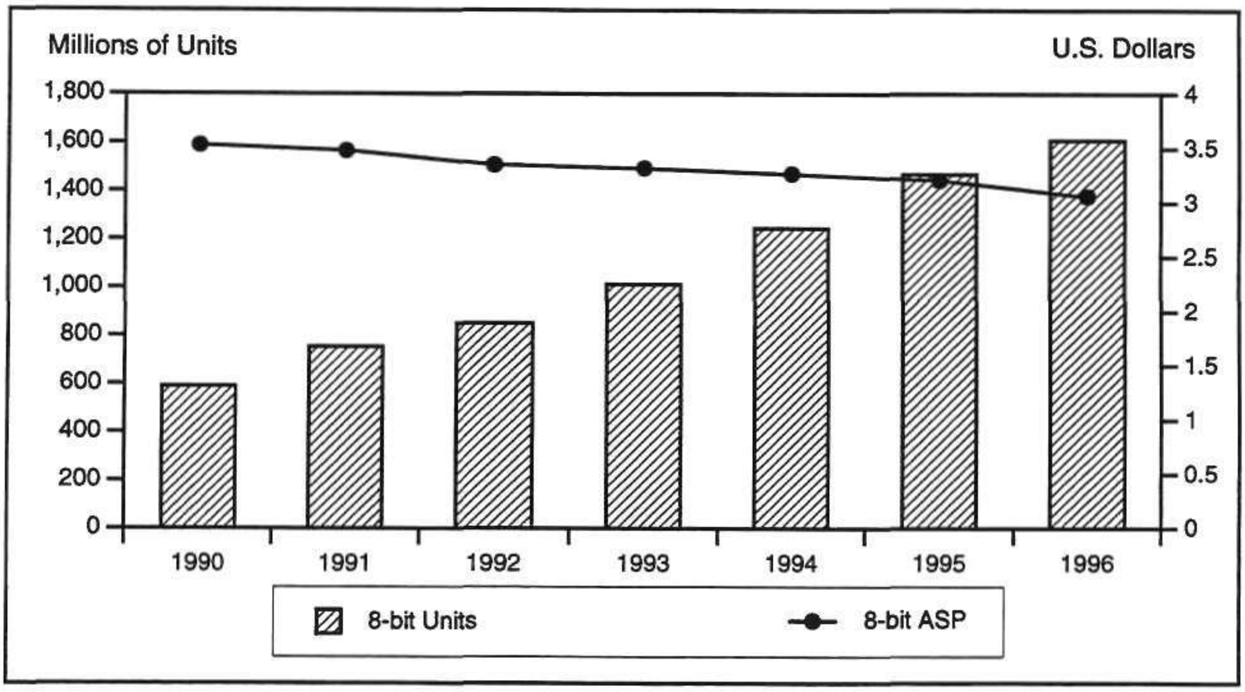
although the declining 8048 remains in high volume. Hitachi, placing much of its emphasis on the high-end H8 series, is the only major vendor that showed a decline in unit volumes in 1991. Of the other vendors with significant market share, Matsushita is most noteworthy, showing 79 percent growth in 1991.

Forecast and Assumptions

As shown in Figure 5-7 and Table 5-10, 8-bit microcontrollers are forecast to show strong growth over the next five years. The key assumptions driving this forecast are as follows:

- Unit volumes will continue to climb, reaching their peak growth rate in 1994 (like the 4-bit microcontrollers), and more than doubling total volume by 1996, taking over unit dominance from the 4-bit devices.
- 8-bit devices will continue replacing 4-bit devices in some of the more feature-rich consumer applications.
- The use of fuzzy logic techniques will expand the control applications for 8-bit devices.
- ASPs will only decline slightly during the forecast because of the strong mixture of 8-bit devices being sold at the two extreme ends of the spectrum ($1 to $2 for low-end devices and $4 to $5 for high-end devices).

Figure 5-7
8-Bit MOS Worldwide Microcontroller ASP and Shipments



Source: Dataquest (December 1992)

G2002638

Table 5-10
8-Bit MOS Worldwide Microcontroller ASP and Shipments

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
8-Bit Units	589	753	851	1,013	1,245	1,470	1,609	16.4
Growth Rate (%)		27.8	13.0	19.0	23.0	18.0	9.5	
Percent of Total	42.4	44.4	45.1	46.1	47.2	48.1	48.5	

DSP units are excluded from this table.
Columns may not add to totals shown due to rounding.
Source: Dataquest (December 1992)

16/32-Bit Microcontrollers

Though overall volume for 16-bit-plus microcontrollers is low, its growth rate far exceeds the other segments. Primary demand for 16-bit microcontrollers is coming from the automotive and data processing markets. Automotive applications include engine control, transmission control, and other critical functions. Data processing applications for 16-bit controllers include disk drives and certain high-end peripherals.

The 16-bit-plus microcontroller segment can be characterized by product families dominating this subsegment, as follows:

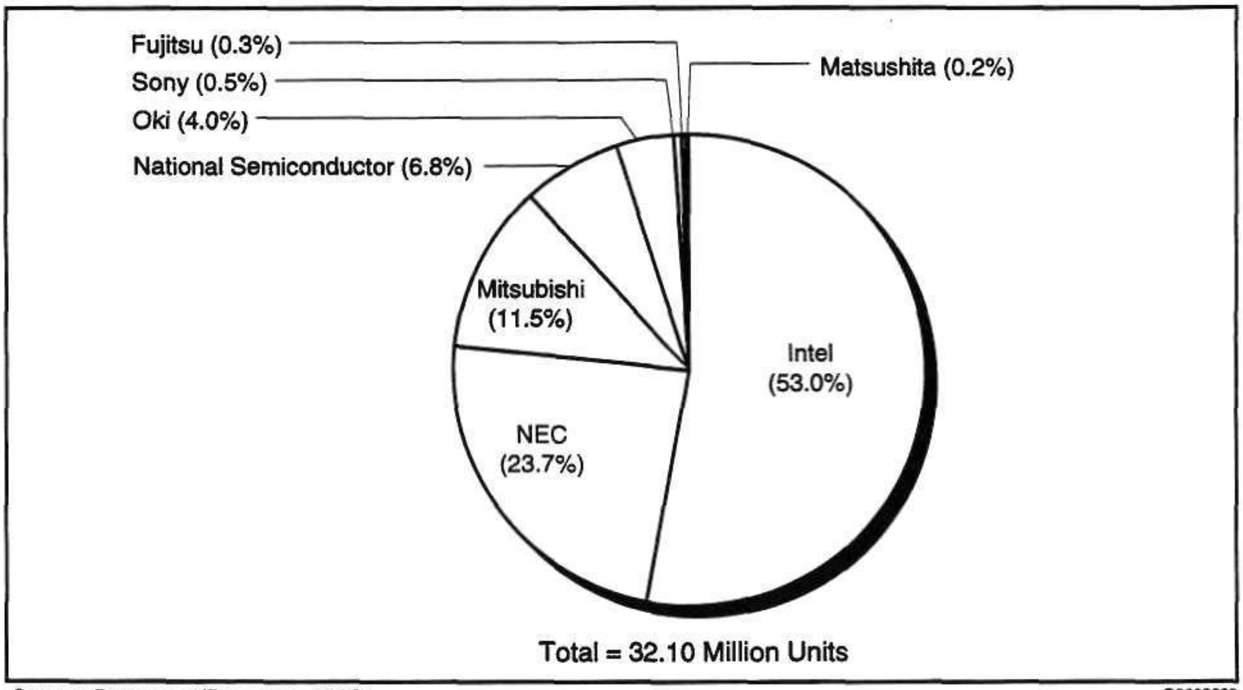
- Intel's MCS-96 family includes the original 8096 and the CMOS 80196 versions, which became top devices for the automotive control market and are leading the 16-bit market growth with a 1991 market share of 53 percent and a more than 100 percent growth rate.
- NEC's uPD78K/3.4 family is the second largest mover and had more than 23 percent of the 16-bit market in 1991, showing moderate growth as well.
- Other major 16-bit products include Mitsubishi's M377XX and National's HPC series, being used primarily in disk drive and digital servo control applications.
- The only 32-bit microcontroller entry is an offshoot of the 683xx microprocessor family (which Motorola markets as a microcontroller family), which offers integrated RAM and ROM.

Pricing of these parts is surprisingly competitive, with ASPs hovering near $8, primarily driven by the dominant MCS-96 family competing for sockets in the hotly competitive disk drive market.

Competitive Positions and Analysis

As was previously pointed out, the competition for 16-bit microcontrollers comes almost entirely from four vendors, with Intel in a dominant position. Intel dominates in both share (53 percent) and growth rate (139 percent) and will almost single-handedly determine the complexion of the 16-bit microcontroller market during the next few years (see Figure 5-8 and Table 5-11). The 16-bit product lines from NEC and Mitsubishi fill out the breadth of their offerings, while the HPC series from National represents a key focus for its microcontroller group. Other vendors making their entry include Oki, Sony, Fujitsu, and Matsushita.

Figure 5-8
1991 Top 8 Companies' 16-Bit Microcontroller Market Share



Source: Dataquest (December 1992)

G2002639

Table 5-11
Company Shipments of 16-Bit Microcontrollers to the World
(Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Intel	7,100	17,000	139	52.9
2	2	NEC	5,300	7,600	43	23.7
3	3	Mitsubishi	1,900	3,700	95	11.5
4	4	National	1,700	2,200	29	6.8
5	5	Oki	1,100	1,300	18	4.0
6	NM	Sony	0	150	NM	.5
7	9	Fujitsu	6	90	1400	.3
8	7	Matsushita	20	80	300	.2
9	8	Matra MHS	14	2	-86	*
10	6	SGS-Thomson	100	0	-100	*
		Total 16-Bit MCU	17,200	32,100	87	100.0

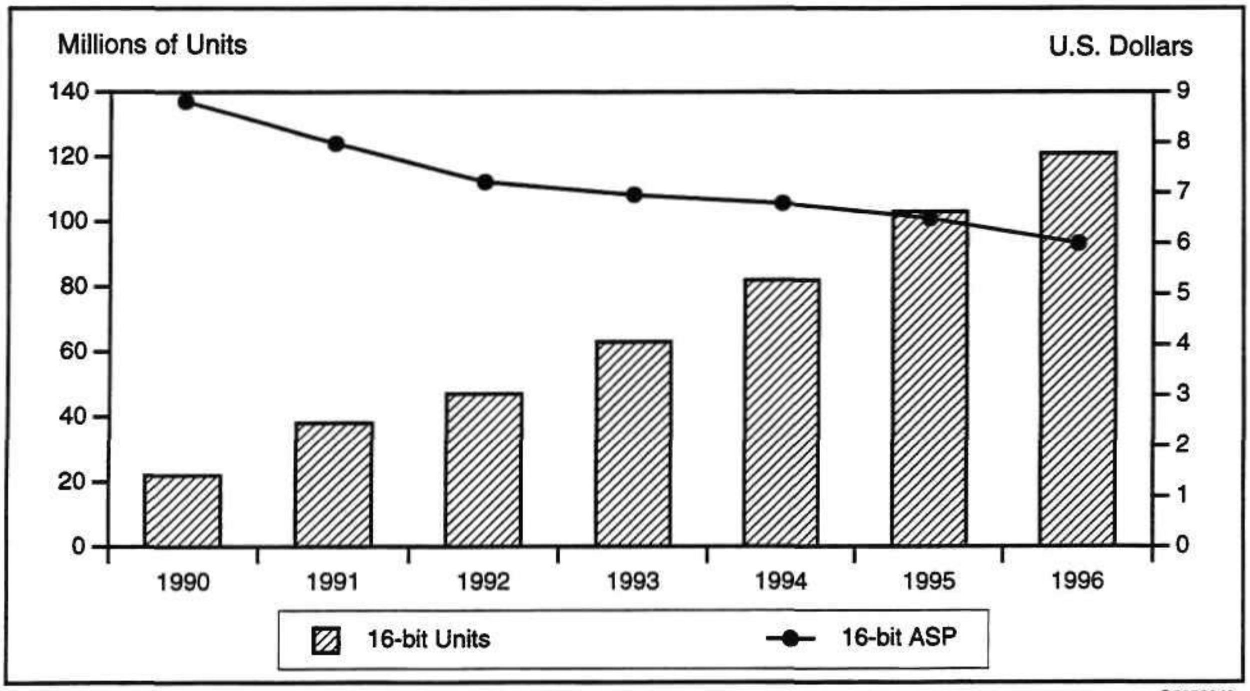
NM = Not meaningful
*Calculated value is less than 0.1 percent.
Note: Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Forecast and Assumptions

16-bit microcontrollers are forecast to show continued strong growth, achieving a substantial 26.1 percent CAGR over the five-year period (see Figure 5-9 and Table 5-12). The key assumptions driving this forecast are as follows:

- The integration of DSPs is expected to open up a wider range of applications not before addressed by microcontrollers.
- Unit volumes will continue strong growth as Intel positions its MCS-96 line to effectively compete for high-end 8-bit sockets.
- ASPs will drop at a reasonable rate during the five-year period, but more importantly, they are expected to reach $6 by 1996, an absolute drop of about $2, which is significant to these low-priced devices.
- This category of devices is expected to meet low-end 16- and 32-bit embedded processors head-on as they go up in integration and come down in price to offer the same types of solutions, with memory remaining as an external element.

Figure 5-9
16-Bit MOS Worldwide Microcontroller ASP and Shipments



Source: Dataquest (December 1992)

G2002640

Table 5-12
16-Bit MOS Microcontroller ASP and Shipments (Millions of Units) to the World

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
16-Bit Units	22	38	47	63	82	103	121	26.1
Growth Rate (%)		72.7	23.0	35.0	30.0	26.0	17.0	
Percent of Total	1.6	2.2	2.5	2.9	3.1	3.4	3.6	

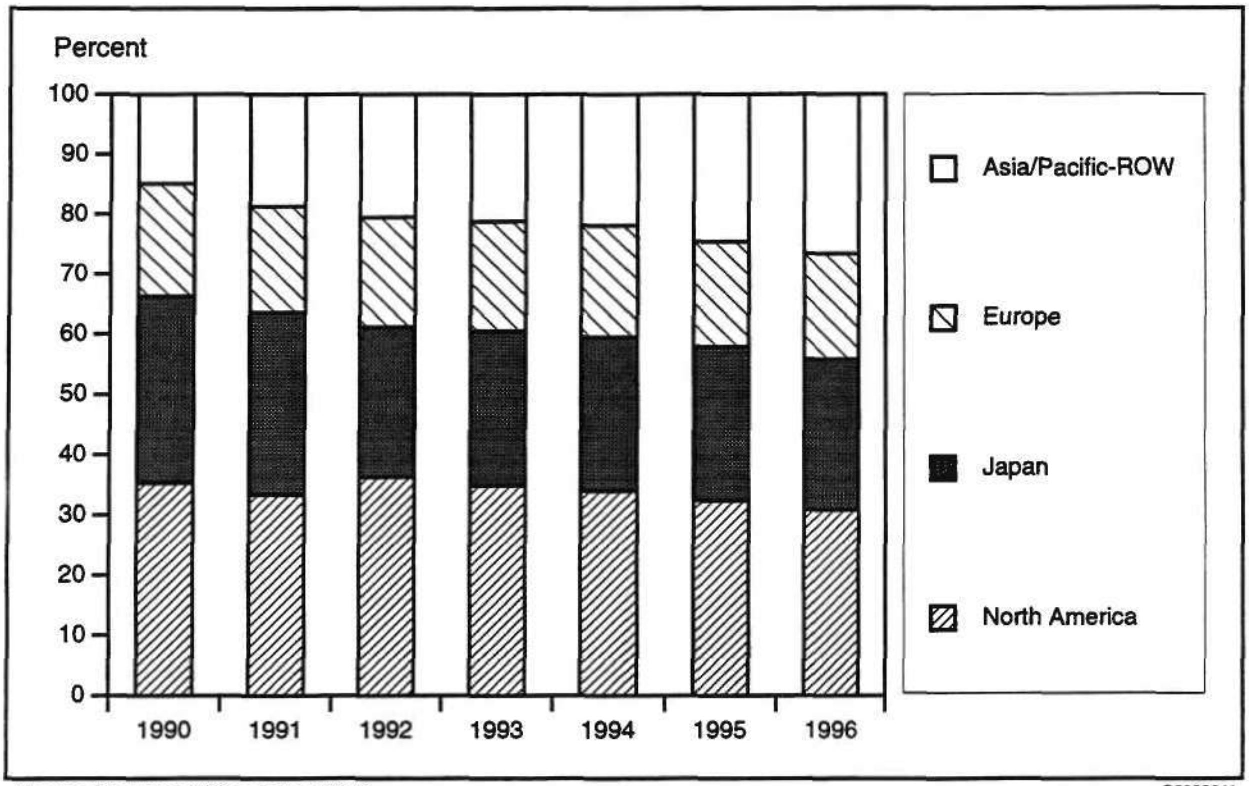
DSP units are excluded from this table.
Columns may not add to totals shown due to rounding.
Source: Dataquest (December 1992)

Chapter 6
Regional Market Outlook

Regional consumption of total microcomponents is quite balanced among the four regional market segments. Each segment represents a sizable revenue base, with North America on top, followed by Japan, Asia/Pacific, and Europe (see Figure 6-1 and Table 6-1). Tables 6-2 through 6-5 shows the mix of companies dominating sales into each region of consumption.

North America has one-third of the total market and will maintain its No. 1 position, driven primarily by the consumption of microprocessors and microperipherals. As might be expected, sales into this region are dominated by Intel, both from microprocessors and microperipherals. Following at a distance are Motorola and a host of other vendors

Figure 6-1
MOS Microcomponent IC Revenue, by Region



Source: Dataquest (December 1992)

G2002641

Table 6-1
Revenue from MOS Microcomponent ICs Shipped by Region, 1990-1996
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total MOS Microcomponent Revenue	9,584	11,774	12,985	14,805	17,258	20,016	21,920	13.2
Growth Rate (%)	22.7	22.9	10.3	14.0	16.6	16.0	9.5	
Percent of Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
North America	3,381	3,916	4,698	5,149	5,847	6,464	6,754	11.5
Growth Rate (%)		15.8	20.0	9.6	13.6	10.6	4.5	
Percent of Total	35.3	33.3	36.2	34.8	33.9	32.3	30.8	
Japan	2,974	3,579	3,252	3,807	4,405	5,127	5,477	8.9
Growth Rate (%)		20.3	-9.1	17.1	15.7	16.4	6.8	
Percent of Total	31.0	30.4	25.0	25.7	25.5	25.6	25.0	
Europe	1,802	2,082	2,377	2,713	3,215	3,508	3,867	13.2
Growth Rate (%)		15.5	14.2	14.1	18.5	9.1	10.2	
Percent of Total	18.8	17.7	18.3	18.3	18.6	17.5	17.6	
Asia/Pacific-Rest of World	1,427	2,197	2,658	3,136	3,791	4,917	5,822	21.5
Growth Rate (%)		54.0	21.0	18.0	20.9	29.7	18.4	
Percent of Total	14.9	18.7	20.5	21.2	22.0	24.6	26.6	

Columns may not add to totals shown due to rounding.
Source: Dataquest (December 1992)

with minor shares. A remarkable 90 percent of the sales into the North American region comes from companies based in North America.

Japan has 30 percent market share and is driven primarily by consumption of microcontrollers. It is projected to drop from second to third place over this forecast period, displaced by the Asia/Pacific region. NEC took over as the leading vendor of microcomponents in Japan, primarily driven by its microcontroller sales, as is the case with Japanese vendors in second through sixth place. Intel, in second place, is the only substantial non-Japanese vendor. Surprisingly, only 76.5 percent of the sales into the Japanese region comes from companies based in Japan.

Europe, the smallest regional segment of consumption, will hold its position as many companies gear up to manufacture goods in the EEC trade community. Again, Intel is the leading vendor in this region, selling microprocessors to European computer companies, with Motorola a distant second and NEC third. It is noteworthy that the three large European vendors—Philips, SGS-Thomson, and Siemens—are fourth, fifth, and seventh, respectively, in their own region, and, along with all other European companies, account for only 17 percent of their region's consumption.

Asia/Pacific showed remarkable growth over this forecast period, moving from 18.7 percent to 26.6 percent of total consumption, driven primarily by the manufacture of computer systems and peripherals. Intel and AMD rank first and third, respectively, clearly from sales of 80x86 microprocessors, with Motorola in second place because of microcontrollers. United Microelectronics is the only local manufacturing presence among the top 10 players and, along with all the other Asia/Pacific vendors, accounts for only 5 percent of the total sales into this region.

Table 6-2
Top 20 Companies' Factory Revenue from Shipments of Microcomponent ICs to North America (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	1,445	1,712	18	43.1
2	2	Motorola	461	545	18	13.7
3	4	Texas Instruments	133	206	55	5.2
4	3	National Semiconductor	178	188	6	4.7
5	8	Advanced Micro Devices	83	150	81	3.8
6	7	LSI Logic	89	91	2	2.3
7	12	Western Digital	56	88	57	2.2
8	16	VLSI Technology	39	87	123	2.2
9	9	NEC	81	82	1	2.1
10	6	Cirrus Logic	94	81	-14	2.0
11	10	Toshiba	69	72	4	1.8
12	11	Hitachi	68	67	-1	1.7
13	13	Zilog	52	54	4	1.4
14	5	Chips & Technologies	123	47	-62	1.2
15	17	Philips	38	42	11	1.1
16	29	Cypress Semiconductor	12	37	208	.9
17	18	SGS-Thomson	35	36	3	.9
17	19	NCR	29	36	24	.9
19	15	Harris	47	35	-26	.9
20	22	Siemens	18	30	67	.8
		All Others	289	286	-1	7.2
		North American Companies	3,051	3,560	17	89.6
		Japanese Companies	277	285	3	7.2
		European Companies	102	121	19	3.0
		Asia/Pacific Companies	9	6	-33	.2
		Total Market	3,439	3,972	15	100.0

Source: Dataquest (December 1992)

Table 6-3
Top 20 Companies' Factory Revenue from Shipments of Microcomponent ICs to Japan (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	NEC	689	831	21	23.2
2	4	Intel	332	430	30	12.0
3	3	Mitsubishi	351	401	14	11.2
4	2	Hitachi	355	384	8	10.7
5	5	Matsushita	235	289	23	8.1
6	6	Toshiba	226	248	10	6.9
7	7	Fujitsu	171	188	10	5.2
8	8	Motorola	124	158	27	4.4
9	9	Sharp	103	114	11	3.2
10	12	Sony	43	85	98	2.4
11	10	Oki	71	76	7	2.1
12	11	Texas Instruments	45	68	51	1.9
13	16	Ricoh	22	62	182	1.7
14	14	National Semiconductor	33	36	9	1.0
15	13	Sanyo	34	32	-6	.9
16	15	Cirrus Logic	23	23	0	.6
16	20	Western Digital	13	23	77	.6
18	16	Advanced Micro Devices	22	20	-9	.6
18	19	Rohm	16	20	25	.6
20	18	Chips & Technologies	18	17	-6	.5
		All Others	59	81	37	2.3
		North American Companies	643	822	28	22.9
		Japanese Companies	2,327	2,745	18	76.5
		European Companies	15	19	27	.5
		Asia/Pacific Companies	0	0	0	.0
		Total Market	2,985	3,586	20	100.0

Source: Dataquest (December 1992)

Table 6-4
Top 20 Companies' Factory Revenue from Shipments of Microcomponent ICs to Europe (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share(%)
1	1	Intel	528	663	26	31.6
2	2	Motorola	233	264	13	12.6
3	3	NEC	138	150	9	7.2
4	5	Philips	113	115	2	5.5
5	4	SGS-Thomson	126	108	-14	5.2
6	6	Texas Instruments	99	107	8	5.1
7	7	Siemens	83	87	5	4.1
8	8	Hitachi	69	75	9	3.6
9	9	Advanced Micro Devices	60	74	23	3.5
10	10	National Semiconductor	56	63	13	3.0
11	11	Toshiba	51	56	10	2.7
12	16	Western Digital	18	38	111	1.8
13	13	VLSI Technology	28	34	21	1.6
14	14	Matra MHS	24	29	21	1.4
15	15	ITT	21	23	10	1.1
16	17	Zilog	17	21	24	1.0
17	12	Harris	31	18	-42	.9
17	18	Oki	15	18	20	.9
19	NM	Matsushita	0	17	NM	.8
20	19	Chips & Technologies	14	15	7	.7
20	20	Fujitsu	10	15	50	.7
20	21	Mitsubishi	9	15	67	.7
		All Others	80	92	15	4.4
		North American Companies	1,164	1,396	20	66.6
		Japanese Companies	294	349	19	16.6
		European Companies	363	349	-4	16.6
		Asia/Pacific Companies	2	3	50	.1
		Total Market	1,823	2,097	15	100.0

NM = Not meaningful
Source: Dataquest (December 1992)

Table 6-5
Top 20 Companies' Factory Revenue from Shipments of Microcomponent ICs to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	421	773	84	34.9
2	2	Motorola	152	204	34	9.2
3	8	Advanced Micro Devices	53	172	225	7.8
4	5	Mitsubishi	71	111	56	5.0
5	3	Chips & Technologies	85	86	1	3.9
5	4	NEC	73	86	18	3.9
7	11	Toshiba	40	78	95	3.5
8	6	Western Digital	61	60	-2	2.7
9	7	Hitachi	54	57	6	2.6
9	15	United Microelectronics	30	57	90	2.6
11	10	National Semiconductor	42	54	29	2.4
12	12	Philips	38	50	32	2.3
13	9	Texas Instruments	43	48	12	2.2
14	26	Cirrus Logic	9	41	356	1.9
15	13	VLSI Technology	36	37	3	1.7
16	14	Sanyo	32	35	9	1.6
17	16	Oki	29	30	3	1.4
18	17	Zilog	25	28	12	1.3
19	19	Samsung	20	24	20	1.1
20	22	Fujitsu	15	23	53	1.0
		All Others	117	158	35	7.1
		North American Companies	993	1,571	58	71.0
		Japanese Companies	338	445	32	20.1
		European Companies	59	78	32	3.5
		Asia/Pacific Companies	56	118	111	5.3
		Total Market	1,446	2,212	53	100.0

Source: Dataquest (December 1992)

Chapter 7
Microcomponent Company Comparisons

Tables 7-1 through 7-5 provide market share distribution for total microcomponents, microprocessors, microperipherals, microcontrollers, and digital signal processors. These data have been included for completeness, showing the historical revenue development by company within each major product segment.

Table 7-1
Total Microcomponent Factory Revenue (Millions of Dollars)

1991 Rank		1987	1988	1989	1990	1991
1	Intel	1,087	1,835	1,929	2,726	3,578
2	Motorola	520	699	767	970	1,171
3	NEC	566	790	841	981	1,149
4	Hitachi	402	525	505	546	583
5	Mitsubishi	267	381	431	441	543
6	Toshiba	283	346	361	386	454
7	Texas Instruments	169	234	252	320	429
8	Advanced Micro Devices	178	183	172	218	416
9	National Semiconductor	140	150	169	309	341
10	Matsushita	199	230	218	250	321
11	Fujitsu	146	202	197	213	244
12	Philips	100	114	131	193	212
13	Western Digital	70	100	135	148	209
14	SGS-Thomson	95	118	161	175	167
15	Chips & Technologies	87	130	216	240	165
16	VLSI Technology	18	54	94	105	165
17	Cirrus Logic	0	0	29	129	151
18	Oki	101	134	142	131	137
19	Sharp	34	54	104	124	134
20	Siemens	44	88	92	116	134
21	LSI Logic	0	18	67	93	115
22	Zilog	75	90	99	100	110
23	Sony	21	37	43	43	88
24	Sanyo	53	70	63	71	69

(Continued)

Table 7-1 (Continued)
Total Microcomponent Factory Revenue (Millions of Dollars)

1991 Rank		1987	1988	1989	1990	1991
25	Harris	44	62	115	110	65
26	Ricoh	14	19	21	22	62
27	United Microelectronics	28	35	43	39	62
28	Cypress Semiconductor	0	7	11	15	48
29	Dallas Semiconductor	0	0	0	0	41
30	Standard Microsystems	36	34	34	40	40
	Total Market	5,108	7,144	7,808	9,693	11,867
	North American Companies	2,663	3,872	4,367	5,851	7,349
	Japanese Companies	2,096	2,817	2,955	3,236	3,824
	European Companies	310	401	433	539	567
	Asia/Pacific Companies	39	54	53	67	127

Source: Dataquest (December 1992)

Table 7-2
Total Microprocessor Factory Revenue (Millions of Dollars)

1991 Rank		1987	1988	1989	1990	1991
1	Intel	468	858	1,204	1,826	2,504
2	Motorola	158	209	275	291	363
3	Advanced Micro Devices	105	118	105	89	317
4	National Semiconductor	45	48	55	66	81
5	NEC	57	74	69	72	76
6	Hitachi	61	74	68	72	76
7	SGS-Thomson	25	28	53	53	55
8	Toshiba	27	33	41	42	47
9	Cypress Semiconductor	0	6	9	13	46
10	LSI Logic	0	0	19	34	45
11	Harris	31	45	48	45	38
12	Zilog	15	16	25	25	31
13	Performance Semiconductor	0	0	13	24	28
14	Siemens	11	26	20	20	21
15	Weitek	0	0	0	0	19
16	Mitsubishi	8	2	23	21	18
17	Fujitsu	14	19	17	19	16
18	Integrated Device Technology	0	0	6	13	14
19	Oki	9	14	19	16	13
20	Philips	10	8	12	8	13
	Total Market	1,193	1,716	2,155	2,808	3,881
	North American Companies	930	1,376	1,795	2,444	3,510
	Japanese Companies	195	257	261	261	269
	European Companies	64	79	94	94	96
	Asia/Pacific Companies	4	4	5	9	6

Source: Dataquest (December 1992)

Table 7-3
Total Microperipheral Factory Revenue (Millions of Dollars)

1991 Rank		1987	1988	1989	1990	1991
1	Intel	351	611	425	544	650
2	Western Digital	70	100	135	148	209
3	Motorola	139	180	145	167	194
4	NEC	175	244	159	176	192
5	Texas Instruments	97	132	117	130	184
6	Chips & Technologies	87	130	216	240	165
7	VLSI Technology	16	50	92	104	161
8	Cirrus Logic	0	0	29	129	151
9	Toshiba	139	145	142	144	149
10	Hitachi	87	122	126	134	139
11	National Semiconductor	39	42	49	83	98
12	Fujitsu	75	104	76	81	88
13	Matsushita	55	58	55	59	67
14	Advanced Micro Devices	55	44	42	68	64
15	Mitsubishi	61	29	50	57	62
16	United Microelectronics	22	27	34	32	61
17	LSI Logic	0	18	45	54	60
18	Zilog	41	49	55	58	58
19	SGS-Thomson	27	30	50	53	45
20	Philips	27	23	26	59	40
21	Standard Microsystems	36	34	34	40	40
	Total Market	1,784	2,420	2,345	2,839	3,138
	North American Companies	1,021	1,519	1,555	1,963	2,179
	Japanese Companies	632	750	652	700	747
	European Companies	107	124	99	135	109
	Asia/Pacific Companies	24	27	39	41	103

Source: Dataquest (December 1992)

Table 7-4
Total Microcontroller Factory Revenue (Millions of Dollars)

1991 Rank		1987	1988	1989	1990	1991
1	NEC	297	420	598	714	860
2	Motorola	223	310	339	486	574
3	Mitsubishi	198	350	358	363	463
4	Intel	268	366	300	356	424
5	Hitachi	254	329	308	337	364
6	Toshiba	117	168	177	197	251
7	Matsushita	140	164	156	182	243
8	Philips	63	82	93	125	159
9	Fujitsu	43	60	85	92	117
10	Sharp	28	46	97	111	117
11	National Semiconductor	56	60	65	93	107
12	Siemens	15	34	56	78	94
13	Oki	56	81	88	82	93
14	Sony	16	25	33	38	81
15	Texas Instruments	27	39	46	70	80
16	SGS-Thomson	43	55	51	69	67
17	Sanyo	53	70	63	70	65
18	Ricoh	9	13	16	17	57
19	Matra MHS	15	17	28	33	37
20	ITT	11	13	25	28	35
21	Zilog	19	25	19	17	21
22	Rohm	0	0	13	13	19
23	Samsung	8	15	3	13	17
24	Seiko Epson	6	12	11	10	16

(Continued)

Table 7-4 (Continued)
Total Microcontroller Factory Revenue (Millions of Dollars)

1991 Rank		1987	1988	1989	1990	1991
25	Advanced Micro Devices	18	21	25	21	14
26	Harris	0	0	25	25	14
27	Microchip Technology	0	0	0	15	14
28	Rockwell	18	18	13	14	9
29	Dallas Semiconductor	0	0	0	0	7
30	GEC Plessey	0	0	0	0	5
	Total Market	2,015	2,819	3,113	3,693	4,427
	North American Companies	648	868	870	1,141	1,301
	Japanese Companies	1,217	1,738	2,003	2,226	2,746
	European Companies	139	190	231	309	362
	Asia/Pacific Companies	11	23	9	17	18

Source: Dataquest (December 1992)

Table 7-5
Total Digital Signal Processor Factory Revenue (Millions of Dollars)

1991 Rank		1987	1988	1989	1990	1991
1	Texas Instruments	39	53	77	110	143
2	Motorola	0	0	8	26	40
3	AT&T	0	18	19	17	33
4	Fujitsu	14	19	19	21	23
5	NEC	37	52	15	19	21
6	Analog Devices	12	20	20	20	20
7	LSI Logic	0	0	3	4	10
8	DSP Group	0	0	0	0	10
9	Toshiba	0	0	1	3	7
10	Hitachi	0	0	3	3	4
11	Harris	0	0	7	10	4
12	Sanyo	0	0	0	1	4
	Total Market	116	189	195	244	328
	North American Companies	64	109	147	195	266
	Japanese Companies	52	72	39	49	62
	European Companies	0	8	9	0	0
	Asia/Pacific Companies	0	0	0	0	0

Source: Dataquest (December 1992)

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a company of
The Dun & Bradstreet Corporation

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

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

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

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

Offices in
Costa Mesa, Munich,
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Microcomponent Market Share

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Microcomponent Market Share

Introduction

This document contains detailed information on Dataquest's view of the microcomponent market. Included in this document are:

- 1989-1991 market share estimates
- 1989-1991 market share rankings

Analyses of market share by company provide insight into high-technology markets and reinforce estimates of consumption, production, and company revenue.

More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of these data is provided in the *Dataquest Perspectives* located in the binder of the same name.

Segmentation

This section outlines the market segments that are specific to this document. For a complete description of all market segments tracked by Dataquest, please refer to the *Dataquest High-Technology Guide: Segmentation and Glossary.*

For market share purposes, Dataquest defines the microcomponent market according to the following functional segmentation scheme:

Digital Microcomponent IC
  Digital Microprocessor (MPU)
  Digital Microcontroller (MCU)
  Digital Microperipheral (MPR)
  Digital Signal Processor (DSP)

Definitions

This section lists the definitions that are used by Dataquest to present the data in this document. Complete definitions for semiconductor devices can be found in the *Dataquest Semiconductor Market Share Survey Guide.*

Digital Microcomponent IC (Digital Microprocessor + Digital Microcontroller + Digital Microperipheral + Digital Signal Processor). Defined as a digital IC that contains a data processing unit or serves as an interface to such a unit. Includes both complex-instruction-set computing (CISC) and reduced-instruction-set computing (RISC) microprocessors. Also includes both MOS and bipolar technologies.

Digital Microprocessor. Defined as a semiconductor product serving as the central processing unit (CPU) of a system. Consists of an instruction decoder, arithmetic logic unit (ALU), registers, and additional logic. An MPU performs general-purpose computing functions by executing external instructions and manipulating data held in external memory. Includes digital MPUs incorporating or originating from an ASIC design.

Digital Microcontroller. Defined as a semiconductor product serving as a dedicated or embedded controller in a system. Consists of an integral MPU, nonvolatile memory containing end-user-specified instructions, and volatile memory for temporary storage of code or data. An MCU can perform basic computing functions without support from microperipheral (MPR) products. Includes digital MCUs incorporating or originating from an ASIC design.

Digital Microperipheral. Defined as a semiconductor product normally serving as a logical support function to an MPU in a system. An MPR provides enhancement of system performance and/or interface with external systems. Includes digital MPRs comprising more than one device, such as PC chip sets. Examples of a digital MPR include: memory and bus controllers (for example, PC logic chip sets, DRAM controllers, memory management units (MMU), and DMA controllers); peripheral interface controllers (for example, graphics controllers, LAN controllers, UARTs, keyboard controllers, and mass storage controllers); and coprocessors (for example, math coprocessors—or FPUs—and other coprocessors).

Digital Signal Processor. Defined as a high-speed general-purpose arithmetic unit used for performing complex mathematical operations such as Fourier transforms.

Merchant versus Captive Consumption. Dataquest includes all revenue, both merchant and captive, for semiconductor suppliers selling to the merchant market. The data exclude completely captive suppliers where devices are manufactured solely for the company's own use. A product that is used internally is valued at market price rather than at transfer or factory price.

Regional Definitions

North America: Includes United States and Canada

Europe: Western Europe

Japan: Japan

Asia-Pacific/Rest of World: All other countries

Line Item Definitions

Factory revenue is defined as the amount of money received by a semiconductor vendor for its goods. Revenue from the sale of semiconductors sold either as finished goods, die, or wafers to another semiconductor vendor for resale is attributed to the semiconductor vendor who sells the product to a distributor or equipment manufacturer.

Shipment is defined as the number of complete products delivered, whether single chips or chip sets.

Average selling price is defined as the mathematical average price received by a manufacturer for a given product type.

For each segment or subsegment of products defined herein, these line items conform to the following equation:

Revenue = Shipments × Average Selling Price

Market Share Methodology

Dataquest utilizes both primary and secondary sources to produce market statistics data. In the fourth quarter of each year, Dataquest surveys all major participants within each industry. Selected companies are resurveyed during the first quarter of the following year to verify final annual results. This primary research is supplemented with additional primary research and secondary research to verify market size, shipment totals, and pricing information. Sources of data utilized by Dataquest include:

- Information published by major industry participants
- Estimates made by knowledgeable and reliable industry spokespersons
- Government data or trade association data
- 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 suppliers.

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 was formerly known as ZyMOS.
2. GEC Plessey revenue includes MEDL and Plessey revenue.
3. Harris revenue includes GE Solid State revenue.
4. Inmos revenue is included in SGS-Thomson revenue.
5. Philips revenue includes Signetics revenue.
6. Other North American Companies and Other Asia/Pacific Companies revenue has been restated to reflect the fewer number of companies published in 1991.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar amounts. The following outlines these rates for 1989 through 1991.

	1989	1990	1991
Japan (Yen/U.S.$)	138	144	136
France (Franc/U.S.$)	6.39	5.44	5.64
Germany (Deutsche Mark/U.S.$)	1.88	1.62	1.66
United Kingdom (U.S.$/Pound Sterling)	1.50	1.79	1.77

Table 1
Each Company's Factory Revenue from Shipments of Microcomponent ICs to the World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1989	1990	1991	1989	1990	1991
Total Market	7,808	9,693	11,867	100	100.0	100.0
North American Companies	4,367	5,851	7,349	55.9	60.4	61.9
Advanced Micro Devices	172	218	416	2.2	2.2	3.5
Analog Devices	20	20	20	.3	.2	.2
Appian Technology	30	38	8	.4	.4	.1
AT&T	21	21	33	.3	.2	.3
Atmel	0	0	2	.0	.0	.0
Chips & Technologies	216	240	165	2.8	2.5	1.4
Cirrus Logic	29	129	151	.4	1.3	1.3
Cypress Semiconductor	11	15	48	.1	.2	.4
Dallas Semiconductor	0	0	41	.0	.0	.3
Harris	115	110	65	1.5	1.1	.5
Hughes	2	2	2	.0	.0	.0
Integrated Device Technology	13	20	20	.2	.2	.2
Intel	1,929	2,726	3,578	24.7	28.1	30.2
ITT	25	28	35	.3	.3	.3
LSI Logic	67	93	115	.9	1.0	1.0
Microchip Technology	18	16	15	.2	.2	.1
Motorola	767	970	1,171	9.8	10.0	9.9
NCR	22	31	39	.3	.3	.3
National Semiconductor	169	309	341	2.2	3.2	2.9
Performance Semiconductor	13	24	28	.2	.2	.2
Rockwell	42	40	20	.5	.4	.2
SEEQ Technology	0	12	6	.0	.1	.1
Sierra Semiconductor	1	1	1	.0	.0	.0
Standard Microsystems	34	40	40	.4	.4	.3
Supertex	0	0	2	.0	.0	.0
Texas Instruments	252	320	429	3.2	3.3	3.6
TRW	5	6	7	.1	.1	.1
VLSI Technology	94	105	165	1.2	1.1	1.4
WaferScale Integration	2	2	7	.0	.0	.1
Weitek	49	57	39	.6	.6	.3
Western Digital	135	148	209	1.7	1.5	1.8
Zilog	99	100	110	1.3	1.0	.9
Other North American Companies	15	10	21	.2	.1	.2
Japanese Companies	2,955	3,236	3,824	37.8	33.4	32.2
Fuji Electric	0	1	1	.0	.0	.0
Fujitsu	197	213	244	2.5	2.2	2.1

(Continued)

Table 1 (Continued)
Each Company's Factory Revenue from Shipments of Microcomponent ICs to the World
(Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1989	1990	1991	1989	1990	1991
Hitachi	505	546	583	6.5	5.6	4.9
Matsushita	218	250	321	2.8	2.6	2.7
Mitsubishi	431	441	543	5.5	4.5	4.6
NEC	841	981	1,149	10.8	10.1	9.7
Oki	142	131	137	1.8	1.4	1.2
Ricoh	21	22	62	.3	.2	.5
Rohm	17	17	23	.2	.2	.2
Sanyo	63	71	69	.8	.7	.6
Seiko Epson	11	10	16	.1	.1	.1
Sharp	104	124	134	1.3	1.3	1.1
Sony	43	43	88	.6	.4	.7
Toshiba	361	386	454	4.6	4.0	3.8
Other Japanese Companies	1	0	0	.0	.0	.0
European Companies	433	539	567	5.5	5.6	4.8
Eurosil	2	4	0	.0	.0	.0
GEC Plessey	0	8	5	.0	.1	.0
Matra MHS	28	33	37	.4	.3	.3
MEDL	3	0	0	.0	.0	.0
Philips	131	193	212	1.7	2.0	1.8
Plessey	3	0	0	.0	.0	.0
SGS-Thomson	161	175	167	2.1	1.8	1.4
Siemens	92	116	134	1.2	1.2	1.1
TMS	13	10	12	.2	.1	.1
Asia/Pacific Companies	53	67	127	.7	.7	1.1
Goldstar	2	3	11	.0	.0	.1
Hualon Microelectronics Corp.	NA	0	9	NA	.0	.1
Samsung	8	22	27	.1	.2	.2
Silicon Integrated Systems	NA	3	4	NA	.0	.0
United Microelectronics	43	39	62	.6	.4	.5
Winbond Electronics	NA	0	14	NA	.0	.1

NA = Not available
Source: Dataquest (June 1992)

Table 2
Top 50 Companies' Factory Revenue from Shipments of Microcomponent ICs to the World (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	2,726	3,578	31	30.2
2	3	Motorola	970	1,171	21	9.9
3	2	NEC	981	1,149	17	9.7
4	4	Hitachi	546	583	7	4.9
5	5	Mitsubishi	441	543	23	4.6
6	6	Toshiba	386	454	18	3.8
7	7	Texas Instruments	320	429	34	3.6
8	11	Advanced Micro Devices	218	416	91	3.5
9	8	National Semiconductor	309	341	10	2.9
10	9	Matsushita	250	321	28	2.7
11	12	Fujitsu	213	244	15	2.1
12	13	Philips	193	212	10	1.8
13	15	Western Digital	148	209	41	1.8
14	14	SGS-Thomson	175	167	-5	1.4
15	10	Chips & Technologies	240	165	-31	1.4
15	21	VLSI Technology	105	165	57	1.4
17	17	Cirrus Logic	129	151	17	1.3
18	16	Oki	131	137	5	1.2
19	18	Sharp	124	134	8	1.1
19	19	Siemens	116	134	16	1.1
21	23	LSI Logic	93	115	24	1.0
22	22	Zilog	100	110	10	.9
23	26	Sony	43	88	105	.7
24	24	Sanyo	71	69	-3	.6
25	20	Harris	110	65	-41	.5
26	29	United Microelectronics	39	62	59	.5
26	35	Ricoh	22	62	182	.5
28	42	Cypress Semiconductor	15	48	220	.4
29	NM	Dallas Semiconductor	0	41	NM	.3
30	27	Standard Microsystems	40	40	0	.3
31	25	Weitek	57	39	-32	.3
31	32	NCR	31	39	26	.3
33	31	Matra MHS	33	37	12	.3
34	33	ITT	28	35	25	.3
35	37	AT&T	21	33	57	.3
36	34	Performance Semiconductor	24	28	17	.2
37	35	Samsung	22	27	23	.2
38	40	Rohm	17	23	35	.2

(Continued)

Table 2 (Continued)
Top 50 Companies' Factory Revenue from Shipments of Microcomponent ICs to the World
(Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
39	27	Rockwell	40	20	-50	.2
39	38	Analog Devices	20	20	0	.2
39	38	Integrated Device Technology	20	20	0	.2
42	44	Seiko Epson	10	16	60	.1
43	41	Microchip Technology	16	15	-6	.1
44	NM	Winbond	0	14	NM	.1
45	44	TMS	10	12	20	.1
46	50	Goldstar	3	11	267	.1
47	NM	Hualon Microelectronic Corp.	0	9	NM	.1
48	30	Appian	38	8	-79	.1
49	47	TRW	6	7	17	.1
49	51	Waferscale Integration	2	7	250	.1
		All Others	41	44	7	.4
		North American Companies	5,851	7,349	26	61.9
		Japanese Companies	3,236	3,824	18	32.2
		European Companies	539	567	5	4.8
		Asia/Pacific Companies	67	127	90	1.1
		Total Market	9,693	11,867	22	100.0

NM = Not meaningful
Source: Dataquest (June 1992)

Table 3
Top 20 Companies' Factory Revenue from Shipments of Microcomponent ICs to North America (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	1,445	1,712	18	43.1
2	2	Motorola	461	545	18	13.7
3	4	Texas Instruments	133	206	55	5.2
4	3	National Semiconductor	178	188	6	4.7
5	8	Advanced Micro Devices	83	150	81	3.8
6	7	LSI Logic	89	91	2	2.3
7	12	Western Digital	56	88	57	2.2
8	16	VLSI Technology	39	87	123	2.2
9	9	NEC	81	82	1	2.1
10	6	Cirrus Logic	94	81	-14	2.0
11	10	Toshiba	69	72	4	1.8
12	11	Hitachi	68	67	-1	1.7
13	13	Zilog	52	54	4	1.4
14	5	Chips & Technologies	123	47	-62	1.2
15	17	Philips	38	42	11	1.1
16	29	Cypress Semiconductor	12	37	208	.9
17	18	SGS-Thomson	35	36	3	.9
17	19	NCR	29	36	24	.9
19	15	Harris	47	35	-26	.9
20	22	Siemens	18	30	67	.8
		All Others	289	286	-1	7.2
		North American Companies	3,051	3,560	17	89.6
		Japanese Companies	277	285	3	7.2
		European Companies	102	121	19	3.0
		Asia/Pacific Companies	9	6	-33	.2
		Total Market	3,439	3,972	15	100.0

Source: Dataquest (June 1992)

Table 4
Top 20 Companies' Factory Revenue from Shipments of Microcomponent ICs to Europe (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	528	663	26	31.6
2	2	Motorola	233	264	13	12.6
3	3	NEC	138	150	9	7.2
4	5	Philips	113	115	2	5.5
5	4	SGS-Thomson	126	108	-14	5.2
6	6	Texas Instruments	99	107	8	5.1
7	7	Siemens	83	87	5	4.1
8	8	Hitachi	69	75	9	3.6
9	9	Advanced Micro Devices	60	74	23	3.5
10	10	National Semiconductor	56	63	13	3.0
11	11	Toshiba	51	56	10	2.7
12	16	Western Digital	18	38	111	1.8
13	13	VLSI Technology	28	34	21	1.6
14	14	Matra MHS	24	29	21	1.4
15	15	ITT	21	23	10	1.1
16	17	Zilog	17	21	24	1.0
17	12	Harris	31	18	-42	.9
17	18	Oki	15	18	20	.9
19	NM	Matsushita	0	17	NM	.8
20	19	Chips & Technologies	14	15	7	.7
20	20	Fujitsu	10	15	50	.7
20	21	Mitsubishi	9	15	67	.7
		All Others	80	92	15	4.4
		North American Companies	1,164	1,396	20	66.6
		Japanese Companies	294	349	19	16.6
		European Companies	363	349	-4	16.6
		Asia/Pacific Companies	2	3	50	.1
		Total Market	1,823	2,097	15	100.0

NM = Not meaningful
Source: Dataquest (June 1992)

Table 5
Top 20 Companies' Factory Revenue from Shipments of Microcomponent ICs to Japan (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	NEC	689	831	21	23.2
2	4	Intel	332	430	30	12.0
3	3	Mitsubishi	351	401	14	11.2
4	2	Hitachi	355	384	8	10.7
5	5	Matsushita	235	289	23	8.1
6	6	Toshiba	226	248	10	6.9
7	7	Fujitsu	171	188	10	5.2
8	8	Motorola	124	158	27	4.4
9	9	Sharp	103	114	11	3.2
10	12	Sony	43	85	98	2.4
11	10	Oki	71	76	7	2.1
12	11	Texas Instruments	45	68	51	1.9
13	16	Ricoh	22	62	182	1.7
14	14	National Semiconductor	33	36	9	1.0
15	13	Sanyo	34	32	-6	.9
16	15	Cirrus Logic	23	23	0	.6
16	20	Western Digital	13	23	77	.6
18	16	Advanced Micro Devices	22	20	-9	.6
18	19	Rohm	16	20	25	.6
20	18	Chips & Technologies	18	17	-6	.5
		All Others	59	81	37	2.3
		North American Companies	643	822	28	22.9
		Japanese Companies	2,327	2,745	18	76.5
		European Companies	15	19	27	.5
		Asia/Pacific Companies	0	0	0	.0
		Total Market	2,985	3,586	20	100.0

Source: Dataquest (June 1992)

Table 6
Top 20 Companies' Factory Revenue from Shipments of Microcomponent ICs to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	421	773	84	34.9
2	2	Motorola	152	204	34	9.2
3	8	Advanced Micro Devices	53	172	225	7.8
4	5	Mitsubishi	71	111	56	5.0
5	3	Chips & Technologies	85	86	1	3.9
5	4	NEC	73	86	18	3.9
7	11	Toshiba	40	78	95	3.5
8	6	Western Digital	61	60	-2	2.7
9	7	Hitachi	54	57	6	2.6
9	15	United Microelectronics	30	57	90	2.6
11	10	National Semiconductor	42	54	29	2.4
12	12	Philips	38	50	32	2.3
13	9	Texas Instruments	43	48	12	2.2
14	26	Cirrus Logic	9	41	356	1.9
15	13	VLSI Technology	36	37	3	1.7
16	14	Sanyo	32	35	9	1.6
17	16	Oki	29	30	3	1.4
18	17	Zilog	25	28	12	1.3
19	19	Samsung	20	24	20	1.1
20	22	Fujitsu	15	23	53	1.0
		All Others	117	158	35	7.1
		North American Companies	993	1,571	58	71.0
		Japanese Companies	338	445	32	20.1
		European Companies	59	78	32	3.5
		Asia/Pacific Companies	56	118	111	5.3
		Total Market	1,446	2,212	53	100.0

Source: Dataquest (June 1992)

Table 7
Factory Revenue from Shipments of Microcomponent ICs by Regional Market and Regional Company Base
(Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1989	1990	1991	1989	1990	1991
Worldwide Market	7,808	9,693	11,867	100.0	100.0	100.0
North American Companies	4,367	5,851	7,349	55.9	60.4	61.9
Japanese Companies	2,955	3,236	3,824	37.8	33.4	32.2
European Companies	433	539	567	5.5	5.6	4.8
Asia/Pacific Companies	53	67	127	.7	.7	1.1
North American Market	2,796	3,439	3,972	35.8	35.5	33.5
North American Companies	2,421	3,051	3,560	31.0	31.5	30.0
Japanese Companies	259	277	285	3.3	2.9	2.4
European Companies	107	102	121	1.4	1.1	1.0
Asia/Pacific Companies	9	9	6	.1	.1	.1
Japanese Market	2,662	2,985	3,586	34.1	30.8	30.2
North American Companies	495	643	822	6.3	6.6	6.9
Japanese Companies	2,144	2,327	2,745	27.5	24.0	23.1
European Companies	23	15	19	.3	.2	.2
Asia/Pacific Companies	0	0	0	.0	.0	.0
European Market	1,442	1,823	2,097	18.5	18.8	17.7
North American Companies	889	1,164	1,396	11.4	12.0	11.8
Japanese Companies	284	294	349	3.6	3.0	2.9
European Companies	265	363	349	3.4	3.7	2.9
Asia/Pacific Companies	4	2	3	.1	.0	.0
Asia/Pacific Market	908	1,446	2,212	11.6	14.9	18.6
North American Companies	562	993	1,571	7.2	10.2	13.2
Japanese Companies	268	338	445	3.4	3.5	3.7
European Companies	38	59	78	.5	.6	.7
Asia/Pacific Market	40	56	118	.5	.6	1.0

Source: Dataquest (June 1992)

Table 8
Factory Revenue from Shipments of Microcomponent ICs by Product and Regional Company Base (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1989	1990	1991	1989	1990	1991
Microcomponent Market	7,808	9,693	11,867	100.0	100.0	100.0
North American Companies	4,367	5,851	7,349	55.9	60.4	61.9
Japanese Companies	2,955	3,236	3,824	37.8	33.4	32.2
European Companies	433	539	567	5.5	5.6	4.8
Asia/Pacific Companies	53	67	127	.7	.7	1.1
Microprocessor Market	2,155	2,831	3,893	27.6	29.2	32.8
North American Companies	1,795	2,466	3,522	23.0	25.4	29.7
Japanese Companies	261	261	269	3.3	2.7	2.3
European Companies	94	95	96	1.2	1.0	.8
Asia/Pacific Companies	5	9	6	.1	.1	.1
Microcontroller Market	3,113	3,693	4,427	39.9	38.1	37.3
North American Companies	870	1,141	1,301	11.1	11.8	11.0
Japanese Companies	2,003	2,226	2,746	25.7	23.0	23.1
European Companies	231	309	362	3.0	3.2	3.1
Asia/Pacific Companies	9	17	18	.1	.2	.2
Microperipheral Market	2,345	2,925	3,219	30.0	30.2	27.1
North American Companies	1,555	2,049	2,260	19.9	21.1	19.0
Japanese Companies	652	700	747	8.4	7.2	6.3
European Companies	99	135	109	1.3	1.4	.9
Asia/Pacific Companies	39	41	103	.5	.4	.9
Digital Signal Processor Market	195	244	328	2.5	2.5	2.8
North American Companies	147	195	266	1.9	2.0	2.2
Japanese Companies	39	49	62	.5	.5	.5
European Companies	9	0	0	.1	.0	.0
Asia/Pacific Market	0	0	0	.0	.0	.0

Source: Dataquest (June 1992)

Table 9
Top 20 Companies' Factory Revenue from Shipments of Microprocessor ICs to the World (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	1,826	2,504	37	64.3
2	2	Motorola	291	363	25	9.3
3	3	Advanced Micro Devices	110	327	197	8.4
4	6	National Semiconductor	66	81	23	2.1
5	4	Hitachi	72	76	6	2.0
5	4	NEC	72	76	6	2.0
7	7	SGS-Thomson	53	55	4	1.4
8	9	Toshiba	42	47	12	1.2
9	17	Cypress Semiconductor	13	46	254	1.2
10	10	LSI Logic	34	45	32	1.2
11	8	Harris	45	38	-16	1.0
12	11	Zilog	25	31	24	.8
13	12	Performance Semiconductor	24	28	17	.7
14	14	Siemens	20	21	5	.5
15	NM	Weitek	0	19	NM	.5
16	13	Mitsubishi	21	18	-14	.5
17	15	Fujitsu	19	16	-16	.4
18	17	Integrated Device Technology	13	14	8	.4
19	16	Oki	16	13	-19	.3
19	20	Philips	9	13	44	.3
		All Others	60	62	3	1.6
		North American Companies	2,466	3,522	43	90.5
		Japanese Companies	261	269	3	6.9
		European Companies	95	96	1	2.5
		Asia/Pacific Companies	9	6	-33	.2
		Total Market	2,831	3,893	38	100.0

NM = Not meaningful
Source: Dataquest (June 1992)

Table 10
Top 20 Companies' Factory Revenue from Shipments of Microcontroller ICs to the World (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	NEC	714	860	20	19.4
2	2	Motorola	486	574	18	13.0
3	3	Mitsubishi	363	463	28	10.5
4	4	Intel	356	424	19	9.6
5	5	Hitachi	337	364	8	8.2
6	6	Toshiba	197	251	27	5.7
7	7	Matsushita	182	243	34	5.5
8	8	Philips	125	159	27	3.6
9	9	Sharp	111	117	5	2.6
9	11	Fujitsu	92	117	27	2.6
11	10	National Semiconductor	93	107	15	2.4
12	13	Siemens	78	94	21	2.1
13	12	Oki	82	93	13	2.1
14	17	Sony	38	81	113	1.8
15	14	Texas Instruments	70	80	14	1.8
16	16	SGS-Thomson	69	67	-3	1.5
17	14	Sanyo	70	65	-7	1.5
18	23	Ricoh	17	57	235	1.3
19	18	Matra MHS	33	37	12	.8
20	19	ITT	28	35	25	.8
		All Others	152	139	-9	3.1
		North American Companies	1,141	1,301	14	29.4
		Japanese Companies	2,226	2,746	23	62.0
		European Companies	309	362	17	8.2
		Asia/Pacific Companies	17	18	6	.4
		Total Market	3,693	4,427	20	100.0

Source: Dataquest (June 1992)

Table 11
Top 10 Companies' Factory Revenue from Shipments of Microperipheral ICs to the World (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	544	650	19	20.2
2	6	Western Digital	148	209	41	6.5
3	4	Motorola	167	194	16	6.0
3	9	Texas Instruments	130	194	49	6.0
5	3	NEC	176	192	9	6.0
6	2	Chips & Technologies	240	165	-31	5.1
7	11	VLSI Technology	104	161	55	5.0
8	5	National Semiconductor	150	153	2	4.8
9	10	Cirrus Logic	129	151	17	4.7
10	7	Toshiba	144	149	3	4.6
		All Others	993	1,001	1	31.1
		North American Companies	2,049	2,260	10	70.2
		Japanese Companies	700	747	7	23.2
		European Companies	135	109	-19	3.4
		Asia/Pacific Companies	41	103	151	3.2
		Total Market	2,925	3,219	10	100.0

Source: Dataquest (June 1992)

Table 12
Top 10 Companies' Factory Revenue from Shipments of Digital Signal Processor ICs to the World (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Texas Instruments	110	143	30	43.6
2	2	Motorola	26	40	54	12.2
3	6	AT&T	17	33	94	10.1
4	3	Fujitsu	21	23	10	7.0
5	5	NEC	19	21	11	6.4
6	4	Analog Devices	20	20	0	6.1
7	8	LSI Logic	4	10	150	3.0
8	9	Toshiba	3	7	133	2.1
9	7	Harris	10	4	-60	1.2
9	9	Hitachi	3	4	33	1.2
9	11	Sanyo	1	4	300	1.2
		All Others	10	19	90	5.8
		North American Companies	195	266	36	81.1
		Japanese Companies	49	62	27	18.9
		European Companies	0	0	0	.0
		Asia/Pacific Companies	0	0	0	.0
		Total Market	244	328	34	100.0

Source: Dataquest (June 1992)

Dataquest

Dataquest Research and Sales Offices:

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

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

Dataquest Incorporated Invitational
Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
United States
Phone: 01-714-957-0171
Facsimile: 01-714-957-0903

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: 61-2-959-4544
Facsimile: 61-2-929-0635

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

Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
Phone: 33-1-48-97-3100
Facsimile: 33-1-48-97-3400

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

Dataquest Germany
In der Schneithohl 17
6242 Kronberg 2
Germany
Phone: 49-6173/61685
Facsimile: 49-6173/67901

Dataquest Hong Kong
Rm. 4A01
HKPC Building
78 Tat Chee Avenue
Kowloon, Hong Kong
Phone: 852-788-5432
Facsimile: 852-788-5433

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

Dataquest Korea
Daeheung Building 1105
648-23 Yeoksam-dong
Kangnam-gu
Seoul 135-080, Korea
Phone: 82-2-556-4166
Facsimile: 82-2-552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 65-4597181
Telex: 38257
Facsimile: 65-4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sec. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: 886-2-501-7960
886-2-501-5592
Facsimile: 886-2-505-4265

Dataquest Thailand
300/31 Rachdapisek Road
Bangkok 10310
Thailand
Phone: 66-2-275-1904/5
66-2-277-8850
Facsimile: 66-2-275-7005

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Microprocessor Market Share and Shipments

June 29, 1992

Source: Dataquest

Market Statistics

Microcomponents *Worldwide*

MCRO-SEG-MS-9203

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Microprocessor Market Statistics

June 29, 1992

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Market Statistics

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Microprocessor Market Statistics

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Note: All tables show estimated data.

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Microprocessor Market Statistics

Introduction

This document contains detailed information on Dataquest's view of the microprocessor market. Included in this document are the following:

- 1990-1991 unit shipment and market share estimates
- 1990-1991 revenue and market share estimates

Analyses of market share by company provide insight into high-technology markets and reinforce estimates of consumption, production, and company revenue. More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of these data is provided in the *Dataquest Perspectives* located in the binder of the same name.

Segmentation

This section outlines the market segments that are specific to this document. For a complete description of all market segments tracked by Dataquest, please refer to the *Dataquest High-Technology Guide: Segmentation and Glossary.*

For market share purposes, Dataquest defines the microcomponent market according to the following functional segmentation scheme:

Digital Microcomponent IC
- Digital Microprocessor (MPU)
- Digital Microcontroller (MCU)
- Digital Microperipheral (MPR)
- Digital Signal Processor (DSP)

Definitions

This section lists the definitions that are used by Dataquest to present the data in this document. Complete definitions for semiconductor devices can be found in the *Dataquest Semiconductor Market Share Survey Guide.*

Digital Microcomponent IC (Digital Microprocessor + Digital Microcontroller + Digital Microperipheral + Digital Signal Processor). Defined as a digital IC that contains a data processing unit or serves as an interface to such a unit. Includes both complex-instruction-set computing (CISC) and reduced-instruction-set computing (RISC) microprocessors. Also includes both MOS and bipolar technologies.

Digital Microprocessor. Defined as a semiconductor product serving as the central processing unit (CPU) of a system. Consists of an instruction decoder, arithmetic logic unit (ALU), registers, and additional logic. An MPU performs general-purpose computing functions by executing external instructions and manipulating data held in external memory. Includes digital MPUs incorporating or originating from an ASIC design.

Digital Microcontroller. Defined as a semiconductor product serving as a dedicated or embedded controller in a system. Consists of an integral MPU, nonvolatile memory containing end-user-specified instructions, and volatile memory for temporary storage of code or data. An MCU can perform basic computing functions without support from microperipheral (MPR) products. Includes digital MCUs incorporating or originating from an ASIC design.

Digital Microperipheral. Defined as a semiconductor product normally serving as a logical support function to an MPU in a system. An MPR provides enhancement of system performance and/or interface with external systems. Includes digital MPRs comprising more than one device, such as PC chip sets. Examples of a digital MPR include: memory and bus controllers (for example, PC logic chip sets, DRAM controllers, memory management units (MMU), and DMA controllers); peripheral interface controllers (for example, graphics controllers, LAN controllers, UARTs, keyboard controllers, and mass storage controllers); and coprocessors (for example, math coprocessors—or FPUs—and other coprocessors).

Digital Signal Processor. Defined as a high-speed general-purpose arithmetic unit used for performing complex mathematical operations such as Fourier transforms.

Regional Definitions

North America: Includes United States and Canada

Europe: Western Europe

Japan: Japan

Asia-Pacific/Rest of World: All other countries

Line Item Definitions

Factory revenue is defined as the amount of money received by a semiconductor vendor for its goods. Revenue from the sale of semiconductors sold either as finished goods, die, or wafers to another semiconductor vendor for resale is attributed to the semiconductor vendor who sells the product to a distributor or equipment manufacturer.

Shipment is defined as the number of complete products delivered, whether single chips or chip sets.

Average selling price is defined as the mathematical average price received by a manufacturer for a given product type.

For each segment or subsegment of products defined herein, these line items conform to the following equation:

Revenue = Shipments × Average Selling Price

Market Share Methodology

Dataquest utilizes both primary and secondary sources to produce market statistics data. In the fourth quarter of each year, Dataquest surveys all major participants within each industry. Selected companies are resurveyed during the first quarter of the following year to verify final annual results. This primary research is supplemented with additional primary research and secondary research to verify market size, shipment totals, and pricing information. Sources of data utilized by Dataquest include:

- Information published by major industry participants
- Estimates made by knowledgeable and reliable industry spokespersons
- Government data or trade association data
- 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 suppliers.

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. The following companies' microprocessor unit shipments for 1990 have been restated:

   Cypress Semiconductor (RISC shipments)

   Fujitsu (RISC shipments)

   Integrated Device Technology (RISC shipments)

Intel (i860 and i960 shipments)

LSI Logic (RISC shipments)

Motorola (32-bit MPU shipments)

Performance Semiconductor (RISC shipments)

Sharp (all shipments)

2. The following products have been added to the 1990 microprocessor tables:

   Matsushita MN10400 32-bit MPU

   Motorola 68332 32-bit MPU

   NEC V3000 32-bit MPU

   Texas Instruments 34010 and 34020 32-bit MPU

3. Beginning in 1991, the following companies were added to the microprocessor tables:

   Goldstar (8-bit MPU)

   NCR (8-bit MPU)

   Seiko Epson (8-bit MPU)

   United Microelectronic Corporation (8-bit MPU)

   Weitek (32-bit MPU)

4. For 1990 and 1991, Signetics unit shipments have been combined with Philips.

5. The following abbreviations have been used within the tables:

   C represents CMOS

   N represents NMOS

   P represents PMOS

6. Some table columns do not add to totals shown because of rounding.

7. Appian Technology was formerly known as ZyMOS.

8. GEC Plessey revenue includes MEDL and Plessey revenue.

9. Harris revenue includes GE Solid State revenue.

10. Inmos revenue is included in SGS-Thomson revenue.

11. Other North American Companies and Other Asia/Pacific Companies revenue has been restated to reflect the fewer number of companies published in 1991.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar amounts. The following outlines these rates for 1989 through 1991.

	1989	1990	1991
Japan (Yen/U.S.$)	138	144	136
France (Franc/U.S.$)	6.39	5.44	5.64
Germany (Deutsche Mark/U.S.$)	1.88	1.62	1.66
United Kingdom (U.S.$/Pound Sterling)	1.50	1.79	1.77

Section 1: Microprocessor Unit Shipments—Overview

Table 1-1
Each Company's Shipments of All Microprocessors to the World
(Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Intel	24,000	28,400	18	19.9
2	2	Zilog	20,700	27,200	31	19.0
3	3	Motorola	15,700	21,600	38	15.1
4	4	NEC	11,200	11,300	1	7.9
4	6	Hitachi	9,300	11,300	22	7.9
6	7	SGS-Thomson	9,100	9,200	1	6.4
7	5	AMD	11,000	8,600	-22	6.0
8	8	Toshiba	6,500	7,700	18	5.4
9	10	Siemens	3,000	2,900	-3	2.0
10	11	Harris	2,900	2,500	-14	1.8
11	9	Oki	3,200	2,200	-31	1.5
11	12	Sharp	2,600	2,100	-19	1.5
13	13	National	1,700	1,700	0	1.2
14	NM	Goldstar	NA	1,200	NM	.8
15	14	Fujitsu	1,200	760	-37	.5
16	16	Texas Instruments	860	690	-20	.5
17	18	Rockwell	600	620	3	.4
18	19	Mitsubishi	420	400	-5	.3
19	NM	NCR	NA	380	NM	.3
20	14	Philips	1,200	360	-70	.3
21	NM	UMC	NA	300	NM	.2
22	17	CA Micro Devices	710	270	-62	.2
23	21	Inmos	240	260	8	.2
24	20	Matsushita	320	220	-31	.2
25	22	Hughes	180	150	-17	.1
26	24	LSI Logic	100	120	20	.1
27	27	Cypress	25	110	340	.1
28	23	Seiko	120	90	-25	.1
29	26	Performance	55	79	44	.1
30	25	VLSI Technology	71	70	-1	*
31	28	IDT	20	45	125	*
32	NM	Weitek	0	12	NM	*
33	29	Bit	5	3	-40	*
		Total MPU	127,000	142,800	12	100.0

NA = Not available
NM = Not meaningful
* = Calculated value is less than 0.1 percent
Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 1-2
Shipments of All Microprocessors By Class to the World
(Thousands of Units)

Processor Class	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
80x86	47,800	49,700	4	34.7
North American Companies	34,200	36,200	6	25.3
Japanese Companies	11,100	10,900	-2	7.6
European Companies	2,500	2,600	4	1.8
68xxx	15,200	21,000	38	14.7
North American Companies	11,700	17,800	52	12.5
Japanese Companies	1,700	2,300	35	1.6
European Companies	1,800	920	-49	.6
Open System RISC	257	545	112	.4
North American Companies	207	404	95	.3
Japanese Companies	50	123	146	.1
European Companies	0	18	NM	*
Low-End	57,900	64,800	12	45.4
North American Companies	28,100	33,000	17	23.1
Japanese Companies	21,400	22,100	3	15.5
European Companies	8,400	8,200	-2	5.7
Asia-Pacific Companies	NA	1,500	NM	1.1
Proprietary/Miscellaneous	5,800	6,800	17	4.7
North American Companies	4,400	5,300	20	3.7
Japanese Companies	560	480	-14	.3
European Companies	860	1,000	16	.7
Total MPU	127,000	142,800	12	100.0

NA = Not available
NM = Not meaningful
* = Calculated value is less than 0.1 percent.
Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 1-3
Shipments of All Microprocessors By Word Width to the World
(Thousands of Units)

Word Width	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
8-Bit	75,100	79,900	6	56.0
North American Companies	38,900	41,500	7	29.1
Japanese Companies	26,800	27,900	4	19.5
European Companies	9,400	9,000	-4	6.3
Asia-Pacific Companies	NA	1,500	NM	1.1
16-Bit	26,300	22,300	-15	15.6
North American Companies	18,000	14,100	-22	9.9
Japanese Companies	6,000	5,400	-10	3.8
European Companies	2,300	2,800	22	2.0
32/16-Bit	17,600	27,000	53	18.9
North American Companies	14,300	23,900	67	16.7
Japanese Companies	1,700	2,300	35	1.6
European Companies	1,600	790	-51	.6
32-Bit	8,000	13,600	70	9.5
North American Companies	7,500	12,900	72	9.0
Japanese Companies	290	410	41	.3
European Companies	240	280	17	.2
Total MPU	127,000	142,800	12	100.0

NA = Not available
NM = Not meaningful
Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 1-4
Shipments of All Microprocessors By Process Technology to the World
(Thousands of Units)

Process Technology	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
NMOS	76,100	62,400	-18	43.7
North American Companies	55,100	42,800	-22	30.0
Japanese Companies	8,900	6,700	-25	4.7
European Companies	12,100	11,400	-6	8.0
Asia-Pacific Companies	NA	1,500	NM	1.1
CMOS	50,800	80,300	58	56.2
North American Companies	23,400	49,700	112	34.8
Japanese Companies	25,900	29,200	13	20.4
European Companies	1,500	1,400	-7	1.0
Bipolar	100	100	0	0.1
North American Companies	100	100	0	0.1
Total MPU	127,000	142,800	12	100.0

NA = Not available
NM = Not meaningful
Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Section 2: Microprocessor Revenue Estimates—Overview

Table 2-1
Each Company's Factory Revenue from Shipments of Microprocessor ICs to the World
(Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1989	1990	1991	1989	1990	1991
Total Market	2,155	2,831	3,893	100.0	100.0	100.0
North American Companies	1,795	2,466	3,522	83.3	87.1	90.5
Advanced Micro Devices	105	110	327	4.9	3.9	8.4
AT&T	1	0	0	.0	.0	.0
Cypress Semiconductor	9	13	46	.4	.5	1.2
Harris	48	45	38	2.2	1.6	1.0
Hughes	2	2	2	.1	.1	.1
Integrated Device Technology	6	13	14	.3	.5	.4
Intel	1,204	1,826	2,504	55.9	64.5	64.3
LSI Logic	19	34	45	.9	1.2	1.2
Microchip Technology	13	0	0	.6	.0	.0
Motorola	275	291	363	12.8	10.3	9.3
NCR	1	1	1	.0	.0	.0
National Semiconductor	55	66	81	2.6	2.3	2.1
Performance Semiconductor	13	24	28	.6	.8	.7
Rockwell	3	3	3	.1	.1	.1
Texas Instruments	12	10	12	.6	.4	.3
TRW	0	1	1	.0	.0	.0
VLSI Technology	2	1	4	.1	.0	.1
Weitek	0	0	19	.0	.0	.5
Zilog	25	25	31	1.2	.9	.8
Other North American Companies	2	1	3	.1	.0	.1
Japanese Companies	261	261	269	12.1	9.2	6.9
Fujitsu	17	19	16	.8	.7	.4
Hitachi	68	72	76	3.2	2.5	2.0
Matsushita	7	8	10	.3	.3	.3
Mitsubishi	23	21	18	1.1	.7	.5
NEC	69	72	76	3.2	2.5	2.0
Oki	19	16	13	.9	.6	.3
Ricoh	4	4	4	.2	.1	.1
Sharp	7	7	9	.3	.2	.2
Sony	5	0	0	.2	.0	.0
Toshiba	41	42	47	1.9	1.5	1.2
Other Japanese Companies	1	0	0	.0	.0	.0

(Continued)

Table 2-1 (Continued)
Each Company's Factory Revenue from Shipments of Microprocessor ICs to the World
(Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1989	1990	1991	1989	1990	1991
European Companies	94	95	96	4.4	3.4	2.5
GEC Plessey	0	8	0	.0	.3	.0
MEDL	3	0	0	.1	.0	.0
Philips	12	9	13	.6	.3	.3
SGS-Thomson	53	53	55	2.5	1.9	1.4
Siemens	20	20	21	.9	.7	.5
TMS	6	5	7	.3	.2	.2
Asia/Pacific Companies	5	9	6	.2	.3	.2
Goldstar	1	2	1	.0	.1	.0
Silicon Integrated Systems	NA	3	4	NA	.1	.1
United Microelectronics	4	4	1	.2	.1	.0

NA = Not available

Source: Dataquest (June 1992)

Table 2-2
Top 30 Companies' Factory Revenue from Shipments of Microprocessor ICs to the World (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	1,826	2,504	37	64.3
2	2	Motorola	291	363	25	9.3
3	3	Advanced Micro Devices	110	327	197	8.4
4	6	National Semiconductor	66	81	23	2.1
5	4	Hitachi	72	76	6	2.0
5	4	NEC	72	76	6	2.0
7	7	SGS-Thomson	53	55	4	1.4
8	9	Toshiba	42	47	12	1.2
9	17	Cypress Semiconductor	13	46	254	1.2
10	10	LSI Logic	34	45	32	1.2
11	8	Harris	45	38	-16	1.0
12	11	Zilog	25	31	24	.8
13	12	Performance Semiconductor	24	28	17	.7
14	14	Siemens	20	21	5	.5
15	NM	Weitek	0	19	NM	.5
16	13	Mitsubishi	21	18	-14	.5
17	15	Fujitsu	19	16	-16	.4
18	17	Integrated Device Technology	13	14	8	.4
19	20	Philips	9	13	44	.3
19	16	Oki	16	13	-19	.3
21	19	Texas Instruments	10	12	20	.3
22	21	Matsushita	8	10	25	.3
23	22	Sharp	7	9	29	.2
24	24	TMS	5	7	40	.2
25	31	VLSI Technology	1	4	300	.1
25	27	Silicon Integrated Systems	3	4	33	.1
25	25	Ricoh	4	4	0	.1
28	27	Rockwell	3	3	0	.1
29	29	Hughes	2	2	0	.1
30	25	United Microelectronics	4	1	-75	*
30	31	TRW	1	1	0	*
30	31	NCR	1	1	0	*
30	29	Goldstar	2	1	-50	*
		All Others	9	3	-67	.1
		North American Companies	2,466	3,522	43	90.5
		Japanese Companies	261	269	3	6.9
		European Companies	95	96	1	2.5
		Asia/Pacific Companies	9	6	-33	.2
		Total Market	2,831	3,893	38	100.0

NM = Not meaningful
* = Calculated value is less than 0.1 percent.
Source: Dataquest (June 1992)

Table 2-3
Top 10 Companies' Factory Revenue from Shipments of Microprocessor ICs to North America (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	946	1,163	23	66.8
2	2	Motorola	144	201	40	11.5
3	3	Advanced Micro Devices	46	118	157	6.8
4	4	National Semiconductor	37	42	14	2.4
5	5	LSI Logic	33	41	24	2.4
6	10	Cypress Semiconductor	11	36	227	2.1
7	6	Performance Semiconductor	18	22	22	1.3
8	6	Harris	18	18	0	1.0
9	9	Zilog	13	15	15	.9
9	10	SGS-Thomson	11	15	36	.9
		All Others	56	70	25	4.0
		North American Companies	1,288	1,695	32	97.4
		Japanese Companies	30	26	-13	1.5
		European Companies	15	20	33	1.1
		Asia/Pacific Companies	0	0	0	.0
		Total Market	1,333	1,741	31	100.0

Source: Dataquest (June 1992)

Table 2-4
Top 10 Companies' Factory Revenue from Shipments of Microprocessor ICs to Japan (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	259	337	30	54.6
2	4	Motorola	36	58	61	9.4
3	2	Hitachi	51	54	6	8.8
4	3	NEC	47	51	9	8.3
5	5	Toshiba	20	20	0	3.2
6	8	National Semiconductor	11	18	64	2.9
7	6	Mitsubishi	18	15	-17	2.4
8	9	Advanced Micro Devices	10	11	10	1.8
9	11	Matsushita	8	10	25	1.6
10	12	Sharp	7	9	29	1.5
		All Others	41	34	-17	5.5
		North American Companies	325	435	34	70.5
		Japanese Companies	177	178	1	28.8
		European Companies	6	4	-33	.6
		Asia/Pacific Companies	0	0	0	.0
		Total Market	508	617	21	100.0

Source: Dataquest (June 1992)

Table 2-5
Top 10 Companies' Factory Revenue from Shipments of Microprocessor ICs to Europe (Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	317	420	32	61.7
2	2	Motorola	67	74	10	10.9
3	5	Advanced Micro Devices	17	38	124	5.6
4	3	SGS-Thomson	36	27	-25	4.0
5	4	Siemens	20	19	-5	2.8
6	6	National Semiconductor	12	16	33	2.3
7	7	Toshiba	11	13	18	1.9
8	8	Hitachi	10	11	10	1.6
9	9	Harris	6	9	50	1.3
10	9	NEC	6	7	17	1.0
		All Others	37	47	27	6.9
		North American Companies	438	590	35	86.6
		Japanese Companies	31	36	16	5.3
		European Companies	70	55	-21	8.1
		Asia/Pacific Companies	0	0	0	.0
		Total Market	539	681	26	100.0

Source: Dataquest (June 1992)

Table 2-6
Top 10 Companies' Factory Revenue from Shipments of Microprocessor ICs to Asia/Pacific-Rest of World
(Millions of U.S. Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	304	584	92	68.4
2	3	Advanced Micro Devices	37	160	332	18.7
3	2	Motorola	44	30	-32	3.5
4	5	Zilog	7	9	29	1.1
4	5	Toshiba	7	9	29	1.1
4	13	SGS-Thomson	2	9	350	1.1
4	4	Harris	16	9	-44	1.1
8	13	Philips	2	8	300	.9
9	7	Hitachi	6	7	17	.8
10	7	National Semiconductor	6	5	-17	.6
10	11	NEC	4	5	25	.6
		All Others	16	19	19	2.2
		North American Companies	415	802	93	93.9
		Japanese Companies	23	29	26	3.4
		European Companies	4	17	325	2.0
		Asia/Pacific Companies	9	6	-33	.7
		Total Market	451	854	89	100.0

Source: Dataquest (June 1992)

Section 3: Microprocessor Unit Shipments by Word Width

Table 3-1
Each Company's Shipments of 8-Bit Microprocessors to the World
(Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Zilog	19,800	25,500	29	31.9
2	2	Hitachi	8,200	10,200	24	12.8
3	3	SGS-Thomson	8,100	8,000	-1	10.0
4	4	NEC	7,000	6,800	-3	8.5
5	6	Toshiba	5,700	6,300	11	7.9
6	5	Intel	5,800	5,500	-5	6.9
7	8	Motorola	4,600	4,200	-9	5.3
8	7	AMD	4,700	2,800	-40	3.5
9	9	Sharp	2,500	2,100	-16	2.6
10	10	Oki	2,200	1,700	-23	2.1
11	11	Harris	1,400	1,200	-14	1.5
11	NM	Goldstar	NA	1,200	NM	1.5
13	12	Siemens	1,300	1,000	-23	1.3
14	16	Rockwell	600	620	3	.8
15	14	National	650	550	-15	.7
16	17	Mitsubishi	420	380	-10	.5
16	NM	NCR	NA	380	NM	.5
18	15	Fujitsu	620	320	-48	.4
19	18	Texas Instruments	410	300	-27	.4
19	NM	UMC	NA	300	NM	.4
		All Others	1,100	510	-54	.6
		Total 8-bit MPU	75,100	79,900	6	100.0

NA = Not available
NM = Not meaningful
Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 3-2
Each Company's Shipments of 16-Bit Microprocessors to the World
(Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Intel	9,300	7,700	-17	34.5
2	3	NEC	4,000	4,200	5	18.8
3	2	AMD	6,200	3,400	-45	15.2
4	4	Siemens	1,700	1,900	12	8.5
5	7	Zilog	930	1,700	83	7.6
6	5	Harris	1,500	1,300	-13	5.8
7	8	SGS-Thomson	620	780	26	3.5
8	6	Oki	1,000	470	-53	2.1
9	9	Fujitsu	500	350	-30	1.6
10	10	Matsushita	320	220	-31	1.0
10	11	Hitachi	95	220	132	1.0
12	13	Sharp	69	28	-59	.1
13	14	Performance	22	24	9	.1
14	15	National	17	19	12	.1
15	12	Toshiba	70	0	-100	*
		Total 16-bit MPU	26,300	22,300	-15	100.0

* = Calculated value is less than 0.1 percent
Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 3-3
Each Company's Shipments of 32/16-Bit Microprocessors to the World (Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Motorola	8,900	13,300	49	49.2
2	2	Intel	4,800	8,700	81	32.2
3	5	Toshiba	720	1,500	108	5.5
4	NM	AMD	0	1,300	NM	4.8
5	4	Hitachi	960	840	-13	3.1
6	6	National	590	610	3	2.3
7	7	SGS-Thomson	410	430	5	1.6
8	3	Philips	1,200	360	-70	1.3
		Total 32/16-bit MPU	17,600	27,000	53	100.0

NM = Not meaningful
Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 3-4
Each Company's Shipments of 32-Bit Microprocessors to the World
(Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Intel	4,100	6,500	59	47.6
2	2	Motorola	2,200	4,100	86	30.0
3	8	AMD	90	1,100	1122	8.1
4	4	National	430	500	16	3.7
5	3	Texas Instruments	445	350	-21	2.6
6	6	NEC	220	280	27	2.1
7	5	Inmos	240	260	8	1.9
8	7	LSI Logic	100	120	20	.9
9	12	Cypress	25	110	340	.8
10	10	Fujitsu	51	93	82	.7
11	9	VLSI Technology	71	70	-1	.5
12	11	Performance	33	55	67	.4
13	13	IDT	20	45	125	.3
14	14	Mitsubishi	8	20	150	.1
15	NM	Siemens	0	18	NM	.1
16	NM	Weitek	0	12	NM	.1
17	16	Hitachi	4	4	0	*
17	16	Toshiba	4	4	0	*
17	18	Matsushita	1	4	300	*
20	15	Bit	5	3	-40	*
		Total 32-bit MPU	8,000	13,600	70	100.0

NM = Not meaningful
* = Calculated value is less than 0.1 percent
Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Section 4: Microprocessor Unit Shipments—80x86 Processor Class

Table 4-1
Each Company's Shipments of 80x86 Microprocessors to the World
(Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Intel	22,200	26,900	21	54.1
2	3	NEC	8,600	9,500	10	19.1
3	2	AMD	10,400	7,900	-24	15.9
4	4	Siemens	2,500	2,600	4	5.2
5	5	Harris	1,600	1,400	-13	2.8
6	5	Oki	1,600	920	-43	1.8
7	7	Fujitsu	820	480	-41	1.0
8	8	Sharp	40	43	8	.1
		Total 80x86 MPU	47,800	49,700	4	100.0

Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 4-2
Shipments of 80x86 Microprocessors By Word Width to the World
(Thousands of Units)

Word Width	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
8-Bit	14,600	13,200	-10	26.5
North American Companies	8,400	6,800	-19	13.7
Japanese Companies	5,300	5,700	8	11.5
European Companies	850	670	-21	1.3
16-Bit	24,200	19,300	-20	38.8
North American Companies	17,000	12,400	-27	24.9
Japanese Companies	5,500	5,000	-9	10.1
European Companies	1,700	1,900	12	3.8
32/16-Bit	4,800	10,000	108	20.1
North American Companies	4,800	10,000	108	20.1
32-Bit	4,200	7,200	71	14.6
North American Companies	4,000	7,000	75	14.1
Japanese Companies	220	240	9	.5
Total 80x86 MPU	47,800	49,700	4	100.0

Columns may not add to totals shown due to rounding.
8-bit MPUs consist of the 8088, 80188, and equivalent families, such as the V20/V40 family.
16-bit MPUs consist of the 8086, 80186, 80286, and equivalent families, such as the V30/V50 family.
32/16-bit MPUs consist of the 80376, 80386SL, and 80386SX families.
32-bit MPUs consist of the 80386DX, 80486SX, 80486DX, and equivalent families, such as the V60/V70/V80 family.
Source: Dataquest (June 1992)

Table 4-3
Shipments of 80x86 Microprocessors By Product to the World
(Thousands of Units)

Product	Word Width	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
8086	16-bit	3,000	1,700	-43	3.4
8088	8-bit	5,900	3,000	-49	6.0
80186	16-bit	4,300	5,600	30	11.3
80188	8-bit	4,300	5,100	19	10.3
80286	16-bit	13,000	7,900	-39	15.9
80376	32/16-bit	90	75	-17	.2
80386DX	32-bit	3,600	4,500	25	9.1
80386SX/SL	32/16-bit	4,700	9,900	111	19.9
80486DX	32-bit	410	1,900	363	3.8
80486SX	32-bit	0	600	NM	1.2
V20/V40	8-bit	4,400	5,100	16	10.3
V30/V50	16-bit	3,900	4,100	5	8.2
V60/V70/V80	32-bit	220	240	9	.5
Total 80x86 MPU		47,800	49,700	4	100.0

NM = Not meaningful
Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 4-4
Each Company's Shipments of Internal 16-Bit 80x86 Microprocessors to the World (Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	2	NEC	8,400	9,200	10	42.3
2	3	Intel	7,200	4,000	-44	18.4
3	1	AMD	8,500	3,600	-58	16.5
4	4	Siemens	2,300	2,200	-4	10.1
5	5	Harris	1,600	1,400	-13	6.4
6	5	Oki	1,600	920	-43	4.2
7	7	Fujitsu	600	400	-33	1.8
8	8	Sharp	40	43	8	.2
		Total Internal 16-Bit 80x86 MPU	30,200	21,800	-28	100.0

Columns may not add to totals shown due to rounding.
Internal 16-bit 80x86 MPUs consist of the 8086, 8088, 80286, and equivalent families, such as the V20/V40 family.
Source: Dataquest (June 1992)

Table 4-5
Each Company's Shipments of Internal 32-Bit 80x86 Microprocessors to the World (Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Intel	8,700	14,800	70	86.3
2	NM	AMD	0	2,100	NM	12.3
3	2	NEC	220	240	9	1.4
		Total Internal 32-Bit 80x86 MPU	8,900	17,100	92	100.0

NM = Not meaningful
Columns may not add to totals shown due to rounding.
Internal 32-bit 80x86 MPUs consist of the 80386, 80486, and equivalent families, such as the V60/70/80 family.
Source: Dataquest (June 1992)

Table 4-6
Each Company's Shipments of Embedded 80x86 Microprocessors to the World (Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Intel	6,300	8,100	29	75.1
2	2	AMD	2,000	2,200	10	20.4
3	4	Siemens	180	400	122	3.7
4	3	Fujitsu	220	80	-64	.7
		Total Embedded 80x86 MPU	8,700	10,800	24	100.0

Columns may not add to totals shown due to rounding.
Embedded 80x86 MPUs consist of the 80186, 80188, and 80376 families.
Source: Dataquest (June 1992)

Section 5: Microprocessor Unit Shipments—68xxx Processor Class

Table 5-1
Each Company's Shipments of 68xxx Microprocessors to the World
(Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Motorola	11,700	17,800	52	84.5
2	4	Toshiba	720	1,500	108	7.1
3	3	Hitachi	960	840	-13	4.0
4	5	SGS-Thomson	570	560	-2	2.7
5	2	Philips	1,200	360	-70	1.7
		Total 68xxx MPU	15,200	21,000	38	100.0

Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 5-2
Shipments of 68xxx Microprocessors By Word Width to the World
(Thousands of Units)

Word Width	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
8-Bit	870	550	-37	2.5
North American Companies	710	420	-41	2.0
European Companies	160	130	-19	.6
32/16-Bit	12,200	16,400	34	78.3
North American Companies	8,900	13,300	49	63.5
Japanese Companies	1,700	2,300	35	11.0
European Companies	1,600	790	-51	3.8
32-Bit	2,100	4,000	90	19.1
North American Companies	2,100	4,000	90	19.1
Total 68xxx MPU	15,200	21,000	38	100.0

Columns may not add to totals shown due to rounding.
8-bit 68xxx MPUs consist of the 68008 family.
32/16-bit 68xxx MPUs consist of the 68000 and 68010 families.
32-bit 68xxx MPUs consist of the 68020, 68030, 68040, and 68300 families.
Source: Dataquest (June 1992)

Table 5-3
Shipments of 68xxx Microprocessors By Product to the World
(Thousands of Units)

1991 Rank	1990 Rank	Product	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	68000	11,300	16,000	42	76.4
2	2	68020	1,100	2,200	100	10.5
3	3	68030	1,000	1,200	20	5.7
4	5	68008	870	550	-37	2.6
5	4	68010	900	430	-52	2.1
6	6	68040	10	220	2100	1.1
		All Others (68300 Family)	20	350	1650	1.7
		Total 68xxx MPU	15,200	21,000	38	100.0

Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 5-4
Each Company's Shipments of Low-End (8- and 32/16-Bit) 68xxx Microprocessors to the World (Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Motorola	9,600	13,700	43	80.8
2	4	Toshiba	720	1,500	108	8.8
3	3	Hitachi	960	840	-13	5.0
4	5	SGS-Thomson	570	560	-2	3.3
5	2	Philips	1,200	360	-70	2.1
		Total Low-End 68xxx MPU	13,100	17,000	30	100.0

Columns may not add to totals shown due to rounding.
Low-End 68xxx MPUs consist of the 68000, 68008, and 68010 families.
Source: Dataquest (June 1992)

Section 6: Microprocessor Unit Shipments—Open Systems RISC Processor Class

Table 6-1
Each Company's Shipments of Open Systems RISC Microprocessors to the World (Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	LSI Logic	103	121	17	22.2
2	4	Cypress	25	110	340	20.2
3	2	Fujitsu	45	83	84	15.2
4	3	Performance	33	55	67	10.1
5	5	IDT	20	45	125	8.3
6	6	IBM (Captive currently)	15	40	167	7.3
6	8	NEC	5	40	700	7.3
8	7	Hewlett-Packard (Captive currently)	6	18	200	3.3
8	NM	Siemens	0	18	NM	3.3
10	NM	Weitek	0	12	NM	2.2
11	8	Bit	5	3	-40	.6
		Total Open Systems RISC MPU	257	545	112	100.0

NM = Not meaningful
Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 6-2
Shipments of Open Systems RISC Microprocessors By Product to the World
(Thousands of Units)

Product	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
SPARC Family	160	301	88	55.2
MIPS Family	76	186	145	34.1
Power	15	40	167	7.3
PA RISC	6	18	200	3.3
Total Open Systems RISC MPU	257	545	112	100.0

Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 6-3
Each Company's Shipments of SPARC Microprocessors to the World
(Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	3	Cypress	25	110	340	36.5
2	1	LSI Logic	85	95	12	31.6
3	2	Fujitsu	45	83	84	27.6
4	NM	Weitek	0	12	NM	4.0
5	4	Bit	5	1	-80	.3
		Total SPARC MPU	160	301	88	100.0

NM = Not meaningful
Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 6-4
Each Company's Shipments of MIPS Microprocessors to the World
(Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Performance	33	55	67	29.6
2	2	IDT	20	45	125	24.2
3	4	NEC	5	40	700	21.5
4	3	LSI Logic	18	26	44	14.0
5	NM	Siemens	0	18	NM	9.7
6	NM	Bit	0	2	NM	1.1
		Total MIPS MPU	76	186	145	100.0

NM = Not meaningful
Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Section 7: Microprocessor Unit Shipments—Low-End Processor Class

Table 7-1
Top 20 Companies' Shipments of Low-End Microprocessors to the World
(Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Zilog	19,800	25,500	29	39.4
2	2	Hitachi	8,200	10,200	24	15.7
3	3	SGS-Thomson	7,900	7,900	0	12.2
4	4	Toshiba	5,700	6,300	11	9.7
5	5	Motorola	3,900	3,800	-3	5.9
6	7	Sharp	2,500	2,000	-20	3.1
7	6	NEC	2,600	1,700	-35	2.6
8	8	Intel	1,700	1,200	-29	1.9
8	9	Oki	1,600	1,200	-25	1.9
8	NM	Goldstar	NA	1,200	NM	1.9
11	12	Rockwell	600	620	3	1.0
12	11	National	650	550	-15	.8
13	15	Mitsubishi	420	380	-10	.6
13	NM	NCR	NA	380	NM	.6
15	13	Siemens	490	350	-29	.5
15	14	AMD	480	350	-27	.5
17	NM	UMC	NA	300	NM	.5
18	17	Harris	270	280	4	.4
19	10	CA Micro Devices	710	270	-62	.4
20	16	Fujitsu	300	200	-33	.3
		All Others	120	90	-25	.1
		Total Low-End MPU	57,900	64,800	12	100.0

NA = Not available
NM = Not meaningful
Columns may not add to totals shown due to rounding.
Low-End MPUs consist of the Z80/8080, 680x, and 6502 families.
Source: Dataquest (June 1992)

Table 7-2
Shipments of Low-End Microprocessors By Product to the World (Thousands of Units)

Product	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
Z80/8080 Family	49,100	52,800	8	81.5
Z80	34,200	37,700	10	58.2
Z180	8,200	10,400	27	16.1
Z280	240	160	-33	.2
8085	6,500	4,500	-31	7.0
680x Family	7,500	10,400	39	16.1
6802	2,600	2,800	8	4.3
6809	4,400	4,400	0	6.8
6800	230	210	-9	.3
Other 680x	270	3,000	1011	4.6
6502 Family	1,300	1,600	23	2.4
6502	600	1,300	117	2.0
G65SCxxx	710	270	-62	.4
Total Low-End MPU	57,900	64,800	12	100.0

Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 7-3
Each Company's Shipments of Z80/8080 Microprocessors to the World (Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Zilog	19,800	25,500	29	48.3
2	3	Hitachi	6,100	7,800	28	14.8
3	4	Toshiba	5,700	6,300	11	11.9
4	2	SGS-Thomson	7,000	4,200	-40	8.0
5	6	Sharp	2,400	2,000	-17	3.8
6	5	NEC	2,600	1,700	-35	3.2
7	7	Intel	1,700	1,200	-29	2.3
7	8	Oki	1,600	1,200	-25	2.3
7	NM	Goldstar	NA	1,200	NM	2.3
10	9	National	650	550	-15	1.0
11	12	Mitsubishi	420	380	-10	.7
12	10	Siemens	490	350	-29	.7
12	11	AMD	480	350	-27	.7
14	13	Seiko	120	90	-25	.2
		Total Z80/8080 MPU	49,100	52,800	8	100.0

NA = Not available
NM = Not meaningful
Columns may not add to totals shown due to rounding.
Z80/8080 MPUs consist of the Z80, 8085, and 8080 families, and equivalents.
Source: Dataquest (June 1992)

Table 7-4
Each Company's Shipments of 680x Microprocessors to the World
(Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	1	Motorola	3,900	3,800	-3	36.6
2	3	SGS-Thomson	920	3,700	302	35.6
3	2	Hitachi	2,100	2,400	14	23.1
4	5	Harris	270	280	4	2.7
5	4	Fujitsu	300	200	-33	1.9
		Total 680x MPU	7,500	10,400	39	100.0

Columns may not add to totals shown due to rounding.
680x MPUs include the 6800, 6802, 6808, and 6809 families, and equivalents.
Source: Dataquest (June 1992)

Table 7-5
Each Company's Shipments of 6502 Microprocessors to the World (Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	2	Rockwell	600	620	3	39.5
2	NM	NCR	NA	380	NM	24.2
3	NM	UMC	NA	300	NM	19.1
4	1	CA Micro Devices	710	270	-62	17.2
		Total 6502 MPU	1,300	1,600	23	100.0

NA = Not available
NM = Not meaningful
Columns may not add to totals shown due to rounding.
6502 MPUs consist of the 6502 and 65SC816/802 families, and equivalents.
Source: Dataquest (June 1992)

Section 8: Microprocessor Unit Shipments—Proprietary/Miscellaneous Processor Class

Table 8-1
Each Company's Shipments of Proprietary/Miscellaneous Microprocessors to the World (Thousands of Units)

1991 Rank	1990 Rank	Company	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
1	3	Zilog	930	1,700	83	25.3
2	1	National	1,000	1,100	10	16.4
3	5	SGS-Thomson	620	780	26	11.6
4	1	Harris	1,000	750	-25	11.2
5	4	Texas Instruments	860	690	-20	10.3
6	9	Intel	110	310	182	4.6
6	10	AMD	100	310	210	4.6
8	7	Inmos	240	260	8	3.9
9	6	Matsushita	320	220	-31	3.3
9	11	Hitachi	99	220	122	3.3
11	8	Hughes	180	150	-17	2.2
12	14	Motorola	62	85	37	1.3
13	13	VLSI Technology	71	70	-1	1.0
14	16	Performance	22	24	9	.4
15	17	Mitsubishi	8	20	150	.3
16	15	Sharp	54	10	-81	.1
16	18	Fujitsu	6	10	67	.1
18	12	Toshiba	74	4	-95	.1
		Total Proprietary/ Miscellaneous MPU	5,800	6,800	17	100.0

Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 8-2
Shipments of Proprietary/Miscellaneous Microprocessors By Word Width to the World (Thousands of Units)

Word Width	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
8-Bit	1,600	1,200	-25	17.7
North American Companies	1,600	1,200	-25	17.7
16-Bit	2,100	3,000	43	43.9
North American Companies	980	1,750	79	25.8
Japanese Companies	540	450	-17	6.6
European Companies	620	780	26	11.5
32/16-Bit	590	610	3	9.0
North American Companies	590	610	3	9.0
32-Bit	1,500	2,000	33	29.4
North American Companies	1,200	1,700	42	25.0
European Companies	240	260	8	3.8
Japanese Companies	23	42	83	.6
Total Proprietary/ Miscellaneous MPU	5,800	6,800	17	100.0

Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Table 8-3
Shipments of Proprietary/Miscellaneous Microprocessors By Product to the World
(Thousands of Units)

Product	1990 Units	1991 Units	Percent Change	1991 Market Share (%)
8-Bit Families	1,600	1,200	-25	17.8
1800	1,200	900	-25	13.3
TMS9995	410	300	-27	4.4
16-Bit Families	2,100	3,000	43	44.2
Z8000	1,700	2,500	47	37.1
TRON	95	220	132	3.3
1750	39	43	10	.6
All Others	320	220	-31	3.3
32/16-Bit Families	590	610	3	9.0
32000	590	610	3	9.0
32-Bit Families	1,500	2,000	33	28.9
290xx	90	300	233	4.4
TRANSPUTER	240	260	8	3.9
80960	60	250	317	3.7
88000	62	85	37	1.3
ARM	71	70	-1	1.0
80860	45	55	22	.8
TRON	9	12	33	.2
All Others (CISC-based MPUs)	890	920	3	13.6
Total Proprietary/ Miscellaneous MPU	5,800	6,800	17	100.0

Columns may not add to totals shown due to rounding.
Source: Dataquest (June 1992)

Dataquest

Dataquest Research and Sales Offices:

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

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

Dataquest Incorporated Invitational Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
United States
Phone: 01-714-957-0171
Facsimile: 01-714-957-0903

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: 61-2-959-4544
Facsimile: 61-2-929-0635

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

Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
Phone: 33-1-48-97-3100
Facsimile: 33-1-48-97-3400

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

Dataquest Germany
In der Schneithohl 17
6242 Kronberg 2
Germany
Phone: 49-6173/61685
Facsimile: 49-6173/67901

Dataquest Hong Kong
Rm. 4A01
HKPC Building
78 Tat Chee Avenue
Kowloon, Hong Kong
Phone: 852-788-5432
Facsimile: 852-788-5433

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

Dataquest Korea
Daeheung Building 1105
648-23 Yeoksam-dong
Kangnam-gu
Seoul 135-080, Korea
Phone: 82-2-556-4166
Facsimile: 82-2-552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 65-4597181
Telex: 38257
Facsimile: 65-4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sec. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: 886-2-501-7960
886-2-501-5592
Facsimile: 886-2-505-4265

Dataquest Thailand
300/31 Rachdapisek Road
Bangkok 10310
Thailand
Phone: 66-2-275-1904/5
66-2-277-8850
Facsimile: 66-2-275-7005

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Microcomponent Consumption Forecast

August 31, 1992

Source: Dataquest

Market Statistics

Microcomponents *Worldwide*

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Microcomponent Consumption Forecast

August 31, 1992

Source: Dataquest

Market Statistics

File behind the *Market Statistics* tab inside the binder labeled Microcomponents *Worldwide*

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Microcomponent Consumption Forecast

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Note: All tables show estimated data.

Microcomponent Consumption Forecast

Introduction

This document contains detailed information on Dataquest's view of the microcomponent market. Included in this document are:

- 1990-1996 MOS microcomponent consumption history and forecast
- 1990-1996 MOS microprocessor consumption history and forecast
- 1990-1996 MOS microcontroller consumption history and forecast

More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of these data is provided in the *Dataquest Perspectives* located in the binder of the same name.

Segmentation

This section defines the market segments that are specific to this document. Dataquest's objective is to provide data along lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to clients.

For a detailed explanation of Dataquest's market segmentation, refer to the *Dataquest Research and Forecast Methodology* document located in the Source: Dataquest binder. For a complete listing of all market segments tracked by Dataquest, please refer to the *Dataquest High-Technology Guide: Segmentation and Glossary.*

Dataquest defines the MOS microcomponent market according to the following functional segmentation scheme:

Digital MOS Microcomponent IC
- Digital MOS Microprocessor (MPU)
- Digital MOS Microcontroller (MCU)
- Digital MOS Microperipheral (MPR)
- Digital Signal Processor (DSP)

Definitions

This section lists the definitions used by Dataquest to present the data in this document.

Complete definitions for all terms associated with Dataquest's segmentation of the high-technology marketplace can be found in the *Dataquest High-Technology Guide: Segmentation and Glossary.*

Digital Microcomponent IC (Digital Microprocessor + Digital Microcontroller + Digital Microperipheral + Digital Signal Processor): Defined as a digital IC that contains a data processing unit or serves as an interface to such a unit. Includes both complex-instruction-set computing (CISC) and reduced-instruction-set computing (RISC) architectures.

Digital Microprocessor: Defined as a semiconductor product serving as the central processing unit (CPU) of a system. Comprises an instruction decoder, arithmetic logic unit (ALU), registers, and additional logic. An MPU performs general-purpose computing functions by executing external instructions and manipulating data held in external memory. Includes digital MPUs incorporating or originating from an ASIC design.

Digital Microcontroller: Defined as a semiconductor product serving as a dedicated or embedded controller in a system. Comprises an integral MPU, some nonvolatile memory containing end-user-specified instructions, and some volatile memory for temporary storage of data. MCUs typically contain microperipherals and as a result MCUs can perform basic computing functions without support from microperipheral (MPR) products. Includes digital MCUs incorporating or originating from an ASIC design.

Digital Microperipheral: Defined as a semiconductor product normally serving as a logical support function to an MPU in a system. An MPR provides enhancement of system performance and/or interface with external systems. Includes digital MPRs comprising more than one device, such as PC chip sets. Examples of a digital MPR include: memory and bus controllers (for example, PC logic chip sets, DRAM controllers, memory management units (MMU), and DMA controllers); peripheral interface controllers (for example, graphics controllers, LAN controllers, UARTs, keyboard controllers, and mass storage controllers); and coprocessors (for example, math coprocessors—or FPUs—and other coprocessors).

Digital Signal Processor: Defined as a high-speed general-purpose arithmetic unit used for performing complex mathematical operations such as Fourier transforms.

Merchant versus Captive Consumption

Dataquest includes all revenue, both merchant and captive, for semiconductor suppliers selling to the merchant market. The data exclude completely captive suppliers where devices are manufactured solely for the company's own use. A product that is used internally is valued at market price rather than at transfer or factory price.

Regional Definitions

North America: Includes United States and Canada
Europe: Western Europe
Japan: Japan
Asia/Pacific-Rest of World: All other countries

Line Item Definitions

Factory revenue is defined as the amount of money received by a semiconductor vendor for its goods. Revenue from the sale of semiconductors sold either as finished goods, die, or wafers to another semiconductor vendor for resale is attributed to the semiconductor vendor that sells the product to a distributor or equipment manufacturer.

Shipment is defined as the number of complete products delivered, whether single chips or chip sets.

Average selling price is defined as the mathematical average price received by all manufacturers for a given product type.

For each segment or subsegment of products defined herein, the line items described conform to the following equation:

Revenue = Shipments × Average Selling Price

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 suppliers.

Forecast Methodology and Assumptions

Dataquest publishes five-year factory revenue forecasts for the microcomponent market during the second quarter of each year. In doing so, Dataquest utilizes a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. An overview of Dataquest forecasting techniques can be found in the *Dataquest Research and Forecast Methodology* document.

Microcomponent Forecast Methodology

Dataquest's forecasting methodology includes the following steps:

- Survey the leading microcomponent vendors (in microprocessors and microcontrollers) throughout the year for their expectations, as well as for their views of the application markets they participate in.
- Examine statistics provided by a number of industry organizations (such as WSTS, MITI, and DOC) for up-to-date monthly trends.
- Perform time-series analysis as well as apply judgmental industry knowledge to product and application trends.
- Compare microcomponent forecast estimates with Dataquest's PC shipments forecast to ensure both groups of numbers correlate.

Microcomponent Forecast Assumptions

Microprocessors

Dataquest's forecast assumptions for microcontrollers include the following:

- Microprocessors are dominated in revenue (and in units) by the 80x86 product family, currently representing nearly three-fourths of the total 1991 revenue. All other product classes except low-end processors will experience 32-bit processors and computer platform applications. Units, on the other hand, are primarily driven by 8-bit processors and embedded processing applications. Regional growth will continue to favor the Asia/Pacific and North American segments.
- 8-bit microprocessor revenue has already peaked and will exhibit a gradual decline over the next four years before beginning a steeper fall. Unit growth will be stemmed during the next two years by the continued redesign of 10-year-old applications using more cost-effective microcontrollers or more powerful 16- and 32-bit microprocessors. Decline in unit shipments at first will be driven by the 80x86 products moving away from 8 bits, followed by the slow decline of the low-end processor class. ASPs will remain relatively stable and may in fact increase as some mature products become obsolete.
- 16-bit microprocessor revenue has already peaked but will see a renaissance in 1994 and 1995, driven by fully integrated 16-bit processors for hand-held information devices. Unit growth is falling because of the shift to 32-bit architectures for most computer applications, but will show another peak in 1996 because of hand-held devices. ASPs will remain relatively stable throughout this period, with price erosion offset by increasing levels of functional integration (such as single-chip PC processors).
- 32/16-bit microprocessor revenue has peaked. Both prices and volumes will begin to erode for the 386SX products that dominate this category. Unit growth will continue to cycle up and down during this forecast period as both 386SX and 68000 peak, then head downward, overlapping the growth of highly integrated products offering high-performance, low power, and low-cost solutions for portable PCs and hand-held devices. ASPs will erode as a whole during this period because of significant price erosion in the 80x86 market somewhat mitigated by the influx of higher-priced integrated processors.
- 32-bit microprocessor revenue will continue to grow during this forecast period as the higher-end 32-bit architectures increase their domination across the board. Unit growth will remain extremely high for the next two years because of computer systems converting to pure 32-bit MPUs (led by 486, 68030/40, and RISC processors), then taper off as we begin to saturate the high-performance MPU demands. ASPs will see a short-term decline over the next year because of competitive pricing pressures, then stabilize for the remainder of the forecast period.

Microcontrollers

Dataquest's forecast assumptions for microcontrollers include the following:

- 4-bit microcontrollers will experience a modest 3.6 percent growth in 1992 because of the severe economic slump in Japan. These devices are primarily used in consumer products, a product category being particularly hard hit by the slowdown in Japan. Dataquest expects this product family to rebound somewhat as the Japanese economy begins to recover. However, Dataquest expects 8-bit microcontrollers to gain market share from some of the traditional 4-bit market over the forecast period.
- 8-bit microcontrollers are also feeling some of the effects of the slowdown in Japan and will grow a moderate 9 percent in 1992. We expect a more robust recovery for 8-bit devices when compared to 4-bit devices, for the following three major reasons:
  - 8-bit devices are beginning to replace 4-bit devices in some consumer applications, such as video camcorders.
  - The integration of DSP blocks in standard 8-bit microcontrollers will expand their use in such applications as mass storage device control.

- Fuzzy logic techniques will expand the control applications for 8-bit devices. Because fuzzy logic typically requires less program code than standard nonfuzzy techniques, 8-bit devices can now be used in higher-performance applications.

- 16-bit microcontrollers are also somewhat affected by the Japanese market downturn and will grow by 11 percent in 1992. As is the case for 8-bit microcontrollers, 16-bit devices are being developed with DSP blocks on board, and they also will benefit from fuzzy logic techniques. This capability will allow 16-bit microcontrollers with embedded DSP to replace much of the standalone DSP chips.

- DSP devices will grow 18 percent in 1992. Long-term DSP growth will be moderated because DSP capabilities are being integrated into microcontrollers. In the next few years, general-purpose DSP chips will be replaced by microcontrollers or application-specific products, with built-in DSP functions, in all but the highest-performance applications.

Exchange Rates

Dataquest utilizes an average annual exchange rate in converting revenue to U.S. dollar amounts. The following outlines these rates for 1989 through 1991:

	1989	1990	1991
Japan (Yen/U.S.$)	138	144	136
France (Franc/U.S.$)	6.39	5.44	5.64
Germany (Deutsche Mark/U.S.$)	1.88	1.62	1.66
United Kingdom (U.S.$/Pound Sterling)	1.50	1.79	1.77

Table 1-1
Revenue from MOS Microcomponent ICs Shipped to the World, 1990-1996
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total MOS Microcomponent Revenue	9,584	11,774	12,985	14,805	17,258	20,016	21,920	13.2
Growth Rate (%)	22.8	22.9	10.3	14.0	16.6	16.0	9.5	
Percent of Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
MOS Microprocessor Revenue	2,401	3,746	4,882	5,341	6,343	7,428	8,341	17.4
Growth Rate (%)		56.0	30.3	9.4	18.8	17.1	12.3	
Percent of Total	25.1	31.8	37.6	36.1	36.8	37.1	38.1	
MOS Microcontroller Revenue	3,959	4,855	5,244	6,090	7,291	8,307	8,624	12.2
Growth Rate (%)		22.6	8.0	16.1	19.7	13.9	3.8	
Percent of Total	41.3	41.2	40.4	41.1	42.3	41.5	39.3	
MOS Microperipheral Revenue	3,224	3,173	2,859	3,374	3,624	4,281	4,955	9.3
Growth Rate (%)		-1.6	-9.9	18.0	7.4	18.1	15.7	
Percent of Total	33.6	26.9	22.0	22.8	21.0	21.4	22.6	

DSP revenue is included in microcontroller revenue.
Columns may not add to totals shown due to rounding.
Source: Dataquest (August 1992)

Table 1-2
Revenue from MOS Microcomponent ICs Shipped by Region, 1990-1996
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total MOS Microcomponent Revenue	9,584	11,774	12,985	14,805	17,258	20,016	21,920	13.2
Growth Rate (%)	22.7	22.9	10.3	14.0	16.6	16.0	9.5	
Percent of Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
North America	3,381	3,916	4,698	5,149	5,847	6,464	6,754	11.5
Growth Rate (%)		15.8	20.0	9.6	13.6	10.6	4.5	
Percent of Total	35.3	33.3	36.2	34.8	33.9	32.3	30.8	
Japan	2,974	3,579	3,252	3,807	4,405	5,127	5,477	8.9
Growth Rate (%)		20.3	-9.1	17.1	15.7	16.4	6.8	
Percent of Total	31.0	30.4	25.0	25.7	25.5	25.6	25.0	
Europe	1,802	2,082	2,377	2,713	3,215	3,508	3,867	13.2
Growth Rate (%)		15.5	14.2	14.1	18.5	9.1	10.2	
Percent of Total	18.8	17.7	18.3	18.3	18.6	17.5	17.6	
Asia/Pacific-Rest of World	1,427	2,197	2,658	3,136	3,791	4,917	5,822	21.5
Growth Rate (%)		54.0	21.0	18.0	20.9	29.7	18.4	
Percent of Total	14.9	18.7	20.5	21.2	22.0	24.6	26.6	

Columns may not add to totals shown due to rounding.
Source: Dataquest (August 1992)

Table 2-1
Revenue from MOS Microprocessor ICs Shipped to the World, 1990-1996
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total MOS Microprocessor Revenue	2,401	3,746	4,882	5,341	6,343	7,428	8,341	17.4
Growth Rate (%)		56.0	30.3	9.4	18.8	17.1	12.3	
Percent of Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
8-Bit Revenue	197	209	181	163	142	121	99	-13.9
Growth Rate (%)		6.1	-13.4	-9.9	-12.9	-14.8	-18.2	
Percent of Total	8.2	5.6	3.7	3.1	2.2	1.6	1.2	
16-Bit Revenue	411	368	362	413	472	457	437	3.5
Growth Rate (%)		-10.5	-1.6	14.1	14.3	-3.2	-4.4	
Percent of Total	17.1	9.8	7.4	7.7	7.4	6.2	5.2	
32/16-Bit Revenue	436	851	866	641	612	682	718	-3.3
Growth Rate (%)		95.2	1.8	-26.0	-4.5	11.4	5.3	
Percent of Total	18.2	22.7	17.7	12.0	9.6	9.2	8.6	
32-Bit and Up Revenue	1,357	2,318	3,473	4,124	5,117	6,168	7,087	25.0
Growth Rate (%)		70.8	49.8	18.7	24.1	20.5	14.9	
Percent of Total	56.5	61.9	71.1	77.2	80.7	83.0	85.0	

Columns may not add to totals shown due to rounding.
Source: Dataquest (August 1992)

Table 2-2
Shipments of MOS Microprocessor ICs to the World, 1990-1996
(Thousands of Units)

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total MOS Microprocessor Units	113,655	136,928	133,921	140,721	145,340	151,048	156,299	2.7
Growth Rate (%)		20.5	-2.2	5.1	3.3	3.9	3.5	
Percent of Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
8-Bit Units	61,090	73,680	57,209	53,930	49,803	45,860	40,834	-11.1
Growth Rate (%)		20.6	-22.4	-5.7	-7.7	-7.9	-11.0	
Percent of Total	53.8	53.8	42.7	38.3	34.3	30.4	26.1	
16-Bit Units	28,040	24,960	24,138	25,428	26,215	25,675	25,206	0.2
Growth Rate (%)		-11.0	-3.3	5.3	3.1	-2.1	-1.8	
Percent of Total	24.7	18.2	18.0	18.1	18.0	17.0	16.1	
32/16-Bit Units	17,010	25,560	31,121	31,418	31,550	33,730	35,979	7.1
Growth Rate (%)		50.3	21.8	1.0	0.4	6.9	6.7	
Percent of Total	15.0	18.7	23.2	22.3	21.7	22.3	23.0	
32-Bit and Up Units	7,515	12,728	21,453	29,945	37,772	45,783	54,280	33.7
Growth Rate (%)		69.4	68.5	39.6	26.1	21.2	18.6	
Percent of Total	6.6	9.3	16.0	21.3	26.0	30.3	34.7	

Columns may not add to totals shown due to rounding.
Source: Dataquest (August 1992)

Table 2-3
All Companies' Average Selling Price for Shipments of MOS Microprocessor ICs to the World, 1990-1996 (Factory ASP in U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total MOS Microprocessor ASP	21.12	27.36	36.46	37.96	43.64	49.18	53.37	14.3
Growth Rate (%)		29.5	33.3	4.1	15.0	12.7	8.5	
8-Bit ASP	3.23	2.83	3.16	3.01	2.84	2.64	2.42	-3.1
Growth Rate (%)		-12.4	11.7	-4.7	-5.6	-7.0	-8.3	
16-Bit ASP	14.66	14.73	15.01	16.23	18.00	17.80	17.34	3.3
Growth Rate (%)		0.5	1.9	8.1	10.9	-1.1	-2.6	
32/16-Bit ASP	25.65	33.30	27.82	20.40	19.41	20.22	19.95	-9.7
Growth Rate (%)		29.8	-16.5	-26.7	-4.9	4.2	-1.3	
32-Bit and Up ASP	180.46	182.12	161.92	137.77	135.47	134.72	130.58	-6.4
Growth Rate (%)		0.9	-11.1	-14.9	-1.7	-0.6	-3.1	

Source: Dataquest (August 1992)

Table 3-1
Revenue from MOS Microcontroller ICs Shipped to the World, 1990-1996
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total MOS Microcontroller Revenue	3,959	4,855	5,244	6,090	7,291	8,307	8,624	12.2
Growth Rate (%)	19.0	22.7	8.0	16.1	19.7	13.9	3.8	
Percent of Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
4-bit Revenue	1,394	1,598	1,654	1,787	2,048	2,222	2,247	7.1
Growth Rate (%)		14.6	3.6	8.0	14.7	8.5	1.1	
Percent of Total	35.2	32.9	31.5	29.3	28.1	26.7	26.1	
8-bit Revenue	2,079	2,618	2,854	3,363	4,074	4,712	4,927	13.5
Growth Rate (%)		25.9	9.0	17.8	21.2	15.6	4.6	
Percent of Total	52.5	53.9	54.4	55.2	55.9	56.7	57.1	
16-bit Revenue	194	303	337	439	557	670	725	19.1
Growth Rate (%)		56.2	11.3	30.3	26.8	20.3	8.2	
Percent of Total	4.9	6.2	6.4	7.2	7.6	8.1	8.4	
DSP Revenue	291	337	398	501	611	703	725	16.6
Growth Rate (%)		15.8	18.0	26.0	22.0	15.0	3.1	
Percent of Total	7.4	6.9	7.6	8.2	8.4	8.5	8.4	

Columns may not add to totals shown due to rounding.
Source: Dataquest (August 1992)

Table 3-2
Shipments of MOS Microcontroller ICs to the World, 1990-1996
(Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total MOS Microcontroller Units	1,390	1,697	1,885	2,196	2,639	3,055	3,316	14.3
Growth Rate (%)	7.3	22.1	11.1	16.5	20.1	15.8	8.5	
Percent of Total MCU	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
4-bit Units	779	906	988	1,121	1,311	1,482	1,586	11.8
Growth Rate (%)		16.3	9.0	13.5	17.0	13.0	7.0	
Percent of Total	56.0	53.4	52.4	51.0	49.7	48.5	47.8	
8-bit Units	589	753	851	1,013	1,245	1,470	1,609	16.4
Growth Rate (%)		27.8	13.0	19.0	23.0	18.0	9.5	
Percent of Total	42.4	44.4	45.1	46.1	47.2	48.1	48.5	
16-bit Units	22	38	47	63	82	103	121	26.1
Growth Rate (%)		72.7	23.0	35.0	30.0	26.0	17.0	
Percent of Total	1.6	2.2	2.5	2.9	3.1	3.4	3.6	

DSP units are excluded from this table.
Columns may not add to totals shown due to rounding.
Source: Dataquest (August 1992)

Table 3-3
All Companies' Average Selling Price for Shipments of MOS Microcontroller ICs, 1990-1996 (Factory ASP in U.S. Dollars)

	1990
Total MOS Microcontroller ASP	2.64
Growth Rate (%)	
4-bit ASP	1.79
Growth Rate (%)	
8-bit ASP	3.53
Growth Rate (%)	
16-bit ASP	8.82
Growth Rate (%)	

DSPs are excluded from this table.
Source: Dataquest (August 1992)

Dataquest

Dataquest Research and Sales Offices:

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

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

Dataquest Incorporated Invitational
Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
United States
Phone: 01-714-957-0171
Facsimile: 01-714-957-0903

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: 61-2-959-4544
Facsimile: 61-2-929-0635

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

Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
Phone: 33-1-48-97-3100
Facsimile: 33-1-48-97-3400

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

Dataquest Germany
In der Schneithohl 17
6242 Kronberg 2
Germany
Phone: 49-6173/61685
Facsimile: 49-6173/67901

Dataquest Hong Kong
Rm. 4A01
HKPC Building
78 Tat Chee Avenue
Kowloon, Hong Kong
Phone: 852-788-5432
Facsimile: 852-788-5433

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

Dataquest Korea
Daeheung Building 1105
648-23 Yeoksam-dong
Kangnam-gu
Seoul 135-080, Korea
Phone: 82-2-556-4166
Facsimile: 82-2-552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 65-4597181
Telex: 38257
Facsimile: 65-4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sec. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: 886-2-501-7960
886-2-501-5592
Facsimile: 886-2-505-4265

Dataquest Thailand
300/31 Rachdapisek Road
Bangkok 10310
Thailand
Phone: 66-2-275-1904/5
66-2-277-8850
Facsimile: 66-2-275-7005

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Dataquest

Dataquest Vendor Profile

Microcomponents *Worldwide*
November 9, 1992

Texas Instruments

Corporate Statistics

Headquarters	Dallas, Texas
Chairman and CEO	Jerry Junkins
President, Semiconductor Group	Pat Weber
Executive Vice President, Semiconductor Group	Wally Rhines
Fiscal Year-End	December 31
Exchange	NYSE
Ticker Symbol	TXN
Employees (1991)	62,939
FY1991 Total Sales	\$6.78 billion
FY1991 Net Income	(\$409 million)
FY1991 Earnings per Share	(\$5.40)
FY1991 Royalty Income	\$256 million

A View from the Top

Texas Instruments Inc. (TI), headquartered in Dallas, Texas, was formed in 1951 as a division of Geophysical Service Inc. In 1952, TI obtained licenses to manufacture transistors and by 1953 had become a volume producer of these devices. TI has since evolved into a high-technology company with sales and/or manufacturing operations in more than 30 countries. TI develops, manufactures, and markets semiconductors, defense electronics systems, software productivity tools, computer systems and peripheral products, custom engineering and manufacturing services, electrical controls, metallurgical materials, and consumer electronic products. Table 1 shows the company's revenue growth and profitability over the past five years.

For more information on Texas Instruments or the microcomponents industry, call Jerry Banks at (408) 437-8677.

In the first half of the 1980s, the company was on a revenue and profit roller coaster. Respective profit and revenue losses in 1983 were \$145 million and \$4.58 billion, followed by profits of \$316 million on revenue of \$5.74 billion in 1984. The roller coaster ride continued in 1985, when the company lost \$119 million on sales of \$4.92 billion and

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Table 1
Five-Year Financial Summary

	1987	1988	1989	1990	1991
Revenue ($B)	5.82	6.45	6.52	6.57	6.78
Net Income ($M)	321	366	292	(39)	(409)
Earnings per Share ($)	3.74	4.05	3.04	(0.92)	(5.40)

Source: Texas Instruments, Dataquest (November 1992)

laid off 7,000 employees. A recovery started in 1986 and lasted four years, peaking in 1988 with sales of $6.45 billion and net income of $366 million. However, TI was not positioned to sustain this growth, and beginning in late 1989 its revenue growth began to slow dramatically and profits turned down, culminating with a significant loss in 1991 of $409 million.

Recent financial results indicate that the company is once again on the upswing. On a quarter-to-quarter basis, the first three quarters of 1992 compared with the same quarters of 1991 provide quantitative evidence that a turnaround is in the making (see Table 2).

When compared with the same quarter in 1991, the first quarter of 1992 experienced a modest 3 percent growth rate. However, net income experienced a $94 million turnaround. The same comparisons applied to the second and third quarters show a strong 11.3 percent growth in revenue and a $229 million turnaround in net income for the second quarter. The third quarter experienced an 8 percent revenue improvement combined with a $170 million turnaround in net income.

Table 3 is an aggregate comparison of the first nine months of 1992 with those of 1991. On a revenue basis, TI has thus far shown a respectable 10.5 percent growth over 1991. On a net profit basis, the company has shown a remarkable $493 million turnaround.

Based upon an unusually strong demand for semiconductors this summer and the continued strong book-to-bill rate, we expect that TI's fourth-quarter results will continue the growth pattern established in the first three quarters and that 1992 will be a strong year for the

Table 2
Quarterly Comparison

	Q1/91	Q1/92	Q2/91	Q2/92	Q3/91	Q3/92
Revenue ($B)	1.64	1.69	1.68	1.87	1.75	1.89
Net Income ($M)	(54)	40	(157)	72	(113)	57
Earnings per Share ($)	(0.77)	0.35	(1.99)	0.73	(1.45)	0.58

Source: Texas Instruments, Dataquest (November 1992)

Table 3
First Half of 1992 versus First Half of 1991

	Nine Months Ended 9/30/91	Nine Months Ended 9/30/92
Revenue ($B)	4.93	5.45
Net Income ($M)	(324)	169

Source: Texas Instruments, Dataquest (November 1992)

company. What makes this all the more astounding is the fact that, as late as the second quarter of this year, many securities analysts had written TI off as a loss leader for the foreseeable future. Is this just another wild upswing for TI, to be followed by another drastic downturn, or will the company's efforts to position itself for long-term sustained and profitable growth pay off?

Integrated Circuits: TI's Key to Future Success

TI, which employed nearly 63,000 in 1991, is segmented into four main product groups (see Table 4).

The components group is TI's largest product segment, with 50 percent of total revenue. It comprises semiconductors, subassemblies, and electrical and electronic control devices. Of these product categories, semiconductors accounts for more than 80 percent of the components segment's total sales. The semiconductor product category within components is made up of integrated circuits (ICs) and optoelectronic and discrete devices. Integrated circuits made up 97 percent of total semiconductor sales in 1991, or 40 percent of TI's total revenue. Consequently, the health of the integrated circuit sector, which is the focus of this profile, has a first-order impact on the health of the whole corporation and is the prime factor driving the company's recent success.

Table 4
1991 Segment Analysis (Millions of Dollars)

Segment	Sales	Percentage of Sales	Operating Income
Components	3,421	50	(188)
Defense Electronics	1,933	29	111
Digital Products	1,306	19	(52)
Metallurgical Materials	121	2	2

Source: Texas Instruments, Dataquest (November 1992)

An Awakening

The year 1985 was one of significant import for Texas Instruments. It lost $119 million on sales of $4.92 billion, laid off 7,000 employees, froze wages, implemented a broad cost-cutting program, and went through a major management restructure when Jerry Junkins replaced Fred Bucy as president and CEO. TI's decline was further accentuated by the fact that after years of fighting off the challenges of Motorola for the position of No. 1 semiconductor manufacturer, TI almost overnight found itself not only falling behind Motorola, but fighting for a position in the top five. The company was in trouble. It had neither the right products nor the right manufacturing capabilities to fight off the challenges of NEC, Toshiba, Hitachi, Motorola, and Intel, as well as a host of smaller niche-oriented companies.

TI quickly found that the market for its staple product line of bipolar logic was rapidly disappearing and that, with few exceptions, the MOS products it did have were not competitive from a price, performance, or cost point of view with those of the rest of the industry. This problem could not be solved by ramping then-existing capacity and improving factory efficiencies; it necessitated that the company's business model be quickly rewritten and put into effect rapidly. TI was in trouble and had lost the confidence of its customers and the investment community. It needed a new vision and it did not have a lot of time to implement this new vision.

Long-Term Vision, or Smoke and Mirrors?

It is said that necessity is the mother of invention, and out of this necessity TI formulated a game plan that it believed would bring itself back into a position of long-term competitiveness, growth, and profitability. Now, for those who watch the semiconductor industry, it is not news to hear new management of a semiconductor company present a new vision designed to position the company for long-term growth and profitability. This seems to be common in our relatively immature industry. More often than not, this "new vision" is overly optimistic, underfunded, and assumes that employees will instantly see the wisdom behind yet another plan to save them from mediocrity or failure. The only true test for any new vision is the test of time, and it is against this test that TI's new vision is being graded. The six key elements to TI's game plan were, and still are, as follows:

1. Vigorously protect intellectual property
2. Increase capacity at a lower cost of capital
3. Develop and ramp submicron CMOS processes
4. Offer design, manufacturing, sales, and support globally
5. Have a market-driven focus
6. Provide differentiated products

Intellectual Property: An Untapped Revenue Source

The first item, it is argued, has been pursued to a fault. Texas Instruments is intent upon extracting every cent of royalties and/or licensing fees from any company it finds to be in violation of its intellectual property and it makes no apologies for this position. At a Dataquest conference in 1986, a senior executive at TI, Kevin McGarity, stated in a speech that if TI could not make money selling DRAMs that it would make money off its DRAM intellectual property. TI's position is that because it is willing to risk the millions of dollars required to develop new inventions, others should not be allowed to use those inventions without reimbursing TI for its time and trouble. To measure its success in capturing this new source of revenue, one need only look at the royalty revenue in Tables 5 and 6.

Table 5
Royalty Income, 1987 through 1991 (Millions of Dollars)

Year	Royalty Income
1987	191
1988	152
1989	165
1990	172
1991	256

Source: Texas Instruments, Dataquest (November 1992)

Table 6
Royalty Income, First, Second, and Third Quarters of 1992 (Millions of Dollars)

Quarter	Royalty Income
Q1/92	95
Q2/92	124
Q3/92	83

Source: Texas Instruments, Dataquest (November 1992)

How Important Is Royalty Income?

Since 1987 and through the third quarter of 1992, TI has received $1.24 billion in licensing fees and royalty payments. The royalty revenue includes one-time amounts totaling $30 million in the first quarter, $45 million in the second quarter, and $9 million the third quarter. These amounts are based upon recent agreements reached with Rohm Co. Ltd., Mitsubishi Electric Corporation, New Japan Radio Co. Ltd., Nippon Precision Ltd., Seiko Epson Corporation, Toko Inc., and others. If these one-time amounts are subtracted from the quarterly statements, it is readily apparent that the company has substantially increased its royalty income run rate. However, if royalty revenue is factored out of the equation, TI is still operating at a net loss, despite the semiconductor sector returning to profitability in the third quarter of 1992 (see Table 7).

This successful implementation of item No. 1 mentioned earlier—vigorously protect intellectual property—and its resultant income stream, was largely responsible for giving TI the time to try to implement the balance of its six-point recovery program.

Table 7
Texas Instruments' Royalty Income versus Profitability

	Q1/92	Q2/92	Q3/92
Revenue ($B)	1.69	1.87	1.89
Net Income (with Royalty, $M)	40	72	57
Net Income (without Royalty, $M)	(55)	(52)	(26)

Source: Texas Instruments, Dataquest (November 1992)

CMOS Fabs Are Not Cheap

Although the royalty income stream was and is not insignificant, implementing item No. 2—increase capacity at a lower cost of capital—and item No. 3—ramp submicron CMOS processes—still required large expenditure for capital equipment and R&D. In order to add this new submicron CMOS capacity, TI would be forced to build several multihundred-million-dollar facilities. Consequently, it developed a plan involving several different strategic partnerships in which partners share the financial burden of building the new fabs and in return they receive either technology or guaranteed capacity. Table 8 lists the new submicron CMOS fabrication facilities, location, and partners.

Table 8
Texas Instruments' Submicron CMOS Facilities

Facility	Location	Status	Partners
Dallas	Texas	In production	None
Miho	Japan	In production	None
Avezzano	Italy	In production	Italian government
TI-Acer	Taiwan	In production	Acer
KTI	Japan	In qualification	Kobe Steel
Singapore	Singapore	In construction	Canon, HP, Singapore government

Source: Texas Instruments, Dataquest (November 1992)

Singing in Harmony

Another key element to achieving a lower cost of capital is to increase the life of these new fabs. To this end, the company has developed a program it calls "Harmonization," which simply means that the fabs, the equipment, and the processes will be capable of running multiple product types, in this case memory (that is, DRAM and flash) and logic. All processes are to be 95 percent compatible with existing equipment and the individual process recipes should share 65 percent of the same process steps. This technique allows TI to optimize a particular process for a specific product while sharing nearly all of the same equipment. If the company is successful in implementing this program, it should achieve substantial savings in the long run, because it will not be tied to the traditional three-year cycle of a typical DRAM fab. By manufacturing other memory and logic products, TI should add years to the life of its new fab facilities, saving tens of millions of dollars per year per fab. TI believes that its product development costs alone will be reduced by as much as 25 to 35 percent because of the harmonization program.

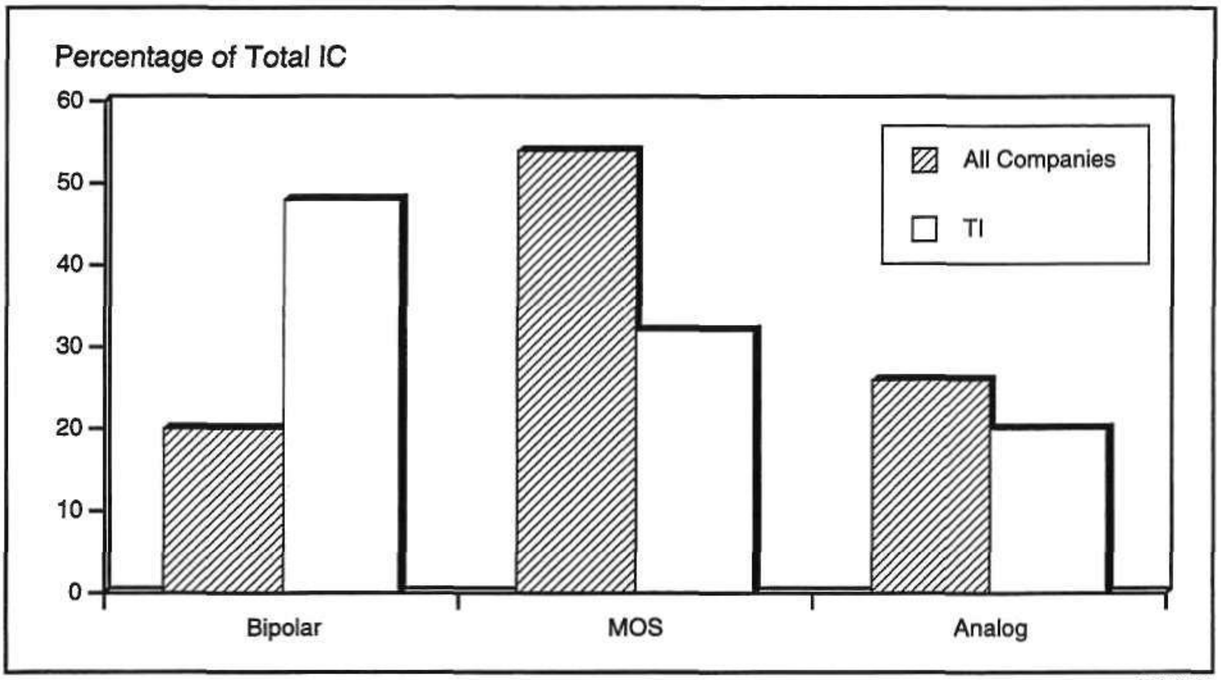
Is Bipolar Still King?

One point not overtly stated in TI's six-point program was the need to obtain or develop a world-class CMOS technology. Figure 1 shows just how far the company was out of step with the rest of the industry in regard to the technological mix of its products.

In 1985 TI derived nearly half its IC revenue from bipolar digital products at a time when bipolar made up only 20 percent of the revenue for the rest of the industry. TI was the undisputed king of bipolar logic. Unfortunately for TI, the rest of the producing and, more importantly, consuming world had begun a massive shift to MOS years earlier.

The company's new management realized that TI's heavy dependence upon products built with bipolar process technology had to change. Although TI had a reputation for a larger than normal "Not Invented

Figure 1
Technology Mix of Products in 1985



Source: Dataquest (November 1992)

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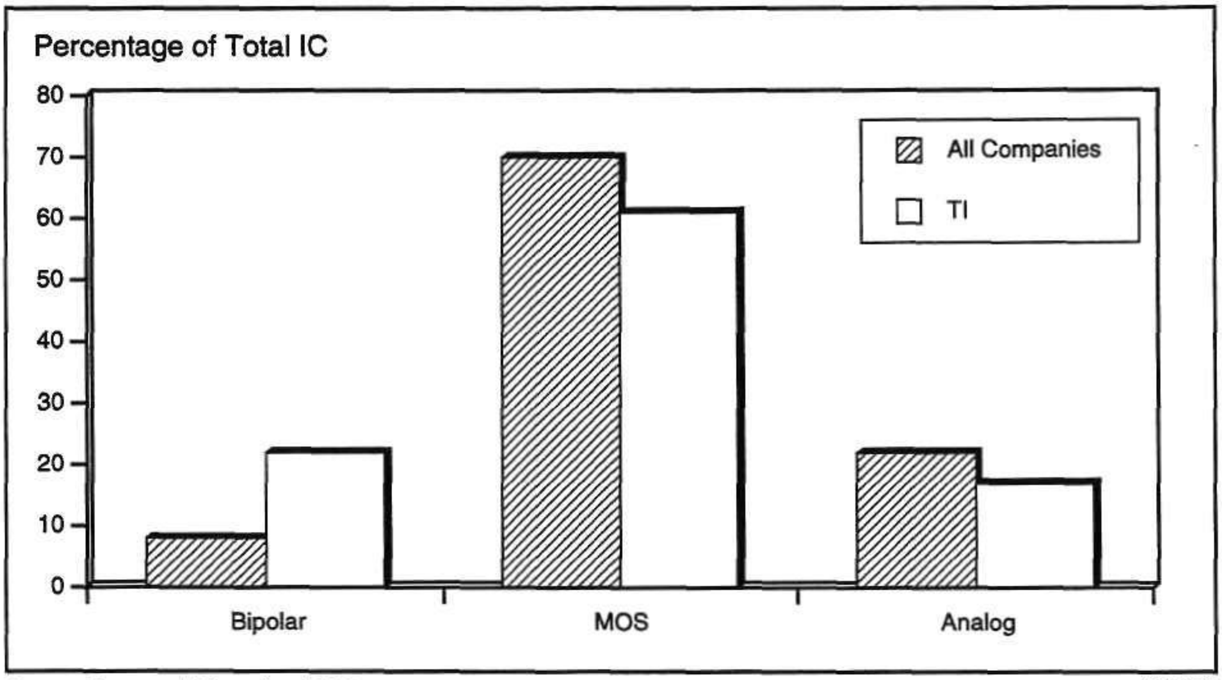
Here" (NIH) bias, it nonetheless developed a relationship with Hitachi, a world leader in CMOS technology, in which the two companies codevelop new technologies. Figure 2 is one indicator of the success of this program.

Figure 2 clearly shows that, when compared with 1985, the company has made dramatic progress in shifting its product technology mix from bipolar to MOS-based products. In 1991, the mix of bipolar products had dropped to 22 percent versus 7.4 percent for the rest of the industry and MOS-based products had risen to 61 percent versus 70.2 percent for the industry. Although it is still not in balance with the rest of the industry, TI is growing its MOS-based revenue—and shrinking its dependence upon bipolar-based products—faster than the rest of the industry.

The most recent major development of the relationship with Hitachi was the announcement of a world-class CMOS 16Mb DRAM technology, which each has separately used to design what appear to be competitive products.

TI's item No. 4—offer design, manufacturing, sales, and support globally—stems from the belief that a company that sells its products on a worldwide basis must design products that meet the needs of the diverse regions of the world. One way to assure that correct products are being defined and built is to regionally locate this responsibility.

Figure 2
Technology Mix of Products in 1991



Source: Dataquest (November 1992)

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Local regional manufacturing assures quick availability of product and when combined with "harmonization" allows TI to shift the mix of products between its worldwide fabs to more closely match the needs of the various regions of the world.

Cultures Are Not Skin Deep

The fifth item of the plan—have a market-driven focus—involved a major cultural change in this historically engineering-driven company. The phrase "market-driven focus" is one normally bandied about by all new management teams when they are repositioning a company. Unfortunately, in most instances it is normally just a hollow shell. However, in TI's case the concept of a market-driven focus is not just a phrase thrown around by management. Late last year when Dataquest met with several levels of TI's engineering staff in different product divisions, the message came out loud and clear that TI must understand the end markets and provide products specifically suited for them. This belief actually went a level below the classic high-level market definitions and into major applications as well as new emerging applications. The company appears to be getting out of the mentality of "they'll buy what we make" and into the mind-set of determining what users want and giving it to them.

No More "Me Too"

The final item of the plan—provide differentiated products—was another new concept to the company. Many products that TI sold were "me-too" kinds of products that required lowest price and fastest delivery. "Added value" was not normally associated with TI's semiconductor group. Although this approach to the market may produce high volumes, it does not produce high margins.

In order for a company to develop products that consistently produce high margins, the products must have some features that differentiate them from those of the competition. Implicit within this goal is that the features provide an added value for the customer. These differentiated products must provide at least three of the following: feature differentiation, higher performance, better price performance, or faster time-to-market.

TI has set about this task by identifying applications within markets in which it chooses to participate. It further makes the effort to learn about those applications, how they are implemented today, and what the needs are for tomorrow. To increase the visibility on this type of application-specific product, TI has set a goal stating that greater than 50 percent of its annual semiconductor product revenue must come from these application-specific products during the latter half of the decade.

The company's stated 50 percent goal is noble and is one it seems intent upon reaching. And although it appears to be making progress toward this end, it is starting from an extremely low base from which high growth is relatively easy. In order to prevent this progress from stalling, TI must continue to drive and reinforce this application-specific spirit throughout the corporation. Decades of NIH and engineering-driven product development are not eliminated overnight.

Have Fabs, Need Products

If one is to assume that, through its worldwide partnerships and alliances, Texas Instruments has overcome its submicron CMOS fabrication dilemma, then all the company must do is make sure it has the right products to fill those new fabs as the industry continues to turn up. Earlier we discussed the progress TI has made in its overall technology mix. Here we look at its product families in more detail.

The short-term outlook for TI's product portfolio is still a question mark. TI breaks into only one of the top five major product categories, bipolar (see Table 9).

Unfortunately, being the No. 1 supplier of bipolar ICs in the world is a rather dubious distinction. In every other category it ranks sixth or lower.

Table 9
Major Product Categories Top Five Rankings

	No. 1	No. 2	No. 3	No. 4	No. 5
Total IC	NEC	Intel	Toshiba	Hitachi	Motorola
Bipolar	*Texas Instruments*	Fujitsu	Hitachi	Motorola	National
MOS	Intel	NEC	Toshiba	Hitachi	Motorola
Memory	Toshiba	Hitachi	NEC	Samsung	Fujitsu
Micro	Intel	Motorola	NEC	Hitachi	Mitsubishi
Logic	NEC	Toshiba	Fujitsu	Motorola	LSI Logic
Analog	Philips	National	Toshiba	Sanyo	SGS-Thomson

Source: Dataquest (November 1992)

Focus on the Future

Because the heart and soul of the company's recovery strategy is centered around its newfound submicron CMOS fabrication capability, the balance of this discussion will ignore TI's bipolar and analog product revenue and instead focus upon its MOS products, present and future.

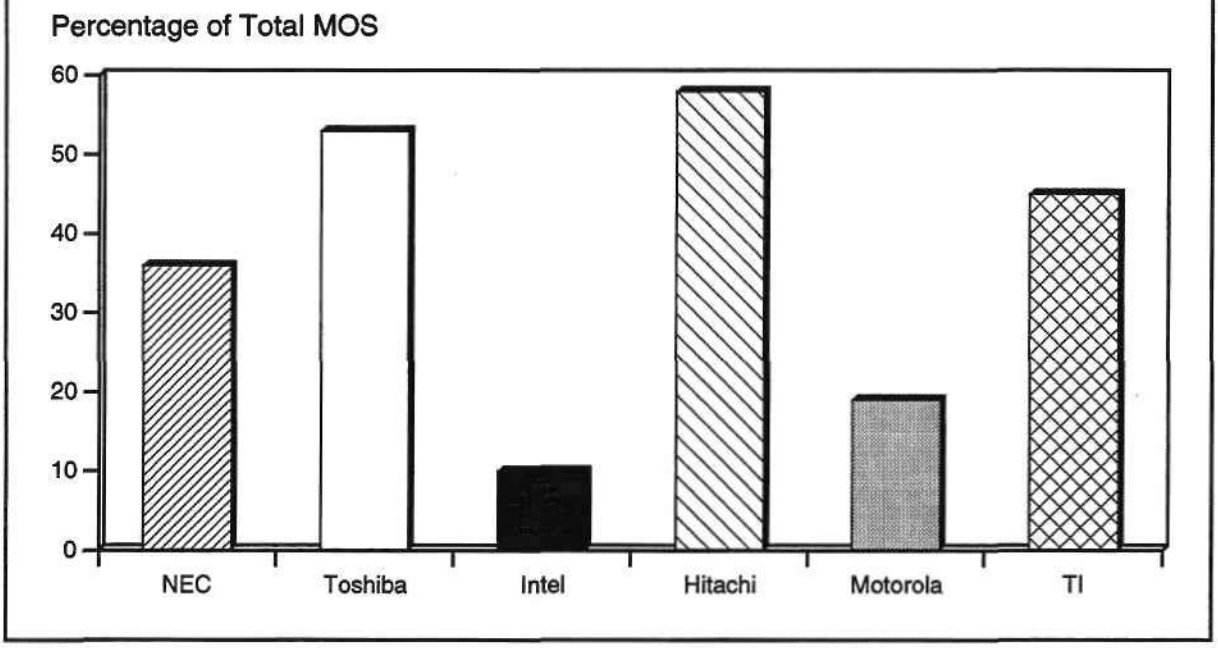
A Relative Comparison

Figure 3 compares the revenue mix of TI's MOS products with that of the top five semiconductor manufacturers in 1991.

It is an understatement that TI relies upon MOS memory revenue far more than either of the two North American companies in the top five. For example, Intel and Motorola rely upon MOS memory for only 10 percent and 19 percent of their total MOS revenue, respectively, while TI relies upon MOS memory for 45 percent of its MOS revenue. Because both Intel and Motorola rely heavily upon foundry services for their MOS memory production, it could be argued that their MOS memory exposure is far less than the numbers shown here. Compared with the three Japanese companies in the top five, TI is surpassed by Toshiba at 53 percent and Hitachi at 58 percent, but its reliance upon MOS memory revenue surpasses the No. 1-ranked semiconductor manufacturer, NEC, by 9 points. Of the remaining top 10 MOS IC manufacturers, only Samsung and Fujitsu have a higher reliance upon MOS memory revenue than TI.

TI appears to be extending its reliance upon MOS memory revenue because it has been quickly ramping its 4Mb DRAM capacity. Although this may produce solid short-term performance, as the Japanese and Korean companies add more capacity, market share battles will grow more fierce and place more price pressure on the 4Mb DRAM, which could easily turn into a long-term negative for the company if other products are not ready to fill in when the DRAM market goes through one of its typical downturns.

Figure 3
MOS Memory As a Percentage of Each Company's Total 1991 MOS Revenue



Source: Dataquest (November 1992)

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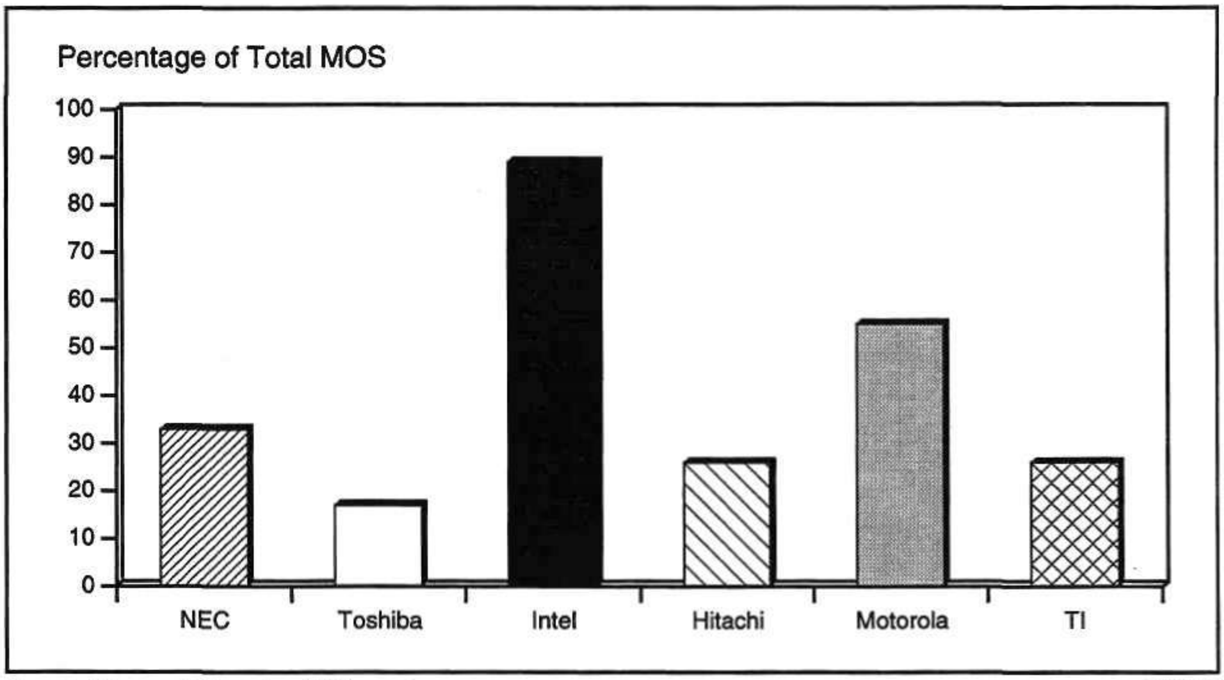
Figure 4 compares TI's MOS microcomponents mix with that of the top five. Compared with the other major semiconductor manufacturers in North America, TI appears to be taking the path less trodden. Only Toshiba had less of a focus in 1991 on MOS microcomponents than did TI. Both Intel at 89 percent and Motorola at 55 percent rely upon MOS microcomponents for the greatest portion of their MOS revenue. This high exposure in MOS microcomponents is relatively safe when compared to MOS memory. Microcomponent architectures are typically proprietary and well protected with intellectual property rights, whereas a strong position in memories can quickly dissipate because of their commodity nature. TI, at 26 percent MOS microcomponents, appears to be more closely modeling itself after the top Japanese companies.

Within the microcomponents arena, one could rightfully argue that TI is by far the No. 1 supplier in the fast-growing and critical area of digital signal processing (DSP) ICs. However, nine years after its first product was introduced, the company's 1991 DSP revenue, while clearly ahead of its competition, was only $143 million and represents about 11 percent of the company's MOS revenue and only 5 percent of its IC revenue.

Figure 4
MOS Microcomponents As a Percentage of Each Company's Total MOS Revenue



Source: Dataquest (November 1992)

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Integration: Who Owns the Micro Wins the Game

The glaring weakness in TI's MOS microcomponents product line has been the lack of an industry-standard microprocessor. This is a larger problem than the missing revenue stream that the processor could conceivably provide. At higher levels of integration, microprocessors are beginning to swallow up entire peripheral functions. If TI does not have a microprocessor onto which its peripheral products can be integrated, it loses this peripheral revenue stream to the company that does have the microprocessor. TI appears to have recognized this fact and has allied itself with Sun Microsystems to develop SPARC microprocessors, and with Cyrix Corporation, which gives TI access to Cyrix's line of x86 products.

Because TI has just recently begun shipping production volumes of the SuperSPARC microprocessor to Sun, it is still unclear how successful this project will be for TI. Sun has a history of being a rather fickle partner. In the last three-plus years, Sun has had numerous partners committed to developing and manufacturing SPARC microprocessors for the use of Sun and for any clone manufacturers of Sun SPARCstations. The first was with LSI Logic, which lasted about one year. This was followed by agreements with Fujitsu, Cypress, and now TI. In a span of less than four years, Sun has had four primary suppliers of SPARC microprocessors. Being the primary supplier of SPARC microprocessors to Sun is not necessarily a long-term relationship.

Also, if history is any indicator of what we should expect in the future, the market for SPARC microprocessor consumption outside of Sun is rather small and should not be expected to experience rapid growth in the foreseeable future. TI should not count on the SPARC to be its long-term solution for a mainstream microprocessor.

TI's opportunity to significantly increase its microprocessor revenue and become a mainstream supplier of microprocessor products should be based on its relationship with Cyrix. This relationship provides TI with a microprocessor core that is instruction-set-compatible with the industry-standard 486 microprocessor. It is doubtful that TI would be able to compete with Intel's 486 offerings on a product-by-product basis. However, if TI can use its ASIC capabilities to develop highly integrated microprocessors for specific applications where compatibility, cost, and integration are of prime importance, it could carve out defensible niches. ASIC is not Intel's strong suit, and as a result TI can place itself in the position of being able to offer feature differentiation to a customer base desperately looking for ways to differentiate itself from its own competitors, while maintaining instruction-set compatibility with the plethora of software applications that exist for the x86 instruction set.

We believe that this program is of such import to Texas Instruments' long-term product positioning, that management's time would be well spent if it kept this program spotlighted—not micromanaged, but closely observed to determine if NIH or any other TI engineering bias were slowing or stalling the program. The spotlighting should also serve to ensure that this project is not underresourced. The importance or significance of this project should not get lost in the multitude of TI's other engineering projects and alliances.

Dataquest Perspective

The key to TI's future success will be focus. New innovative ideas are not in short supply at this historically engineering-oriented company. It has major efforts going in DSP, graphics, networking, ASIC, mixed-signal, cell-based mixed-signal (or PRISM), DRAMs, Flash, FPGAs, and many more. If TI is to succeed, it must pick its major projects carefully, supply them with adequate resources, give them target dates, and get out of the way. As stated earlier, watch their progress but do not micromanage. The early days of the company's highly successful DSP division would be a good paradigm to follow.

In the short term, the company has made a definite commitment to developing its own world-class manufacturing facilities. But now that it has made this commitment, it most certainly will focus its efforts on finding products that can fill these facilities. It must find existing products that can quickly generate large volumes. In the near term, the only products in TI's product portfolio that can quickly generate the necessary volume are the 1, 4, and 16Mb DRAMs. This will place TI in direct competition with Toshiba, Hitachi, NEC, Samsung, and the fast-rising stars of Goldstar and Hyundai, as well as smaller players such as Micron Technology. Although TI might argue that its new fab lines are second to none and that its new 4 and 16Mb DRAM designs are world class, its current position as the seventh largest supplier of MOS memories indicates that there are at least six other MOS memory manufacturers with state-of-the-art facilities and more experience in manufacturing and selling these devices. Although TI may be in a strong position if any temporary DRAM shortages occur, it greatly increases its risk by not having a more balanced product portfolio.

Texas Instruments must accelerate its pursuit of new application-specific standard products and value-added x86-based products that it can use to fill its fabs when the inevitable MOS memory product crash occurs.

Dataquest Vendor Profile

Microcomponents *Worldwide*

September 7, 1992

Intel Corporation

Corporate Statistics

Headquarters Location	Santa Clara, California
President and CEO	Andy Grove
Primary Business	Microcomputer components
Annual Sales (FY1991)	$4,779 million (U.S. Dollars)
Total Employees	24,600
Manufacturing Locations	10 worldwide
Founding Date	July 1968
Fiscal Year	January-December
Ownership	Public (NASDAQ ... INTC)

Corporate Overview

Over the last five years, Intel has recovered from a downhill slide capped by heavy losses in 1986 to become the kingpin of microprocessors and perhaps the most powerful semiconductor company in existence. Driven by Intel toward increased performance levels, the enormous market for 80x86-based PCs grew in 1991 to more than $2.5 billion in microprocessor revenue and about $1.0 billion in related peripheral products. Now at the pinnacle of its success, Intel faces its toughest challenge: to keep its 80x86 family ahead of competing RISC families and other 80x86 clone products while maintaining attractive profit margins.

Intel defines its mission to be the leading supplier of microcomputer building blocks at the component, module, or system level used within computers and embedded control equipment. Today, most of the company's activities are focused on growing its business derived from the IBM-compatible PC market. This direction means that Intel must remain the dominant leader in 80x86 microprocessors and microperipherals.

Founded in 1968, Intel originally concentrated on semiconductor memory products, which still remain an important part of its business. Among its many innovations (see Table 1), Intel is credited with inventing the most important memory in use today, the dynamic

For more information on Intel Corporation or the microcomponents industry, call Ken Lowe at (408) 437-8366.

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Table 1
Major Milestones for Intel Corporation

Year	Description
1968	Intel Corporation founded.
1970	Introduced the first commercial DRAM (1Kb).
1971	Introduced the first commercial EPROM (1Kb). Introduced the first commercial microprocessor (4004). Goes public.
1973	Introduced the first microprocessor development system.
1974	Introduced the 8080 (initiated major growth of MPU industry). Achieved more than $100 million in net sales.
1976	Introduced the first microcontroller with EPROM.
1978	Introduced the 8086 (spawning the most successful line of MPU in history).
1979	Introduced the first 5V DRAM (previously all 12V).
1980	Introduced the 8051 microcontroller (most widely used MCU in world). Introduced the first math coprocessor (8087).
1981	Intel 8088 selected by IBM for its first personal computer (IBM PC).
1982	Introduced the 80286 (used in IBM PC AT).
1983	Achieved more than $1 billion in net sales.
1985	Exits the DRAM business (after developing 1Mb working silicon). Enters the PC enhancement market (AboveBoard memory adapters). Introduced the 80386, first 32-bit x86-compatible generation.
1987	Enters the market for parallel supercomputers.
1988	Introduced its first flash memory product. Introduced the i960 embedded RISC processor family.
1989	Introduced the first 1-million-transistor microprocessor (i860). Introduced the 80486, first MPU with integrated CPU, FPU, and cache.
1990	Exits EPROM development race (at 4Mb) to focus on flash.
1991	Achieves fastest installed supercomputer (32 gflops). Introduced the first 2.5-million-transistor microprocessor (i860XP).
1992	Introduced the first 8Mb flash memory component.

Source: Intel, Dataquest

random access memory (DRAM). Its strategy has always been built on innovation: invent something unique, enjoy higher profits from that uniqueness, then move on when competition crowds the market. Yet, as it entered the 1980s, Intel (like most semiconductor companies) sold a broad range of mostly commodity products. Then, in 1981, IBM chose the 8088 as the engine for its first PC, eventually changing the profile of Intel's entire business.

By 1985 it was clear that the DRAM business was at best a low-margin proposition where the Japanese were taking over in the midst of a chip recession. As a result, Intel accumulated operating losses of $250 million over 1985 and 1986. These and other factors drove Intel's decision to exit the commodity-oriented DRAM business in favor of the innovation-oriented microprocessor business. At that time, Intel's future hinged on the success of its proprietary 386 microprocessor, an advanced 32-bit architecture compatible with the 16-bit 8086 PC standard.

As history shows, this was the best decision Intel could have made. The 386 became the most successful logic chip in the semiconductor industry, accounting for nearly half of Intel's 1988 revenue of $2.9 billion. Intel followed up with the 387 math coprocessor and later, in 1989, with the 486, a 1.2-million-transistor chip that combined the functions of the 386 and 387 and had a primary cache yielding a twofold performance improvement at a fourfold pricing increase. As a result, the 486 now represents Intel's leading revenue generator, which will account for more than $1.4 billion in revenue for 1992.

Intel's 386 monopoly weakened in 1991 when Advanced Micro Devices (AMD) became the first of several vendors to enter the 386-compatible market, taking considerable unit volumes and effectively lowering the exceptionally high pricing structure Intel had enjoyed. At the same time, RISC microprocessors were reaching the peak of their momentum with IBM, Apple, and Motorola teaming up to create next-generation systems based on the PowerPC architecture. Meanwhile, Intel has increased its penetration into other markets, trying to balance its portfolio of products to increase its non-80x86 revenue.

Business Strategy and Segmentation

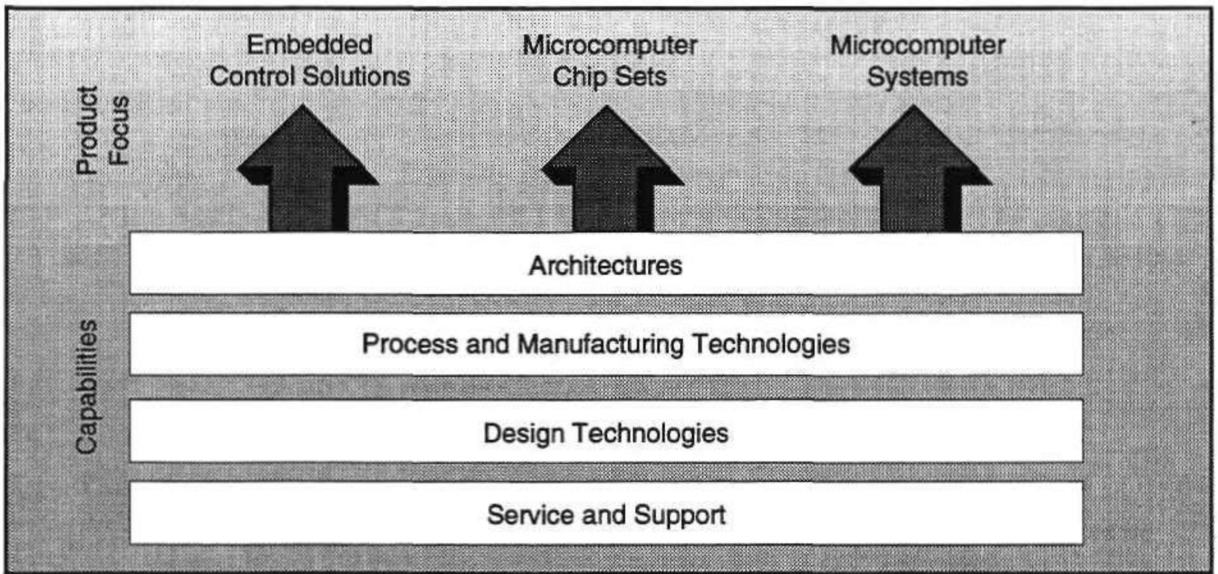
Intel's vision for the 1990s centers around a concept referred to as "computer-supported collaboration. " It believes that as the pace of competition picks up (among businesses in general) there will be a transition to a "just-in-time" business environment, where getting the right information to where it is needed quickly becomes a primary competitive advantage. This transition will be achieved through cooperative work facilitated by interconnected, interactive electronic communication in which all forms of data are shared quickly and easily. The worldwide computer infrastructure will be extended to become a communications infrastructure, hence "computer-supported collaboration." Intel integrates its product mix around this central theme, paving the way for increasing levels of processing power, miniaturization, and communications capabilities.

To realize this overall vision, Intel pursues the evolution of its primary target market, computer systems, by focusing on three main product areas supported by four key capabilities (see Figure 1). Intel's overall business strategy anticipates integration of the computer and communications industries and positions the company to pursue the additional opportunities that will result. Intel's primary product focuses are microcomputer chip sets, embedded control solutions, and microcomputer systems, the first two of which are semiconductor product businesses representing the bulk of Intel's total sales. The key capabilities developed by Intel to support its growth in these areas include proprietary architectures (mainly microprocessors), manufacturing and process technologies, design technologies, and support services.

Major Market Segments

Intel participates in a wide range of market segments. However, sales are dominated by the data processing market, which accounts for an estimated 70 percent of its total revenue. Sales into this segment include semiconductor components (microprocessors, microperipherals, and memory devices), computer upgrade modules (coprocessors, memory cards, and add-in adapters), and supercomputers—all sold to computer companies, distributors, or end users. Intel has targeted the computer systems markets since the mid-1980s because of the higher margins afforded to the components that serve that market. Other market segments served (in order of decreasing revenue) are industrial, communication, automotive, military, and consumer.

Figure 1
Intel Core Strategy

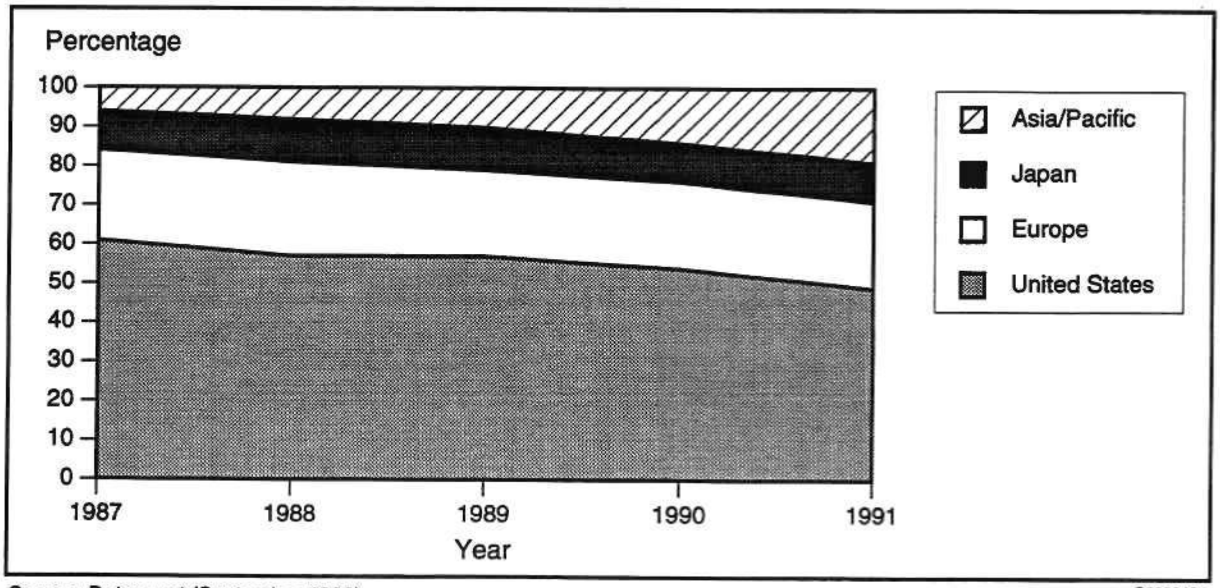


Source: Intel Corporation

Intel sells most of its components directly to companies that incorporate them into their products. These customers primarily are computer systems manufacturers such as IBM and Compaq, but they also include producers of telecommunications equipment, industrial equipment, and automobiles. Intel maintains a broad, balanced customer base; no single customer accounted for more than 10 percent of its revenue during the last two years (in 1989, IBM accounted for 10.5 percent of Intel's revenue). Intel also sells certain products through distribution, which accounted for about 25 percent of its net revenue during 1991.

An expanding base of international customers, primarily in the Asia-Pacific region, has driven Intel's sales mix to an all-time high of 51 percent non-U.S. revenue (see Figure 2). Over the last five years, Intel's sales from the Asia-Pacific region have steadily increased from 6 percent in 1987 to 19 percent in 1991, making it the No. 1 vendor in the region, primarily driven by the growth of the PC clone industry in Taiwan. However, as a result of AMD and other x86 clones entering the 386/486 market and penetrating primarily the Asia-Pacific clone vendors, this shift in regional sales mix is expected to come to a halt during 1992. In exchange for this increase in international business, sales in the United States decreased from 61 percent in 1987 to only 49 percent in 1991, which also indicates the shift toward offshore manufacturing of PCs. During this same period, the percentage of regional sales to both Europe and Japan remained relatively constant at about 22 percent and 10 percent, respectively.

Figure 2
Intel Sales, by Geographic Region



Source: Dataquest (September 1992)

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Major Product Segments

Though its product mix includes items as diverse as supercomputers and adapter boards, Intel is primarily a semiconductor company, with microprocessors central to its entire product mix. This section will provide an overview of Intel's product mix as defined by the company. A subsequent section will provide a complete analysis of Intel's semiconductor-related businesses, which accounted for a combined total of about $4.0 billion, or 84 percent of its 1991 revenue.

The first product segment, microcomputer chip sets, feeds the bulk of Intel's growth, 65 percent of 1991 revenue or about $3.1 billion (see Figure 3). This segment includes semiconductors and integrated modules as building blocks for computer systems ranging from desktops to floortops to portables. Specifically, this segment includes the following products:

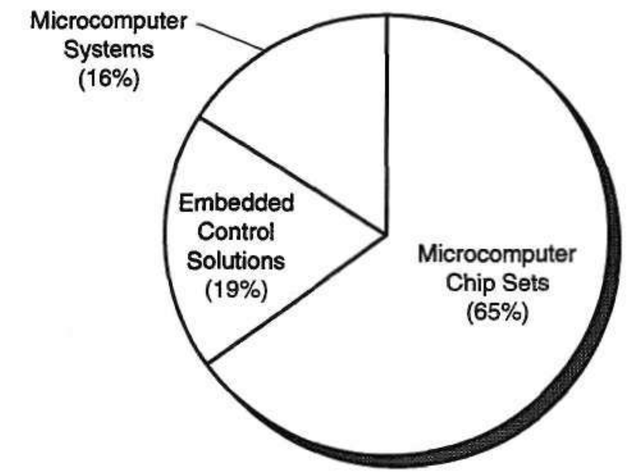
- Computer microprocessors, the central control units used for computer systems, now primarily focused on 32-bit 80x86 processors (that is, 386, 486, and P5). Also includes the older 16-bit 80x86 processors (8088/86/286) and the i860 processor for supercomputing and graphics.
- Microperipherals, which work directly with the microprocessors to handle specific I/O and processing functions. Intel's sales here are dominated by math coprocessors but also include PC core logic chips, network controller chips, multimedia, and modem chips.
- SRAM memory and CPU/cache modules (sold for the 486DX-50), which account for a small amount of revenue but represent a strategic technology for integration with the CPU.

Embedded control solutions, the second semiconductor business area, accounted for about $900 million (19 percent) of 1991 revenue. This business segment includes components used in various embedded applications such as laser printers, communications systems, and automobiles. This segment spreads out the use of Intel components as the core of intelligent noncomputer electronic systems. Specifically, this segment includes the following products:

- Microcontrollers, which represent the largest revenue source for this product segment, integrate microprocessor and memory technologies on one chip and include the 8048, 8051, and proprietary MCS-96 families of components.
- Nonvolatile memory/logic, which permanently store control programs, includes Intel's line of EPROMs, flash memory devices, and PLD devices.
- Embedded microprocessors, the processors used to control the actions and data flow in noncomputer applications, include the i960 family as well as the embedded versions of the 80x86 family (80186/188/376).

Microcomputer systems, a nonsemiconductor business area, accounted for about $800 million of Intel's 1991 revenue. This business segment supports the proliferation of the other two segments,

Figure 3
Intel Sales, by Product Segment



Source: Dataquest (September 1992) G2000482

creating and manufacturing systems designed around Intel components at both the commodity level (PC motherboards) and leading edge (supercomputers). Specifically, this segment includes the following:

- PC motherboards, based primarily on Intel microprocessor and I/O components, are manufactured by Intel for OEMs such as Digital Equipment Corporation.
- PC enhancement products, which are sold through retail computer stores, include add-in adapter boards (memory, fax/modem, network controllers), PCMCIA cards (memory, fax/modem), and component upgrades (math coprocessors, overdrive processors).
- Supercomputer systems, ultra-high-performance computers utilizing massively parallel processing primarily for scientific and engineering problems, are designed around Intel's i860 microprocessor and sold directly to large end users.
- Software products, which include microcomputer operating systems (iRMX real-time kernel for industrial control applications), development/debug support tools, and high-level networking software support.

Key Capabilities and Competencies

Intel to date has been successful in optimizing its four key capabilities around its product mix to leverage its position as the incumbent king of microprocessors.

The first of Intel's four key capabilities is proprietary architectures. Leveraging the momentum of the IBM PC legacy, Intel pushes leading-edge performance and integration while maintaining pull-through 80x86 compatibility. The 80x86 microcomputer architecture is the most widely used in the industry, representing more than 80 percent of the PC units shipped. Intel works closely with major software vendors to ensure that the 80x86 family maintains the largest complement of operating systems and application packages available. Intel also maintains two proprietary RISC microprocessor architectures, the i960 for the 32-bit embedded processing market and the i860 for supercomputers and graphics/imaging subsystems.

Intel's next emphasis is advanced process and manufacturing technology. Intel's strength in manufacturing capability is underscored by its enormous capital investment (nearly $1 billion in 1991) used for continually upgrading facilities. Intel's process technology developments have enabled it to double the number of transistors it can integrate on one chip about every 18 months since the early 1970s. Its strategy is to gain a twofold leverage from the following leading-edge processes:

- Enable state-of-the-art products not possible or economical without the investment in fabrication expertise
- Lower unit cost through smaller die sizes and higher yields as older products become commodities, affording them higher margins

Intel's third key capability is design technology, where it has long been recognized that design time is a bottleneck in bringing new chips to the market. Intel's level of design technology is reinforced by its continued high spending in R&D, which represented 13 percent of total sales in 1990 and 1991. As a result, Intel expects to reduce its time to market for next-generation chips while significantly increasing their complexity. Thus, as the P5 is introduced in early 1993, the P6 generation should be out in mid-1994 and the P7 in early 1996.

Intel's fourth key capability is service and support. As with most major companies, service is a key element in the overall marketing mix. At Intel, the differential advantage focuses on extensive documentation, training programs, and hardware/software development tools that make its components easy to design with.

Marketing Strategy and Alliances

Though not included under key capabilities, another key Intel strength is its marketing program, which is an integrated mix of brand promotion, competitive counterattacks, and high-impact product introductions. Combined with its position in the 80x86 microprocessor market, Intel delivers the image of leadership within the PC industry through its marketing programs.

Intel's brand promotion program has been aimed at increasing the awareness of its brand products and their advantages at the end-user level. To date, more than 340 manufacturers have participated in the "Intel Inside" cooperative advertising program. Intel hopes to use this program to develop preference for PCs with Intel microprocessors because of their absolute compatibility, upgradability paths, and other features.

Intel has also begun strengthening its relationships with key customers and third parties because it faces increasing competition on its mainstream microprocessors. As a result, Intel is forming more and more strategic alliances, such as its recent cross-licensing agreement with VLSI Technology. This agreement establishes a program for developing highly integrated 386-based processors for the handheld market through a vendor that leads in PC logic chip sets and excels in customization services. In addition, it focuses VLSI's development and marketing efforts on Intel's microprocessors, rather than on AMD, Cyrix, or others.

Intel's 1992 alliances were as follows:

- VLSI Technology and Intel entered into a cross-licensing and equity exchange agreement (Intel now owns 16 percent of VLSI) to design integrated 386-based products primarily for the handheld market.
- IBM and Intel entered into a licensing agreement for IBM's XGA graphics architecture in which Intel will integrate XGA features into IBM's multimedia and microcomputer products.
- Defense Advanced Research Projects Agency (DARPA) and Intel announced a joint research program to produce a 1-teraflop-level supercomputer system.

Intel's 1991 alliances were as follows:

- IBM and Intel jointly announced the formation of the Noyce Development Center, a 100-engineer design center to develop very highly integrated 80x86 microprocessors.
- Digital and Intel entered into an agreement in which Digital would introduce a new family of PC products based on Intel 386/486 microprocessors and manufactured by Intel.
- NMB Semiconductor and Intel entered into a supply agreement in which NMB will turn one of its plants into a flash memory foundry (for die only) dedicated to Intel.
- Pacific Bell and Intel signed an agreement to market network integration services and equipment in conjunction with Pacific Bell's Data Communications Group.
- Tartan Laboratories and Intel's military division signed an agreement to jointly market Tartan's i960 ADA compilation system.

In 1990, IBM and Intel entered into an agreement providing Intel exclusive rights to its parallel interface (PI) bus interface unit, currently used in IBM's Common Avionics Modules.

Intel's 1989 alliances were as follows:

- AT&T, Convergent Technologies, Ing. C. Olivetti S.p.A., Prime Computer, and Intel announced a joint engineering effort to create a multiprocessing version of UNIX for the i860.
- AT&T Microelectronics and Intel signed a five-year agreement to provide OEMs with an array of products supporting ISDN and LANs from a common source.
- (DARPA) and Intel signed a $7.6 million research agreement to develop prototypes of a CRAY-1-level supercomputer.
- IBM and Intel signed an agreement in which Intel would develop an MCA board to utilize DVI for the IBM PS/2 computer.

Company Organization and Operations

Intel is organized around a business unit structure (see Figure 4) that focuses on the development and marketing of its product segments while relying on centralized departments for all of the support functions including manufacturing, sales, finance, and administration. There are five product groups, four of which focus strictly on one product segment while the fifth splits attention between two product segments. At the top is an executive office shared by Chairman Gordon Moore, President Andy Grove, and Executive Vice President Craig Barrett. As the company's chief strategist and visionary, Andy Grove maintains the most visible role of the three executives in shaping Intel's direction. Craig Barrett, currently positioned as the heir-apparent, primarily focuses on day-to-day operations.

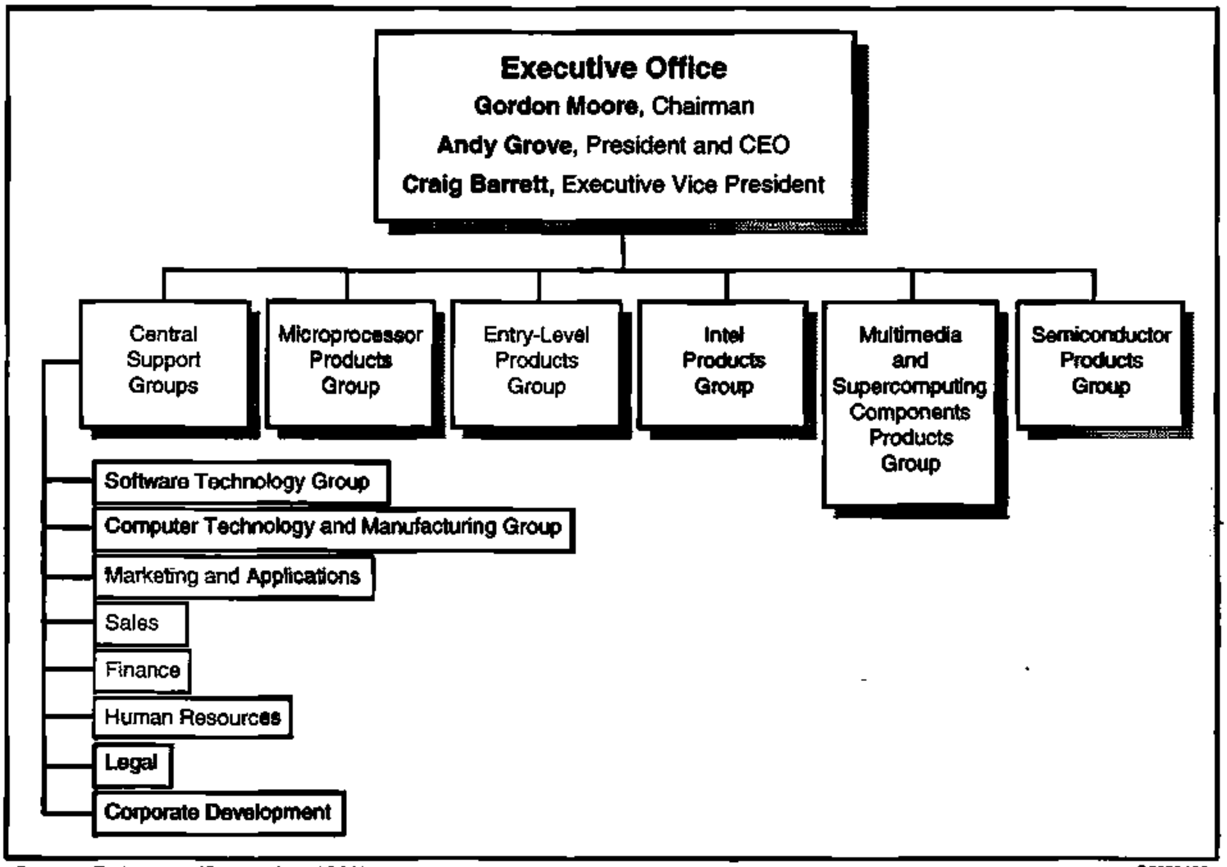
Development of the 80x86 product line is split between two separate operating groups based on both product and market focus, the first of which is the Microprocessor Products Group. This group is responsible for the development of high-performance 80x86 processors targeted primarily for office systems (PC desktops, workstations, and servers). The group is headed by Paul Otellini and Albert Yu, both vice presidents who share the general manager position. Specific products under this group include the following:

- i486 product line (SX, DX, and other desktop versions)
- Future 80x86 architectures including P5 (due out in the first quarter of 1993), P6, and P7

Intel's second 80x86 group is Entry-Level Products, which is responsible for development of highly integrated 80x86 microprocessors and standard microperipheral chips used to manufacture mainstream PC systems. This group is headed by Mike Aymar, vice president and general manager. Specific products under this group include the following:

- Intel's SL product line of integrated architectures, including i386SL and H4C (486SL)

Figure 4
Intel Organization Structure



Source: Dataquest (September 1992)

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- Core logic chip sets including EISA, cache controllers, PCI, and other related chips
- I/O modules including Intel's ExCA (Exchange Cards) and other I/O chips and adapters

Multimedia and Supercomputing Component Products was formed in May 1991 to pursue non-80x86 architectures that extend the current bounds of computing. This group is headed by Ken Fine, vice president and general manager. Specific products under this group include the following:

- Digital Video Interactive (DVI) product line (i750 series)
- i860 family of supercomputer microprocessors
- i960 family of embedded microprocessors

The Intel Products Group is actually a collection of separate divisions, each focused on a different line of Intel-branded components, software, or systems. This group is headed by Frank Gill, senior vice president and general manager. Included in this product group are the following divisions and specific products:

- PC Enhancement Division, which includes adapter products such as fax/modems and network controllers
- End-User Components Division, which includes math coprocessors and overdrive processors
- OEM Products Division, which includes multibus products, iRMX software, and PC platforms
- Supercomputer Systems Division, which includes the iPSC/860 supercomputer products
- Networks and Services Division, which includes other deliverable software and services

The Semiconductor Products Group is responsible for the development of nonvolatile memories, microcontrollers, and related products. This group is headed by Robert Reed, senior vice president and general manager. Specific products under this group include the following:

- Nonvolatile memories, which includes standard EPROMs and flash products
- Microcontrollers, which includes 8048, 8051, and MCS-96 families

Sales Channels and Distribution

Most of Intel's products are sold or licensed directly to OEMs through a network of 68 sales offices located in 20 nations. Intel also uses distributors and representatives to sell products indirectly to smaller OEMs and end users. Intel's sales channels and distributors are managed directly by a centralized sales department.

In North America, Intel maintains 43 direct sales offices; 39 are located throughout the United States and 4 are in various parts of Canada. Intel also has the following distributors throughout the United States and Canada:

- Alliance Electronics
- Almac Electronics (United States and Canada)
- Arrow Commercial Systems and Arrow/Schweber (United States and Canada)
- Avnet Computer and Hamilton/Avnet Electronics (United States and Canada)
- MTI Systems
- North Atlantic Industries
- Pioneer-Standard and Pioneer Technologies Group
- WYLE Laboratories
- Zentronics (Canada only)

In Europe, Intel has 9 direct sales offices and 28 distributors providing complete regional coverage on a country-by-country basis. Direct Intel sales offices are located in the following countries:

- Germany
- United Kingdom
- France
- Italy
- Sweden
- Finland
- Netherlands
- Spain
- Israel

In Japan, Asia, and the Rest-of-Word (ROW), Intel maintains 16 direct sales offices and a host of distributors. Direct Intel sales offices are located in the following countries:

- Japan (7)
- Australia (2)
- Brazil
- China
- Hong Kong
- India
- Korea
- Singapore
- Taiwan

Manufacturing Plants and Subsidiaries

Intel operates 10 major manufacturing facilities throughout the world, 6 in the United States, 1 in Europe, and 3 in ROW. Intel also has 25 subsidiaries throughout the world, 20 of which are direct sales/service operations in various countries. The other 5 are primarily holding companies or acquisitions and include Intel Electronics Ltd. (United States), Intel International Inc. (United States), Intel Investment Ltd. (United States), Intel Overseas Corporation (United States), Intel Puerto Rico (Puerto Rico), and Jupiter Technology Inc. (United States). Table 2 lists the locations and describes the major semiconductor fabrication facilities.

Intel closed its oldest fabrication facility, located in Livermore, California, in the third quarter of 1991. This 17-year-old facility was reportedly last used for producing 386 microprocessors; its closing was delayed by more than a year because of parts shortages.

Table 2
Intel Semiconductor Fabrication Facilities

Plant Location	Fab Name	Began Operating	Technology and Products Produced	Line Width (µm)	Wafer Size
Aloha, OR	Fab 4	1981	High-volume commodity, logic	2.0	4
	D1(Fab 5)	1987	MPU: 386, 486, SRAM, logic	1.0	6
Chandler, AZ	Fab 6	1984	MCU, MPU: 286, 186	1.5	6
Jerusalem, Israel	Fab 8	1985	MPU: 286, 386	0.8	6
Rio Rancho, NM	Fab 7	1984	EPROM, MCU: military standard	1.0	6
	Fab 9.1	1988	MPU: 386, 486	0.8	6
	Fab 9.2	1991	MPU: 486, EPROM	1.0	6
	Fab 9.3	1992	MPU: P5, EPROM	0.8	6
Santa Clara, CA	Fab 1	1987	EPROM, flash, MCU, logic	1.5	4
	R1*	1986	NA	NA	6
	D2*	1989	EPROM development	0.8	8
	PED*	NA	NA	1.0	6

NA = Not available
Notes: All fab facilities are full production unless noted with an asterisk (*). All process technology used is CMOS unless noted under products.
Source: Dataquest (September 1992)

Intel is spending more than $1 billion a year in plant and capital equipment to build new fabrication plants and refurbish existing ones. This investment is focused on development of the following facilities:

- Aloha, Oregon D1A Fab: Intel started construction in June 1991 and plans to bring this facility on-line in the second quarter of 1993. This 430,000-square-foot facility will cost $200 million to $300 million and will offer capabilities of running 8-inch wafers, from 0.6 to 0.35 µm, aimed at supporting the P5 and future processors. The present D1 facility will simultaneously be converted to 0.6 µm and 8-inch wafers.
- Dublin, Ireland: Intel will spend about $500 million to build this state-of-the-art facility to support the European market. This plant is scheduled to go on-line by the end of 1992.
- New Mexico: Intel is reportedly expanding fab lines to accommodate the P5 as it goes into volume production.

Intel also operates the following manufacturing plants for component and board-level assembly operations:

- Hillsboro, Oregon: Memory boards and microcomputer systems.
- Las Piedras, Puerto Rico: Memory boards and microcomputer systems.
- Leixlip, Ireland: Memory boards and microcomputer systems.
- Manila, Philippines: Component assembly and final testing.
- Penang, Malaysia: Component assembly and final testing.

Adding to its list of operations, in 1991 Intel acquired the Network Products Division of New York-based LANSystems Inc. as a part of an ongoing thrust into the market for LAN software and hardware. In 1990, Intel acquired Jupiter Technology, a supplier of data communications computers, operating systems, and networking products, to broaden its technology and offerings in the connectivity market.

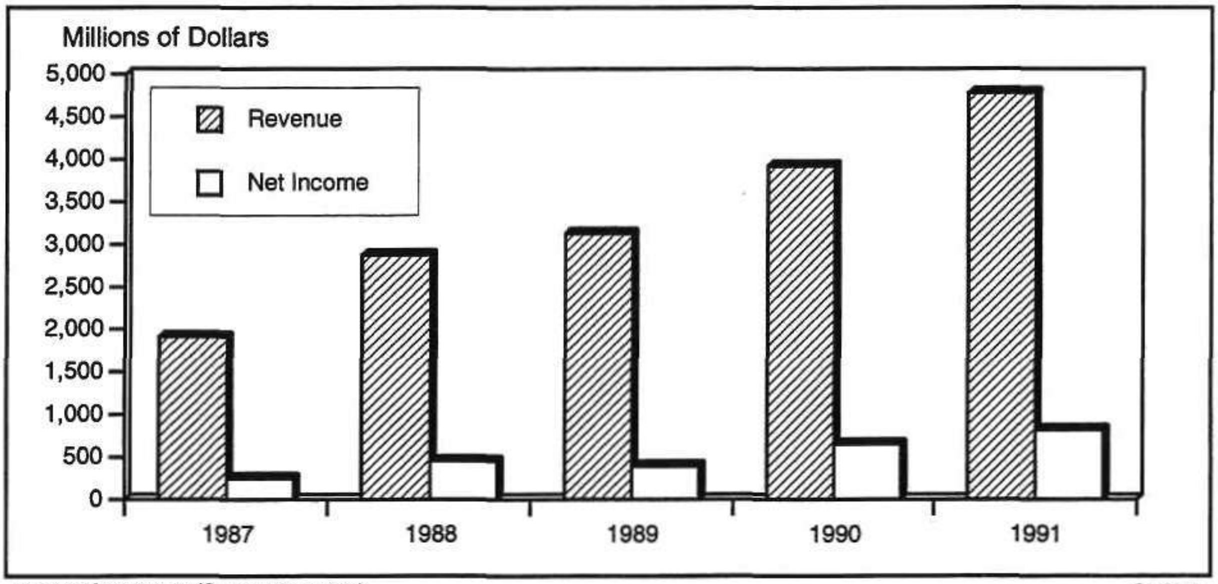
Financial Performance and Conditions

Five-Year Financial Highlights

Over the last five years, Intel's revenue has continued to grow at an industry leading pace with a five-year compound annual growth rate (CAGR) of 20 percent (see Figure 5). Despite increasing competition in its primary product segments (386/486 microprocessors), Intel still enjoys healthy financial growth and is expected to turn in about 15 percent growth in revenue for 1992.

Net income has generally kept pace with revenue growth, with the exception of 1989, when a slowdown in revenue growth resulted in a decrease in net income (see Table 3). This is a direct result of the high gross margins Intel is able to sustain because of its monopoly in the 386/486 microprocessor market, which is just now coming into fierce competition. As a result, average selling prices have

Figure 5
Intel Historical Growth



Source: Dataquest (September 1992)

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Table 3
Intel's Five-Year Financial Summary

	1987	1988	1989	1990	1991
Revenue ($M)	1,907	2,875	3,127	3,921	4,779
Growth Rate (%)	51	51	9	25	22
Cost of Sales ($M)	1,044	1,506	1,721	1,930	2,316
Gross Margin (%)	45	48	45	51	52
Net Income ($M)	248	453	391	650	819
Net ROS (%)	13	16	13	17	17
Total Employees	19,200	20,800	21,700	23,900	24,600
Sales/Employee ($)	99,323	138,221	144,101	164,059	194,268
Total Equity ($M)	1,276	2,080	2,549	3,592	4,418
Return on Equity (%)	19	22	15	18	19
R&D Expenses ($M)	260	318	365	517	618
Percent of Sales	14	11	12	13	13
Capital Expenses ($M)	302	477	422	680	948
Percent of Sales	16	17	13	17	20
Total Assets ($M)	2,499	3,550	3,994	5,376	6,292

Source: Dataquest (September 1992)

eroded significantly and Intel is expected to see a drop in gross margins for 1992.

Intel has seen its most dramatic changes in productivity, as indicated by the sales per employee ratio climbing from $99,000 in 1987 to more than $194,000 in 1991. Intel has been investing in the tools that are critical to enabling high productivity, primarily those used in design and development. These tools reduce the time to complete design tasks and thus reduce work hours per design and time to market. Intel also runs on a highly disciplined structure where planning is an essential element, decision-making is done quickly, and people are encouraged to take risks to move ahead.

Comparison to Industry Conditions

In comparison to other large semiconductor companies, Intel has exhibited nothing short of stellar performance from a financial operating standpoint. Intel revenue grew 250 percent from 1987 to 1991 (see Table 4). In comparison, AMD's revenue grew 23 percent, TI's 17 percent, Motorola's 168 percent, and National's 71 percent.

Intel's profitability and productivity ratios also stand out, again stemming from higher-than-average gross margins, which led the industry at 52 percent. Intel led the industry in 1991 in return on sales (net income) and return on equity. However, its most dramatic lead is in sales per employee, which reached an all-time high in 1991 of $194,000, nearly twice that of the competition.

Table 4
Comparative Industry Financial Conditions

	Company				
	Intel	AMD	TI	Motorola	National
1987-1991 Revenue Growth (%)	250	23	17	168	71
Gross Profit Margin* (%)	52	46	17	36	24
Return on Sales* (%)	17	12	-6	4	-9
Return on Equity* (%)	19	19	-21	10	-23
Sales/Employee* ($K)	194	109	108	111	57
Sum of 1989-1991 R&D Expense ($M)	1,500	620	1,600	2,893	703
Sum of 1989-1991 Capital Expense ($M)	2,050	609	2,276	3,701	570
Total Revenue* ($M)	4,779	1,227	6,784	11,341	1,702
Semiconductor Revenue* (%)	84	100	40	34	94

*1991 calendar year.
Source: Dataquest (September 1992)

Intel has been investing heavily in R&D and capital equipment, positioning itself as a world-class semiconductor manufacturer. When investment expenses accumulated over the last three years are compared, Intel is in the middle in total R&D expenses and capital expenses. However, for the semiconductor business segment, if it is assumed that these expenses are allocated as a percentage of revenue, Intel is probably the leading U.S. semiconductor investor in both categories.

Semiconductor Business Analysis

This section will focus on analyzing the position, opportunities, and threats for Intel's $4.0 billion semiconductor business segments. After providing an overview of the semiconductor market, our discussion will divide into three major areas: the 80x86 microprocessor, other microcomponents, and memories.

Semiconductor Market Outlook

The worldwide semiconductor market represented a $60 billion business in 1991 and is forecast to grow 58 percent over the next five years, reaching about $95 billion by 1996 (see Table 5 and Figure 6). The market can be divided into six product-type segments: MOS microcomponents, MOS memory, MOS logic, analog, bipolar digital, and discrete/optoelectronic. The first five of these segments comprise the integrated circuit (IC) subset; the first three comprise the MOS digital subset. All segments except bipolar digital are projected to grow over the next five years, with the strongest growth coming in MOS microcomponents and MOS memory, the two areas Intel competes in.

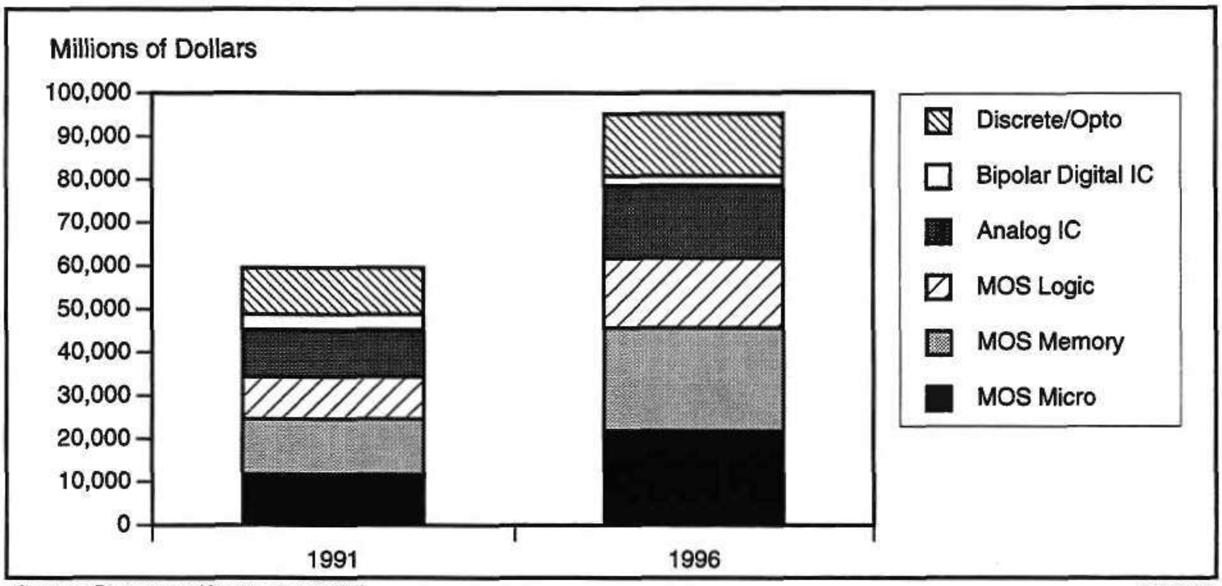
MOS microcomponents represent the brainpower behind most electronic devices performing data processing, numerical calculations,

Table 5
1991 Worldwide Revenue, Top 10 Vendors in Total Semiconductors

Rank	Vendor	Revenue ($M)	Share (%)
1	NEC	4,774	8.00
2	Toshiba	4,579	7.67
3	*Intel*	*4,019*	*6.73*
4	Motorola	3,802	6.37
5	Hitachi	3,765	6.31
6	Texas Instruments	2,738	4.59
7	Fujitsu	2,705	4.53
8	Mitsubishi	2,303	3.86
9	Matsushita	2,037	3.41
10	Philips	2,022	3.39
	Total Worldwide Revenue	59,694	100.00

Source: Dataquest (September 1992)

Figure 6
Semiconductor Market Overview



Source: Dataquest (September 1992)

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Table 6
1991 Worldwide Revenue, Top 5 Vendors in MOS Microcomponents

Rank	Vendor	Revenue ($M)	Share (%)
1	*Intel*	*3,578*	*30.15*
2	Motorola	1,171	9.87
3	NEC	1,149	9.68
4	Hitachi	583	4.91
5	Mitsubishi	543	4.58
	Total Worldwide Revenue	11,867	100.00

Source: Dataquest (September 1992)

and I/O control functions. Intel holds the dominant position in the MOS microcomponents segment, turning in $3.6 billion of the total $11.8 billion potential, or a 30 percent market share (see Table 6). The only two competitors close to Intel are Motorola and NEC, each with a 10 percent share and each less than one-third Intel's size in microcomponents.

Microcomponents comprises three related subsegments: microprocessors, microcontrollers, and microperipherals. Intel is the kingpin of microprocessors, taking $2.5 billion or nearly two-thirds of this $3.9 billion market (see Table 7). More than 95 percent of this revenue results from the 80x86 family of microprocessors, and nearly 95 percent of this 80x86 revenue comes from the 32-bit 386/486 generation of processors. Microprocessors will be the growth leader in MOS microcomponents and will be Intel's market to lose over the next five years.

Intel is also the leader in MOS microperipherals with a 20 percent market share—$650 million of this $3.2 billion segment (see Table 8). Its largest contributor is the math coprocessor, which accounts for some $300 million in revenue completely tied to the 80x86 market growth, as are most of Intel's microperipheral sales. The math coprocessor portion of this market will go away over the next few years but in turn will lead to further growth in the microprocessor market as the function is absorbed inside the CPU.

Ranking fourth in MOS microcontroller revenue, Intel finds itself catching up in the race for microcontrollers (see Table 9). Because the largest portion of microcontroller shipments are consumed in Japan, its not surprising that NEC is the leading vendor, followed by several other Japanese vendors. However, second-ranked Motorola is actually Intel's top competitor and will give it a tough fight.

Table 7
1991 Worldwide Revenue, Top 5 Vendors in MOS Microprocessors

Rank	Vendor	Revenue ($M)	Share (%)
1	*Intel*	*2,504*	*64.32*
2	Motorola	363	9.32
3	AMD	327	8.40
4	National	81	2.08
5	Hitachi	76	1.95
	Total Worldwide Revenue	3,893	100.00

Source: Dataquest (September 1992)

Table 8
1991 Worldwide Revenue, Top 5 Vendors in MOS Microperipherals

Rank	Vendor	Revenue ($M)	Share (%)
1	*Intel*	*650*	*20.19*
2	Western Digital	209	6.49
3	Motorola	194	6.03
4	Texas Instruments	194	6.03
5	NEC	192	5.96
	Total Worldwide Revenue	3,219	100.00

Source: Dataquest (September 1992)

Table 9
1991 Worldwide Revenue, Top 5 Vendors in MOS Microcontrollers

Rank	Vendor	Revenue ($M)	Share (%)
1	NEC	860	19.43
2	Motorola	574	12.97
3	Mitsubishi	463	10.46
4	*Intel*	*424*	*9.58*
5	Hitachi	364	8.22
	Total Worldwide Revenue	4,427	100.00

Source: Dataquest (September 1992)

Table 10
1991 Worldwide Revenue, Top 5 Vendors in MOS Nonvolatile Memories

Rank	Vendor	Revenue ($M)	Share (%)
1	*Intel*	*311*	*10.13*
2	Sharp	306	9.96
3	NEC	258	8.40
4	AMD	237	7.72
5	Toshiba	226	7.36
	Total Worldwide Revenue	3,071	100.00

Source: Dataquest (September 1992)

MOS memory provides exactly what its name suggests, data retention capability for digital systems, and can be divided between volatile and nonvolatile types. Intel does not hold a significant share of the overall MOS memory market. However, it is the leader in nonvolatile memories (see Table 10), a $3.1 billion segment of this market. Volatile memories are the bulk (more than 75 percent) of the market, which is further divided between DRAMs and SRAMs. Intel invented the commercial DRAM and developed technology all the way to the 1Mb level before deciding to exit the market in 1985 because of its commodity nature, low margins, and the high capital investment required. Intel does produce some SRAMs, primarily for military use and use with its high-end microprocessors, though these are not of financial consequence to the company.

Intel's 80x86 Microprocessor Business

Intel has had four generations of upward-compatible microprocessors since the 80x86 family was first introduced (see Table 11). The original 8086 introduced by Intel in 1978 had 29,000 transistors (then state-of-the-art), ran at under 5 MHz, had a die size of 51,000 square mils, and initially sold for nearly $200 (now a

Table 11
Intel 80x86 Product Line

Microprocessor	Introduction Date	Word Width (int-ext)	Transistor Count (K)	Performance Range (mips)	Price Range ($ per 1,000)
8086	1978	16-16	29	<1	5-6
8088	1979	16-8	29	<1	3-5
80286	1982	16-16	130	1-2	7-9
80386SX	1988	32-16	275	2-4	49-79
80386DX	1985	32-32	275	6-11	99-119
80386SL	1990	32-16	855	4-5	48-96
80486SX	1991	32-32	1,185	13-20	99-119
80486DX	1989	32-32	1,200	20-40	367-536
80486DX2	1991	32-32	1,200	40-54	487-650
P5 ("586")*	1992	32-64	3,100	80-100	900-1,400

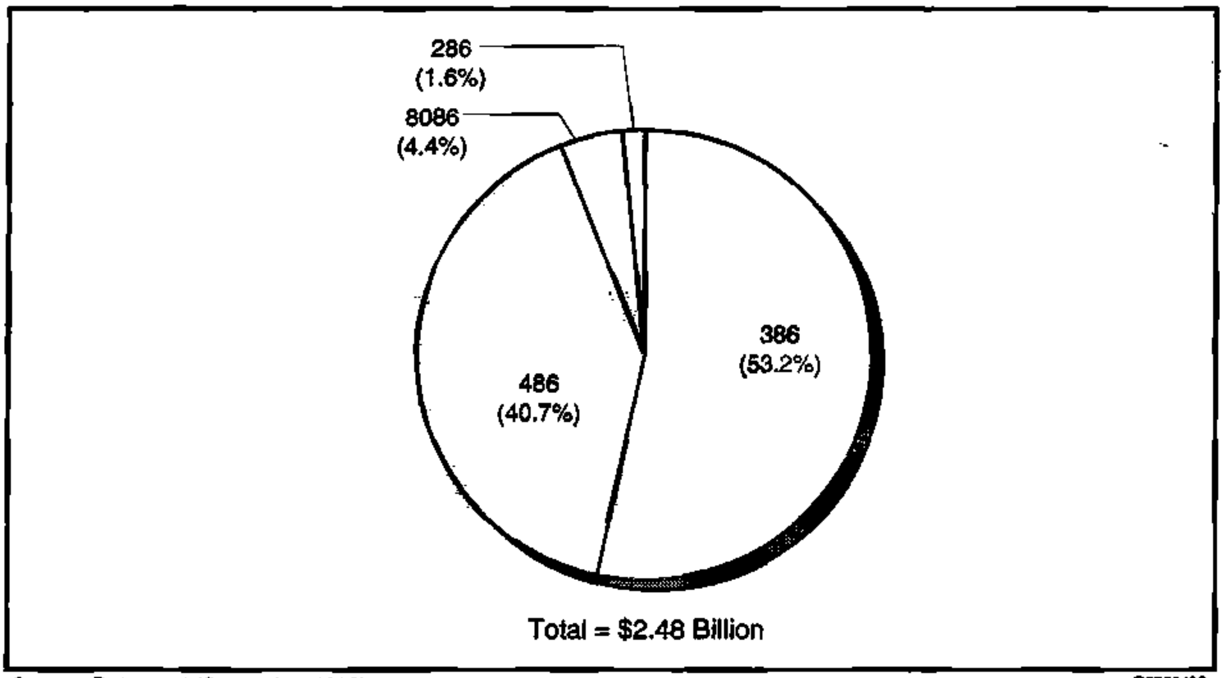
*Estimated parameters
Source: Dataquest (September 1992)

$6 part). Now the 80486 has 1.2 million transistors, runs up to 50 MHz, has a die size of 261,000 square mils, and initially sold for nearly $800. What these parts have in common is the power of compatibility with more than 10,000 software applications, with chips and systems cloned by anyone that can make them. This power has driven 80x86 microprocessor volumes to more than 50 million units per year, with increasing ASPs that have made the cloning of this golden goose a very hot target.

Intel makes nearly 95 percent of its 80x86 revenue from its proprietary 386/486 products (see Figure 7). The 80x86 market was originally opened through second-source licensing agreements, pushed by IBM as a result of its selecting the 8088 for its PC. The scene changed after growing critical mass in the market, using the early 8088 and 80286 processors, both of which were widely second-sourced. Intel introduced the 32-bit generation of 80x86 processors with the intent to grow its business around a family of single-sourced, upward-compatible processors that would eventually reach workstation performance.

As of 1991, Intel had only about 50 percent of the 80x86 unit volume (see Figure 8) but took an estimated 85 percent of the total revenue. A rapid decline is beginning for the 16-bit 80x86 processors (8086/88 and 286 generations), except the integrated versions

Figure 7
Intel 80x86 Revenue Breakdown



Source: Dataquest (September 1992)

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such as the 80186 and Chips and Technologies' PC-Chip, which will continue to grow in embedded and hand-held devices. These processors were the lifeblood of the 1980s' PC, which is now dominated by the 386/486 generation. However, these proprietary products face competition from two angles: direct 386/486 clones and the various members of the RISC camp.

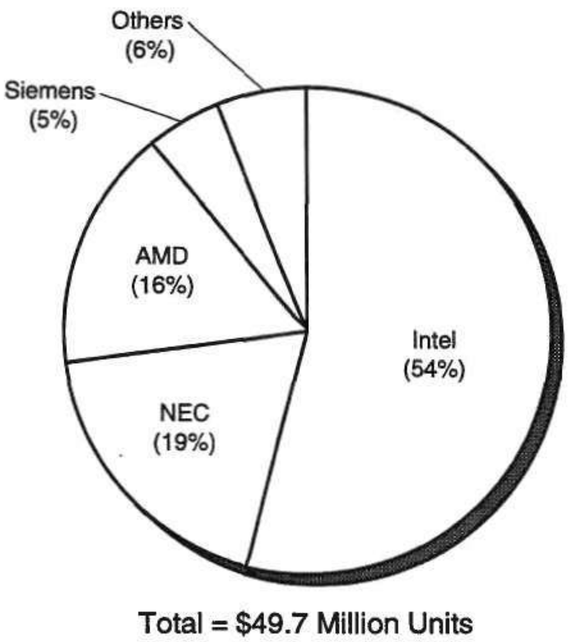
From the RISC front, there is only one viable long-term competitor to the 80x86 family, the PowerPC from the IBM-Motorola-Apple alliance. It has a large pull component from joint systems marketing by Apple and IBM, excellent design expertise from IBM and Motorola, plenty of manufacturing muscle from Motorola, and planned strong mainstream operating systems development from the roots of the Macintosh. The primary problem with the other RISC camps, including MIPS, SPARC, PA-RISC, and ALPHA, is lack of critical mass from system vendor support, lack of mainstream operating systems, or both.

As for the 386/486 clones, until last year Intel had 100 percent of the market, but after AMD's successful entry in 1991 the scene has changed. The following sections discuss competitive positions.

AMD

AMD entered the market in the second quarter of 1991 with exact copies (including microcode) of the 386DX and 386SX versions. Its

Figure 8
80x86 Microprocessor Market Share



Source: Dataquest (September 1992)

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strategy has been to use its "licensed rights" to Intel's intellectual property to reverse-engineer fully compatible clones of Intel's products, including microcode, and offer higher-speed grades at the same price Intel offers the standard speed grades. This strategy paid off initially as AMD attained about 15 percent of the 386 market by the end of 1991 and about 35 percent by the end of the second quarter of 1992. Keeping the momentum going, in January 1992 the company preannounced plans for 486 clones to be sampled in the third quarter and shipped in the fourth quarter. However, these plans were severely impacted in June 1992 when AMD lost a court battle over intellectual property rights (the 287 microcode case). It will suffer a significant setback because it must now forward-engineer its 486 clones, which will result in AMD moving them out to mid-1993 for shipments and taking away its "exact replica" advantage over other clones. AMD is expected to provide additional focus during 1993 on versions of 386 and 486 products for the portable market.

Cyrix

Cyrix entered the market in the second quarter of 1992 with a proprietary design representing a cross between the 486SX (instruction-set, cache) and 386SX and DX versions. Its strategy has been to forward-engineer its designs with 486 instruction-set compatibility and attack the installed base of 386 designs and units, offering OEMs a pin-compatible option to upgrade their 386 system designs to 486s, and offering corporate end users the option to upgrade their installed 386s to 486s. Furthermore, Cyrix intends to do the same thing for the 486 installed base as it starts releasing upscaled versions of its product line in the coming months. Having recently won a court battle contesting its rights to use SGS-Thomson as its foundry, Cyrix is successfully growing its sales and will probably ship some 400,000 units by the end of this year, representing a growing threat to Intel.

C&T

C&T entered the market in the fourth quarter of 1991 with a combination of exact clones and proprietary enhancements to the 386, as well as a single-chip PC based on an enhanced 8086 core. Having suffered severe technical problems in addition to poor financial health, C&T has announced its departure from the 386/486 clone race to pursue only integrated versions of the x86 family for handheld and portable devices. In its current condition, it does not pose a real threat to Intel.

Texas Instruments

TI announced that it will enter the market in the fourth quarter of 1992 using the Cyrix design with intentions of following up with more highly integrated versions using its wide array of technologies. Based on its manufacturing capabilities and widespread sales channels, TI presents a potential long-term threat to Intel. However, its limited microprocessor design expertise mitigates some of this threat.

Nexgen

Nexgen has preannounced plans for years to enter the market and now aims at a P5-like product, expected to be announced during the first quarter of 1993. Nexgen has an historical credibility problem to overcome in the industry and must align itself with an appropriate foundry for its parts.

UMC

UMC is working on a clone of the 486SX, expected to be introduced in the first quarter of 1993, having acquired design house Meridian Technology during 1991. With limited manufacturing muscle, a relatively low technology base, and limited sales channels (except in Asia-Pacific), UMC may have a difficult time sustaining its growth in this ultimately competitive arena.

Other companies rumored to be working on 386/486 clone products include VM Technology, a Japanese company reportedly with funding from Fujitsu; Seiko-Epson, which is working on a version of the 486 primarily for captive use; and IIT, a competitor in the math coprocessor arena working on a 486-type product with ultrahigh floating point performance.

Intel's 80x86 road map for the future calls for a dual focus on both desktops and portables, delivered in concert with its central strategy. It has long believed that its ultimate marketing edge is to drive up available transistor count through process and design technology and use that transistor count to do the following:

- Create leading-edge performance (desktop focus). This direction will result in the introduction of the P5 during the first quarter of 1993, a 100-mips class microprocessor with workstation-level floating point performance. Following this at 18- to 24-month intervals will be the P6 and P7, offering additional increases in performance level and multiprocessor support.
- Create leading-edge integration (portable focus). This direction will result in the 486SL, a 486 equivalent to the 386SL providing the ideal match for color notebooks. Following this will be the 386SC (single chip) class of devices, now being jointly developed with VLSI Technology.
- Continually decrease manufacturing costs. This direction will result in continued shrinkage of existing 486 and SL lines of products, reducing the die sizes and thus costs, enabling Intel to offer high-end (relative to competition) performance and integration at mainstream prices.
- Continually increase barriers to entry. This direction will result in limiting the available foundry capacity to the industry because of the level of design and process technology required to be performance- or cost-competitive, creating a strategic weakness for fabless vendors.

To maintain momentum in the marketplace, Intel uses a two-pronged marketing strategy as a countermeasure to the insurgence of competition. First, extensive litigation is used to slow existing competitors, discourage potential new competitors, and create anxiety within the market over using potentially illegal competitive products. Second, Intel is driving the PC market transition into its second-wave products (486 and SL versions) where end users gain better performance/features, competition is limited, and barriers to entry are much higher. Intel also intends to increase its brand preference through aggressive advertising of the "Intel Inside" concept and its "overdrive processor" upgrade programs.

Intel's Other Microcomponents

Beyond the 80x86 product line, Intel has two other families of microprocessors, the i960 embedded microprocessor and the i860 microprocessor. Together, these two families represented a combined total of about $25 million in business for Intel in 1991, or 1 percent of 80x86 revenue. The i960 is beginning to pick up momentum and is winning designs in many embedded areas including communication, X terminals, and laser printers. Having shipped about 250,000 units in 1991, Intel claims it is on track to ship close to 1 million units this year, a fourfold increase. Based on evidence at hand, we expect the i960 family to reach respectable business levels in two to three years. On the other hand, the i860 family is expected to remain a niche part for supercomputers and very high end graphic subsystems and to not provide a substantial revenue contribution for the foreseeable future.

Most of Intel's microperipheral products are designed to be fully compatible with one of its microprocessors. As mentioned earlier, Intel's line of 80x86-compatible math coprocessors has accounted for nearly 50 percent of the microperipheral revenue. With an estimated 1991 market size of more than $350 million, 80x86 math coprocessors are poised to head downward fast as the coprocessor function becomes integrated into the microprocessor, as it has in the 486 generation of devices. Intel has maintained the lion's share of this market, taking more than 75 percent of the market, leaving the remainder to Cyrix, IIT, and others. Having planned this evolution of coprocessor integration, Intel has now switched its strategy to overdrive processors (microprocessors for field upgrades) and will supplant this microperipheral revenue loss with gains in microprocessor revenue.

Among Intel's other microperipherals, PC chip sets—specifically high-performance versions—have been a focal point. After the AT bus became mature and performance needs exceeded its capacity, the industry spawned the EISA (Compaq-driven) and MCA (IBM-created) busses. Intel was the first to create compatible chip sets for these busses and remains the dominant vendor for each type. Unfortunately, the ISA bus remains the dominant standard and the others have not risen to great proportions. Thus PC chip sets represent a small contribution to the overall revenue (estimated at $100 million) and are expected to remain that way for the near future.

Intel is the third largest producer of ethernet controller chips, producing high-performance versions for workstations, X terminals, network routers/bridges, and high-end PCs, yielding some $25 million in revenue. Fax/modem chip sets, cache controllers, and its DVI line of multimedia controllers are examples of other minor revenue-producing microperipheral chips for Intel. Intel is expected to grow market share in each of these other areas as they become more central to its overall strategies.

Microcontrollers will present Intel with its toughest challenge to maintain or grow market share. Currently ranked fourth, Intel will have to place a greater emphasis on these components to pose a threat to Motorola or the Japanese vendors. Its focus has been on the proprietary MCS-96 family of 16-bit microcontrollers, where it currently dominates, attempting to change the industry momentum from 8-bit to 16-bit products. Though expected to continue success in the 16-bit segment, Motorola and other vendors will be attempting to shift focus to 32-bit parts as a counter to Intel's strategy.

Intel's Memory Business

Intel's bent toward innovation has also paid off in memories, yielding it substantial revenue (more than $300 million in 1991) from its leadership in the nonvolatile market (which it invented) and from royalties on DRAM and SRAM products (well over $60 million since 1990). There also is potential exploitation of its flash products. Though Intel is now primarily a microcomponents company, its inventions in the memory area include the following:

- The first DRAM (a 1Kb part in 1970)
- The first EPROM (a 1Kb part in 1971)
- The first high-speed MOS technology SRAM

Ironically, Intel does not plan to pursue market share using any of its own original inventions in the memory business, but it will place its emphasis on flash memories, a device first conceived by Toshiba.

Intel announced in 1990 that it would discontinue pursuit of EPROM developments to pursue the development of flash technology. Intel leads the industry in flash technology and holds an 85 percent market share in this subsegment of the nonvolatile market. In April 1992, Intel introduced the highest-density flash device, an 8Mb part, aggressively priced at $29 in low quantities. Intel also just entered an agreement to provide Sharp with rights to Intel's flash technology in exchange for Sharp building a $700 million facility for the production of Intel and Sharp flash memory products. This move may afford Intel a competitive manufacturing cost structure it has lacked in the past.

Intel's vision for flash includes being able to overcome problems with endurance (cycles), write speed, and programming voltage to produce the ideal memory that is nonvolatile, reads as fast as DRAM, writes quickly enough to keep up with an input write buffer, and is scalable in density beyond that of any other technology. This means that the bulk of portable products could replace DRAM and magnetic storage with one type of solid-state memory product. Intel's arguments carry enough weight that Microsoft has produced a FlashFile system for its operating systems that supports the Intel 8Mb flash memories. Based on current momentum, Intel should gain market share in memories over the next five years, providing a positive contribution to its overall growth.

Dataquest Perspective

Intel's strengths

Strategically Balanced Product Mix

Intel has gained leadership positions in all forms of computational systems and has structured its participation toward maximum leverage at each level. At the center is the PC, where the 80x86 family reigns supreme and Intel uses its microprocessor design and manufacturing expertise on top of compatibility to offer a range of industry-leading products with high revenue and attractive margins. At the low end are the hand-held devices where Intel will use its intellectual property and alliances with VLSI technology (integrated 386 cores) and Sharp (flash memories) to proliferate large volumes with reasonable royalties. At the high end are supercomputer systems where Intel develops and markets the complete system (including microprocessors) to gain high sales and margins in a low-volume business. In addition, Intel gains the technological synergy from participating in all areas, enabling it to push supercomputing advances into the desktop or take desktop performance into a hand-held device.

Strong Momentum in the PC Market

Intel is the leader in microprocessors for PCs and can drive the transition toward microprocessors that result in higher performance, higher ASPs, and higher barriers to entry. This transition includes support by all the top PC manufacturers, which includes very close relationships with IBM, which remains a steadfast customer and joint-developer of Intel's 80x86 processors; Compaq, which is a joint developer/tester at the systems-level that dropped the MIPS/ACE initiative to focus on Intel's P5; NCR, which works directly with Intel on innovative directions in servers and pen-based systems; Digital, which entered into an agreement for Intel to manufacture its systems; and all major Japanese vendors including Toshiba, NEC, and Epson, which have remained 100 percent Intel houses.

Leader in 80x86 Microprocessor Products

Intel maintains the leading position in performance, integration, and product breadth. With planned R&D investment of $800 million per year, 75 percent of which ($600 million) will directly apply to the 80x86 product line, Intel will most likely maintain this lead. Adding to this, Intel's joint development programs with IBM and VLSI technology for highly integrated processors will also strengthen its position. Furthermore, Intel's relentless pursuit of intellectual property protection using the legal system presents an additional financial drain to many smaller would-be cloners.

Strong Process and Manufacturing Capabilities

Intel was yielding 1-million-transistor processors (486) two years before the competition and began producing a 2.5-million-transistor chip (i860XP) more than one year ahead of any others. As competition begins to form by pairing innovative fabless design companies with large semiconductor manufacturers, Intel will have the cost advantage of vertical integration. We believe that Intel has a significant advantage in manufacturing technology for logic products, which will give it an edge for the next several years.

Leader in Flash Memory Products

Intel's focus on flash technology, its partnership with Sharp, and its captive ExCA marketing program for portable PCs and hand-helds will keep it ahead of the market for some time.

Leader in Supercomputer Performance

Intel's move into the supercomputer business strengthens its ability to design leading-edge microprocessors, especially as the move into an era of multiprocessor systems begins.

Intel's Weaknesses

Strategic Shift Upcoming in the PC Market

The first PCs came from IBM. Then vendors produced IBM-compatible PCs—clones of the complete system design. Then Intel drove the transition to PCs that were 80x86-compatible, clones of the instruction-set architecture, starting with the Compaq 386. Now Microsoft is driving the transition to PCs that are Windows-compatible, clones of the operating system environment, starting with the MIPS/ACE environment. As we enter the mid-1990s, this paradigm will be in full swing with users purchasing Windows NT systems or PowerOpen systems on various microprocessor-based systems. Though the 80x86 family has the most operating system support of any microprocessor, the loss of instruction-set compatibility as a requirement will level the playing field and enable competition to grow where a monopoly once was.

Lack of PC Systems Profitability

The same power that created demand for more than 100 million installed 80x86-compatible PCs has resulted in lack of differentiation, weak prices, and thus low profits for nearly all vendors in the PC industry. Though stuck for now in the mode of moving low-margin undifferentiated PCs, many of these vendors must change to remain financially viable for the long term. This means either using a differentiated approach with a non-Intel 386/486 product, or moving to a RISC architecture with an upscale pricing structure.

Growing 80x86 Competition

As the lure of high profits draws more competitors into the 386/486 clone game, Intel's product monopolies become shorter and harder to defend. In the past, Intel's product positioning left holes in its product line, such as 25-MHz 386SXs. Existing and future holes are prime targets for competition looking for differentiation among the compatibility. Furthermore, the period over which Intel can monopolize the market will shrink and increase pressure on time-to-market of next-generation products.

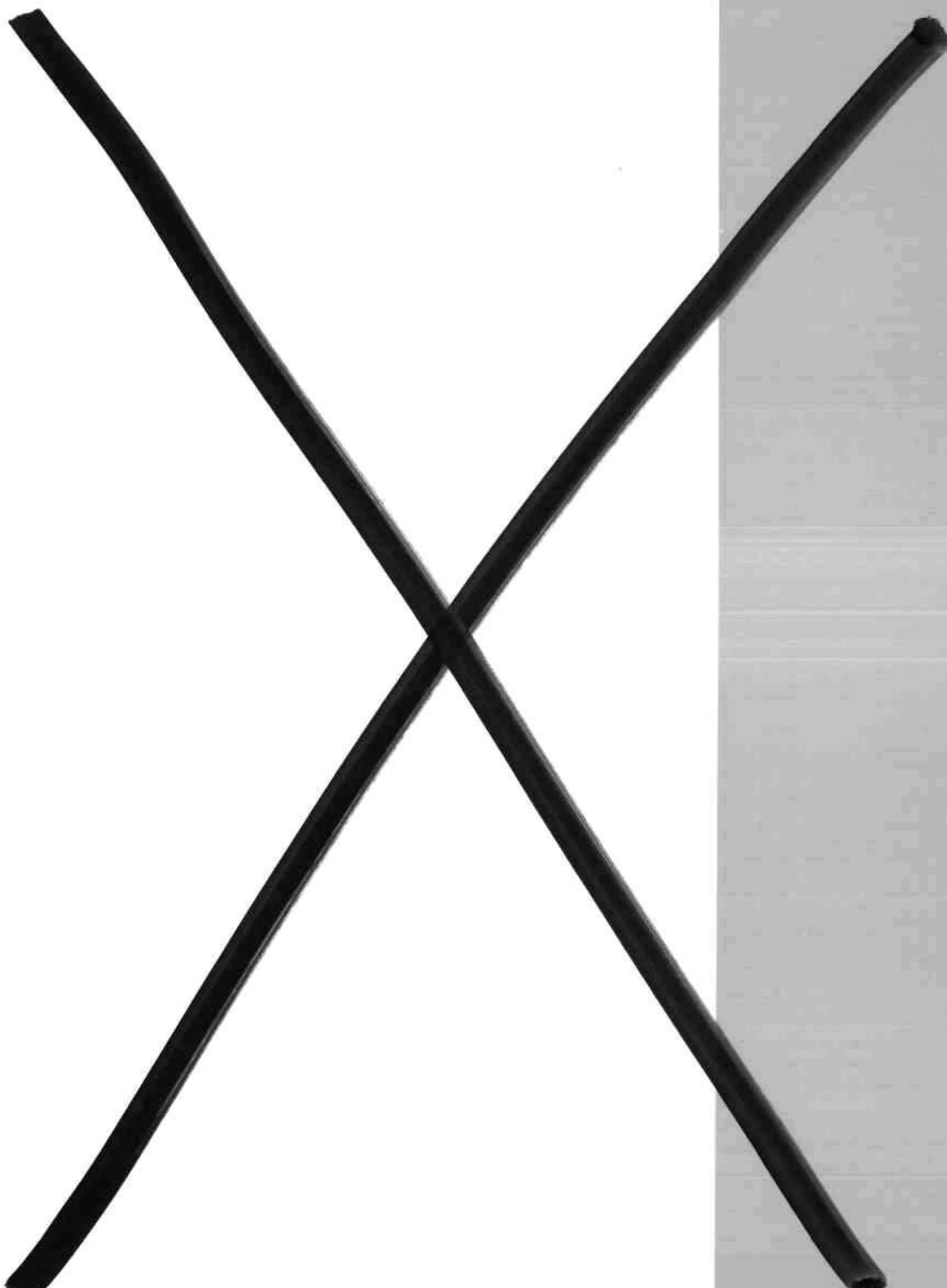
Weak Products in PC Microperipherals

Outside of math coprocessors, Intel has had problems developing a strong line of support chips. This includes failures in PC core-logic chip sets (it was reselling ISA chip sets from VLSI Technology), graphics controllers (82786 and various VGA controllers), and its early DVI chip sets.

Summary and Outlook

Intel's future depends on leveraging its strengths in the semiconductor business segments, particularly the 80x86 microcomputer chip sets. It was clearly evident during 1991 that the future for the 80x86 class of processors will be a competitive arena filled with Intel, AMD, and others. Intel intends to migrate desktop computers to the increasingly fast 486s (and soon to be P5s) and portables to the increasingly integrated SL line of 386s (and soon to be 486s). Dataquest believes that Intel has the power to make this happen by 1993, which will impose increasingly high barriers to competition. However, as Intel repositions its products to maintain market share, it will begin to lower its gross margins and thus some of its revenue growth will come at the expense of profits.

Using the projected growth of the microcomponent and memory segments and assuming Intel's market share remains constant over the next five years, its semiconductor revenue should grow 85 percent or from $4.0 billion to $7.4 billion. Based on the current environment, this is a likely scenario because we believe that Intel will maintain market share in microcomponents while slightly growing its share in memories over the next five years. Assuming an equivalent growth rate for its nonsemiconductor businesses, Intel could see a $10 billion business by the end of 1997.



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Dataquest Perspective

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Microcomponents *Worldwide*

MCRO-SEG-DP-9202 June 15, 1992

In This Issue...

Market Analysis

Low-End Processors Maintain Their Ground

Microprocessors have shaped the architectures for all electronic devices and continue to push the features and performance for all given applications. Though the Intel 4004, a 4-bit device, was the first product referred to as a microprocessor, it was the 8-bit class of devices beginning with the 8080 that began the era of microprocessor-based design. However high-level languages became the norm, more robust software required larger address spaces, and applications began to consolidate around a few well-supported processors. As we enter the 1990s, essentially five classes of microprocessors exist: the X86 class, the 68K class, the OSR (Open Systems RISC) class, the low-end class, and the proprietary class. This article focuses on the low-end processor class, an outdated but thriving set of 8-bit architectures that still account for 50 percent of the overall microprocessor unit volumes. But, at ASPs under $3, these processors only represent 6 percent of revenue.

The low-end class of processors is actually a collection of the first real microprocessors to hit the market and gain widespread use. The following families are included:

- Z80/8080 family--Includes the Z80, 8085, and 8080
- 680X family--Includes 6800/02/08/09 and equivalents
- 6502 family--Includes 6502, 65SC816/802 and equivalents

These processors became the basis of many new products, including the following:

- The early high-volume PCs, such as the Apple IIs, Commodore 64s, and Radio Shack TRS-80s

- The modern instrumentation such as function generators, logic analyzers, and medical diagnostic equipment
- The new era of industrial control designs such as modern traffic lights and manufacturing process controls

In addition, the 8-bit processors are the architectural basis for some of the most successful lines of microcontrollers in use today.

As shown in Figure 1, this entire class and each family in it is still growing, albeit very slowly, totaling more than 63 million units in 1991. All the vendors involved in this class essentially compete in only one family, with the exception of Hitachi and SGS-Thomson. Furthermore, because the Z80/8080 class is so dominant in volume, market shares are listed only within each of these processor families.

The Leading Microprocessor Family Breaks 50 Million Units

The actual microprocessor that is credited with starting the microprocessor revolution, the 8080, in fact no longer ships. But its code lives on compatibly in its direct successor, the 8085, and in the eminently more successful Z80. In the case of the Z80, volume continues to grow, having broken through 50 million units in 1991. The 8085 on the other hand is very close to the end of its long life and has a decreasing unit volume, accounting for just more than 5 million of the 53 million total.

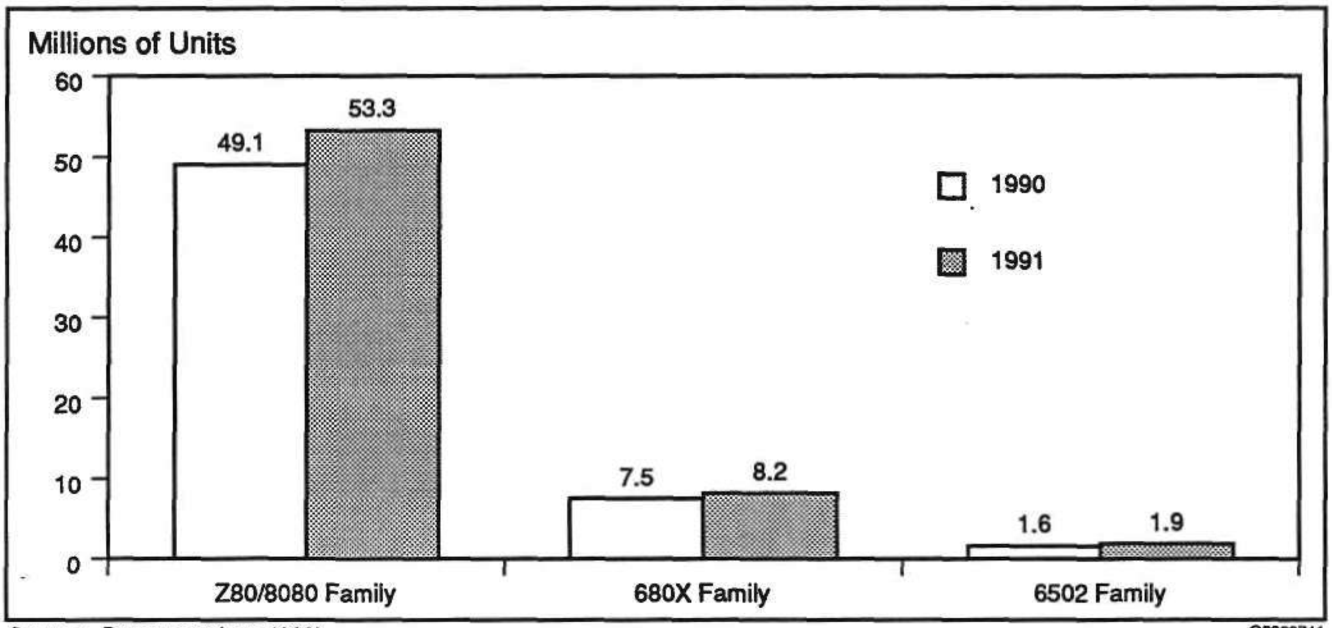
Although you won't find Radio Shack shipping any more TRS-80s, the bulk of Z80 applications are hidden in many obscure places that just continue to live. These volumes are being actively supported through the availability of Z80 cores and enhanced versions, such as the Z180.

Zilog, the inventor of the Z80, has been regaining market share in the last two years, having grown back to nearly 50 percent market share in 1991, as shown in Figure 2. The other active player, which also grew its Z80 volumes in 1991, is Hitachi, ranking second in this field. Both Zilog and Hitachi are involved in growing their Z80 business, having jointly developed the more integrated CMOS Z180 (Hitachi 64180), in addition to Zilog's Z280. Volumes for the remaining vendors were essentially down or flat, indicating a decreasing interest in this low-margin product.

Motorola Backs Away from Its 680X Line

Motorola first introduced the 6800 in 1974, which has since become the foundation for one of the broadest groups of microcomponent products. Among its derivative members (not all totally code-compatible) are the 6802/08/09 microprocessors represented here as well as the

Figure 1
Low-End Processor Shipments by Family



Source: Dataquest (June 1992)

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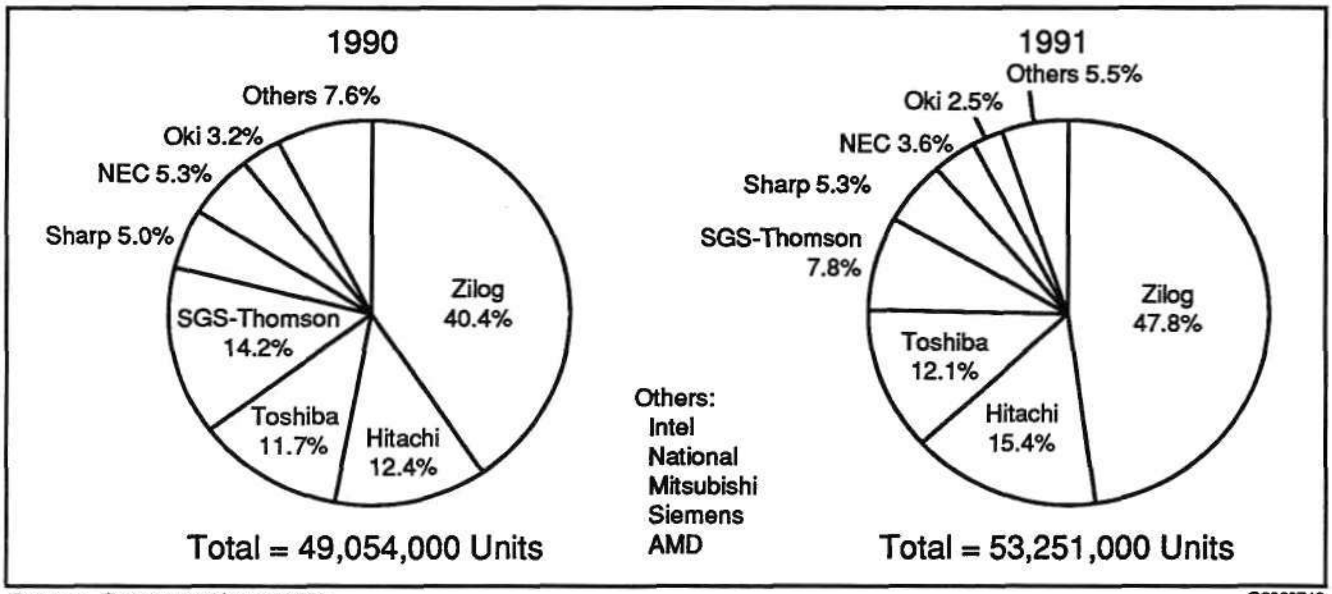
Figure 2
8080/Z80 Processor Market Share by Units



Source: Dataquest (June 1992)

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6805 and 6801/HC11 microcontroller families. In fact, the combined 1991 unit volume for these derivative members is substantially more than 200 million units.

The 6800 is well past its prime and is not recommended for new designs. The newer 6802 and 6809 versions do not win many new designs either, but they continue to be shipped in volume by multiple sources. For new designs, Motorola steers designers to either the embedded versions of its 68K family, which can be reasonably cost-effective with much more power, or its microcontroller products, which are more cost-effective.

Until last year, Motorola dominated the 680X volumes with more than 50 percent market share (see Figure 3). However, with its focus on other areas, the company's 680X volumes have dropped to leave it with only 22 percent of the 1991 market. Having moved from third position in 1991 to first position in 1991, SGS-Thomson is absorbing Motorola's lost share. Hitachi, unlike its Z80 business, seems to place little emphasis on this family, as do the other minor shareholders in this field.

6502 Market Still Hanging On

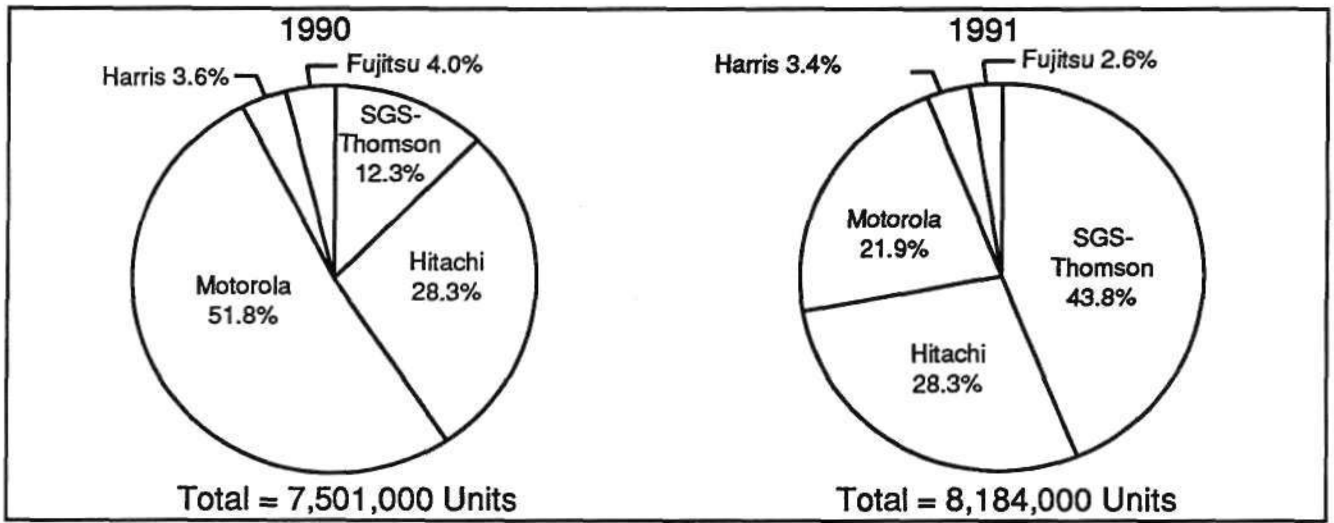
At just less than 2 million units for a low-priced, low-growth component, it seems certain that the 6502 family is near the end. However, with nearly 1 million units a year being consumed between Commodore and Apple, one could imagine a slow death over the next three to four years. As shown in Figure 4, this is a slim field of competitors, with NCR moving into the No. 1 position in 1991. The originator of the 6502, Commodore, no longer sells chip to the merchant market, but Western Design Center has taken over design revisions and has licensed CMOS versions.

Dataquest Perspective

Low-end processors combine the highest unit volumes with the lowest ongoing R&D investment. With volume almost flat, this class of 8-bit architectures represents a dinosaur whose ice age is just around the corner. Keeping them alive is the obscurity of their applications, most of which are not high-technology goods that do not get redesigned very often. Most new designs either migrate to the more robust embedded 32-bit architectures, which can work with 8-bit external words, or the more integrated microcontrollers. The longest living of these dinosaurs will definitely be the Z80 with its exceptional volumes and reasonably active development and support efforts.

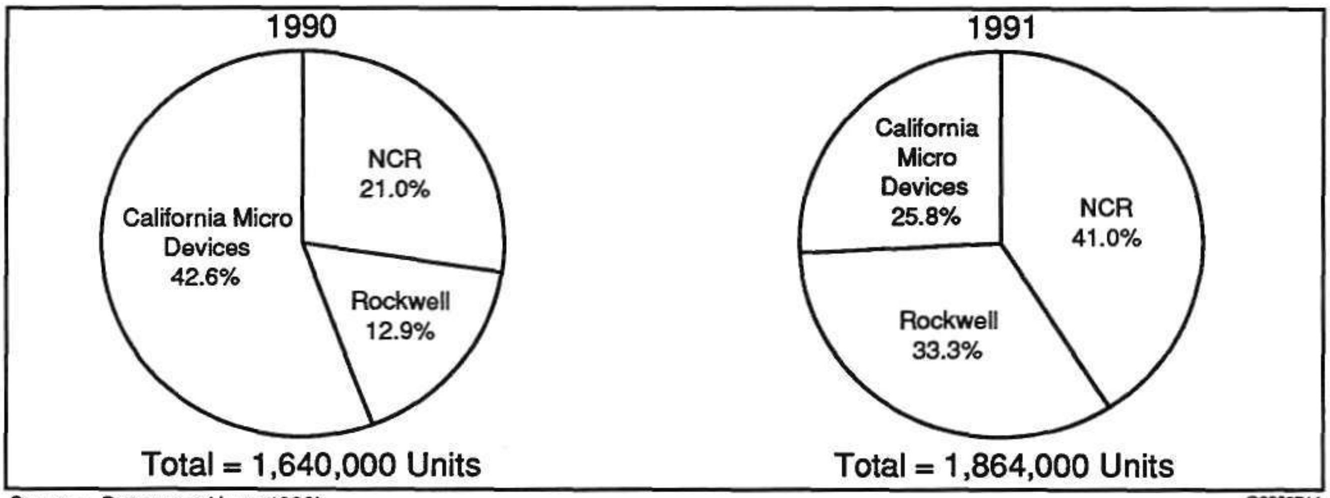
By Ken Lowe

Figure 3
680X Processor Market Share by Units



Source: Dataquest (June 1992)
G2000743

Figure 4
6502 Processor Market Share by Units



Source: Dataquest (June 1992)
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Dataquest Perspective

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Microcomponents *Worldwide*

MCRO-SEG-DP-9201 February 3, 1992

In This Issue...

Market Analysis

Microprocessor Market Overview

Microprocessors continue to push their way into more types of existing products while breaking ground on entirely new applications. Starting in the mid-1970s, the microprocessor was the key enabling technology behind the current $50 billion PC industry, as well as the fast-growing workstation industry. Then again in the early 1980s, microprocessors and microcontrollers enabled a new range of intelligent consumer products from the Speak-N-Spell toys to cellular telephones. Yet another era is about to begin to unfold with the emergence of several new market segments.

The computing platform or reprogrammable market is now being split into these two very distinct segments: desktops and portables, both of which must address the issues concerning new operating systems and graphical user interfaces. The embedded or nonreprogrammable market is also splitting into two distinct segments. The first is process control applications, which is dominated by microcontrollers. The second is data flow equipment, which is being addressed by application-oriented embedded processors. Hand-held information devices, ranging from electronic daytimers to personal communicators, is one of the most exciting new segments and is expected to project enormous growth in the next five years. In total, these emerging segments are creating new challenges for both microprocessor product development and marketing programs.

Microprocessor technology is also moving ahead rapidly with chip complexity increasing at an uncompromising rate. Available transistor count for microprocessors is currently at 2.5 million to 3.5 million transistors (for example, Intel i860XP and TI SuperSPARC) and is projected to reach 15 million to 20 million transistors by 1996. This available transistor count is being used for increased performance at the high end and increased integration at the low end. Additional improvements in CPU architecture (for example, superscaler, superpipelining, and multiprocessing) clock rates, now at 66 MHz, and word widths, now at 64 bits, will also yield increasing performance for high-end units. At the same time, the average selling price (ASP) for microprocessors that now range from 50 cents to more than $1,000 is increasing as more semiconductor functions are integrated within electronic-based equipment.

Overall Microprocessor Market Share Distribution

In 1991, the total worldwide microprocessor market grew to $3,287 million in revenue (see Table 1), a 36 percent increase over 1990, reflecting both increased volume and increased ASP overall. During the same time frame, total volume (see Table 2) increased by just less than 10 percent to nearly 140 million units, reflecting

Table 1
Worldwide MPU Revenue by Company—1991

Ranking	Company	Segment Revenue ($)	Market Share (%)	1990-1991 % Change
1	Intel	1,992	58.0	39
2	Motorola	359	10.8	23
3	AMD	251	7.6	130
4	Hitachi	90	2.7	10
5	NEC	86	2.6	8
6	National	85	2.6	29
7	SGS-Thomson	55	1.7	4
8	Toshiba	55	1.7	15
9	Cypress	46	1.4	254
10	LSI Logic	42	1.3	24
	All Others	321	9.7	16
	Total	3,312	100.0	36

Source: Dataquest (February 1992)

Table 2
Worldwide MPU Shipments by Company—1991

Ranking	Company	Unit Shipments	Market Share (%)	1990-1991 % Change
1	Zilog	27,173	19.5	31
2	Intel	25,850	18.6	77
3	Motorola	19,955	14.4	24
4	NEC	11,719	8.4	5
5	Hitachi	11,348	8.2	23
6	SGS-Thomson	9,039	6.5	-1
7	AMD	8,600	6.2	-28
8	Toshiba	7,964	5.7	24
9	Siemens	2,975	2.1	-1
10	Sharp	2,877	2.1	10
	All Others	11,531	91.7	NA
	Total	139,031	100.0	10

NA = Not available
Source: Dataquest (February 1992)

last year's recessionary conditions. However, overall ASP for microprocessors increased to $23.65 per unit, a 24 percent increase over 1990, reflecting the increasing value-added functions being integrated into microprocessors.

Market share distribution, which is most meaningful in revenue at this level of aggregation, shows quite a different picture in revenue and unit volumes. Intel is the single dominant player with 58 percent market share by revenue, generated with only 19 percent of unit shipments. This figure is the combined result of focusing on the highest ASP microprocessor market, the computer platforms, and controlling the highest volume segment of this market, the X86 DOS PC. On a revenue basis, both Motorola Incorporated and Advanced Micro Devices (AMD) also have respectable shares.

Based on unit volume, Zilog takes the No. 1 spot with nearly 20 percent (due to the unceasing shipments of the Z80), followed closely by Intel with 18.6 percent and Motorola with 14.4 percent. As an interesting comparison, the overall microprocessor ASP for Zilog, which had $31 million in revenue, is only $1.14, down from $1.20 in 1990, compared with Intel at $74.50, up from $57.60 in 1990, or with Motorola at $18.00 (constant from 1990). AMD's phenomenal 130 percent growth in revenue compared with its reduction in unit volume indicates its new focus on ASP, high-margin, 386-type processors.

New Structure for Microprocessor Segmentation

Starting this year, the Microcomponents segment of Dataquest's Semiconductors Worldwide service will analyze the microprocessor market by processor class rather than by word length (now a secondary dimension). The preliminary processor classes that will be studied include the following:

- 80X86 processor family—All 80X86 family processors
- 68XXX processor family—All 68XXX family processors
- Platform RISC Processors—Includes SPARC, MIPS, PowerPC, and Others
- Low-end architectures—Includes 8080/Z80 family, 68XX family, and 6502 family
- Proprietary/other processors—All other processors

This change moves us toward a more strategically sound model for analyzing market dynamics and intense competitive rivalry. Microprocessor market segments and the forces that drive them fall more generally along these lines of processor classes. In addition, technology development is also normally centered around a line of architecturally common products. Later this year, an additional segment focused on embedded processors will be defined and introduced.

Figure 1 clearly shows the shared unit dominance of the low-end architectures (most belonging to the Z80/8080 family) and the 80X86 family of processors. A noteworthy statistic is the lack of any volume growth for the 80X86 class where platform use dominates, compared with that of the Platform RISC class, which turned in a remarkable 112 percent growth rate. Figures for the other classes include 9 percent for the 8-bit architectures, 37 percent for 68XXX processors, and 28 percent for proprietary/others.

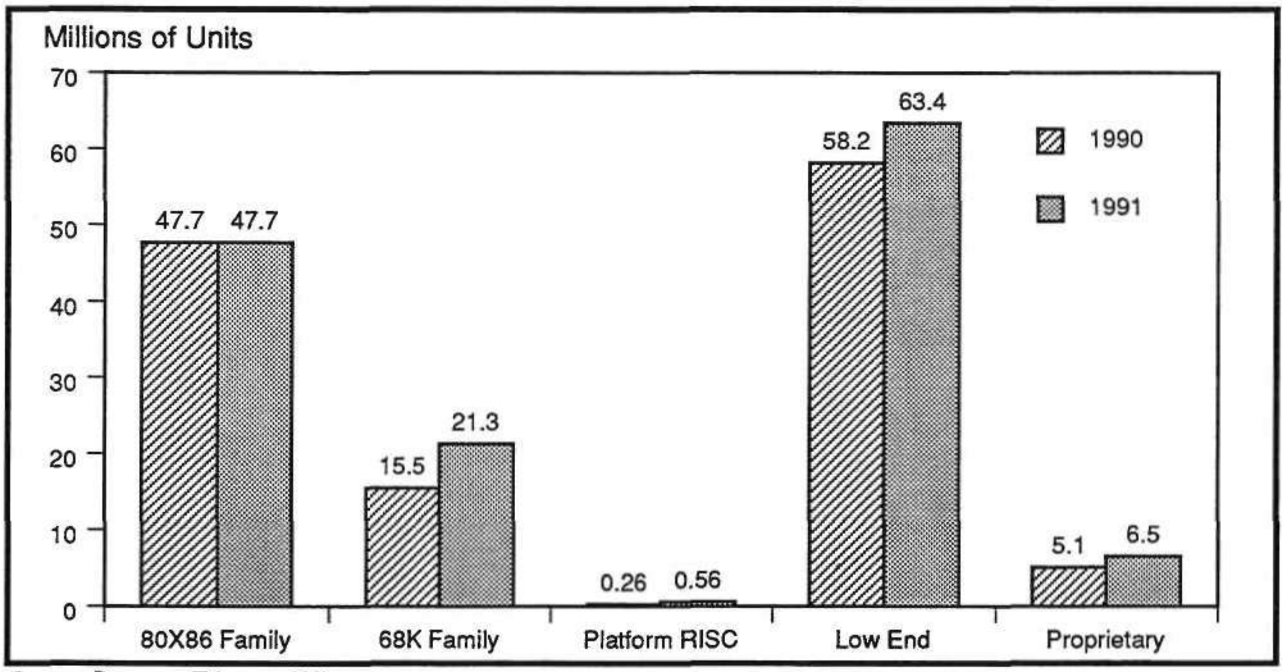
Figure 2 shows the more traditional top-level breakdown of microprocessors by word width, which is currently defined by external data bus width except for the 32/16-bit category. Correlating to the unit dominance of the Z80 family, which accounts for 65 percent of the 8-bit units, the 8-bit word length currently dominates the unit volumes but with growth having nearly flattened. The big news, however, is the dominance of 32/16-bit processors over that of 16-bit processors. Pushing a 50 percent growth rate, the 32/16-bit outstripped the 16-bit, which dropped in unit volumes by nearly 17 percent. If we aggregate total 32-bit architecture volume (that is, pure 32-bit with 32/16-bit), it appears that it will take over unit dominance in microprocessors by the end of 1993.

Dataquest Perspective

The microprocessor market is growing at an industry-leading pace and is setting the architectural trend for all forms of electronics. Competition is becoming more intense at the strategic level among classes as well as at the tactical level within each class. The remaining portion of this *Dataquest Perspective* examines the current state of the microprocessor industry focusing on what changes in market size, shares, and trends took place in 1991. Dataquest includes a comparison of unit volumes, applications, and competitors for the first three of these microprocessor groups.

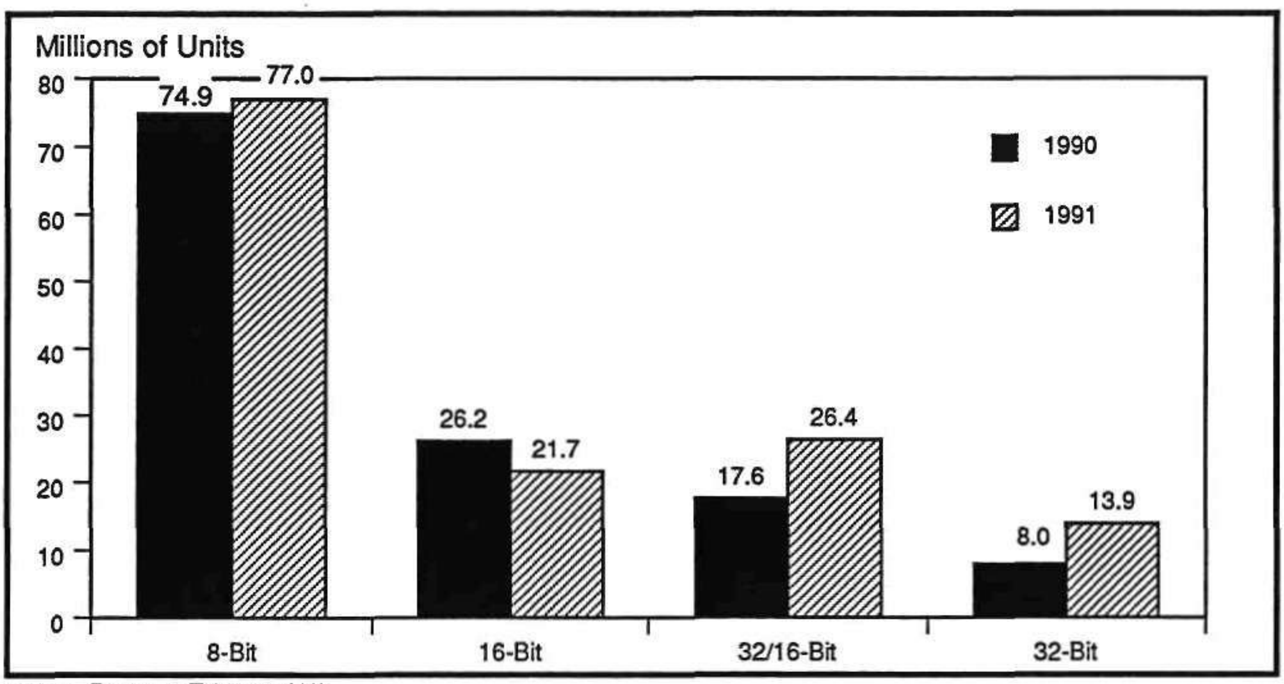
By Ken Lowe and Ken Dalle-Molle

Figure 1
MPU Units by Class



Source: Dataquest (February 1992)

Figure 2
MPU Units by Word Length



Source: Dataquest (February 1992)

80X86 Processor Family Readies for Transition

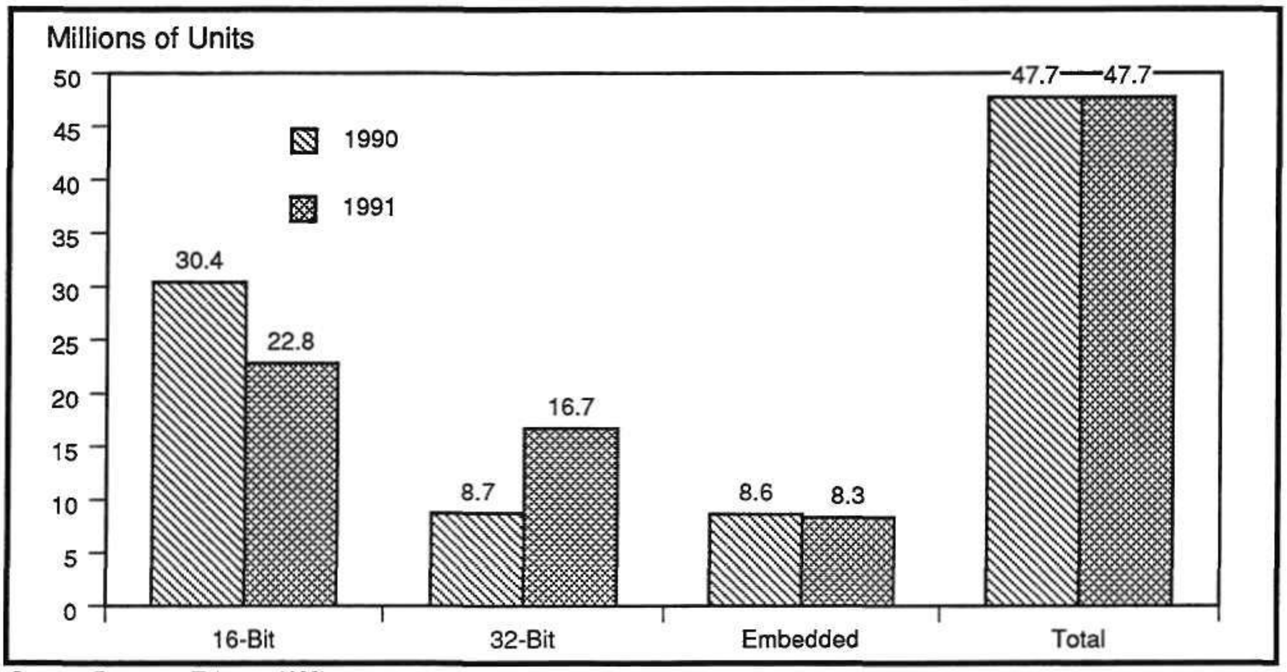
The 80X86 processor class is defined as all upward-compatible versions of the 8086 microprocessor, regardless of word length, instruction extensions, or level of integration. The following are also broken out as sub-segments to enable a more focused analysis of market trends and competitive positions:

- 16-bit general versions—8086, 8088, 80286, and equivalents, for example, the V20 and others
- 32-bit general versions—80386, 80486, all versions
- Embedded versions—80186, 80188, 80376 and equivalents

The original 8086 was introduced by Intel Corporation in 1978, had 29,000 transistors (then state of the art), ran at under 5 MHz, had a die size of 51,000 square mils, and initially sold for nearly $200. It is now a $6 part. Now the 80486 has 1.2 million transistors, runs up to 50 MHz, has a die size of 261,000 square mils, and initially sold for nearly $800. What these parts have in common is the power of compatibility with more than 10,000 software applications, IBM's blessing, and chips and systems cloned by anyone that can make them. This power has driven volumes to more than 40 million units per year with increasing ASPs that have made the cloning of this golden goose a very hot target.

As of the end of 1991, Intel had just more than 50 percent of the 80X86 class volume (see Figure 1) with several vendors lining up to steal even more market share. The 80X86 market was originally opened up through second-source licensing agreements with Intel. After growing critical mass in the market, using the early 8088 and 80286 processors, both of which were widely second-sourced, the scene changed. Intel introduced the 32-bit generation of 80X86 processors intending to grow its business around a family of single-sourced, upward-compatible processors that would eventually reach work-station performance. Meanwhile, Intel used the older 16-bit core as the heart of an embedded processor family, the 80186/188, which has been very successful. As shown in this figure, the 16-bit family volume still dominates in unit volumes. However, at current growth rates, the 32-bit family will take the lead by the end of this year.

Figure 1
80X86 Units by Subclass



Source: Dataquest (February 1992)

The 16-Bit Family Enters Its Twilight Years

Based on these preliminary estimates, it is not hard to imagine that we are at the beginning of a rapid decline for the 16-bit 80X86 processors—not including embedded versions. These processors were the lifeblood of the 1980s PC, which is now dominated by the 386 processor and shows no signs of turning back. Although some contend that single-chip PC components, such as Chips & Technologies' new PC-chip product, will extend this family by living on in hand-held computers, Intel feels differently, focusing everything on the 386 and up.

As depicted in Figure 2, unit shipments for these processors decreased for all vendors except the leader, NEC Corporation. Unit shipments for both Advanced Micro Devices (AMD) and Intel declined sharply as they focused on the 386/486 32-bit families. NEC markets the V-series 8086 equivalents and consumes many of them in its dominant Japanese PC family. Although primarily considered a PC microprocessor, a large percentage of 16-bit 80X86 processors have been used in other applications, including small systems, instrumentation, and certain embedded applications.

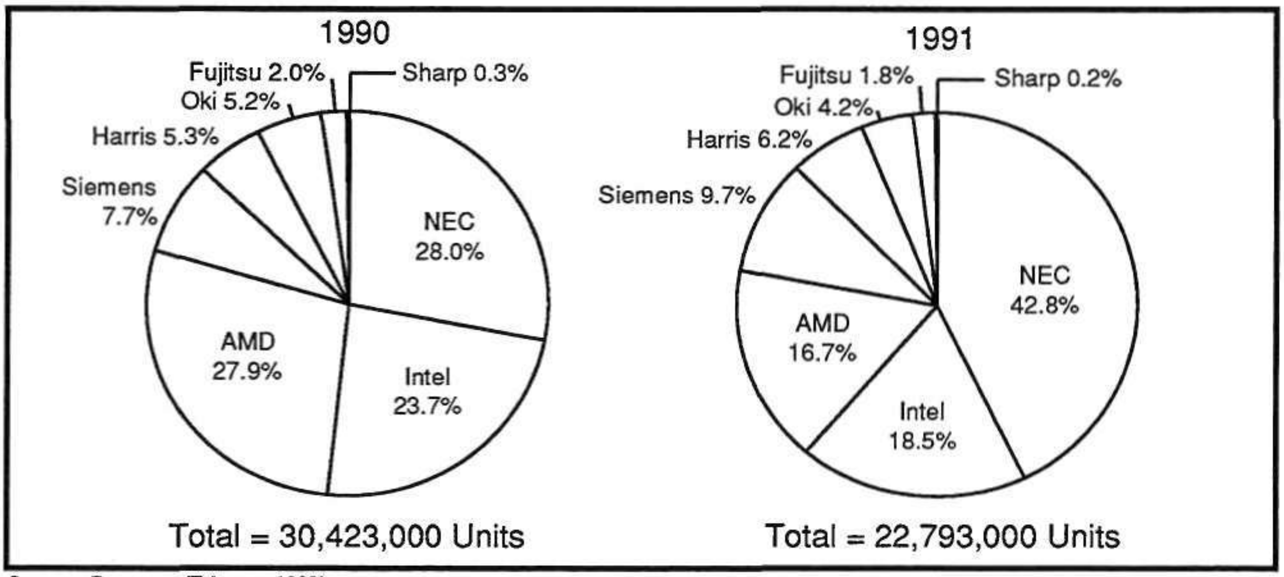
386/486 Processors Are the Target

In 1985, Intel introduced the 386, a superior part with much greater performance, advanced 32-bit features, and one other major change—Intel was the single source. In the years that followed, hundreds of system vendors built an endless stream of nearly identical 386-based clone PCs at ever-dropping prices to the point where up to 75 percent of the profit derived from each system made its way to Intel. Thus, the attraction to second-source this new 32-bit series of parts the hard way, without Intel's help or blessing. The key issue is whether anyone will be able to successfully grow and sustain a healthy portion of this incredibly profitable market.

This processor family has two basic types and five total models, each of which shares the same basic 32-bit 386 core architecture. The primary versions and their characteristics are listed in Table 1. To date, only Intel ships every model listed, AMD ships versions of all 386 models (except SL Versions), and Chips & Technologies has introduced, but is not yet shipping, its 386 equivalents. Not incidentally, IBM internally ships some of its own versions of 386 processors and will be doing more so as the joint development with Intel at Noyce Development Center gets under way.

As shown in Figure 3, Intel had 100 percent market share until last year, when AMD entered the field. For 1991, AMD took about 12.5 percent of the total 386/486 market or 15 percent of the

Figure 2
80X86 16-Bit Processor Market Share



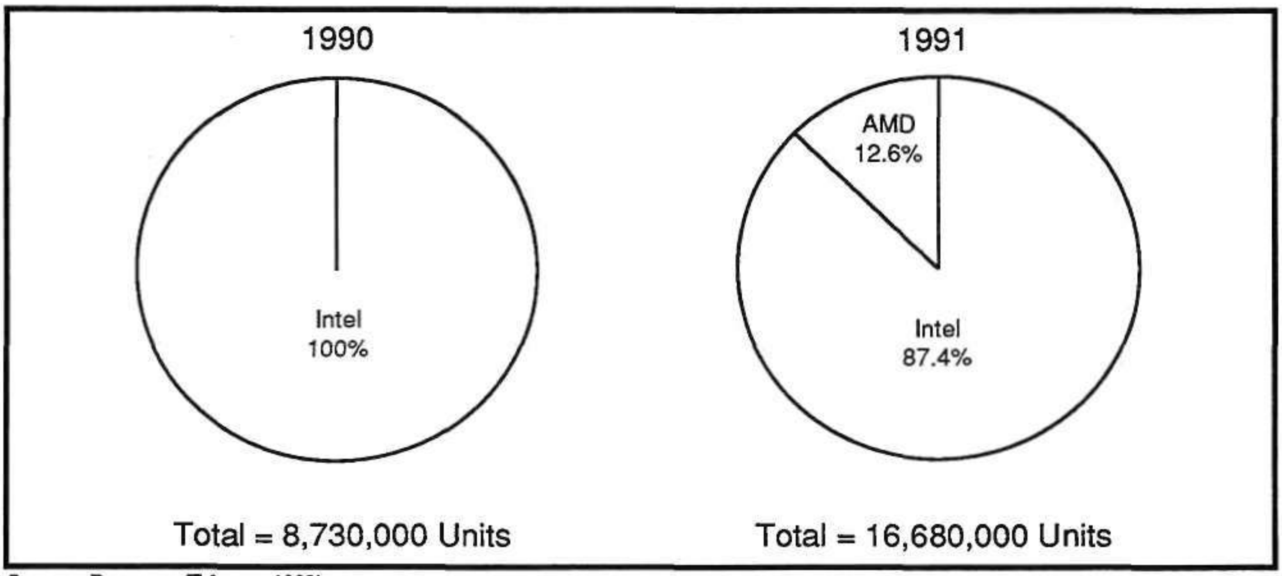
Source: Dataquest (February 1992)

Table 1
80X86 32-Bit Family Comparison

Model	386SX	386SL	386DX	486SX	486DX
Ext. Bus	16-bit	16-bit	32-bit	32-bit	32-bit
Clock Rate*	16-25	0-25	20-40	16-25	25-50
Coprocessor	387SX	387SX	387DX	487SX	Built-in
Cache Controller	Ext	Built-in	Ext	Built-in	Built-in

* Regarding clock rates: Intel just released a 25-MHz 386SX, and AMD is the only vendor shipping a 40-MHz 386DX.
Source: Dataquest (February 1992)

Figure 3
80X86 32-Bit Market Shares



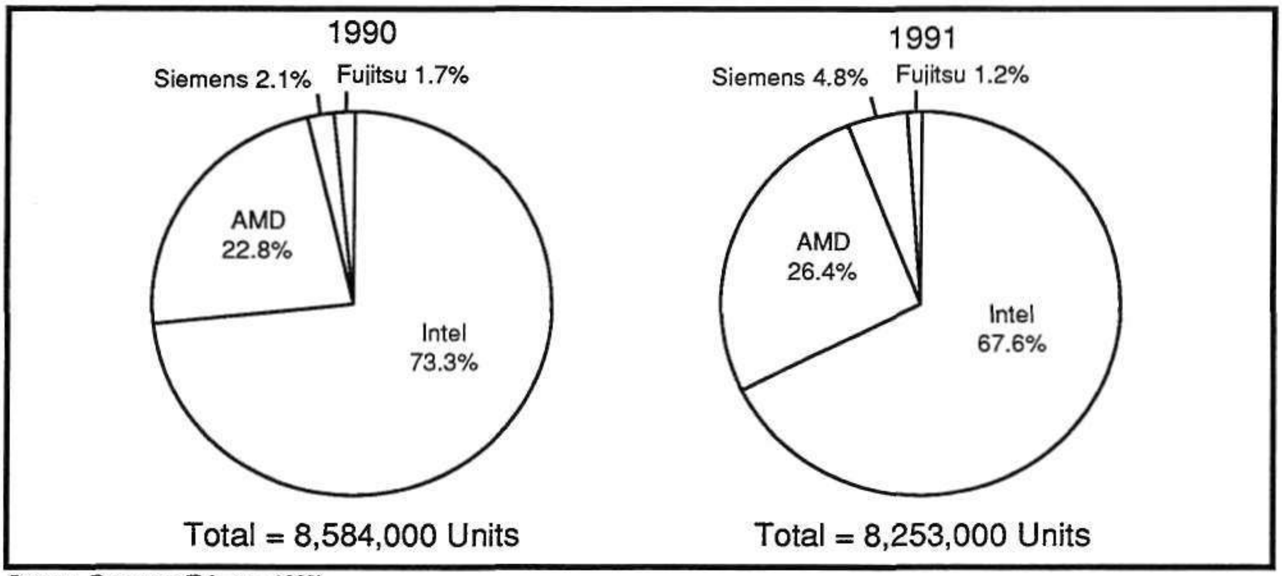
Source: Dataquest (February 1992)

386-specific market with a year-end run rate of nearly 30 percent of 386 unit volumes (90 percent of which is in the Asia/Pacific region).

Although three vendors are currently in this field and more are expected shortly, the structure of competition here is quite complex and involves legal, financial, technical, and marketing issues. Briefly, Intel sets the standards for all of these advanced 80X86 processors and has the financial, technical, and marketing means to remain a step ahead in new products for the foreseeable future. In fact, Intel will set a new high watermark when it introduces the 586 in the second half of this year, beginning a new 64-bit family of X86 processors.

AMD has achieved excellent success in 1991 as a second source for 386 processors and will enter the 486 market in the second half of this year. The primary reason for its immediate success is also the primary legal risk at hand. AMD markets an identical 386 part to Intel's, right down to the microcode. Because these parts are identical, and AMD has been a credible and dominant supplier of 286s, it has had few technical hurdles in selling 386s. But its ability to continue selling these parts is hinged primarily on winning a microcode-based lawsuit, filed by Intel. Although many signs point to AMD'S legal victory (including Intel's recent, unprecedented, 35 percent decrease in 386 pricing), the company could win the battle but lose the war. In essence, Intel could retain 386 dominance but drive its profit margins down to zero while switching demand to 486s before AMD can efficiently yield its 486s. Given AMD's

Figure 4
80X86 Embedded Processors



Source: Dataquest (February 1992)

current dependence on 386 profits, this strategy could have devastating consequences.

The remaining field of potential competitors falls under a different category because of forward engineering (not copying) their 386 or 486 equivalents. Although this prevents direct legal action from ensuing, it sets up a tremendous technical hurdle to overcome to qualify their parts. Because the microprocessor and its microcode have an infinitely large number of state changes, exhaustive compatibility testing becomes mandatory, which is almost unmanageable given the number of DOS applications.

Embedded 80X86 Processors Flatten Out

Embedded processing started showing up in the early 80s and continued to grow into enormous proportions. During this period, the 186/188 family of integrated processors was introduced to capture this embedded market. Part of their appeal (to date) is their architectural commonality with the IBM PC and relatively rich set of tools available for programming and debugging. However, with the wide range of other processors available with equal or better development tools, demand for this family is nearing its decline.

As is evident in Figure 4, this segment is dominated by Intel, which still has over two-thirds of the market. However, Intel is the only vendor showing a decline in unit volumes, mainly because of the demand shifting to its proprietary i960 family. AMD also has a healthy and growing portion of this segment, but it is also migrating customers to its proprietary 29K family. As a final note, this category includes the 80376, an embedded version of the 386, which is only shipped by Intel and represents only nominal demand in the 100,000-unit range.

Dataquest Perspective

It was clearly evident during 1991 that the future for the 80X86 class of processors lies in the 32-bit versions, leaving the real battle among Intel, AMD, and other potential entrants. Intel intends to migrate desktop computers to the increasingly fast 486s (and soon to be 586s) and portables to the increasingly integrated SL line of 386s (and soon to be 486s). Dataquest believes that Intel has the power to make this happen by 1993, which will impose increasingly high barriers to competition. However, Intel could win this battle and lose the war as a lack of competition has allowed it to take all the profits and push the premier PC vendors toward multisourced RISC architectures.

By Ken Lowe

68K Processor Family Goes Embedded

The 68XXX processor class is defined as all upward-compatible versions of the 68000 microprocessor, regardless of word length, instruction extensions, or level of integration. The following are also broken out as subsegments to enable a more focused analysis of market trends and competitive positions:

- Low-end 32/16-bit series—68000/008/010
- High-end 32-bit series—68020/030/040/LC040
- Embedded series—68ECXXX and 683XX series

As shown in Figure 1, the low-end series accounts for the bulk of the volume, which grew a total of 37 percent during 1990. However, the fastest-growing segment is the embedded series. As of the end of 1991, Motorola maintains nearly 85 percent of the 68K market volume. Furthermore, the 15 percent volume shared with other vendors is only in the 32/16-bit segment (the only licensed parts), leaving all the high-ASP, high-margin parts to Motorola.

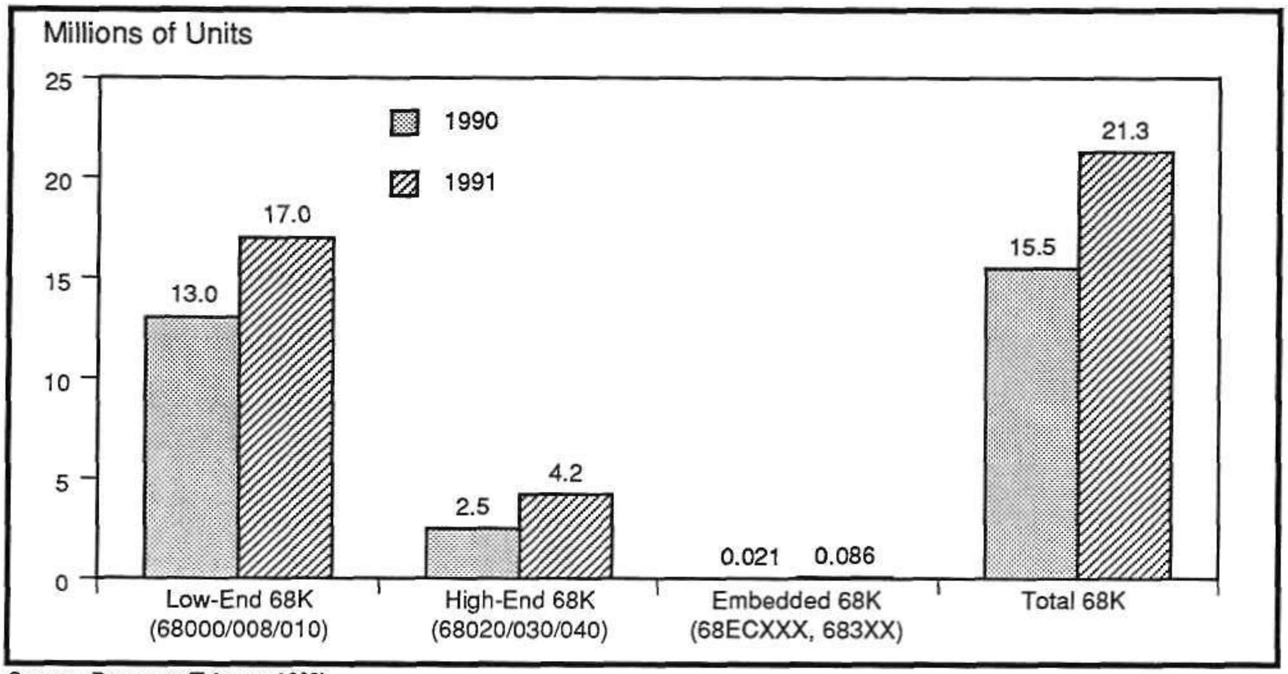
The original 68000 was introduced in 1979 with a 32-bit architecture, using 68,000 transistors and only 68,200 square mils. This level of production was very state of the art in microprocessors compared with the 8086 that was introduced in 1978, a 16-bit architecture with 29,000 transistors and taking 51,000 square mils. Through technical advantages, the 68K became a widely used processor, breaking above 20 million units in 1990.

The 68000 family has found its way into a wide variety of systems and embedded applications. It became the processor of choice for Apple's Macintosh and Commodore's Amiga. It became the first processor of choice for the leading workstation vendors, Sun and Apollo, and the processor of choice for the leading laser printer vendors, HP and Apple. The 68K family also became the first processor of choice for several vendors of X Window terminals including market leader Network Computing Devices Inc.

Low-End 68K Series Poised for Additional Growth

The low-end series of 68K processors continues to exhibit growth more than 12 years after introduction. However, some weeding out is occurring. The 68008 with its 8-bit external data bus is on its way down, partially made obsolete by the new 68EC000, which can manage either 8- or 16-bit external operations. The 68010 is also dropping off although not as sharply as the 68008. The 68000 and 68HC000 are still growing

Figure 1
68000 Units by Subclass



Source: Dataquest (February 1992)

and winning new applications. This upswing is being assisted, in part, by the availability of the 68000 as a core for fully integrated custom designs.

Growth in this series comes from continued shipments of high-volume laser printers, a few Macintosh systems, and graphics-oriented games. In a major design win for Motorola, Sega chose the 68000 in 1991 for its new Genesis game, beating out an 80186 part for the socket. On the combined basis of price/performance and upward growth path, the 68K will gain more than 7 million units per year from this single design win.

As shown in Figure 2, Motorola has more than 80 percent of this processor series and 100 percent of the others. Other than Toshiba, which doubled its sales of 68000 parts in 1991, unit volumes for all other vendors are decreasing. It is noteworthy that each of these other vendors listed has other more highly visible processors that its marketing programs are focused on.

68040 and Derivatives Finally Shipping

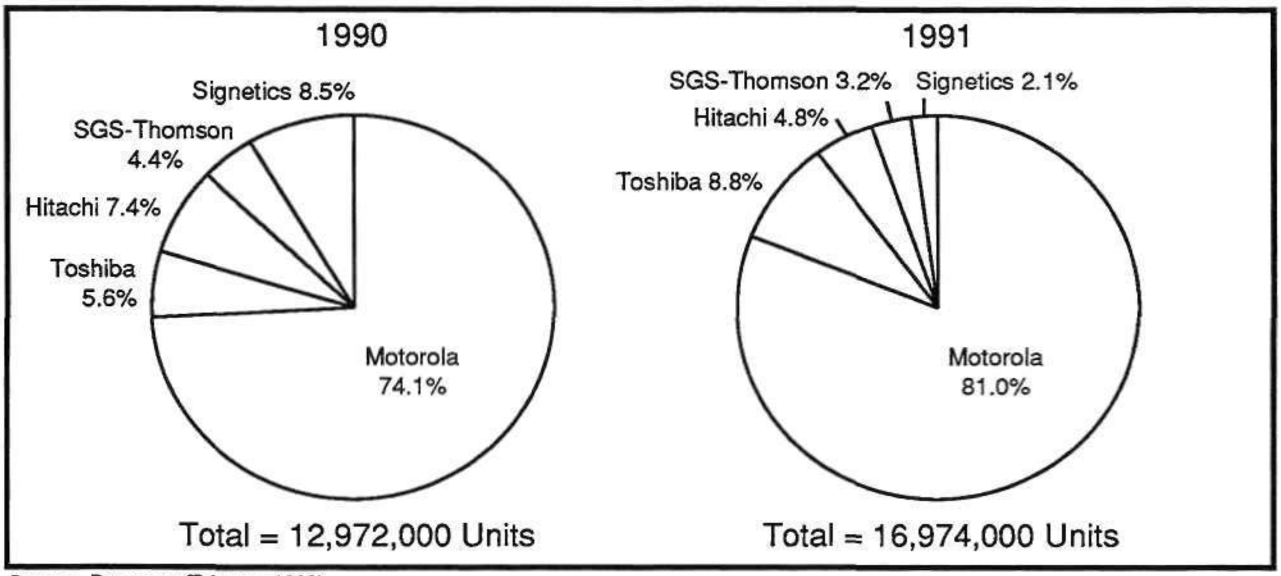
As previously shown in Figure 1, the high-end series of 68K processors grew by 68 percent last year to more than 4 million units. Most of the unit volume for these versions comes from platform sales, most notably the Apple Macintosh. All individual processors in this group experienced growth during 1991. Motorola achieved a milestone in 1991 by shipping the 68040 processor, although much later than originally anticipated, moving just over 200,000 units in its first year. Additionally, in January 1992, Motorola released a 33-MHz version of the 68040, turning in nearly 29-mips performance.

A second new part based on the 68040 was also introduced in 1991. The 68LC040 series is a lower-cost version of the 68040, actually targeted toward low-cost PCs including portables and O/S-related embedded applications such as communications controllers and X Window terminals. This part is identical to the 68040 except that it removes the FPU and adds low-power buffers, lowering its price to $185 for a 25-MHz, 22-mips processor. According to sources, we can expect to see a similar version for the 68030 introduced shortly, targeted toward low-end PCs such as Macintoshes for the home.

Motorola Broadens Its Range of Embedded Solutions

As part of its strategy to deliver a range of highly integrated embedded control devices, Motorola offers two series of 68K-compatible

Figure 2
68K Low-End (68000/008/010) Market Share by Units



Source: Dataquest (February 1992)

parts. The combination of these parts offers a range of $2 to 22 mips, and Motorola plans to extend it from $1 to 100 mips within five years. As previously shown in Figure 1, these parts account for only a small portion of volume but are growing quickly.

The 68ECXXX series was introduced in 1991 and provides 68XXX compatibility and performance with reduced features and cost for embedded control applications. Each 68ECXXX chip is identical to its 68XXX counterpart (that is, the 68EC040 and 68040), except that nonessential features such as MMUs and FPUs are stripped out, reducing cost. This series is targeted at high-performance, processing-intensive embedded applications.

The 683XXX series has been in production for over two years and is marketed as a microcontroller, but at this time it is basically a microprocessor with integrated I/O with no internal EPROM. This series takes a different course toward functional integration and low cost. Each 68300 is a virtual system on a chip, combining 68XXX processor core, intermodule bus, and peripheral modules such as memories, timers, and I/O circuits. In fact, future versions may be complete microcontrollers. In addition, these are fully static parts, enabling standby modes and lower power consumption, making it attractive for products such as hand-held instruments.

Dataquest Perspective

The 68K family has had a history of taking leadership positions within many high-growth markets. Although workstations, X Window terminals, and some of Apple's future systems have shifted toward RISC-based architectures, Motorola has adapted well by strengthening the family's focus on embedded applications. The current product line provides the widest range of price and performance available, from $2 to 29 mips under one single architecture. Future growth prospects for the 68K family and Motorola will be due to increased use of advanced technology in consumer products. It is unknown whether any of the other 68K chip vendors, now only competing in the low end, will continue to support this line.

By Ken Lowe

Platform RISC Processors Begin Their Ramp

Platform RISC processors in total accounted for barely over 500,000 units in 1991. Although statistically insignificant in volume, this class is setting the pace for future competition in the reprogrammable market. This class is defined as RISC-based microprocessors, focused primarily on computing platforms such as workstations and PCs and backed (or potentially backed) by some form of open systems consortium, making them a candidate for mainstream adoption. Based on this definition, we have included the following families to which DEC's new Alpha chip may soon be added:

- SPARC processor family
- MIPS processor family
- PowerPC processor family
- PA-RISC processor family

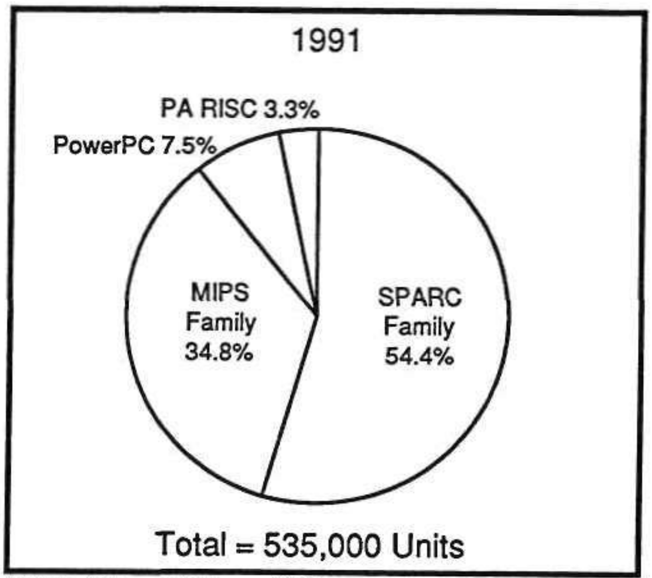
Each of these segments really stands for a major industry alliance aimed at the future mainstream desktop. Each alliance includes a standardized microprocessor architecture (instruction set level), operating system strategy, multiple sources of chips, and one or more top systems vendors. Interestingly, each also has its own exclusive list of chip vendors, with the exception of LSI Logic, which participates in both MIPS and SPARC families.

As shown in Figure 1, this entire class is growing at 112 percent, more than doubling its size every year. If this rate of growth continues, Platform RISC processors would represent one-half the combined PC/workstation volume in five years. Currently, SPARC processors account for over one-half the total unit volume, having started their industry movement earlier than the others. MIPS processors represent about another third of the total, although many of these are used for embedded applications. The PowerPC and PA-RISC families together only account for less than 15 percent of the total volume and are currently being captively consumed by the IBM Corporation and Hewlett-Packard Company (HP), respectively.

Vendor Shares Shift Dramatically in SPARC Market

SPARC microprocessors grew less than 100 percent last year, still primarily tied to the growth of Sun Microsystems. This slowing growth is a result of SPARC's primary driving force becoming its primary weakness. Sun is a dominant player in the workstation market, and its continued growth directly results in increased sales of SPARC chips. However, the company's aggressive pricing and channel dominance prevented any other SPARC-based system vendor from entering the market. We expect 1992 to be the crucial year for SPARC, either growing up and around Sun and the Solaris operating system or being reduced to an industry alliance of one.

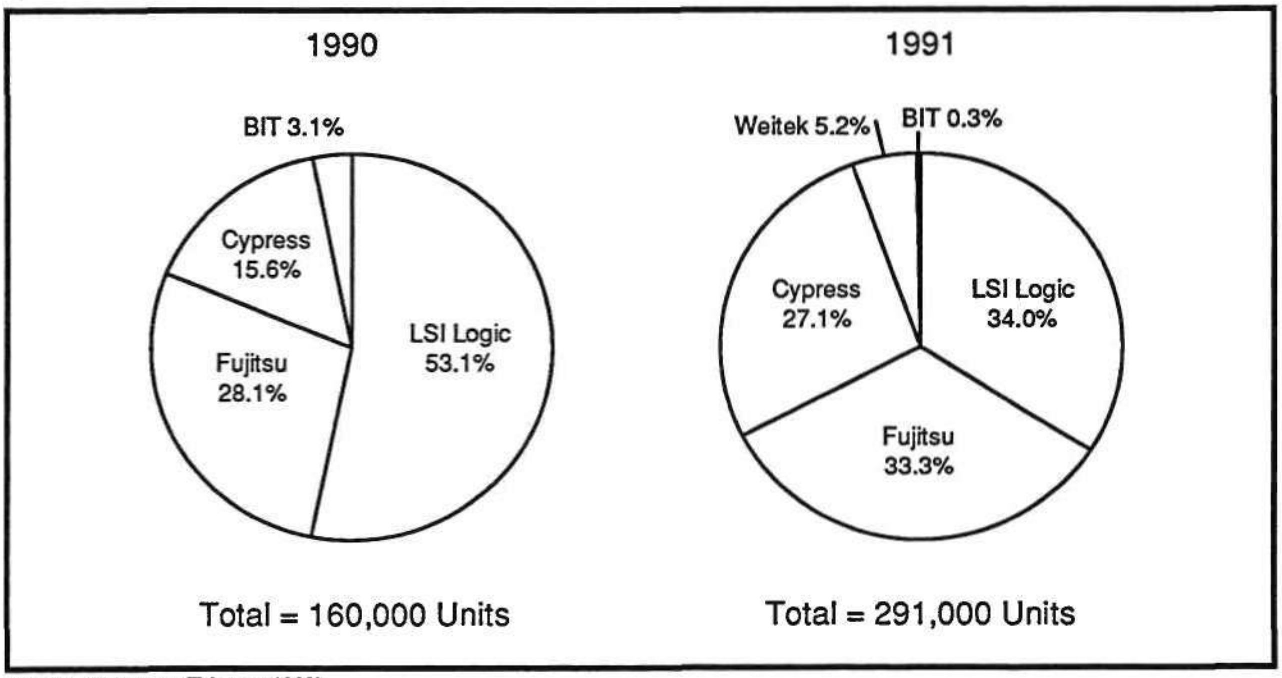
Figure 1
RISC Processor Shipments by Family



Source: Dataquest (February 1992)

On the competitive front, Figure 2 clearly shows the exceptional growth experienced by Fujitsu and Cypress Semiconductor, both of which offer integrated IU/FPU chips. These market share gains were made at the expense of LSI Logic, which was singularly dominant in 1990 and appears likely to lose its No. 1 position shortly. Fujitsu's sales were boosted by Sun's introduction of the SPARCstation IPX and ELC and further by the beginning of its embedded sales with its SPARC-Lite series. Cypress also picked up a larger portion of Sun's business including its 600 series SPARCservers as well as other accounts such as Solborne. During 1991, we saw Weitek get started with its first SPARC processors, and Texas Instruments along with Sun showed off the new Viking SuperSPARC chip scheduled to ship later this year. The year also saw Bipolar Integrated Technologies (BIT) pull out of the market in favor of the MIPS processor.

Figure 2
SPARC Processor Market Share by Units



Source: Dataquest (February 1992)

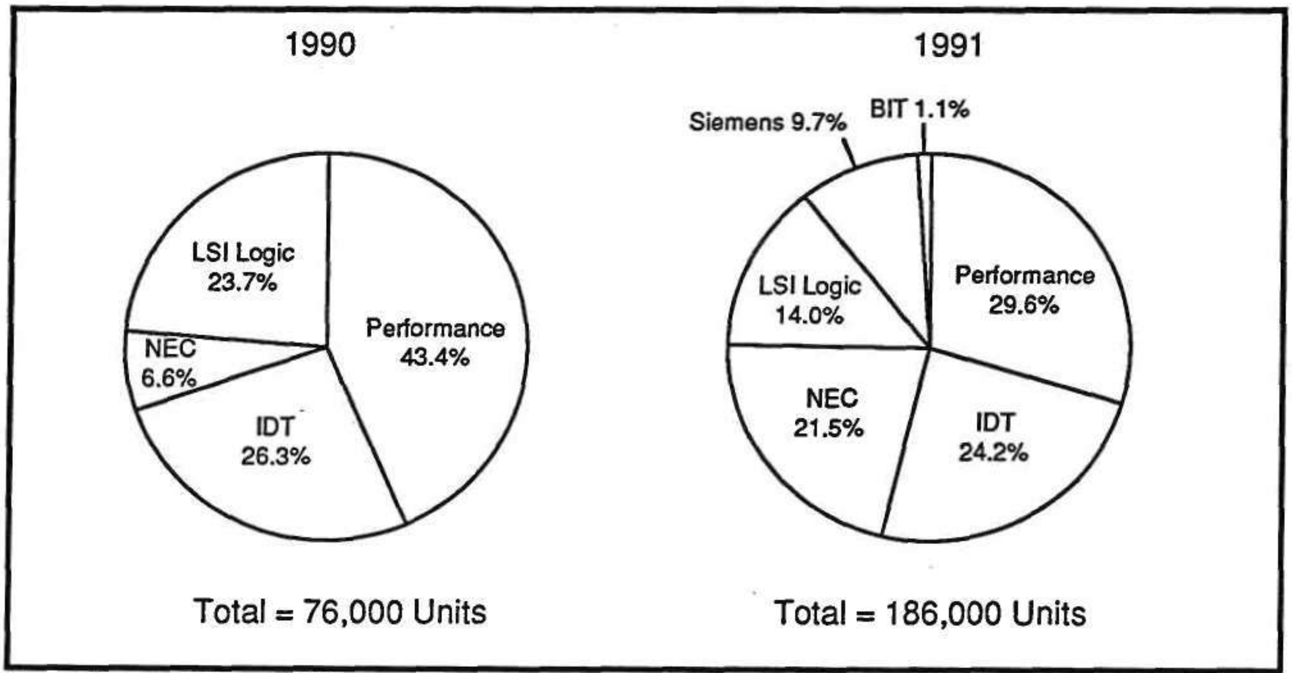
MIPS Computer Plays Its ACE Card

The market for MIPS processors grew by 142 percent during 1991 on top of the dramatic momentum picked up through the formation of the Advanced Computing Environment (ACE) initiative. Although the MIPS processor movement is now primarily focused on developing platform sales, embedded applications accounted for about 40 percent of total volume. Thus, just more than 100,000 units were shipped into platform sales—primarily workstations. Two-thirds of these platform units are shipped to just two customers—DEC being the larger, followed closely by Silicon Graphics.

The ACE initiative is a collaborative industry effort crucial to the MIPS camp success and crafted to springboard this architecture into mainstream computing. This initiative is being driven by MIPS Computer (the architects), enabled by Microsoft (the operating system), and loosely supported by more than 75 system vendors, most prominently Digital Equipment Company and Compaq Computer Corporation. The plan is to compete directly with the 80X86 processors (486 and up) under the same NT-Windows operating environment and promote the performance advantage gained through RISC technology. Although its outlook receives mixed reviews, if successful, this movement could produce 20 times the annual volume of what they are today by 1995.

As of the end of 1991, a total of seven vendors signed up as MIPS processor manufacturers. As Figure 3 shows, Performance Semiconductor and Integrated Device Technologies (IDT) were able to maintain their No. 1 and No. 2 positions, respectively. Performance sells the majority of its units to DEC and announced an integrated processor with on-chip IU, FPU, and cache. IDT has the most balanced position, selling chips to workstation vendors such as Silicon Graphics, to embedded applications using its proprietary 3051/52 series (now second-sourced by Siemens), and in system modules to accounts such as AT&T. NEC came on strong in 1991, capturing part of the DEC account and shooting to the No. 3 position. LSI Logic lost significant share, as it also did in the SPARC processor market, but introduced a well-positioned integrated chip for X Window terminals. Siemens, at No. 5 position, showed healthy growth in its first year of shipping. Finally, we saw the entry of Bipolar Integrated Technologies, which is focused on the R6000 ECL version, and Toshiba, which is setting up to become a major supplier for ACE/ARC systems.

Figure 3
MIPS Processor Market Share by Units



Source: Dataquest (February 1992)

Power and Precision Come into Play

The PowerPC family, the primary processor for the PowerOpen Computing Environment formed by the IBM/Apple/Motorola relationship, represents an outgrowth of IBM's RS/6000 POWER architecture. This new family is to be jointly developed and separately manufactured by IBM and Motorola. Current plans call for initial models designed to service the entire platform market for workstations, PCs, notebooks, and servers. Sporting a tuned instruction set and driven by optimizing compiler considerations, IBM is successfully growing its workstation business using this architecture. In 1991, IBM shipped approximately 40,000 units for its own captive use. Moreover, starting in 1993, this new architecture, supported by a new advanced architecture, will be offered on the merchant market following standards set by the two leading PC vendors, IBM and Apple. To date, the only chip production has been IBM and the only merchant chip source announced is Motorola.

The Precision Architecture RISC (PA-RISC) microprocessor was developed by HP with early versions having shipped since 1987. Using new advanced VLSI technology announced by HP in 1989 enabled the company to significantly increase performance of systems based on the PA-RISC. This new generation of PA-RISC first appeared in April 1991 in the HP 700 series of workstations, delivering the fastest benchmarks to date—66 MHz, 77 mips, and 76 SPECmarks. A lower-speed version of the PA-RISC processor running at 35 MHz was introduced in January 1992 offering 35 mips for under $5,000. The PA-RISC camp now includes Hitachi and Samsung, both planning to ship PA-RISC chips and system products. In 1991, HP produced about 18,000 units for its own captive consumption with 3 times that volume expected for this year.

Dataquest Perspective

The Platform RISC class of microprocessors represents a dichotomy, having the lowest unit volume of all classes but the most industry heavyweights and highest R&D investments of all other classes. As a whole, there is no doubt that the unit volumes will continue to grow substantially during the next 10 years, perhaps capturing 35 percent of the platform processor market by the year 2000 as projected by Dataquest. The major issue at hand is which of these alliances will take the lead and at whose expense—the other RISC families or the dominant 80X86 family?

By Ken Lowe

In Future Issues

The following topics will be addressed in future issues of *Dataquest Perspective:*

- Microcontrollers
- PC Chip Sets

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On the topics in this issue .... Ken Lowe, Sr. Industry Analyst	(408) 437-8366
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