Dataquest
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February 1996

Dear Dataquest Client,

By now, you should have received the 1996 Dataquest research program binders for filing the newsletters and reports that will be sent to you throughout the year.

To let you know what documents you can expect to receive as part of your subscription, enclosed please find the 1996 datasheet for the research program to which you subscribe. The back side of the datasheet lists the Dataquest Perspectives, Market Trends reports, Market Statistics books, reports, and electronic newsletters that are included in this year's research portfolio.

If you have any questions about the research schedule, please contact your Dataquest research analyst or client services representative.

Sincerely,

Jeffrey A. Byrne
Vice President
Worldwide Marketing

EMBEDDED MICROCOMPONENTS WORLDWIDE

Dataquest's Embedded Microcomponents Worldwide program provides a thorough understanding of the trends, issues, players, and products that drive the markets for microprocessors, microcontrollers, digital signal processors, and peripherals designed for embedded applications. To provide a more complete picture of the total microcomponents market, top-level market data on microprocessors used in computational applications are also included.

Partnering to Provide Solutions

As a client, you have direct access to experienced analysts who can provide insights and advice on market dynamics, industry events, and competitive issues.

Inquiry Support

Personalized inquiry support is a primary component of your Dataquest annual subscription program.

Through an interactive approach, Dataquest analysts work with you to tailor the program to meet the unique needs of your organization.

Electronic Delivery

A variety of electronic delivery options, known collectively as *Dataquest on the Desktop*, are available.

Information Resource Centers

Clients have unlimited access to Dataquest's extensive print and online resource libraries worldwide.

Optional Custom Research

Should your needs exceed the scope of this program, Dataquest offers extensive primary research and consulting services.

Market Coverage

Dataquest separates microcomponent use into two broad application categories: computing and embedded systems.

The microcomponent in an embedded system performs one set of operations as determined by code provided by the OEM, based on the type of equipment it is in. Its function is programmed in ROM or possibly on disk, but the equipment user has no direct method of reprogramming the processor.

All microcontrollers and DSPs go into embedded applications, as do many microprocessors—this program will cover all three product types.

Application Categories

The primary application segments for embedded microcomponents in electronic equipment are:

- Embedded data processing
- Communications
- Industrial control
- Consumer products
- Transportation
- Military/civil aerospace

Market Statistics

Dataquest's market statistics and growth projections have been indispensable tools for product managers and strategic planners for more than two decades.

Market estimates and forecasts are provided for the following categories:

- Microprocessors
  - Embedded processors
  - Computational processors
- Microcontrollers
  - 4-bit
  - 8-bit
  - 16-bit and larger
- Digital signal processors

PC-Processor Coverage – *Clients heavily involved in the PC industry, or closely watching the central processor of personal computers, workstations, and servers should consider the greater detail to be found in Dataquest's Semiconductor Directions in PCs & PC Multimedia program.*

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WHAT YOU WILL RECEIVE AS A CLIENT

EMBEDDED MICROCOMPONENTS WORLDWIDE

Perspectives

Dataquest Perspectives present analysis and commentary on key technologies, companies, market opportunities, trends, and issues in the microcomponents market. A minimum of six Perspectives will be published on an event-driven basis throughout the year, as well as two *Dataquest Predicts*. Scheduled Perspectives for 1996 include:

Product Analysis: Evaluations of significant new microprocessor, microcontroller, and digital signal processing products and architectures, and comments on their positions and prospects for success.

Event-driven

Applications: Review of specific embedded applications with an assessment of the market's products, vendors, OEMs, size and forecast, influences, and standards. The opportunities for vendors and microcomponents to serve these markets will be given. Potential applications for 1996 include set-top boxes, automotive, and digital video.

Three Issues per Year

Embedded Architectures: Review of microcomponent architectures which are dominant in embedded applications, analysis of their strengths and weaknesses, assessment of the primary vendors' strategies, and projections of their future directions.

Available in the Second Quarter 1996

Competitive Analysis: Analysis of the strategies, products, strengths and challenges of key companies that are shaping the industry.

Available in the Fourth Quarter 1996

Market Trends

Market Trends and Forecast: Regional and worldwide revenue projections for microprocessors, microcontrollers, and programmable DSPs. Clients will receive the following two reports:

- **Embedded Microprocessor Market Trends and Forecast** — ***Available in May 1996***
- **Microcontroller and DSP Market Trends and Forecast** — ***Available in August 1996***

Market Statistics

Microcomponents Market Share: Annual, regional, and worldwide market share and unit shipments by company for microprocessors, microcontrollers, programmable DSPs, and microperipherals (top-line data only). Clients will receive the following three reports:

- **Detailed Microprocessor Market Share** — ***Available in May 1996***
- **Detailed Microcontroller Market Share** — ***Available in May 1996***
- **Microcomponents Market Share** — ***Available in June 1996***

Electronic News

Dataquest Alerts: Event-driven news and analysis, delivered by fax, giving a concise overview of significant, fast-breaking events in the industry.

Event-driven Faxes

The DQ Monday Report: Weekly news and commentary on semiconductor industry events with a monthly snapshot of semiconductor pricing for 25 key semiconductors in 6 regions. Clients may wish to subscribe to this newsletter for a broad view of the industry.

Available Weekly via Electronic Mail

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Program Code: MCRO-WW
MKTG 1/96 (JCG)

December 1995

Dear Dataquest Client:

In 1996, Dataquest will celebrate its 25th year as the leading global supplier of market intelligence to the IT vendor and financial communities. I would like to thank you, on behalf of all Dataquest associates worldwide, for your support. We are proud to be your information partner by providing the IT market insight and analysis you need to make crucial business and planning decisions.

The enclosed binder is for filing and storing the printed market research newsletters and reports that you will receive on an ongoing basis throughout 1996 as part of your subscription to Dataquest. You may notice that we've streamlined the binder tab and document filing structure this year. We hope that this 5-tab scheme increases your efficiency in filing and locating documents.

You probably know that in addition to paper-based delivery, Dataquest is also committed to delivering our market statistics and analysis electronically. We expect that our electronic products, known collectively as *Dataquest on the Desktop*, will play an increasing role in our ability to deliver information to you in a timely, efficient way. For your information, our electronic tools include:

- ***Dataquest on Demand***—Our monthly CD-ROM containing a rolling 13 months of Dataquest's printed documents
- ***MarketView***—A data analysis tool containing many of Dataquest's market statistics databases
- ***Electronic NewsTakes and Dataquest Alerts***—Weekly/event-driven summary and analysis of top IT news, published via e-mail or fax by most Dataquest research groups
- ***Dataquest Interactive***—Our Internet-based electronic delivery system that you are invited to preview at this URL: http://www.dataquest.com

One last note: an optional binder called *Electronic News* is available on request for clients who wish to file their electronic newsletters and Dataquest Alerts. To order your copy, please fill out the FaxBack form found in the binder pocket and fax it back to us.

We look forward to working with you in our continuing process to improve the content, quality, and timeliness of our products and services. I encourage you to share with us your comments about our publications and electronic delivery tools.

Sincerely,

Jeffrey A. Byrne
Vice President, Worldwide Marketing

1996 RESEARCH PROGRAMS

From semiconductors to systems, software to services, telecommunications to document management, Dataquest's scope of expertise provides clients with a clear view of the relationships among information technology segments – relationships that can have a profound impact on making strategic business decisions.

Computer Systems and Peripherals

Computer Systems
- Client/Server Computing *Worldwide*
- Computer and Client/Server Systems *Europe*
- Servers *Europe*
- UNIX and Open Systems *Europe*

Workstations
- Advanced Desktop and Workstation Computing *Worldwide*
- Workstations *Europe*

Computer Storage
- Removable Storage *Worldwide*
- Optical Disk Drives *Worldwide*
- Optical Disk Drives *Europe*
- Rigid Disk Drives *Worldwide*
  - RAID Storage Systems *Worldwide*
- Rigid Disk Drives *Europe*
- Tape Drives *Worldwide*
- Tape Drives *Europe*

Graphics
- Graphics and Displays *Worldwide*

Personal Computing
- Personal Computers *Worldwide*
- Personal Computers Strategic Service *Europe*
- Personal Computers *Asia/Pacific*
- Mobile Computing *Worldwide*
- PC Distribution Channels *Worldwide*
- PC Distribution Channels *Europe*
- Desktop PC Technology Directions *Worldwide*
- Mobile PC Technology Directions *Worldwide*
- Personal Computers *Central and Eastern Europe*

Quarterly Statistics
- Advanced Desktop and Workstation Quarterly Statistics *Worldwide*
- Workstation Quarterly Statistics *Europe*
- Server Quarterly Statistics *North America*
- Server Quarterly Statistics *Europe*
- PC Quarterly Statistics *United States*
- PC Quarterly Statistics *Europe*
- PC Quarterly Statistics *Japan*
- PC Quarterly Statistics *Asia/Pacific*
- PC Quarterly Statistics *Worldwide by Region*

Online, Multimedia, and Software

Emerging Technologies
- Multimedia *Worldwide*
- Multimedia *Europe* (Module)
- Online Strategies *Worldwide*
- Online Strategies *Europe* (Module)

Productivity/Development Tools
- Client/Server Software *Worldwide*
- Workgroup Computing *Worldwide*
- Workgroup Computing *Europe* (Module)
- Personal Computing Software *Worldwide*
- Personal Computing Software *Europe* (Module)

Technical Applications
- AEC and GIS Applications *Worldwide*
- Electronic Design Automation (EDA) *Worldwide*
- Mechanical CAD/CAM/CAE *Worldwide*
- CAD/CAM/CAE/GIS *Europe* (Module)
- CAD/CAM/CAE *Asia/Pacific* (Module)

Services

Customer Services
- Customer ServiceTrends *North America*
- Customer Services and Management Trends *Europe*

Professional Services
- Professional Service Trends *North America*
  - Systems Integration and Applications Development
  - Consulting and Education
  - Systems Management
- Vertical Market Opportunities *North America*
- Professional Services *Europe*
  - Systems Integration
  - Consulting and Education
  - Systems Management
- Professional Services Vertical Market Opportunities *Europe*
- Professional Service Trends *Asia/Pacific*

Sector Programs
- System Services *North America*
  - Desktop Services
  - Notebook Services
  - Server Services
- User Computing Services *Europe*
- Network Integration and Support Services *North America*
- Network Integration and Support Services *Europe*
- Software Services *North America*
- Strategic Service Partnering *North America*

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1996 RESEARCH PROGRAMS

Document Management

Copiers
- Copiers *North America*
- Copiers *Europe*

Facsimile
- Facsimile *North America*

Printers
- Printers *North America*
- Printers *Europe*
- Colour Products *Europe* (Module)
- Printer Quarterly Statistics *Europe*
- Printer Distribution Channels *Europe*
- Printers *Asia/Pacific*
- Printer Quarterly Statistics *Asia/Pacific*

Semiconductors

Regional Markets
- Semiconductors *Worldwide*
- Semiconductors *Europe*
- Semiconductors *Japan*
- Semiconductors *Asia/Pacific*
  - China/Hong Kong
  - Taiwan
  - Korea
  - Singapore

Devices
- ASICs *Worldwide*
- ASIC Applications *Europe*
- Memories *Worldwide*
- Memory Applications *Europe*
- Memory IC Quarterly Statistics *Worldwide*
- Embedded Microcomponents *Worldwide*
- Microcomponent Applications *Europe*
- DRAM Quarterly Supply/Demand Report

User Issues
- Semiconductor Supply and Pricing Worldwide

Application Markets
- Semiconductor Application Markets *Worldwide*
- Semiconductor Application Markets *Europe*
- Semiconductor Application Markets *Asia/Pacific*
- Communications Semiconductors & Applications *WW*
- Consumer Multimedia Semiconductors & Applications *Worldwide*
- Semiconductor Directions in PCs & PC Multimedia *WW*
- PC Teardown Analysis
- PC Watch *Europe*
- Electronic Equipment Production Monitor *Europe*
- Electronic Application Markets *Europe* —Automotive
- Electronic Application Markets *Europe* —Communications
- Electronic Application Markets *Europe* —Consumer
- Electronic Application Markets *Europe* —EDP

Manufacturing
- Semiconductor Equipment, Manufacturing, & Materials *Worldwide*
- LCD Industry *Worldwide*
- Semiconductor Contract Manufacturing *Worldwide*

Telecommunications

Networking
- Networking *North America*
  - Local Area Networks *North America*
  - Wide Area Networks *North America*
  - Modems *North America*
- Networking *Europe*
  - Asynchronous Transfer Mode *Europe*
  - ISDN *Europe*
  - Modems *Europe*
  - Local Area Networks *Europe*
  - WANs *Europe*
- Quarterly Market Watch *North America*
  - Intelligent Hubs & Switches
  - Network Interface Cards
- Network Distribution Channels *Europe*

Voice
- Voice Communications *North America*
  - Voice Processing *North America*
  - Computer-Integrated Telephony & Automatic Call Distributors *North America*
  - Premise Switching Systems *North America*
- Voice Communications *Europe*
  - Voice Processing *Europe*
  - Call Centres *Europe*
  - Telephones *Europe*
  - PBX/KTS Systems *Europe*

Public
- Public Network Equipment & Services *North America*
  - Public Network Equipment *North America*
  - Public Network Services *North America*
- Public Network Equipment & Services *Europe*
  - Public Network Equipment *Europe*
  - Public Network Services *Europe*

Personal
- Cellular Telephony *Worldwide*
- Personal Communications *North America*
- Personal Communications *Europe*
  - Infrastructure and Services *Europe*
  - Terminals *Europe*
- Personal Communications Distribution Europe

Cross-Technology Programs

Technology Insights for:
- Financial Services
- Government Agencies
- Publishing, Media, and Consulting Firms
- IT Business Development for Financial Organizations
- IS and Purchasing Organizations
- IT Supporting Industries

Emerging IT Markets

Central and Eastern Europe
- Personal Computers
- Telecommunications

Latin America
- Personal Computers
- Printers

Asia/Pacific
- IT Market Insight *Asia/Pacific*
- Personal Computers *Asia/Pacific* & Quarterly Statistics
- Printers *Asia/Pacific* & Quarterly Statistics
- Professional Service Trends *Asia/Pacific*
  - Country-level reports on Asia/Pacific IT markets

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Program Code: NONE-WW MKTG 1/96 (PSB)

DATAQUEST 1996 CONFERENCES

Dataquest sponsors an on-going series of conferences and invitational events focusing on trends and issues in information technology and IT services. These conferences are the preeminent source of insight and analysis of global IT market dynamics.

North America	January 24	Capitalizing on the Wireless Phenomenon	San Jose, California
	January 30	Dataquest Predicts	Boston, Massachusetts
	February 20	Dataquest Predicts	San Jose, California
	March 7	Channel Trends Conference	San Jose, California
	April 1-2	ServiceTrends Conference	Orlando, Florida
	April 1 *	Mining the Internet	Boston, Massachusetts
	May 6-7	Personal Computer Conference	San Jose, California
	May 13-14	Copier Conference	Boston, Massachusetts
	June 26-27	Storage Track Conference	Monterey, California
	July 1 *	SEMICON/West	San Francisco, California
	September 25-26 *	Multimedia	San Jose, California
	October 24-25	Semiconductors '96	Palm Desert, California
	December 1 *	Mining the Internet	San Jose, California
Europe	January 24	Computer Storage	Munich, Germany
	May 22-23	Semiconductors '96	Frankfurt, Germany
	September 10	Computer Storage	London, England
Japan	May 13-14	Semiconductors '96	Tokyo, Japan
	September 10-12	Computers and Peripherals	Tokyo, Japan
	December 6	Telecommunications	Tokyo, Japan
Dataquest Invitational Computer Conferences	December 1 *	Asia/Pacific Series	Tokyo, Japan
	December 1 *	Asia/Pacific Series	Seoul, Korea
	December 1 *	Asia/Pacific Series	Beijing, PRC
	December 1 *	Asia/Pacific Series	Shanghai, PRC
	December 1 *	Asia/Pacific Series	Xi'an, PRC
	December 1 *	Asia/Pacific Series	Guangzhou, PRC
	March 5	Dataquest Storage Solutions Series - USA	San Jose, California
	April 10	Dataquest Storage Solutions Series - USA	Irvine, California
	April 24	Dataquest Storage Solutions Series - USA	Nashua, New Hampshire
	September 24	Dataquest Storage Solutions Series - USA	Newton, Massachusetts
	April 1	Mediterranean Series	Dubai, UAE
	May 21	Mediterranean Series	Athens, Greece
	October 30	Mediterranean Series	Tel Aviv, Israel
	November 6	Mediterranean Series	Istanbul, Turkey

**** Date tentative/may change***

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Dataquest Invitational Computer Conferences *(continued)*

January 17	Dataquest Storage Solutions Series-Europe	Paris, France
January 23	Dataquest Storage Solutions Series-Europe	Munich, Germany
January 30	Dataquest Storage Solutions Series-Europe	Milan, Italy
February 1	Dataquest Storage Solutions Series-Europe	Rome, Italy
June 10	Dataquest Storage Solutions Series-Europe	Budapest, Hungary
June 12	Dataquest Storage Solutions Series-Europe	Prague, Czech Republic
June 21	Dataquest Storage Solutions Series-Europe	St. Petersburg, Russia
June 25	Dataquest Storage Solutions Series-Europe	Moscow, Russia
July 1	Dataquest Storage Solutions Series-Europe	Warsaw, Poland
September 1	Dataquest Storage Solutions Series-Europe	Amsterdam, Holland
September 5	Dataquest Storage Solutions Series-Europe	Stockholm, Sweden
September 11	Dataquest Storage Solutions Series-Europe	London, England
September 19	Dataquest Storage Solutions Series-Europe	Frankfurt, Germany
October 1 *	Latin America Series	Caracas, Venezuela
October 1 *	Latin America Series	Mexico City, Mexico
October 1 *	Latin America Series	São Paulo, Brazil
October 1 *	Latin America Series	Buenos Aires, Argentina
October 1 *	Latin America Series	Santiago, Chile
October 1 *	Latin America Series	Bogotà, Columbia
October 1 *	Latin America Series	Lima, Peru
February 19	South Africa Series	Capetown, South Africa
February 22	South Africa Series	Johannesburg, South Africa
April 11	LINK Series - North America	Orlando, Florida
April 30	LINK Series - North America	Austin, Texas
May 1	LINK Series - North America	Philadelphia, Pennsylvania
May 9	LINK Series - North America	Charlotte, North Carolina
May 14	LINK Series - North America	Denver, Colorado
May 21	LINK Series - North America	Portland, Oregon
November 1 *	LINK Series - North America	Montréal, Québec
November 1 *	LINK Series - North America	Ottawa, Ontario
November 1 *	LINK Series - North America	Calgary, Alberta
November 1 *	LINK Series - North America	Vancouver, BC
November 1 *	LINK Series - North America	Toronto, Ontario

Want more information about Dataquest?

Place your request by calling our Fax-on-Demand system at ***1-800-328-2954***

**Date tentative/may change*

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Here's How to Order Your *Electronic News* Binder

Dataquest provides a separate binder called *Electronic News* to help you organize your printouts of the electronic newsletters and Dataquest Alerts that will be sent to you by your Dataquest North America research programs throughout the year.

Although not all clients will print out electronic news bulletins or file faxes, the *Electronic News* binder is available by request for those who do.

To order your *Electronic News* binder, just fill out the form below and fax it back to us. We will mail your binder to you immediately.

Note: If you subscribe to more than one Dataquest North America research program, then indicate how many binders you need in the space provided below (plan on one binder per research program), and we'll send them to you in one shipment.

Thank you for helping us serve you better.

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251 River Oaks Parkway, San Jose, CA 95134-1913

EMBEDDED MICROCOMPONENTS WORLDWIDE 1996
TABLE OF CONTENTS

Dataquest ALERT

251 River Oaks Parkway • San Jose • CA • 95134-1913 • Phone 408-468-8000 • Fax 408-954-1780

Texas Instruments Resets DSP Targets

Texas Instruments unveiled a new high-end digital signal processor (DSP) in the first week of February that will reset all of the targets for the high end of digital signal processing. The new chip should assure the company of the highest performance available from a monolithic DSP. The sophisticated architecture implements some advanced techniques that allow the software to squeeze the greatest performance out of the chip. The 200-MHz clocking frequency and multiple processing components pump up the performance so that one chip can handle the work of many older DSPs. Applications like communications infrastructure, pooled modems, and remote access servers can suck up as much DSP horsepower as anyone can throw at them. With a price under $100, TI is ensuring that this will get a lot of attention from the biggest DSP applications.

This new chip is very impressive: brand, spanking new architecture with unheard-of performance, higher-level software to support it, and a price far lower than one might expect. The architecture raises many of the old RISC versus CISC arguments, now in the DSP world, but overall, the performance and capability appear to be far and above what is otherwise available.

MIPS in CISC versus RISC

The peak speed is stated as 1,600 MIPS on the new TMS320C6x family. That's a number that hasn't been seen in MIPS ratings for any type of processor. When discussing DSPs, MIPS usually refers to DSP instructions that perform a multitude of operations equivalent to three to eight times the work done by normal CISC and RISC processor instructions. Even among DSP manufacturers, some profess instruction sets that do more in each individual stroke than the other guy. In much the same way that RISC vendors count their simpler instructions, TI's 1,600 MIPS rating is counting smaller steps (sometimes referred to as operations) as the instruction. Indeed, in the TI part, the programmer has access to and great control of each of these smaller instructions. Nonetheless, it would be difficult to argue that the more complete instructions outstrip the 15 to 20 times rating difference between the new TI chip and the others.

To get its high performance, Texas Instruments took a radical approach to the design, borrowing concepts that have been gaining popularity in the high-performance microprocessor world. The 'C6x uses a very long instruction word (VLIW) architecture (cleverly called "VelociTI") to control 8-, 16-, or 32-bit data down two different paths, each with four functional units. These arithmetic logic units (ALUs), shifters, multipliers, and data movers can be individually controlled by a portion of the VLIW, and each can be conditionally exercised with every clock pulse. The RISC-like chip is essentially a 16-bit fixed-point DSP with 16-bit multiplies and 40-bit shifts and adds (floating point, in the future). The program code is fetched in 256-bit swaths, while data routes around on two 32-bit buses coming from four separate data spaces. Addresses are 32 bits long and, if fully utilized, might help sagging DRAM markets (4 gig of 256-bit words is 2^{40} or 10^{12} [quadrillion] bits—it's like the U.S. national debt counted in the old Italian lira).

Assembly Code Good, Compiler Code Better

Management of the algorithm through the eight functional units is best left to the sophisticated C compiler that Texas Instruments is offering with the 'C6x. Although most ("real men") DSP programmers revel in the fine tuning of their algorithms' core loops in assembly language, with intimate knowledge of the DSP's structure, Texas Instruments believes this new power tool should be entrusted to compilers. This seems like a prudent move for those trying to get a product out before the market has been claimed. The compiler was designed along with the chip architecture, and the new assembly-language optimizer is intended to maximize the advantage afforded by access to those smaller functional units. If a shifter is not going to be used during a cycle for task two, it might be used to ready data for task three or to tidy up the results of task one. The "real men" can still get in there and twiddle the machine code, but most of the work will already have been done by the development tools, which are proposed to have three times the efficiency of previous compilers.

Features

The first of the family is the TMS320C6201. The core DSP processor is supplemented with a 2Kx256 program cache/memory, 0.5Mb of data RAM, an external memory interface (synchronous and burst DRAM with refresh and SRAM), host port, two-channel direct memory access (DMA), two enhanced serial ports for T1/E1 interfacing, two 32-bit timers, oscillator, and power management circuitry. It runs on 2.5V at an astonishing 200 MHz through five layers of metal in a 0.25μ process (0.18μ in the future) and handles 3.3V input/output. Samples without the timers and serial ports are available now, with the full 'C6201 to be available second quarter 1997 in its 352-lead ball grid array at a price of $96 in quantities of 25,000.

Outlook

There is little doubt that this is a blazing DSP, faster than any other. Wisely, TI has supplied sophisticated development software to manage the programming of the parallel processing elements to which it has given access. Automatic control is desirable in nuclear power plants. Applications where multiple DSPs are needed just to get the needed performance or to duplicate operations for multiple channels should be impressed with TI's showing this chip's capability to cut the DSP bill in half while finding a four to fifteen times improvement in the channel-handling capability of the DSP. Texas Instruments continues its leadership role in DSP.

Watch for additional information in an Embedded Microcomponents Worldwide Perspective (MCRO-WW-DP-9703, to be published in February).

By Tom Starnes

Dataquest ALERT

251 River Oaks Parkway • San Jose • CA • 95134-1913 • Phone 408-468-8000 • Fax 408-954-1780

Samsung Licenses Digital's Alpha Technology: Third Time's a Charm?

Earlier this week, Digital Equipment Corporation and Samsung Electronics Co. Ltd. announced that Samsung has licensed Digital's Alpha microprocessor technology and has worldwide rights to market, sell, and distribute Alpha microprocessors. The companies suggested that Samsung will produce its first Alpha chips in 1997.

Samsung has already entered into a licensing agreement with Advanced RISC Machines for its ARM microprocessor and last month announced that it intends to license Sun Microsystems' PicoJava processor as well. The ARM and PicoJava efforts both focus on the embedded microprocessor (MPU) applications market, one where Samsung's size and capacity greatly increase the likelihood of success. These factors play a much smaller role in determining the likely success of processors aimed at the computational market.

This agreement represents Samsung's third attempt to enter the computational microprocessor market via licensing arrangements. Its earlier attempts, with Intergraph's CLIPPER in 1989 and Hewlett-Packard's PA-RISC in 1992, both ended in failure. In this Alert, Dataquest reviews what Digital and Samsung have to gain from this alliance, and what they are doing to avoid a repeat of the earlier missteps.

In its prior efforts with Intergraph and Hewlett-Packard, Samsung licensed "also-ran" architectures that had failed to gain acceptance beyond a narrow user community and that therefore attracted relatively small bases of applications software. The availability of applications software has proven to be *the* barrier to mass-market acceptance for all architectures except x86, 68000, and PowerPC. The CLIPPER and PA-RISC products depended on UNIX-based software environments; in 25 years of trying, UNIX has never been able to capture more than a small fraction of the overall computer market. The earlier ill-fated ventures also gave Samsung valuable lessons in the difference between selling "commodity" semiconductors like DRAMs and proprietary chips like microprocessors; the latter require a far more sophisticated sales and support structure.

This time around, Samsung is licensing the second most popular architecture in the small but rapidly growing Windows NT market that already exceeds the UNIX market as measured by unit shipments. Further, Digital (alone among non-x86 MPU vendors) has recognized the need to run the installed base of x86 software and provides a new translation facility (FX!32) that lets customers run all x86/Windows NT applications at acceptable levels of performance. FX!32 will be distributed as a standard part of this summer's Windows NT 4.0 release but runs only on Alpha-based systems. The net of all this is that this time Samsung needs to focus on delivering a competitive chip but should not have to put too much effort into creating demand for the environment surrounding that chip. Instead, it can leave the demand creation to Bill Gates, who has demonstrated some ability in this regard in prior ventures. This is a *big* advantage.

Samsung indicates that its initial efforts will focus on high-end Windows NT/Alpha products. Digital's sales of Alpha-based servers have been aided immeasurably by the high performance levels 64-bit database applications achieve when executing on multigigabyte configurations. Given the 32MB memory granularity possible with current 64Mb DRAM technology, such servers must look very tempting to a company like Samsung. The company also indicates that it sees a market for Alpha chips in its consumer and communications product lines. This seems like more of a stretch—cell phones need to transmit at 800 MHz, but it is hard to imagine why they need to compute at 400 MHz.

This agreement also gives Samsung access to Digital's semiconductor manufacturing technology. Although it is certainly no slouch in this area (Samsung is shipping production versions of its 64Mb DRAM and sampling versions of a 256Mb device), DRAM manufacturing processes differ from those used for logic devices in many key regards. DRAMs require only two interconnect layers, while advanced MPUs need four or five; adding these extra layers has proven difficult for many producers, and the technology to do this cannot be purchased off the shelf. Digital developed a respectable salicide process, along with the chemical mechanical polishing (CMP) skills needed to implement three-layer and four-layer metal interconnect schemes. Samsung can use Digital's experience in this area to jump-start its own programs.

Digital certainly gains as well from this alliance. Although its Alpha architecture usually holds one of the top two positions with regard to computational performance, it lags with regard to market share and lags even more with regard to strategic partnerships. Few vendors can succeed on their own in today's rapidly evolving markets and technology. Until now, Digital has had to provide virtually all the muscle with regard to Alpha's architecture, production, and systems marketing. Once Samsung gets up to speed, we would expect it to share many of these burdens with Digital. Looking even further down the road, one can foresee a manufacturing partnership that allows Samsung and Digital to share the huge costs of moving to 0.28-micron process technology.

By Nathan Brookwood

Dataquest ALERT

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Worldwide Microcomponents Market Grew 33 Percent to $34.3 Billion in 1995

Dataquest's preliminary look at the 1995 microcomponents market, which includes microprocessors, microcontrollers, microperipherals, and digital signal processors, shows the market to have grown to $34.3 billion, a 33 percent increase in revenue over 1994. This remarkable microcomponents growth outpaced last year's 29.7 percent growth and was surpassed this year only by the incredible 66 percent growth experienced in the memory market. Overall semiconductor consumption grew 40 percent in 1995. Last year, memory suppliers generally grew faster than broadline semiconductor suppliers concentrating in microcomponents.

Microprocessors and digital signal processors (DSPs) made small, almost imperceptible, gains in share against the microperipherals and microcontroller market segments. Similarly, vendors based in Europe and Asia/Pacific appear to have gained slightly in this category at the expense of vendors in Japan. It would be risky to read too much into such shifts before the publication of final market share figures later this spring. Table 1 shows the 1995 market shares by product category, as compared with 1994 shares, and Table 2 shows market share by vendor region of origin.

Table 1

Worldwide Microcomponent Market Revenue—Preliminary (Millions of U.S. Dollars)

Market Segment	1994 Market Share (%)	1995 Market Share (%)	1994 Revenue	1995 Revenue	Growth (%) 1994-1995
Microprocessors	44.2	45.0	11,436	15,431	35
Microcontrollers	29.1	28.7	7,517	9,860	31
Microperipherals	22.7	21.6	5,885	7,406	26
DSPs	4.0	4.7	1,030	1,608	56
All Microcomponents	100.0	100.0	25,868	34,305	33

Source: Dataquest, January 1996

Dataquest

Perspective

Embedded Microcomponents Worldwide

Market Analysis

Digital Signal Processors—A Brilliant Light in an Overcast Year

Abstract: *Digital signal processors (DSPs) are wonders of embedded microcomponents that adapt and control real-world, real-time signals with the consistency and precision that digital electronics can afford. With the boon in communications that will continue well into the new millennium, DSPs, which are at the heart of most electronic communications, will outshine most other semiconductor categories in terms of growth—in a tough 1996, as well as in the foreseeable future. This review presents forecast data and highlights some of the participants in the programmable DSP market.*
By Tom Starnes

A Spot of Growth in Gloomy Semiconductors

Generally, semiconductors in 1996 have had a gloomy year, with anticipation of a 9 percent drop in revenue compared with 1995. DRAMs led the decline by taking a beating on prices while having to keep production volumes up. Embedded microcomponents in general are slightly positive, with the microprocessors going into the CPU slot in the PC continuing on a high teens growth curve. A second, even higher growth area in microcomponents is the digital signal processor (DSP). In fact, DSPs may have the highest growth in 1996 of any major semiconductor category. These remarkable products will show a 33.2 percent growth in 1996 compared to their 1995 revenue, which in itself was a whopping 62 percent improvement. The next four years are expected to continue to drive a dependable 30 percent growth rate for DSPs. There are relatively few vendors of these highly specialized processors, although elements of digital signal processing can be found in many products of other classifications.

Military applications drove presemiconductor development investigation of DSPs, but communications have driven the blossoming of DSP in the last

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decade. The use of DSP will continue to expand in the near future with applications in many other areas picking up the benefits of digital signal processing. With the constant emphasis on higher quality and faster transmission of voice, audio, picture, and video, the DSP is only just starting to show its face in the world.

Digital Signal Processing

Electrical signals that represent real-world, time-dependent events, such as sound, light, and vibration, can be captured or generated. These signals can then be filtered, mixed, and manipulated using complex mathematical transformations to improve, isolate, or alter the original event. This is considered signal processing. Signal processing can also generate or synthesize sound and images that have their source in electronics rather than the real world.

Voice signals can be compressed so that they consume less time or transmission bandwidth. Then they can be more efficiently transmitted long distances where eventually they are decompressed to almost the original voice sounds with unnoticeable degradation of the sound quality. This process may involve the removal of portions of the original sound that is imperceptible, masked, or insignificant to the listener, which can be determined with a thorough understanding of all aspects of the natural transmission of the signal, the human hearing mechanism and process, and the intention of the signal. This is one example of signal processing.

This signal processing can be performed different ways, but in the last two decades, digital processing of the signal has gained favor over analog processing, given digital's better stability and greater precision, coupled with the DSP chip's ever-increasing performance and ever-decreasing cost.

The mathematical algorithms used in digital signal processing vary, depending on the use of the signal information, but the concept is similar for all uses. Directional information may be important in video game sound, but not in telephone transmissions. The intensity of some frequencies can be minimized or readily reconstructed without noticeable degradation. Telephone conversation requires speaker recognition and distinguishable words, but nowhere near the fidelity of the soothing classical music coming over the stereo audio gear. Speech requires real-time processing, but prerecorded video can take a week to encode, as long as its reproduction is essentially instantaneous.

Applications

DSPs typically interface with the natural world and the signals found there, or are wrestling with complex signals to put more information in less space and time, and often are involved in both. The most common application of DSPs is in telecommunications. This includes data and voice communications. In the transmission portion of telecommunications, it doesn't matter what the bits represent—data, sound, or images—they simply need to be pushed down the wire (or fiber) and pulled off the wire accurately. In the original signal encoding and the eventual decoding, it is very important whether the signal represents data, voice, music, seismic information, still images, or moving pictures so that the terminating equipment can properly present the data.

The amount of digitized and transmitted information over the telephone network has grown phenomenally in recent years, with the boom in the use of telephony for commerce, information and data, and the tremendous growth of the computer communications via networks and modems. The enormous growth of cellular phones, especially digital cellular phones such as the Global System for Mobile Communications (GSM) in Europe, has contributed to the growth in DSPs. In digital cellular, DSPs perform voice coding in the handset, in addition to running the modem transmitting over the channel frequency in the handset as well as again in the base stations.

The huge growth of data communications out the back of the PC and over the telephone system has made the high-speed modem market blossom. The use of DSPs in the higher-speed modems has been an attractive market for the chips. The recent explosion on the World Wide Web has driven the need for even higher-speed modems in an insatiable demand for faster data. The result is greater and greater demands on the DSP, and higher and higher volume for the modems, with the replacement market obsoleting modems in spite of the fact that they are only a year or two old. It is no wonder that the DSP business is shining so brightly. These aren't just promises and visions of technology looking for optimistic future markets. This is reality—it's history—and it's going to continue.

There are two primary categories of DSPs: fixed-point (which would be called "integer" in most processors) and floating-point. Fixed-point DSPs typically utilize 16-bit data (though 20- and 24-bit data is used for higher resolution) to operate on most audio and motion processing. Floating-point DSPs have a dynamic range factor included in their 32 bits of data and so can better handle processing on visual images. In the overall market, 95 percent of the DSP revenue goes to fixed-point applications, even though prices on floating-point DSPs can be three to seven times higher. But these dynamics are changing as digitized images and motion pictures will emerge in the next few years.

The Programmable Digital Signal Processor Market

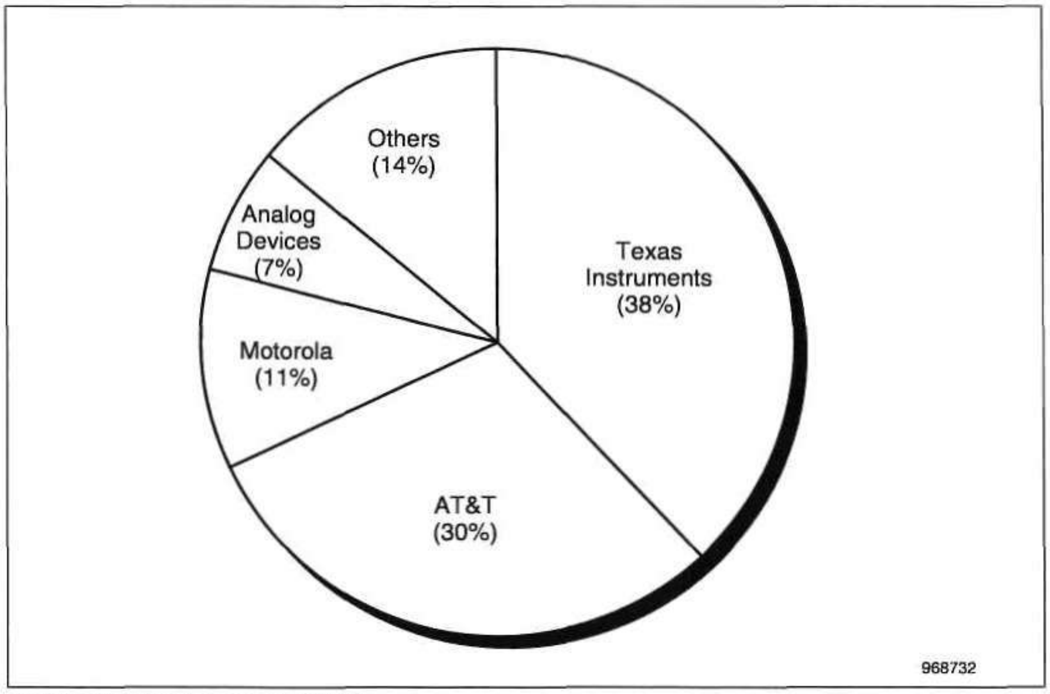
The year 1995 was a big one for programmable DSPs. The total consumption for programmable DSPs grew 62.1 percent to $1.67 billion. Only four major vendors served 86 percent of this market: Texas Instruments, AT&T (now Lucent Technologies), Motorola, and Analog Devices (see Table 1 and Figure 1). Two facts stand out about this group of companies—they are all based in the United States, and only Motorola is a significant microprocessor or microcontroller vendor. Some Japanese microcomponent vendors and Zilog have relatively small market presence in DSPs to make up the balance of the $1.67 billion business.

Table 1
1995 Digital Signal Processor Vendor Revenue
(Millions of U.S. Dollars)

	Revenue	Market Share
Texas Instruments	635	38
AT&T	510	30
Motorola	178	11
Analog Devices	117	7
Zilog	75	4
NEC	49	3
Fujitsu	46	3
Toshiba	28	2
Hitachi	13	1
IBM	10	1
Sanyo	10	1
GEC Plessey	7	
Matsushita	5	
OKI	3	
Total	1,686	

Source: Dataquest (December 1996)

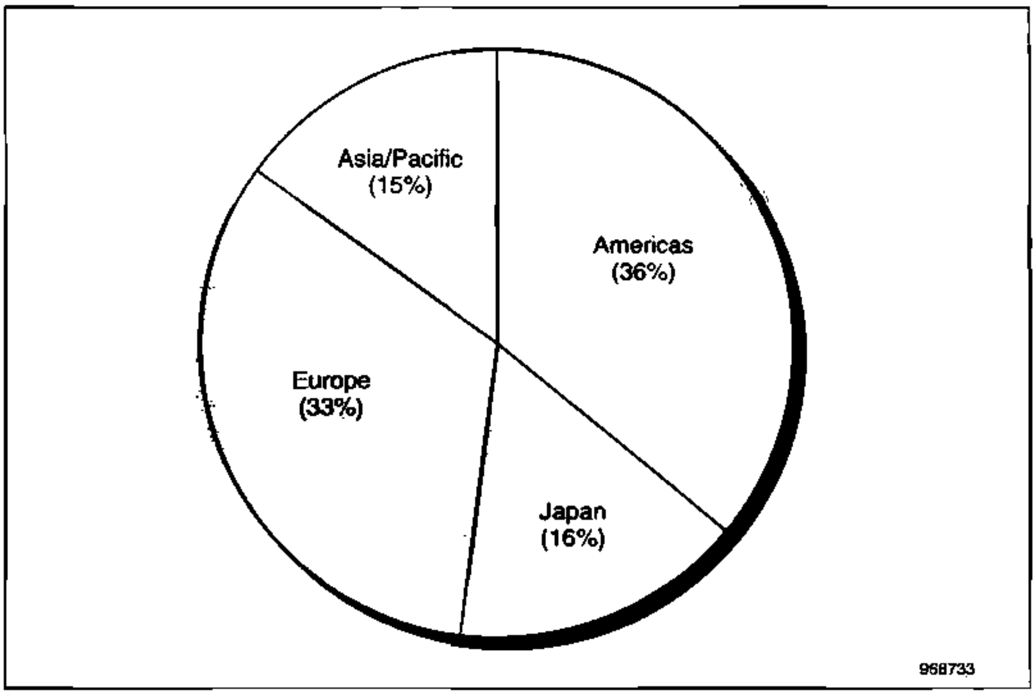
Figure 1
Market Share of the Major Digital Signal Processor Vendors



Source: Dataquest (December 1996)

As shown in Figure 2, about one-third of the DSPs are consumed in the Americas and one-third in Europe, with the final third evenly split between Japan and Asia/Pacific. Europe shows stronger in DSPs than it does for most semiconductors in part because of its early adaptation of GSM. This cellular telephone system is digital and requires digital signal processing for both the channel modem and to encode and decode the voice signal in the handset, generally resulting in two DSPs per cellular phone. Additionally, some very high-performance DSPs are back in the base stations handling their end of the transmission. When a conversation takes place over a GSM cellular system, six different DSPs could be running full bore to keep the conversation going. Every time the participants move to a new cell, another DSP would swap out in the base stations to keep up with the movement. And the cell phone users have probably never heard of a DSP.

Figure 2
Regional Consumption of Digital Signal Processors



Source: Dataquest (December 1996)

The Primary DSP Vendors

Each of the four primary programmable DSP vendors has a different company profile. TI is a major semiconductor vendor that has DSPs as its driving leading-edge logic product. Lucent (more so in the past as the larger AT&T) and Motorola are more vertical companies feeding a significant portion of their output to their internal system groups. Analog Devices is a smaller semiconductor vendor with a total company focus on DSP and its related technologies. A closer look at these four major DSP vendors follows.

Texas Instruments

Texas Instruments was the first to bring a monolithic DSP to the general marketplace in 1982, and has held a commanding lead over competitors ever since. TI has a broad range of programmable DSPs in the popular 320 series, ranging from under-$5 TMS320C200 16-bit DSPs to its C80 series of parallel processing floating-point DSPs that can produce over two billion operations a second.

Texas Instruments is a major semiconductor manufacturer and it is dedicated to digital signal processing like no other. TI has a moderate microcontroller business that is highly focused on the automotive market. In microprocessors, TI has dated many lovely women, but has never stayed married for very long. Last year, its 486 business faded to the background as the demand for 486s was overtaken by the Pentium. Most recently, it has engaged with Advanced RISC Machines Ltd. to market some Thumb-based microprocessors.

But for the size semiconductor manufacturer that TI is, it has had very little in the micro business—except for digital signal processors—and there TI is big. TI realized the significance of digital signal processing early on and foresaw the growth potential of DSP. This is unusual because TI does not have an internal equipment group that would consume any significant quantity of these highly specialized chips. The company must have also realized that to remain a major semiconductor vendor, it had to have a significant position in a sophisticated logic product line and its MPUs and MCUs weren't providing that. TI put its head down and methodically put its mind to dominating in DSP.

Texas Instruments has seven or eight product families to cover almost any price, performance, or feature need for a DSP. Each family has many different members, available in a number of speeds, with different memory configurations, and with varied peripherals. TI has 16-bit fixed-point DSPs, and 32-bit floating-point DSPs, and a program of customizable DSPs where a customer can select the right combination of DSP core processor, memory, peripherals, and package for a particular application. When the industry was booming and it was a suppliers' market, TI's focused efforts kept its on-time deliveries well above its competitors, earning long-term relations with its customers and winning some new ones from the other guys.

This year, Texas Instruments brought out flash ROM-based DSPs, announced an AV7000 series to handle the decoding of digital video for set-top boxes in a single chip (which also incorporates the ARM processor), introduced a DSP designed to control motors (large air conditioning motors or small disk drive motors), and purchased Tartan Inc., a third-party tool developer specializing in C and C++ compilers for DSPs.

Recently Tom Engibous, TI president and chief executive officer, has re-emphasized the corporation's strategic direction as being that of providing DSP solutions, with "solutions" referring to the total package, including the analog front ends, software to program the DSPs, and a thorough understanding of the application that the DSP will be running. This is the culmination of TI elevating its DSP success to be strategically more important to the entire corporation in recent years. TI is building a new fab in Dallas (DMOS 6), which will be primarily building DSPs on the 10,000 8-inch wafers it will initially produce a month. That's commitment!

Dataquest expects Texas Instruments to continue to dominate the market in DSP, relinquishing little of its 38 percent market share.

Lucent Technologies

AT&T and the Bell System were communications giants. Telecommunications was the rich market that nurtured the exotic signal processing theory into digital signal processing technology and products. AT&T had been designing digital signal processors of various sorts for many years to support its internal telecommunications, with many products being offered on the merchant market. This year AT&T spun off Lucent Technologies, with the microelectronics group comprised largely of the former AT&T Microelectronics.

AT&T's background and experience in all facets of digital signal processing is impressive. It should be, as DSP is a fundamental element of the telephone transmission system, present and future. Lucent inherited a great deal of this knowledge and certainly would know who to talk to for the rest. Lucent has very good analog and linear circuits to complement its DSP capability, and a thorough understanding of the standards, algorithms, and software that drive the DSP in telecommunications.

Lucent supplies most of the DSP chips to other Lucent organizations, AT&T companies and former organizations, and Baby Bells, but does not have all of those companies' DSP business. Lucent also has had a very effective program marketing its DSPs on the open market. Lucent focuses on major customers who will be leaders in their industry. Lucent's greatest success has been in the subscriber end of the cellular telephone market, but also are used on the network side. It currently focuses on PC multimedia, which includes products targeting high-speed modems, and consumer products with low-cost DSPs going into digital answering machines. Lucent also has a stake in DSPs in the disk storage market with some new products directed toward that voluminous market.

Lucent's DSP1600 family of programmable DSPs are 16-bit fixed-point (integer) digital signal processors designed primarily for one application or another in telecommunications. Lucent's 32-bit DSPs aren't seen much, but floating-point DSP is typically used for image processing rather than sound, and video doesn't seem to align much with Lucent's strategic direction. Customized or ASIC versions of DSP chips are available from Lucent for customers needing just the right combination of core MCU, DSP, peripherals, and memory.

Motorola

Motorola joined the DSP business around 1984 with an extended approach to DSP. Rather than the 16-bit data size that typifies communications signal processing, Motorola sought an advantage with a 24-bit data type. The extra

8 bits give Motorola's DSP56000 products the ability to operate on audio signals that are superior to what the human ear can distinguish, rather than the more limited 16-bit range that is only good enough so that a person can recognize the words and the person speaking on the other end of the phone. Although this makes Motorola's DSPs ideal for high-fidelity audio gear and true-to-life audio reproduction, as is found in the soundtrack of a movie, this market is small relative to the telecommunications business.

Even as PCs have been using digital signal processing to produce audio, much of this has been to liven up video games with beeps, bops, and booms (which 8-bit sound could handle). "Multimedia" has so far meant listening to a scratchy recording of JFK encouraging the Americans to go to the moon. For a PC to act as a telephone device (it needed to do no better than the original equipment). Thus, the 24-bit DSPs have a more limited market, even though they offer superior quality. Indeed, Motorola has recently reconfigured some of its 24-bit products to perform more like 16-bit DSPs (for more information, see the Dataquest Perspective "Searching for the Best of All Possible DSP Worlds," MCRO-WW-DP-9602).

Motorola did add a 16-bit DSP line a little later on, but has only a handful of options available, and has struggled to win external designs with it against the more focused competitors. Even designs within Motorola's own communications equipment groups do not appear to be assured, as essentially all of the other three DSP majors proudly announce their design-wins in Motorola cellular and pager operations. Motorola also has a 32-bit floating-point DSP96000 offering, but has laid low on emphasizing it in recent years. Motorola will have trouble holding on to its No. 3 position this year.

Analog Devices

The company name of Analog Devices is actually a good clue to the drive they have in DSPs. The critical function that most DSPs perform is to detect, shape, or enhance the analog signals that are present in the world around us. Analog Devices (ADI) grew up working with the precise control of analog signals, originally in the linear and analog world, and then the digital representations of them with analog-to-digital converters (ADC). Moving to the processing of those signals was a natural for Analog Devices, so that the company can provide more than just the signal acquisition function.

Analog Devices is dedicated to the entire signal processing system from data acquisition to conversion, to signal processing and algorithms, to control or output. As a billion-dollar company, Analog Devices is the smallest of the four companies highlighted here, and the one most dependent on its success in DSP, with about a quarter of its revenue coming from various forms of digital signal processing. This should provide the company great motivation to continue in its success.

For the DSP chips, Analog Devices markets a wide selection in its ADSP-2100 products. These DSPs operate on 16-bit fixed-point (integer) data but utilize 24-bit wide instructions. As with Motorola, the extra-wide instructions make a greater variety of operations available, resulting in fewer instructions to perform a given function, which ADI proclaims makes its "MIPS" more powerful than 16-bit competitors. There is some penalty to pay for this wider instruction word with minor increases in die size and a more complex external memory system to accommodate the wider program store. Analog Devices also has a fairly new 21 cps family of "concurrent" signal processors that make use of additional parallelism to more quickly operate on multiple pieces of data.

Analog Devices' SHARC (Super Harvard Architecture Computer) floating-point DSPs challenge the highest-performance DSPs with their parallel processing capability and their huge (2Mb) memory on-chip. In spite of some industry beliefs that there isn't much demand in the floating-point arena, Analog Devices has found this to be a very lucrative business with applications flocking to their door that need all the DSP MIPS they can get and that like loads of programming or data space.

Recently, Analog Devices licensed Hitachi's H8 microcontroller architecture for integration with ADI's DSPs for things like cellular telephones. ADI also has announced participation in a joint fab in Washington state to increase its capacity for producing DSPs.

Outlook

The outlook for DSP is very bright indeed. Even though digital signal processing assistance is becoming available in microcontrollers, microprocessors, peripheral circuits, and ASICs, the programmable DSP will continue to play a vital, continuing, and growing part of many new applications. This will result in a very large growth in DSP sales (see Table 2) in all regions, averaging a 32 percent compound annual growth rate (CAGR) through the year 2000, and reaching $6.7 billion worldwide. This compares to the entire semiconductor industry's forecast CAGR of only 13.9 percent. Admittedly, DSPs are only 1 percent of the total semiconductor revenue right now, but by the new millennium DSPs will double to be 2.3 percent of all semiconductors, so their impact in electronics will be significant.

The digital signal processing industry has been given a low profile in recent years while they quietly developed their exotic products, jockeying for some turf, and making significant progress in some key industries. But the

Table 2
Digital Signal Processor Regional Consumption Forecast (Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Worldwide	1,030	1,669	2,223	3,004	3,978	5,187	6,700	32.0
Americas	421	595	803	1,130	1,540	2,030	2,650	34.8
Japan	166	274	350	459	590	740	920	27.4
Europe	305	548	685	874	1,120	1,480	1,920	28.5
Asia/Pacific	138	252	385	541	728	937	1,210	36.9

Source: Dataquest (December 1996)

phenomenal success that products using DSPs have had in recent years has given DSPs a new level of recognition. Even though these products are "embedded" and the users rarely care what makes them tick, at some point they are popular enough that people are looking under the hood to find out.

Plus, now that the PC is so popular, but actually running out of things to do with all its performance, many more minds are looking for ways of expanding the PC's use. The recent "media engines" and multimedia extensions to the processors that run the PC and workstations are bringing additional light to digital signal processing, though they don't often use that term. Indeed, the fact that Intel, Sun, and others are starting to be interested in DSP techniques, oddly adds credence to what TI, AT&T, Analog Devices, and Motorola knew all along—that DSPs can provide an exciting level of capability to interfacing with the natural world in which we live and want to control.

The forecast for DSPs is very promising, in part because the technology is well-proven in today's applications and not just a lot of pipe dreams. The dreams are there as well, and will evolve as all futures do. Dataquest is forecasting a very aggressive growth in programmable DSPs, and some tempering of that could come later if the explosive growth in communications and PCs hits a wall, but right now that is not foreseen. DSPs look like a very bright light in our future, and a lively business for the vendors who have tackled the products.

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Perspective

Embedded Microcomponents Worldwide

Event Summary

Microcomponents Showcased at Electronica in Spite of Declining Semiconductor Support

Abstract: *The Electronica 1996 show, recently held in Munich, proved to have a cornucopia of new devices on view. Two areas in which there were a considerable number of new product introductions were microcontrollers and digital signal processors. Within both categories, there were general-purpose devices and core-derived application-specific standard products highlighting today's modular design methodology. This Perspective gives details of some of the more significant and interesting of these devices, both in the general-purpose application field and those addressing specific application problems.*
By Joe D'Elia

It's a somber reflection that the 1996 Electronica show, held in Munich, Germany, from November 12 through 15, is one of the last, if not the last, of the old-fashioned megashows focused on the electronic components industry. Another consideration is that this will be the last Electronica as we know it. The next time around, Electronica 1998 will be sporting a brand-new face as it moves to a custom-built showground on the site of Munich's old Rheim airport.

Although the show was busy, it is clear that major semiconductor companies continue to abandon it, with several more abstaining or downgrading their presence to a nominal representation on a distributor's stand. Among those not in their traditional places were LSI Logic, Hyundai, IBM, Altera, and Digital Equipment Corporation. Whether these companies chose to stay away because of budget constraints in a down year or whether they have decided that the show no longer satisfies their needs as they focus their attention on selling systems solutions rather than mere components is debatable. Certainly both reasons have been put forward, but the most

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worrying to the organizers must be the latter—this will continue to become a more compelling reason in the future as systems on silicon become the norm.

This report focuses on developments in the microcomponent arena and is the author's view of significant products launched or highlighted at the show. As always in these cases, it does not purport to be a complete representation of the show activities, only of those that caught our eye.

Microcomponents from Many Vendors

As always, there were many new additions to existing product families. Of particular interest in the European market were the number of new controller area network-enabled (CAN-enabled) derivatives of existing architectures from Siemens, Mitsubishi, and Motorola. Digital signal processor (DSP) and RISC cores were on offer from a variety of companies, one of the most interesting being the CoolRisc 88 from Centre Suisse d'Electonique et de Microtechnique SA (CSEM). This has an architecture and instruction set optimized for low-power applications, enabling the claim of a 5,000 MIPS/watt rating when running from a 3V supply. Another interesting device is the Hyperstone E1-32, which is a 32-bit processor that integrates DSP functionality in a RISC architecture. This core has been licensed by LG Semicon and is aimed at the telecommunications and data communications markets, where the combination of DSP and a performance MPU is often required.

Devices that specifically caught our attention are described below and are from a diverse range of suppliers, covering both general-purpose and application-specific devices.

Analog Devices Inc.

Analog Devices was featuring its new ADMC330 single-chip motor-controlling DSP. This is the first single-chip implementation of an AC motor controller using a DSP core as the main control block. Using Analog Devices' ADSP-2171 fixed-point DSP core, the device can run at 20 MHz and employs 24-bit instructions and 16-bit data. The device is aimed at high-volume applications such as washing machines and as such provides all the functionality to allow a complete control unit to be built with no other controller. Among its features are seven analog input channels and a 12-bit three-phase pulse-width modulation (PWM) generator. Should more functionality be required in a more upmarket application, then the device provides comprehensive communications channels to link to a control processor. Solidly aimed at the high-volume applications, the ADMC330 is priced at about $10 in quantities of 50,000.

Atmel Corporation

Atmel went over the top at Electronica by announcing two new families of RISC microcontrollers plus various additions to its existing AT89 family of 8-bit microcontrollers (MCUs). The two new families are the AT90 family of 8-bit devices and the AT91 family of 16-bit devices. The interesting thing about both of these families of devices is that both originate in Europe, with the AT90 designed in Norway and the AT91 in France.

AT90 AVR is Atmel's attempt to bring 8-bit MCU architecture into the 1990s. The device is a true register-based RISC architecture optimized to run C language programs with fast context switching so that it can run multiple threads. Features include 32 8-bit registers, and most instructions are a single-cycle, scalable design, which maintains code compatibility. Currently implemented in Atmel's 0.8-micron flash process, the devices can run at a maximum of 20 MHz. Optimized for running C, the devices should be able to run more compact code faster than competing 8-bit architectures, which date back 20 years in design.

The AT91 is a 16/32-bit microcontroller based on Advanced RISC Machine Ltd.'s ARM7TDMI core. This core is renowned for its extremely small size and its use of the Thumb's compressed 16-bit instruction set as well as the normal 32-bit ARM instruction set. As with all other ARM cores, it is also very frugal in its power consumption, making the AT91 devices extremely useful in portable, low-cost applications. As a key player in the flash and EEPROM market, Atmel will bring devices out of the chute with both types of memory incorporated as well as the normal complement of ROM and RAM. The devices use a highly modularized approach to integration, with the memory and core separated from the peripherals by the Advanced Microcontroller Bus Architecture (AMBA) bus. This enables derivatives to be introduced rapidly, as peripherals can easily be added or removed from the AMBA bus without impacting the main part of the device.

The on-chip flash and EEPROM memories are in-system programmable (ISP) using the industry-standard SPI bus, allowing the capability to download new software versions in the field or to use special test programs at final test before loading the final system software. The use of two instruction sets allows the optimization of code for either maximum performance or maximum code density. All on-chip memories are organized as 32-bit words and store either one ARM instruction or two Thumb instructions.

Fujitsu Ltd.

Another product designed in Europe is Fujitsu's Whispers Generic Control Processor, which is an integrated signal-processing system based on a 16-bit fixed-point DSP core that has all the analog peripherals on board to do analog-in-to-analog-out signal processing. The device is designed to replace complex analog filter functions through digital filtering techniques. Because of the low latency and extremely low power consumption, it is ideally suited for ambient noise reduction applications in mobile communications systems such as telephone handsets. Other feedback-based systems that depend on low latency in the feedback signal are ideal candidates for the Whisper device. Examples of this are high-speed motor control and phase-locked loops.

Mitsubishi Corporation

One of the more interesting new entries to the 16-bit MCU market is Mitsubishi's M16C family, which is a totally new design optimized for high-level language programming and high-speed processing, with integral electromagnetic interference (EMI) reduction circuitry and ROM program correction. This latter capability is a first for Mitsubishi and allows the user to correct up to two software bugs after going to mask. The M16C employs an address-matching interrupt that redirects program execution to bypass the faulty code, thereby minimizing debug time and avoiding the need for running a new mask, in many cases.

Other features include two interchangeable instruction sets optimized for either speed or functionality, sophisticated bit manipulation, and a large number of instructions that execute in a single cycle. The combination of these features allows the M16C to reduce code size to about half that of RISC devices while matching their performance.

Motorola Inc.

Motorola launched two significant derivatives of its existing microcontroller and microprocessor families. Both are aimed at the automotive marketplace, although each addresses very different requirements. The more interesting of the two is the 68HC805PV8. This 8-bit device incorporates Motorola's new Seamless Silicon Systems (S3) technology, which eliminates the need for external protective devices in the harsh automotive environment. First, the device has high-voltage and high-current protection on chip, which enables the devices to withstand automotive line voltages of 16V and load dump of 40V. This, together with a built-in 5V regulator, means that the device can be coupled directly to the car's wiring harness and battery without the external protection normally needed.

A common application of this class of controller is in power window mechanisms, where in the past the controller and associated protection components were mounted on a separate board near the window lift motor. With this new device, the controller can now be mounted directly in the motor, minimizing system cost by removing extra wiring harnesses. As well as having 8KB of flash memory, the device has 192 bytes of RAM and 128 bytes of EEPROM. ROM-based versions will follow in late 1997. The 5V regulator has high- and low-voltage resets, plus being able to source 20mA to external devices. The peripheral complement on this device is truly impressive and includes a single-channel high-speed PWM, a six-channel 8-bit analog-to-digital converter (ADC), and a five-channel 16mA contact monitor, plus a two-channel 3-ohm line-side relay driver.

On the 32-bit front, Motorola has added CAN capability to its 68300 family of integrated devices. The first of these to incorporate Motorola's TouCAN module is the 68376. The 68376 is targeted at automotive applications such as automotive diagnostics, power train control, and other high-performance distributed control applications where the CAN capability is a necessity. The device is also targeted at the industrial market, where it is expected to find applications in automated manufacturing systems, banking machines, industrial control, and data logging systems. Key features of this device apart from the CAN module are the Time Processor Unit (TPU), which is an on-chip coprocessor with a microengine dedicated to complex timing tasks, the Configurable Timer Module (CTM) with various timers and PWM channels, the Queued Serial Module (QSM) enhanced serial communications interface, and the 10-bit Queued ADC (QADC).

Sharp Electronics Corporation

Sharp also announced an ARM-based product, the LH77790 integrated processor. This product is based on the 32-bit ARM7DI core and is very specifically targeted to portable electronic devices, such as portable data acquisition terminals, bar code readers, portable oscilloscopes, global positioning systems (GPS), mobile communications devices, and personal digital assistants (PDAs). To this end, the ARM7DI core has been surrounded by a comprehensive selection of suitable peripherals. Among these are a monochrome LCD controller with 1024 x 2048 pixel resolution, three universal asynchronous receiver/transmitters (UARTs), three PWM channels, hardware watchdog timer, infrared interface supporting IrDA/DASK protocols, 2KB onboard cache plus a separate 2KB SRAM, and a comprehensive complement of input/output (I/O) ports. As it is targeted at portable applications, the LH77790 has a comprehensive power management unit that allows software control of the clock frequency from halt to full speed. A choice of 5V or 3.3V power supplies allows the choice of maximum speed or maximum efficiency.

Siemens AG

Siemens launched the first three members of the SAB-C161 family of low-cost 16-bit microcontrollers. Using a derivative of the C166 RISC-like core, the new family is aimed at the high-end consumer, computer peripherals, communications, and industrial control markets. Siemens intends to develop a new 16-bit market where 8-bit units are at their limits of address range or processor and peripheral performance envelope. To do this, the company is aggressively pricing the devices to compete with existing 8-bit devices and has quoted a $3 price for high-volume applications. Although aimed at low-cost, competitive applications, the C161 does not skimp on features and manages to combine high processor performance (up to 8 MIPS) with high peripheral functionality and enhanced I/O subsystems.

As well as providing comprehensive hardware and software support through the current extensive set of tool partners Siemens is also making available a low-cost starter kit. Priced at DM 299, this includes evaluation hardware and software with compiler, monitor, assembler, and debugger, among others.

Texas Instruments Inc.

Texas Instruments had its usual plethora of DSP devices on display, but buried among all the standard parts was the TMS320AV7000 device family, which integrates all the network-independent processing power needed to manufacture a set-top box in one device. The device integrates an ARM 7TDMI core with its dual instruction sets, plus MPEG-2 video and MPEG audio decoders, an advanced graphics accelerator, and a comprehensive set of interfaces to external peripherals and memory. Also included is an IEEE-1394 interface for connecting the set-top box to other devices, such as a PC, or in future to provide direct digital video connectivity to digital televisions or video recorders and printers. Apart from the high functionality offered, one of the biggest differentiating features of these devices is the rich level of graphics formats supported. The device is offered with two versions of the Transport Packet modules: the TMS320AV7100, which is designed for digital satellite systems, and the TMS320AV7110, which is designed to support digital video broadcast.

Toshiba Corporation

The Automotive System LSI Department at Toshiba was exhibiting an interesting device that, while aimed specifically at in-car navigation systems, could also be used in PDAs and video games. The R3903F is based on Toshiba's R3900 MIPS core, which is an R3000A enhanced device for use in embedded applications. As well as all the usual timers, serial I/O, parallel I/O, and other peripherals needed for a complete system, the R3903F also has a complete graphics display controller, including color palette and DAC on board. The high level of integration on this device reduces a navigation system to the GPS front end plus the R3903F and three memory devices.

Dataquest Perspective

With the 16-bit-plus segment of the MCU market growing the fastest, it is not surprising that most of the new product introductions in the MCU segment at Electronica were of the 16- and 32-bit variety. This segment of the market is still wide open and has few constraints that make customers automatically select a 16-bit implementation of the MCU in their existing 8-bit applications. Many programs are now so complex that assembled code is no longer practical, and C compilers are used to get the product out on time. Without having to support legacy code, designers are free to look at new controllers using the best architecture, giving the optimum price/performance for their current application. With the code being written in C, and therefore portable, and with most families of devices being supported on various third-party development tools, designers are not committed to sticking with their newly chosen architecture for the next project should an alternative architecture give a better return. This factor has meant that a clear leader has not yet emerged among the existing 16/32-bit MCU devices and that there is still room for new products, as those showcased at Electronica demonstrated.

Although the 16-bit-plus MCU market is the fastest growing, the 8-bit market is still the biggest. The players in this field are well known, including Motorola, NEC, Siemens, Hitachi, Microchip, and Philips. While these vendors have continued innovating in this market, it has been mainly on the basis of adding more variants of a particular family, extending the performance envelope to keep devices competitive, adding flash/EEPROM on board, and other such tweaking of established architectures, some of which date back to the late 1970s. With this background, it was refreshing to see Atmel introduce a new 8-bit RISC architecture based on meeting today's needs, such as chip optimization to execute compiled C, and with no carryover of baggage from previous device families. Motorola's extension of its venerable 68HC05 family is also exciting, as the various protection features plus high drive capabilities will give this device family a well-needed midlife enhancement that will enable it to remain the low-end workhorse of the automotive and other industries.

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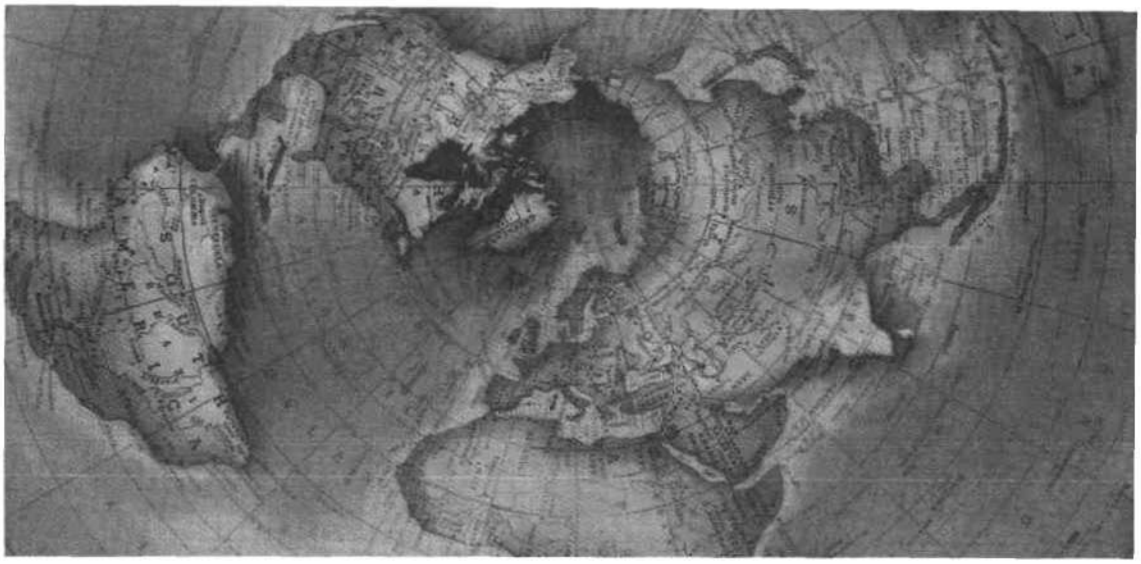

Perspective

Embedded Microcomponents Worldwide

Technology Analysis

Deeply Embedding Microprocessors with DRAM—A Great Marriage

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

By Tom Starnes

Typical Embedded System Design and Memory Selection

The design of the traditional embedded electronic system involves choosing a microprocessor from the selection available in the architecture that best accommodates the particular type of product being built, be it a laser printer, a set-top box, or a palm-size communicator. The best combination of peripheral circuits is determined by the interfaces, inputs, and outputs that the new product will make use of. Some serial communications, parallel input/output (I/O), timers, and direct memory access (DMA) peripherals might be picked.

The memory system must be configured to feed the instructions into the processor and to supply data to the programs at run time. The memory might consist of semiconductor products like read only memory (ROM) or it

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may involve a disk drive in larger systems. Static random-access memory (SRAM) will be used for the fastest parts of the memory system, especially in caches, but in most systems the largest portion of semiconductor memory will be dynamic random-access memory (DRAM). DRAM has the best combination of a low cost per bit with very good (but not the best) performance. This combination and selection of memory allows a cost-effective product to be built without serious compromise in performance. Traditionally the large DRAM memory has been a separate set of chips from the processor (see Figure 1), partly to give flexibility to the system designer to select the appropriate quantity of memory for the application, and partly to allow vendors to optimize the manufacture of the processor independent from the manufacture of the memory chips. DRAMs have been driven to constantly put the greatest number of bits possible on the chip for a price, now sitting at 16Mb, and this isn't always the best for embedded applications. (Note: Mb indicates megabits while MB indicates megabytes of memory.)

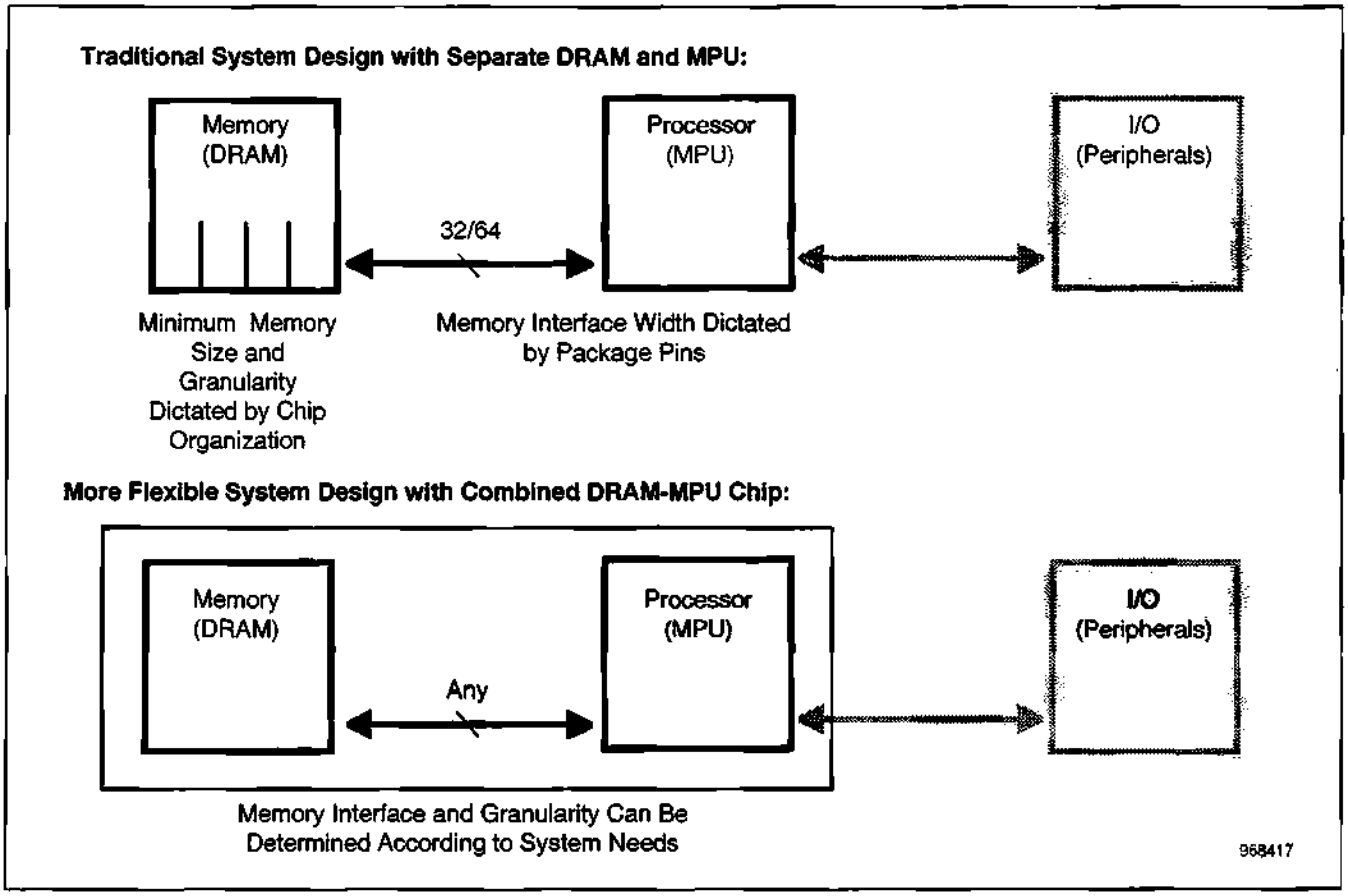
The PC's Influence on Memory

In recent years, the enormous popularity of the personal computer (PC) has caused the PC to become the primary driving force in the design, configuration, and sale of DRAMs. DRAMs are designed to provide an interface to the PC processor that will maximize the performance of the processor. When the 200-MHz Pentium Pro goes to memory, it doesn't want to be slowed down waiting for data. Extremely wide data paths with burst capabilities have been backed up with fast cache memories so that once the processor does go through the wait, it gets a truckload of data when it finally starts showing up. The depth of the memory chip is selected to be as big as possible considering the bit width, on an even power of two (2^x), that pushes the current technology to the optimum point. In 1996, this is moving to 2Mb by eight DRAMs. Eight of these are used in parallel to get the 64-bit wide data paths to the processor/cache. Doubling, tripling, and quadrupling the sets of DRAM feed the seemingly insatiable appetite of the PC or workstation with 32, 48, and 64MB of memory.

PCs consume huge quantities of DRAMs in today's markets. Entire fabs are dedicated to cranking out nothing but DRAMs to get the lowest cost. The yields in the fab for the precise combination of speed, grade, and configuration (width and depth) at a point in time determines the manufacturing cost of that DRAM. The ability to match that DRAM with the key central processor in PCs (and some nontechnical things called demand and competition) determines the selling price and ultimately the profit margin of the DRAM. The folks in the fab try to move the "sweet spot" of their processes to get the highest quantity of the most desirable speed and configuration of DRAM. Sometimes they lead the market, and sometimes they are behind the real demand.

PC central processors and many embedded processors have outpaced memory chips in terms of performance. Fine-tuning a processor memory interface with clock speeds of the processor versus nanoseconds of access

Figure 1
System Organization with and without Same-Chip DRAM-MPUs



Source: Dataquest (November 1996)

time in the memory is a careful balancing act where the engineer is trying to optimize performance for cost. A memory with access times that are just a little bit slower than the processor needs will incur a big penalty waiting for the next time the processor can take the data. It is similar to trying to get to a wedding on an airplane. If you just miss one plane's departure, you will have to wait until the next flight before you can continue, and you're bound to be late for the wedding, incurring the wrath of the bride and the in-laws.

The size of the most-available DRAM is driven by the PC market, of late. As the PC industry wants a higher speed or different configuration of DRAM, the people in the fab push for better yields on that specific part. Pricing is adjusted to generate demand for less desirable speeds and configurations that may be more readily manufactured to maximize the revenue of the total fab output. Woe be the poor embedded systems engineer who designed in a set of DRAMs that was popular with the PC designers a whole year ago. Once it is overrun and abandoned by the time-compressed PC junkies, manufacturing of the desired DRAM is left to scant few vendors limiting availability and halting enhancements. With competition reduced, price becomes what the market will bear, and the price begins to rise. System cost reduction or performance enhancement over time is limited by the fixed pricing and the static access times on the DRAM.

Frustrations of Embedded Design

Many embedded applications do not need the great quantity of memory that can be assembled in a minimal set of DRAMs. Take the example of the 2Mbx8 DRAMs fitted to a 32-bit wide embedded processor illustrated in Figure 2. Four of these chips are put side by side to feed 32 bits to the processor. This makes a minimal system of 2Mbx32 which yields an 8MB memory system. This is a huge bank of memory for most embedded applications, and it is only the minimum, determined by the width and depth of the individual memory chips. Going back to the wedding, what happens if the hotels only have guest rooms intended for four people? The individuals and couples wanting to spend the night have to pay for rooms with more space than they need. The embedded system designer figures out ways of using the excessive memory, but doesn't get the full value out of it. The couple attending the wedding might share their extra bed space, but they get Uncle Bob snoring through the night. Both situations are less desirable since they are matching the needs to the available resources rather than finding the resources to fit the needs.

The granularity of PC DRAM systems is typically much larger than what is needed in the embedded world. The embedded application designer has a choice of going to older, slower DRAMs to get a more appropriate size, but the price per bit for earlier generations of DRAM is significantly higher. If the embedded application needs only a wee bit more memory, the next increment of DRAM is in the same 8MB chunk. The family-of-five attending the wedding has to pay for two four-people rooms at the hotel. The cost of the memory system in an electronic product is not trivial, and running the price up in large increments can break a product's cost structure. Usually the product programmer is told to figure out how to make the system work in the smaller increment of memory, much as the family-of-five just takes a single hotel room and makes Junior sleep on the floor. The programmer and the kid on the pallet are equally happy.

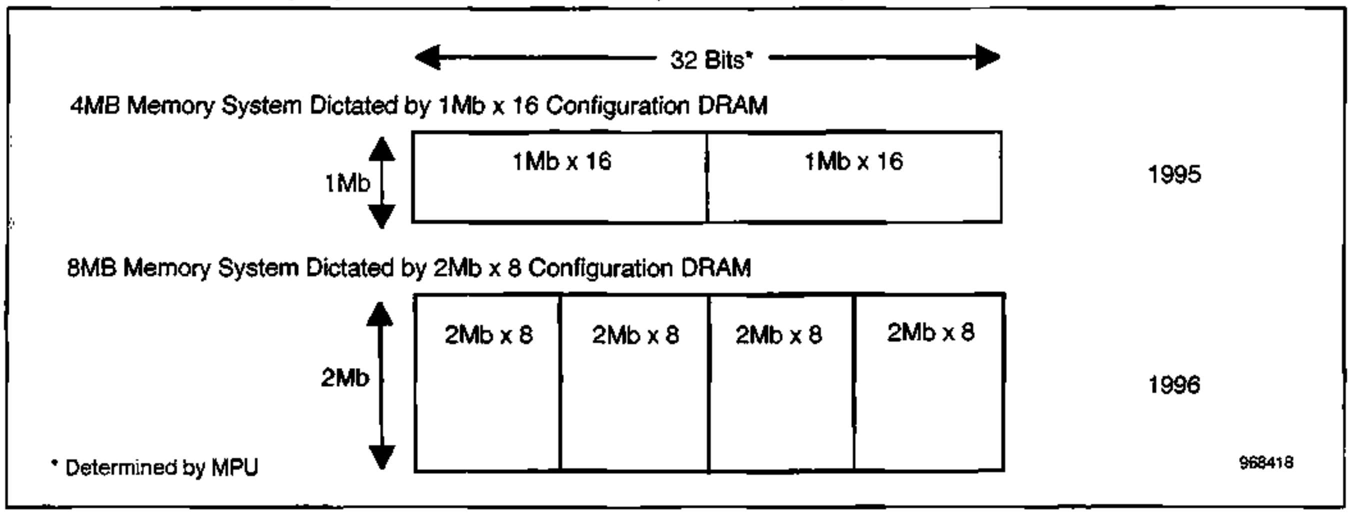
Another alternative would be for the system designer to use a wider 16Mb DRAM which would shrink the minimum system size and granularity. However, only Toshiba offers a 16Mb DRAM that is 32 bits wide, which would offer the designer a 2MB granularity.

Use of SRAM

Static RAM has the advantage of being significantly faster than DRAM (15nS versus 60nS), but does so at a very high cost. On a standalone SRAM chip, four transistors make up the typical SRAM memory cell, while six transistors are needed for the SRAM cell that is processed on the same chip as logic circuits like microprocessors. But just a single transistor makes up the DRAM cell in a DRAM chip—a four- or sixfold improvement. The higher packing density of DRAM is what provides a price advantage over SRAM.

When one looks at adding memory to processor chips, fast SRAM is attractive for caches, in part because it can be easily fabricated in the same process lines as the processor logic. If too much SRAM is put in a system then the father of the bride will complain about the cost of the wedding.

Figure 2
Minimum Memory System and Granularity Allowed by DRAM Choice



Source: Dataquest (November 1996)

DRAM, on the other hand, strives so hard for ever-lower cost with its high density that it uses very different techniques through the production line than what logic circuits use. The large caches put on the highest performance RISC processors dedicate the greater part of their die size to putting in caches that range from 64KB to 128KB (512Kb to 1Mb), which is large for SRAM, but small compared to available DRAM chips. If DRAM cells could be used, the density of this memory could quadruple.

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

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

Mitsubishi has been a significant player in the DRAM memory market for some years now. In 1995 it was the No. 9 supplier of DRAM to the world with over 5 percent market share (see Table 1). Mitsubishi has been sampling the larger 64Mb EDO DRAM and is looking for success in this next generation of DRAMs, which is expected to bear fruit in 1998. Mitsubishi has also been developing some exotic application-specific memories such as their CD-RAM, which blends cache SRAM and DRAM, and 3D-RAM, which adds special acceleration hardware to the cache and DRAM to speed up video graphic operations.

Table 1
Mitsubishi's Factory Revenue from Worldwide Shipments of Dynamic RAM (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995
DRAM	515	628	930	1,372	2,201

Source: Dataquest (November 1996)

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

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

The design of the M32R/D is well thought out with consideration for the advantage it has with its sizable on-chip DRAM, perhaps the beginning of what system and chip designers should be considering in their system layout.

Mitsubishi made a second, very important achievement in developing the M32R/D. It made a DRAM cell that can be processed on the same wafer, with much the same steps, as a typical logic (MPU or ASIC) production line, and it's as small as those that run in the usual fabs dedicated to processing DRAM (for the same process geometries). This is a very valuable technology. DRAM, as a library element available to microprocessor, microcontroller, or customer-designed ASIC developers, opens a whole new world of opportunities. Maybe Motorola would be interested in this.

Motorola's Established 68000 Family

Motorola's 68000 architecture is the leading microprocessor architecture for applications outside of DOS-based PCs. Last year, like many years before, the 68000 family was the No. 1 microprocessor architecture in embedded applications. Table 2 shows Motorola's 68000 family revenue over the past five years (the declining numbers are due to the changeover from the 68000 processors to the PowerPC in the Macintosh computers—not embedded applications).

Table 2
Motorola's Factory Revenue from Worldwide Shipments of 32-Bit Microprocessors (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995
32-Bit CISC (68000-Family)	363	428	685	561	479

Source: Dataquest (November 1996)

In the embedded microprocessor world, one of the most critical decision factors is a processor's support products that help an OEM design the microprocessor into its end products. The history and market share of a microprocessor determines just how much support may be available, whether it is development tools and languages or simply the ability of the OEM to hire qualified programmers with an intimate knowledge of the architecture. Motorola's 68000 has a huge advantage here.

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

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

Two Companies Engage to Get Things Really Rolling

In early 1996, Mitsubishi and Motorola got together to compare notes. In October, they announced their intention to work together to put microprocessor cores together with DRAM on a single chip. In the arrangement, Motorola will give their 68EC000 and the ColdFire core processors to Mitsubishi for use in customer-specific ASICs. In return, Mitsubishi will give Motorola their logic-processed-DRAM technology for use in integrated microprocessors and ASIC-type products as well as giving Motorola access to their new M32R processor core. Both companies are expected to market products with the 68EC000, ColdFire, and M32R core processor integrated with a set of peripheral circuits and an appropriate quantity of DRAM on a single piece of silicon. Mitsubishi may produce customer-specific devices, while Motorola may also produce standard products as a result of the exchange.

This is an exciting engagement for both Mitsubishi and Motorola, and the industry as well. It will change the way engineers design their electronic products. Now, engineers can get their hands on not just a processor and some peripherals but they can also bolt large (or small) quantities of DRAM onto their own unique chip—just the right size of DRAM. There are many advantages: fewer chips, fewer solder joints, smaller packages, lower power consumption, less excess. Plus they can use their favorite processor architecture with all the support and tools that they're used to. This is an idea that could really take off.

If an application needed a fast 68000 processor and about half a megabyte of memory, Motorola or Mitsubishi could combine a ColdFire core processor, some peripheral circuits, and 512KB of DRAM on the chip. If additional performance was needed, a special hardware accelerator could be added (for example, for graphics or signal processing). Perhaps a 48-bit memory interface would speed up the accelerator, because that's closer to the natural size of the data operands, then the DRAM could be organized as 48 bits wide (refer to Figure 1). If some massively parallel operations were to take place and the data would be held in a large buffer, a 256-bit wide bus could connect a 256-bit wide DRAM block to the parallel accelerator. If the buffer needed to be a little bigger than 1MB, an additional 128KB block could be added with minimal die size increase. With on-chip memory there is much greater flexibility for adding memory or organizing the memory in the best way for the application, without doubling the cost of the expanded or reorganized memory, as might happen with external DRAM.

Applications of DRAM MPUs

Motorola was drawn to this arrangement through its new Imaging and Storage Division, made up largely of its earlier 68000 product groups. For years 68000 products have run the laser printer sitting alongside personal computers. In fact, they were integral to the birth of the entire desktop printer industry and nurtured the maturing of that infant industry. Most laser printers ship with about 1MB of memory on the formatter board, although they can use another 1MB to 2MB to accelerate PostScript processing. A laser printer can't be sold for $400 if it has $100 of memory in it—they have lots of metal and motors and fancy engines in the bill of material as well. If the formatter card had a new MPU-with-DRAM chip on it that included a half a megabyte of memory, the base model laser printer would have a controller that was smaller and less expensive. Additional imaging products that could make use of DRAM embedded with an MPU include Internet terminals, digital cameras, and scanners.

Many disk and tape drives use the 68000 architecture. Cost and integration are key factors in the selection of the processor for mass storage, two areas where Motorola does well. A disk drive needs some memory for buffering data, but doesn't need 2MB for that. Disk drives are under such price pressure that any savings in cost can be a big highlight in their end market or on their accountant's face.

Set-top boxes and multimedia processing systems are other applications that can benefit from the DRAM MPU. In these systems, high-performance memory systems are needed to keep up with the continuous flow of video and audio data, yet cost is an important factor, too. When a cable or telephone company has to pay for a box to be left at the customer premise, they will be far happier for that box to cost $400 rather than $500. Satellite receivers have shown to have a reasonable sales elasticity when the price for the base unit is lowered.

Other types of applications that could benefit from the DRAM MPU include those where space or power consumption are a concern. Personal digital assistants (PDAs) have struggled to meet their full potential, but are still a hot item. Battery life, capability, and size or form factors are all very key to the acceptance of these highly portable devices. People continue to look at expanded uses of cellular phones, pagers, and portable Web browsers that could also use thrifty, reasonable-size memory bolted to their processor.

The Power of Pins on the Package

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

Any time electrical signals must be driven from one chip to another, quite a bit of current is consumed. It multiplies linearly as the number of signals increases, and is worst when the signals must be driven to an array of chips as is typical with memories. A processor with enough on-chip DRAM doesn't need all the extra pins and power (battery drain) that are required for external memory accesses.

With every high-speed switched signal driven across a circuit board comes electrical noise. Higher voltage swings and longer traces make it worse. This noise is not only noticeable, but must be contained to meet FCC and similar regulatory agency standards. Eliminating or minimizing the distribution of signals off-chip will greatly reduce the noise they generate. When the DRAM is all on-chip, much lower voltage swings move data over much shorter and smaller spaces to accomplish the same work, minimizing power consumption and noise.

Nothing is free, of course. Fewer pins can affect testing of these chips. As it is, all of the tests typically done on DRAM would need to be performed on the embedded DRAM. Having fewer pins to access the DRAM could dramatically slow down the test procedure, and test time is extremely valuable (longer test time = greater cost). Also, all of the functionality of the microprocessor and peripheral circuits must be verified, and that will take its share of test time. Overall, one would expect test time to be about the same as or slightly longer than the sum of the time to test the standalone equivalent MPU and to test a similar-size DRAM.

The Value Proposition—Can Two Live as Cheaply as One?

The price competitiveness of the new DRAM MPUs may need some rationalization, and so could be a harder sell. The prime reason DRAMs are processed separately from logic is because this results in a much lower cost for the DRAM. Incredible volume on a single product is what drives the cost out of standalone DRAMs. Every time that volume is cut in half by adding another type of DRAM to the production, it impacts the cost of the original. When the DRAM is part of an MPU, especially when the MPU is customized for an application or customer, the volume of that MPU is severely limited compared to the standalone DRAM, and its cost cannot be as competitive.

Many applications that are not as constrained may be happy to pay for blocks of memory that may be excessive, but allow for sloppier software to be used, or that have room for growth or new features over time. With the model of the PC, many programmers and products have become used to staking out more room than is needed because the memory manager was set up for powers of two, or just to make sure the space is there if they end up wanting it. Sleeping alone in a hotel room that is made for four isn't unpleasant, and can even be considered luxurious. It's certainly more comfortable than having to contend with too little room.

Pricing of DRAM MPUs could be tricky and may go through some transitions early on. The year 1996 showed everyone that standalone DRAM prices can go down quite radically. Most of the price decline is going to come out of the profits of the vendors in these circumstances, and much of the drop will bring DRAM down to the price curve that most semiconductors must live on anyway. Such drops do make standalone DRAM far more attractive in cost. A designer might not mind wasting half a DRAM if it costs half as much as it did last year; however, the boss might and that price can rocket back up just as quickly.

The 64Mb question is: "What value will the OEM place on a DRAM MPU?" Will it be the price of a DRAM + the price of the processor? Will it be the price of a DRAM + 20 percent for the processor? Will it be the price of the processor + three times more for the amount of the die taken up by the DRAM? Will it be the price of an equivalent size ASIC? Will the price change in step with the changes in the price of standalone DRAM? At introduction halfway through the 1996 DRAM price crash, the M32R/D was priced at $65 in 10,000-piece quantities for mid-1997 delivery. Well-integrated 68000 products without significant memory on them typically sell for well under $25. The vendors of these DRAM MPUs must establish in the mind of their users a proper value of the technology, intellectual property, convenience, and conservation embodied in their products. Otherwise they will suffer from having the customer set its value as a simple multiplier of the transistor count, which would rob the vendors of the products' true value.

Each Partner Is Better after the Marriage

Mitsubishi has a healthy DRAM business, a healthy microcontroller business, and a small microprocessor business. Mitsubishi is a Japanese company with natural connections with the Japanese OEMs. Motorola has a healthy microprocessor business and a robust microcontroller business. Motorola's 1.5 percent of the DRAM market is supplied through a joint venture with Toshiba. Mitsubishi developed a competitive DRAM cell that can be processed on the logic fab lines and proved it in with its combination DRAM-MPU chip. Motorola has the No. 1 integrated MPU architecture for embedded systems, but has no DRAM module. The two companies get married with the intention of producing beautiful children, though not necessarily together.

Mitsubishi gains access to a very successful, established microprocessor architecture. It can make chips with the 68EC000 or the ColdFire core processor on them along with peripheral modules and as much DRAM as a customer wants (up to the manufacturable die size) and sell customized products to its customers. Japanese OEMs might feel more comfortable working on a customized microcomponent with a company close at hand, providing strong local support. Mitsubishi will pursue their desired markets and customers that they serve well with other products.

Motorola has a significant new piece in its integration puzzle. Already Motorola can combine 68000, 68020, and ColdFire core processors with caches and a variety of peripheral modules, some of which contain processor elements themselves. Now it can also offer the M32R/D core processor, although that is not expected to have a strong calling. More importantly, Motorola will now be able to add just the right amount of DRAM onto those chips so the system designer doesn't have to buy any separate DRAM chips. Motorola can offer these as catalog parts, or make them especially for a particular customer or market. (The DRAM technology cannot be used by Motorola's memory chip operations.) Each company may or may not find competition directly from the other at their customers.

Both companies have the opportunity to further capitalize on the new technology. Mitsubishi is ahead of Motorola in taking advantage of the on-chip memory as it already designed the M32R/D to improve its throughput using a very wide bus between the caches and the DRAM. The next step could be to open up the processor architecture to take advantage of the very wide buses that are now possible. For years, DSPs have been designed with parallel memory structures to maximize their processing of unique data types and algorithms. With multimedia and video data peaking over the horizon, large quantities of even wide on-chip data types could be more quickly processed by specially designed processors or accelerators. Perhaps the 68000 architecture could gain another step of performance with more parallel processing of its instructions and data, yet still retain valuable compatibility. These issues, which the designers at Motorola and Mitsubishi need to study and act upon, raise interesting possibilities.

Of course, OEMs win, too. With appropriate unit volumes, a customer can configure their own special integrated processor that optimizes the data size, bus width, memory size, performance, power consumption, and price for their particular application. Customers can request that Mitsubishi or Motorola pull the part together and manufacture it, whichever provides the best options. Maybe one of them will have an off-the-shelf part that fits the bill. Either way the OEM can open its mind a bit more now and fine-tune its system design using customized DRAM MPUs to meet its specific application needs.

It's a New Way to Design

The announcement by Mitsubishi and Motorola adds new excitement to the concept of deeply embedding a microprocessor in DRAM, and greatly improves its chances for success. Mitsubishi and Motorola are actually breaking the mold of how engineers can think about system design, giving them a better selection of parts with which to build their equipment. Each company now has lots of memory to put on its customized MPUs. There will be refinements in the processor interfaces, the semiconductor processes, and the way the OEM designs systems, now that some traditional bottlenecks and constraints are removed from the designers' path. Watch for interesting developments in the next few years from vendors with MPUs with on-chip DRAM and from OEMs using them creatively to enhance their system designs.

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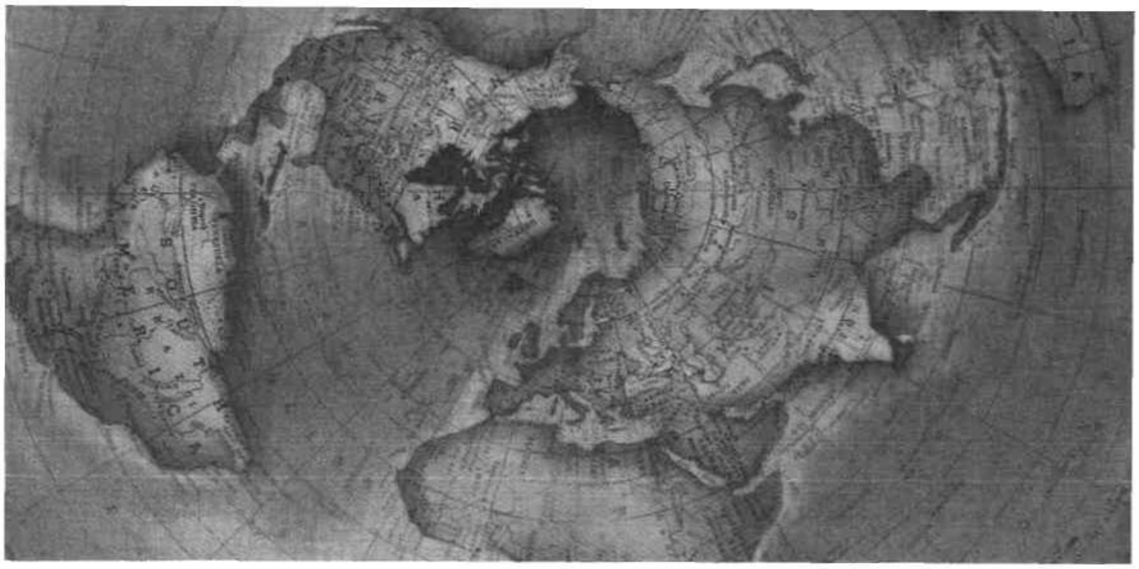

Embedded Microcomponents Worldwide

Dataquest Predicts

Good News: Microprocessor Market to Grow 18 Percent per Year through the Year 2000

Abstract: *Dataquest has updated its microprocessor forecast through the year 2000. This detailed forecast has been released to clients of the Embedded Microcomponents Worldwide program as* Microprocessor Forecast and Embedded Microprocessor Trends through the Year 2000 *(MCRO-WW-MT-9602) and to clients of the Semiconductor Directions in PCs and PC Multimedia Worldwide program as* Compute Microprocessor Market Trends and Forecast *(PSAM-WW-MT-9604). This Perspective summarizes the key points of the two detailed forecasts. Dataquest will also hold a telebriefing on October 21 at 11:00 a.m. PDT to further discuss the microprocessor forecast. Details on the telebriefing will follow.*
By Nathan Brookwood and Tom Starnes

Dataquest's detailed microprocessor forecast through the year 2000 has been updated and released to clients of the Embedded Microcomponents Worldwide program as *Microprocessor Forecast and Embedded Microprocessor Trends through the Year 2000* (MCRO-WW-MT-9602) and to clients of the Semiconductor Directions in PCs and PC Multimedia Worldwide program as *Compute Microprocessor Market Trends and Forecast* (PSAM-WW-MT-9604).

The good news is that we anticipate that this segment will show continual growth in unit shipments and sales for each of the next five years and anticipate no downturns in either unit shipments or sales in the foreseeable future. Microprocessor sales will grow slightly faster than the overall semiconductor market during this period and will account for \$0.10 out of every \$1 spent on semiconductors in the year 2000, up from \$0.094 today. MPU sales will total \$29 billion at the turn of the century, up from \$14.3 billion in 1995. Table 1 provides Dataquest's estimates for the size of the microprocessor market, measured in both units and revenue, from 1994 to the year 2000.

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Table 1
Microprocessor Units and Revenue

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	191,437	236,066	249,858	278,955	318,077	362,700	417,529	12
ASP ($)	61	61	69	74	77	80	81	6
Revenue ($)	11,603,980	14,465,398	17,123,198	20,643,664	24,611,221	29,022,426	33,690,948	18

Source: Dataquest (October 1996)

Dataquest measures the processor market by CISC and RISC architectures and also by computational and embedded applications. The *computational CISC segment* accounted for 80 percent of all microprocessor revenue in 1995 but only 28 percent of the units and included 486, Pentium, Pentium Pro, and Pentium clones from Advanced Micro Devices, Cyrix, IBM, and Texas Instruments. The good news is that Dataquest expects this segment to continue as the most profitable single category in the entire semiconductor market. We anticipate that it will grow by 19 percent per year from $11.5 billion in 1995 to $29 billion by the year 2000. A pot of gold awaits any vendor able to achieve success in this market. The bad news is that a dragon named Intel stands watch over this pot of gold, and any contender must first defeat, or at least distract, the dragon before removing any of the gold. This has proven to be a formidable task.

The *computational RISC market* rewarded successful participants with above-average selling prices and gross margins, but it was far smaller than the compute CISC category and only accounted for 2 percent of MPU units and 8 percent of MPU revenue in 1995. Dataquest anticipates only modest growth in revenue, from $1.1 billion to $1.5 billion, in this category over the next five years. The good news is that the average selling prices (ASPs) in this category ($227 in 1995) actually exceeded ASPs in the corresponding CISC category, at $173. The bad news is that ASPs are falling for the RISC category and rising for the CISC compute devices. Dataquest anticipates that these ASPs will meet in 1998 at about $195. More bad news: Although this category has grown rapidly over the past three years, as Apple transitioned its Macintosh base from the 68000 CISC architecture to the PowerPC RISC design, growth will slow following the completion of this transition in 1996. Even more bad news: Although the Intel dragon resides in the CISC segment, smoke and ashes from its fiery breath occasionally drift into this sector and may inadvertently affect the health of its participants.

The *embedded CISC market* consisted of a variety of low-end x86 and 68000 devices and accounted for 142.3 million units, the majority (60 percent) of all 1995 MPU unit shipments. ASPs in this segment were far lower than in computational applications; consequently, this large unit volume represented only 8 percent of microprocessor revenue. Motorola dominates this segment with countless varieties of its 68000-based products, sold with and without integrated peripherals, that address a wide range of cost, performance, and functionality requirements. The good news is that Dataquest expects revenue in this segment to grow slightly faster than that of the embedded RISC segment, from $1.16 billion in 1995 to almost $2 billion in five years, on a 13 percent growth (per year) in unit shipments.

Dataquest expects the *embedded RISC market* to grow dramatically from 22.2 million units valued at $650 million in 1995 to 65.8 million units worth $1.3 billion by the turn of the century. This growth will be driven by a need for increased computing power in a variety of everyday devices, from automobile engines, which might soon be measured in mips rather than horsepower, to video games, office machines, and a never-ending variety of handheld devices and mobile communicators. In 1995 and again in 1996, Dataquest expects video games to consume the lion's share of these devices, and this will drive the proliferation of the MIPS-architecture-compatible devices that are used in the Nintendo 64 and Sony PlayStation. The bad news is that the video game market has proven a fickle one, and an architecture's success in one game generation has yet to lead to a successful follow-on design around the same chip architecture. Unlike computational vendors that are, in effect, wedded to their chip suppliers, game vendors tend to play around.

Two Forecasts Are Better than One

In 1996, Dataquest divided its former microcomponents program into two programs. The new Semiconductor Directions in PCs and PC Multimedia Worldwide program addresses all the major semiconductor categories that contribute to contemporary PCs, including microprocessors, graphics, audio, and core logic devices. Embedded Microcomponents Worldwide addresses products of interest within embedded (that is, noncomputational) applications, including embedded microprocessors, microcontrollers, programmable digital signal processors, and microperipherals. These changes mirror the evolution of the microprocessor market, where vendors that once could ship the same devices into both computational and embedded applications must now design more specialized devices more closely tailored to the needs of the intended application segment. These changes allow Dataquest to create separate forecasts for microprocessor usage in these separate market segments, in which divergent forces and issues affect future sales.

Compute Microprocessor Forecast

Dataquest forecasts that the computational microprocessor market will grow at a compound rate of 19 percent, from 71.6 million units worth $12.7 billion in 1995 to 155.5 million units valued at $30.5 billion at the turn of the century. Compute microprocessors will garner over 90 percent of microprocessor revenue, although they account for less than half of unit shipments. Nice work if you can get it, but remember to watch out for the fire-breathing Intel dragon. Our computational forecast reflects the following key assumptions:

- Worldwide personal computer shipments will increase from 60 million, as measured by Dataquest in 1995, to 130 million in 2000.

- New applications will continue to drive demand for higher-performance systems, with most users upgrading their systems every two to three years. *The concept that demand for increased computing performance is essentially insatiable is central to the continued growth of the market.*
- Average selling prices (ASPs) for compute microprocessors will continue to inch upward as these devices incorporate more of the functions previously handled by separate chips within the computing system.
- A major shift from Pentium-based systems to Pentium Pro-based systems will begin in 1997 and continue for at least two years.
- Intel will introduce its P7 (Merced) design late in 1998, but this product will not proliferate until early in the next decade.
- The so-called "network computer" will end up having only limited markets and will not seriously impact PC market growth during the forecast period.
- The Apple Macintosh line will grow more slowly than the overall market and will lose market share as current customers defect to a Wintel platform while fewer Wintel customers migrate to Macintosh.
- UNIX-based systems from Sun Microsystems, Silicon Graphics Inc., and IBM will grow more slowly than the overall market and will lose market share as current customers defect to a Wintel platform while fewer Wintel customers migrate to UNIX platforms.

Embedded Microprocessor Forecast

Dataquest forecasts that the embedded microprocessor market will grow at a compound rate of 12 percent, from 165 million units worth $1.8 billion in 1995 to 262 million units valued at $3.2 billion at the turn of the century. The 68000 family will continue as the dominant architecture in embedded systems. Unlike the compute segment, which is effectively closed to new participants, the embedded market still contains opportunities for vendors that can offer an architecture that satisfies basic general requirements and features that provide superior support in specific applications. Our embedded forecast reflects the following key assumptions:

- The inventory correction and general slowdown in the embedded marketplace seen in early 1996 turns around in the second half and returns to "normal" buying levels.
- The x86 may emerge as a more significant architecture in embedded applications because of a carry-over effect from its utter dominance of the PC industry.
- The PowerPC architecture, driven by IBM and, more narrowly, by Motorola, experiences rapid growth in embedded applications.
- The RISC architectures that grew rapidly as a result of their use in video games will continue to grow, albeit at a lower rate, and will achieve additional significant design-wins, even if the primary customer jumps to another architecture for a next-generation game.

- At least some emerging or as-yet-unproven markets and applications, including personal digital assistants, digital cameras, and set-top boxes, will achieve commercial success and drive unit volume growth in the latter part of the decade.

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Perspective

Embedded Microcomponents Worldwide

Market Analysis

Japan's Embedded Microcomponent Market: Promise and Challenge

Abstract: *MOS microcomponents are designed into a wide variety of consumer, peripheral, and communications applications. Many of these applications are designed in Japan, and Japanese vendors do an excellent job of serving them. This article analyzes the five largest Japanese suppliers of microcomponents and discusses recent market trends.*
By Satoru Oyama

The Embedded MOS Microcomponent Market and Applications

Some of the major application markets for embedded microcomponents are consumer equipment, led by audio and video equipment; computer peripherals, including storage and printers; and communications equipment such as telephones. With few exceptions, MOS microcomponents used for this equipment are dominated by low-end 4-bit and 8-bit microcontrollers (MCUs) in Japan, and the marketing channels are founded on long-term business relationships between vendors and users. Because new entrants are rarely seen, MCU manufacturers inhabit a fairly comfortable marketplace where market share changes slowly.

Now, however, the growth center is shifting to the high-end segment, led by 16-bit and 32-bit devices. This market is still in an early stage of development, and market share constantly changes and there are frequent new entrants, in contrast to the calmness in the low-end segment. Also, high-end MCU implementation is no longer limited to the conventional single-chip configuration with internal ROM (a true microcontroller), and an increasing number of embedded microprocessors (MPUs) do not use ROM. Most

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commercially available 32-bit products are embedded MPU implementations, largely because of the need for accommodating an increasing size of embedded software running on the microcomponents. Software programs greater in size, ranging between 100KB and 500KB or more, are not easy to store in internal ROM without a significant increase in chip size and cost. Also, fixing large programs on the ROM leads to disadvantages in debugging, maintenance, and delivery schedules.

Japan's embedded MOS microcomponents market (MCUs and MPUs) is analyzed by bit size in the following sections.

The 4-Bit Market

The 4-bit MCU market is nearly monopolized by Japanese companies, with a minimal share being held by Korean companies. Moreover, it is increasingly concentrated in a handful of Japanese vendors, including NEC, because it is difficult to improve production efficiency for 4-bit MCUs for embedded software, and functional enhancement on the system side is prompting a demand shift to 8-bit products. In the future, 4-bit MCUs will be consumed mainly in a limited number of applications, including remote control units, calculators, and some household appliances (such as white goods).

The 8-Bit Market

Demand for 8-bit MCUs, which previously faced a declining trend, is now expanding rapidly. The 8-bit segment is a gravity center of the worldwide MCU market and is largest in terms of unit shipments, revenue, and number of participants. The market is, in effect, further partitioned into low-end products that accommodate upward demand shift from the 4-bit segment and high-end products that are one step below 16-bit products. In any case, competitive advantage is governed by the production and supply capacities of manufacturers. Traditionally, Motorola has been the market leader with a 30 percent share, but accelerated market expansion similar to that experienced by DRAMs has caused market share to move from a state of concentration to dispersion.

The 16-Bit Market

The growth rate of the 16-bit MCU market is about to outpace the 8-bit market's rate. Conventionally, the 16-bit device has been consumed mainly by rigid disk drives, with Intel leading most of the market. Since last year, however, the market has gone through a structural change and has become a battleground for several companies, including Japanese suppliers. Booming production of cellular phones has undoubtedly contributed to this. Increasingly, upgrades from the high-end 8-bit segment for PC peripherals and consumer equipment are spurring the market.

The 32-Bit Market

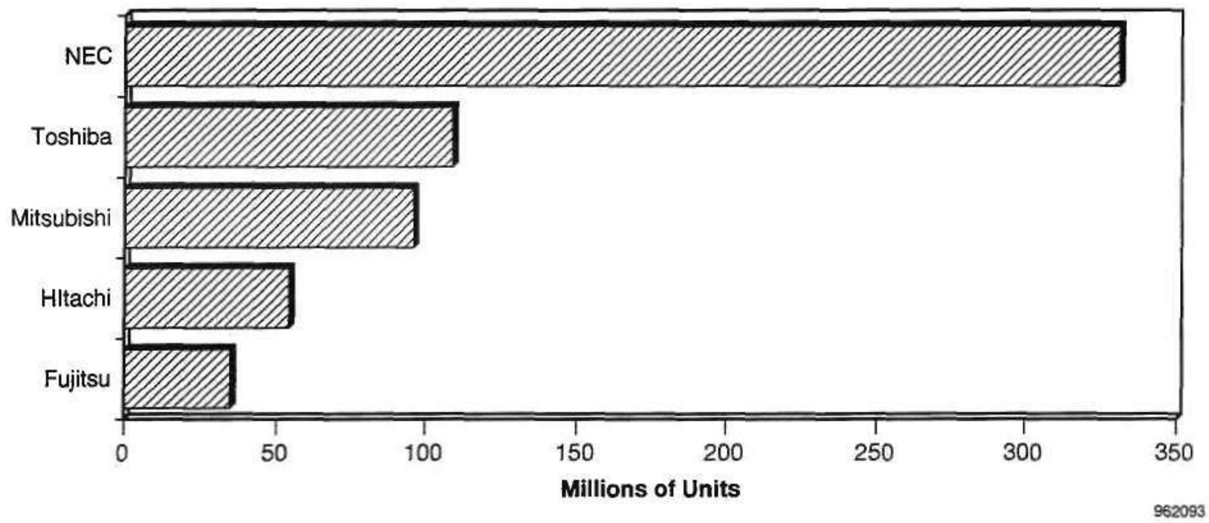
Still small, this market is notable for the emergence of embedded 32-bit microcomponents. Some application markets, including page printers and automotive engine controllers, have been early adopters of these parts. Demand for image processing applications in the consumer market, including video game systems, digital still cameras, and automotive navigation systems, has recently been on the rise. Although some of these applications can be accommodated in on-chip ROM, most favor the flexibility and larger memory spaces available from 32-bit microprocessor configurations.

These markets share a common element, the extremely heavy emphasis on software development and ASIC design environments, compared with smaller embedded microcomponents. The need for expertise in system design prohibits microcomponent manufacturers from relying solely on product specifications as the differentiating factor. This market in Japan is led by Hitachi, which has established leadership in high-end microcomponents, and LSI Logic, a leading ASIC supplier, indicating that the 32-bit microcomponent core in the ASIC development environment is becoming one of the survival tools for this market.

Comparative Analysis of the Big Five Japanese Vendors

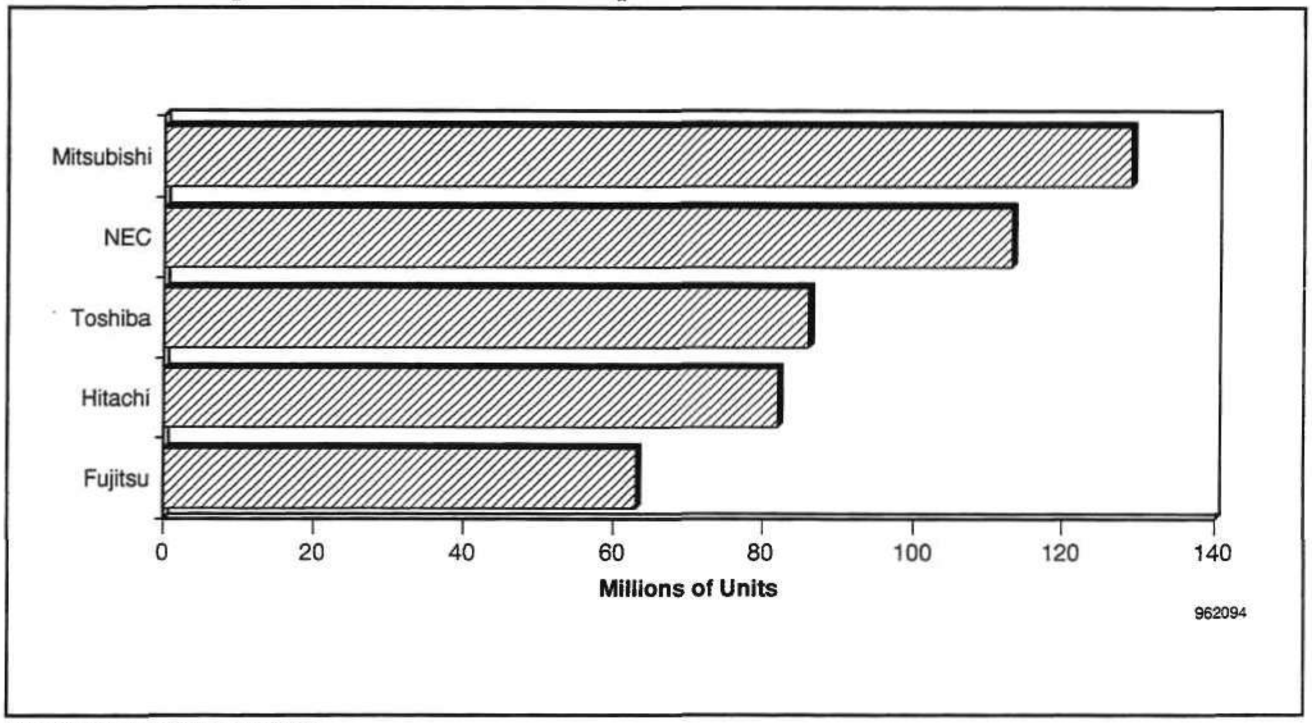
The worldwide microcomponents market seems to be the realm of Intel, which essentially dominates the PC MPU market. Looking at the embedded microcomponent market reveals a different picture, however: Japanese companies hold a majority of worldwide market share. The Japanese market is the largest in size and sets the pace for the rest of the world. Figures 1 through 4 compare leading Japanese suppliers' unit shipments of embedded microcomponents by bit size. Five leading Japanese companies, NEC, Hitachi, Mitsubishi, Toshiba, and Fujitsu, are analyzed in the following sections, with a focus on their microcomponents strategies.

Figure 1
Worldwide Shipments of 4-Bit Microcomponents in 1995



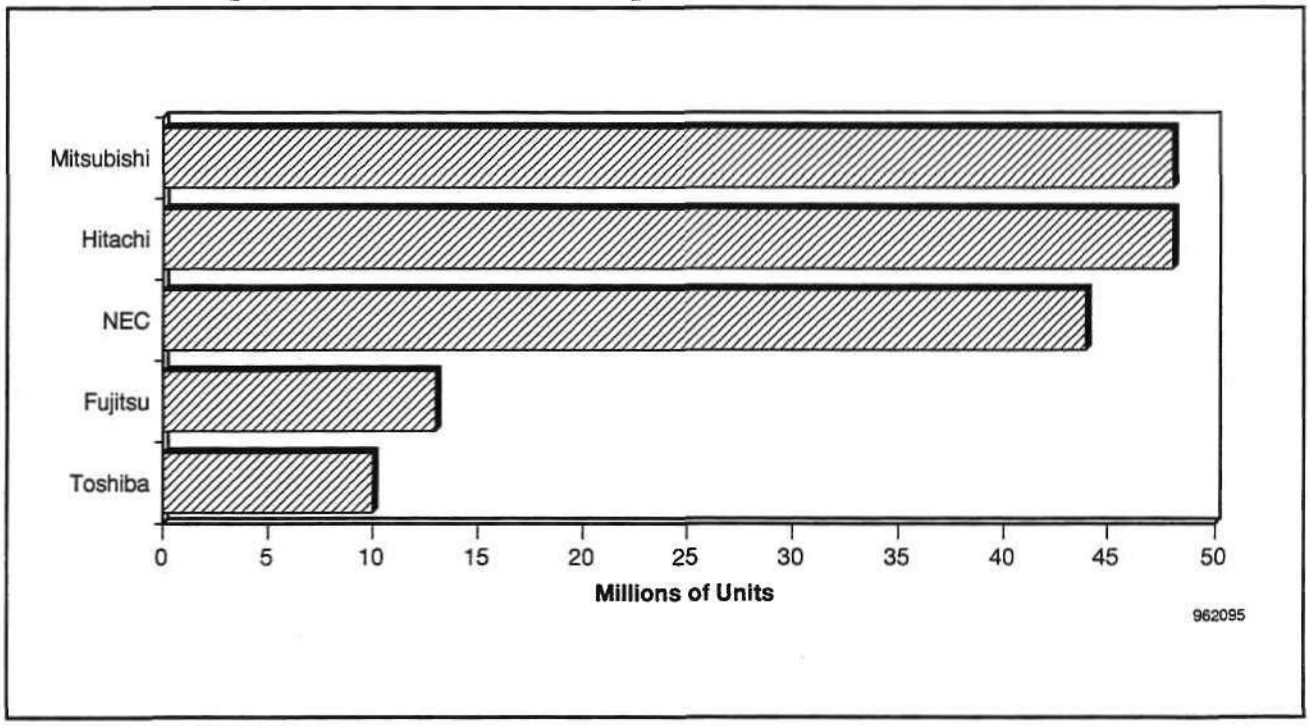
Source: Dataquest (August 1996)

Figure 2
Worldwide Shipments of 8-Bit Microcomponents in 1995



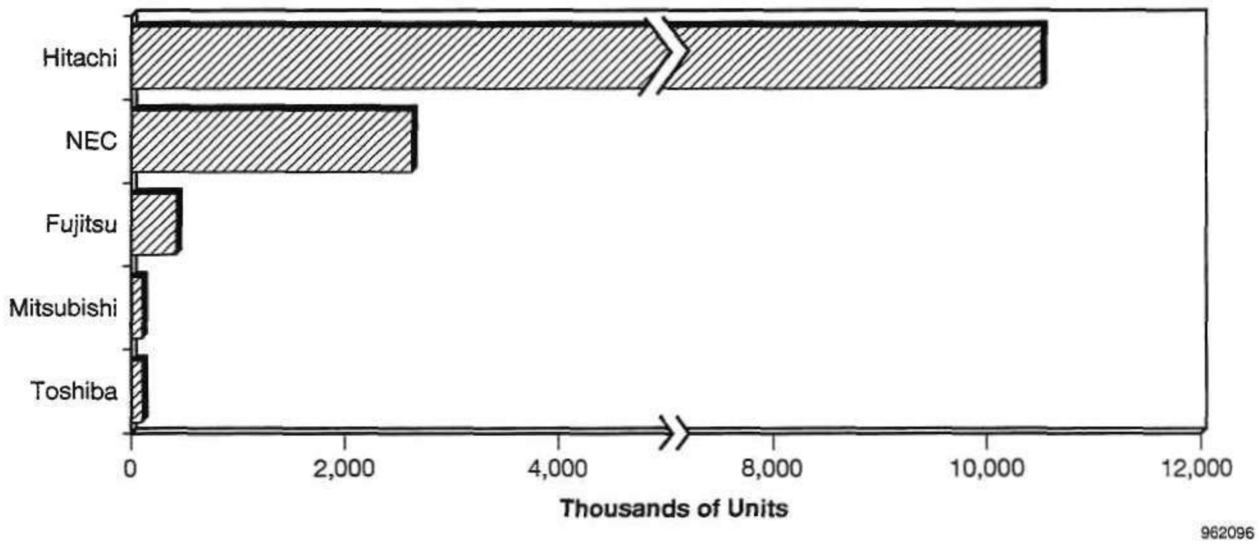
Source: Dataquest (August 1996)

Figure 3
Worldwide Shipments of 16-Bit Microcomponents in 1995



Source: Dataquest (August 1996)

Figure 4
Worldwide Shipments of 32-Bit Microcomponents in 1995



Source: Dataquest (August 1996)

NEC

NEC is the leading vendor among Japanese competitors, both in terms of unit shipments and revenue. It boasts 4-bit shipments of over 300 million units, for 30 percent or more of the worldwide market, but it shows some weaknesses in the 16-bit or higher segment.

Until 1993, NEC was far ahead of other Japanese companies in the 16-bit market. However, the company continued to rely on a single application market—rigid disk drives, accounting for more than 60 percent of the total—and failed to explore new market opportunities. NEC is now in the third place, after Hitachi and Mitsubishi Electric, in unit shipments of 16-bit parts.

In the 32-bit segment, the company allowed Hitachi to take the lead. Because both companies have taken steps to enter the video game market, targeting image processing applications, NEC must follow in Hitachi's footsteps for the time being. What will determine success in the 32-bit market is the ability to implement a strategy to integrate individual microcomponent technology with design of peripheral features in the ASIC environment. NEC, which leads the worldwide ASIC market, stands a good chance of succeeding.

Hitachi

Compared with NEC and Mitsubishi, Hitachi is a relative newcomer in the microcomponents business, which is reflected in the company's larger proportion of high-end products.

Hitachi's microcomponents business recorded dramatic growth in 1994. Shipments of 16-bit products grew fivefold compared with the previous year, mainly going to the cellular phone market. Hitachi pulled ahead of

NEC to become the largest supplier among Japanese companies. It was quick to start volume shipments of 32-bit products—video game systems were the major market—and became the largest vendor worldwide in embedded versions. In 1995, Hitachi expanded its application markets for 32-bit MCUs to other image processing areas, including car navigation systems and digital still cameras.

Hitachi is a company that is steadily becoming more entrenched in the worldwide market, and it is difficult to find a significant weakness except for ASIC technology. The company needs to quickly reinforce a development environment for ASICs that add peripheral features to image processing equipment, its major target market.

Mitsubishi Electric

Mitsubishi Electric, like NEC, has been a bellwether of the Japanese microcomponents market. It always led NEC in unit shipments of 8-bit products, with strength in audiovisual equipment, particularly in video equipment.

The company has achieved notably rapid growth of 16-bit shipments in two years. After lagging behind Hitachi in 1994, it exceeded this powerful competitor in unit shipments in 1995 and gained the top position. In the process, applications expanded from the conventional market—rigid disk drives and other electronic data processing (EDP) equipment—to include video and other consumer equipment.

However, the company is well behind Hitachi and NEC in the 32-bit market and is struggling to catch up with them. While Mitsubishi Electric's two competitors have a springboard for volume production, the video game market, Mitsubishi Electric has yet to find a principal application market it can count on. Unless target application markets are narrowed down, the company will be unable to select a core strategy for the ASIC environment. Given these circumstances, Mitsubishi Electric will probably struggle for a while.

Toshiba

Toshiba's microcomponents business is characterized by a high proportion of low-end products, including 4-bit and 8-bit parts. Its cumulative shipments of 4-bit MCUs amount to more than 400 million units, although unit shipments are declining owing to a demand shift to 8-bit products that occurred in 1995.

Toshiba's dominant position in the low-end segment contrasts strongly with its low profile in the high-end segment, where it trails NEC, Hitachi, and Mitsubishi by a great margin. This is because of the company's lack of penetration in any of the major application markets for 16-bit microcomponents, including rigid disk drives and other storage, air conditioners, automotive engine controllers, and, more recently, cellular phones and video equipment. Again, it is a clear case of losing strategic focus in these areas.

A strategic focus for Toshiba in the high-end market must lie in integrating microcomponent expertise with ASIC technology. Although Toshiba is a second-tier vendor in the microcomponent business, it ranks high in the ASIC arena. A major challenge will be to redirect its solutions for system-based ASICs to compensate for its weakness in individual microcomponent product offerings.

Fujitsu

Like Toshiba, Fujitsu is in the less exalted position of second-tier supplier in the microcomponents market. It differs from Toshiba, however, in that its product portfolio is weighted toward the high-end segment. Notably, it slashed 4-bit shipments in 1995 and embarked on a high-end shift, boosting 16-bit products by more than four times the previous year's shipments. A major application is storage, including rigid disk drives and CD-ROM drives, indicating successful selection of strategic markets.

The company rightly focused on the page printer market for its 32-bit MCUs, at once securing a leading position against NEC and Hitachi. However, these two competitors quickly caught up by capitalizing on the fast-growing video game market, leaving Fujitsu far behind in growth rate.

Nevertheless, the company's formidable strength in the ASIC business will be a powerful tool in its exploration of new 32-bit markets. The key to fighting back against NEC and Hitachi will be effective product differentiation.

Dataquest Perspective

Clearly, there are two important points for MOS microcomponents manufacturers to bear in mind if they are to sustain growth.

First, product strategy in the 16-bit or higher segment is very important. As noted, the image processing market will create rapidly growing demand for 32-bit products, and that demand is largely found in the Japanese market. Japanese companies must establish a product strategy, taking into account critical factors—for example, which area they should target in joint development with which system manufacturer, which features will be required around microcomponents, and what should be done to enable the design of such peripheral features in the ASIC environment.

Second, a global market strategy will be vital. So far, tacit boundaries have been drawn between Japanese microcomponent manufacturers and European and U.S. companies. Japanese companies specialized in the Japanese market and the consumer market, while European and U.S. companies have to a great extent focused on their local markets, electronic data processing, and communications. The main reason for this territorial separation was the importance of technical support, especially of MCUs that house custom ROMs. This made it difficult for microcomponent companies to design a global strategy, unlike DRAM suppliers. As a result, strong localization tended to become the norm.

The embedded microcomponents market, prompted by robust demand centered around 8-bit or higher products, is entering the era of more intense global competition seen in other markets. There are numerous system manufacturers in the fast-growing Asia/Pacific market longing for a supply of microcomponents with good technical support. Dataquest believes that Japanese manufacturers, which tend to equate "overseas marketing" with "memory exports," as well as non-Japanese vendors will need an effective overseas strategy for microcomponent products to get their share of this promising market.

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Vendor Analysis

Microchip Technology on the Move

Abstract: *In a few short years, Microchip Technology has become a significant participant in the $6.4 billion 8-bit microcontroller business. This was accomplished with some careful assessment of the marketplace and reflection on its unique set of capabilities, followed by proper execution of its plan to capitalize on neglected market niches. In this Perspective, Dataquest evaluates the very low end of Microchip's MCU products and the company's recent expansion into ASIC offerings.*
By Tom Starnes

Microchip Technology Inc. earned $189 million of its $285 million corporate revenue in fiscal year 1995 from sales of its microcontrollers (MCUs). Microchip's MCUs are unusual in that they are largely programmable individually by the customer and generally sell for under $4 each. Even so, Microchip is still ranked No. 10 in revenue in the 8-bit microcontroller market, dodging the steps of such giants as Motorola, NEC, and the 8051 contingent. Its serial EEPROM business quietly makes up most of the rest of Microchip's revenue. But Microchip is not standing still and continues to carve itself out a slightly bigger piece of the pie.

Microchip Technology built its business from a unique angle. Buy an older, underutilized fab. Keep the production overhead low by using well-wrung-out process technology. Combine the technologies and products that are your strengths. Look where the big vendors are not looking. Deliver product when others cannot. Minimize the customers' time to market. Stay focused.

Recently Microchip made some new moves relating to microcontrollers. Let's look at Microchip's new extension into 8-pin MCUs and a new venture in ASICs. Each of these charts new territory, both for Microchip and for the industry.

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Opening New Markets with an 8-Pin Microcontroller

Everyone has heard of 8-bit microcontrollers. Now there are 8-pin microcontrollers. That's not a misprint, but an entirely new level of MCU. Late in May, Microchip Technology announced the first of its tiny new 8-pin, 8-bit microcontrollers. Like all the company's microcontrollers, which go by the designation "PIC," these new MCUs use a RISC processor at their heart that is compatible with their entire product line. This one uses Microchip's most common, 12-bit instruction word. The two versions announced include 512 words or 1,024 words of one-time programmable (OTP) EPROM and 25 bytes or 41 bytes of data RAM, a timer, and a direct LED drive. The PIC12C508 and 509 run at 4 MHz using an on-chip oscillator (no crystal is necessary, which would consume pins and add cost) and draw less than 2mA. But most remarkably, the parts contain only eight pins. With two dedicated to power and ground, this leaves six pins for input/output (I/O).

Count the Pins on the Fingers of One Hand (Almost)

What can be done with only six I/O lines? The question is best answered by opening the horizon with a different question: Could those who have not even heard of an I/O line use some simple, if powerful, intelligence in their toasters, hair dryers, battery chargers, and so on? Don't just think about the high end of these product lines, which might be designed for the person with everything, but the large middle section, where electrical or electromechanical methods have traditionally been used. This is not the top-of-the-line dishwasher or clothes washer where an extra $100 will provide an LED display that constantly reads "Status OK." These are the $5 to $25 products that collect in the bathroom, the kitchen, and the garage. They make great gifts. They are made in great quantities. They are remote controls, lighting controls, security sensors, and just plain switches. If it has electricity in it, one day these new MCUs might well control it.

What can be done with just six I/O lines? "Just enough" is the answer. Just enough to make it useful. Just enough to make it interesting. Just enough to make it simpler than putting together a PLD, ASIC, or pile of TTL. Not enough to make it expensive.

Does a dollar sound reasonable? The price for 50,000 of them is under a dollar. Microchip will be opening up some completely new markets with the 12C508/9 and stealing some business from traditional 4-bit MCUs. But opening new markets is what gives vigor to an industry, especially when the market is at the low end of the spectrum. Here, extremely large volumes can be tapped, and price is a driving factor. This is where mature, well-understood markets exist, which can be revitalized by adding features and convenience empowered by technologies such as microcontrollers.

But even the idea of an 8-pin MCU is bold. Most vendors push toward the upper end of the business, looking for profitability. They look at how their customers are using their product line and try to figure out how to get more of the system functions into their chips. Then they can ask for more money for expanded chips because they are providing more of the needed functions. To provide the least functionality is a different twist, but then it has a different purpose—to open more applications, simpler applications, or high-volume applications into the realm of products using microcontrollers. The price is going to be much lower, and the old adage "make it up in volume" really comes into play here. That is an approach with which Microchip is comfortable—it has made its volume in many markets already. Microchip actually ranks No. 5 in terms of volume for 8-bit MCUs. The company has found that there are a lot of designers looking for a powerful MCU core processor with less-sophisticated peripheral circuits.

Getting the design-in can also be a problem in totally new markets. The system designer has to be aware of the possibility of using an MCU where previously there was none. Advertising, articles, and a lot of feet on the pavement can help there. Microchip already sells far more of its products through distributors than most vendors, and distribution is the channel that calls on the smaller accounts. Smaller often means low-dollar accounts, low dollar because they do not buy much semiconductor product. This is exactly the area that the 8-pin MCU is looking for. Yesterday: only wires. Tomorrow: all the wires plus a small MCU. Zero dollars becomes nice dollars, and Microchip is successful.

Microchip is in an excellent position to package 8-pin MCUs successfully, as well. Microchip has shipped truckloads of serial EEPROMs for the past several years—with almost all of these in 8-pin packages. It has learned how to mass-produce these tiny (by microprocessor standards) packages at a very low cost. It has the handlers, marking, and packing equipment to deal with the small-body parts. And it has the cost structure to make it profitable. Other vendors have large investments in high-pin-count assembly and test equipment and might not be too keen to wheel in some small-package equipment. With Microchip, it's almost a natural.

The beauty of the 8-pin MCU is that it is so simple, so small, and so cheap that it will find its way into applications that have not previously used MCUs, opening new business at the bottom end of the market and growing the base of PIC microcontroller users. Microchip is well positioned to be successful here.

Microchip Adds ASIC Technology

Microchip Technology announced late in June that it would purchase ASIC Technical Solutions. Microchip, the Chandler, Arizona-based serial EEPROM and microcontroller vendor, will pick up ATS' QuickASIC arrays, which provide a short time-to-market transition from field-programmable gate arrays (FPGAs) to an application-specific integrated circuit (ASIC), with substantial cost savings. In the near future, Microchip's MCU cores could be available in the QuickASIC for greater systems integration.

ASICs Made Easy—Step 1

FPGAs have been used by designers for years to collect an assortment of random logic and gates (usually 5,000 to 10,000 total). These typically glue together a system's larger microprocessor, memory, peripherals, and bus interface chips or perform specific functions (perhaps the bus interface itself) that are not otherwise available. The interconnects within the FPGA's gates can be established, or "blown," by the engineer as the design is tested. As errors are revealed, a new FPGA is programmed and inserted into the board being debugged for further analysis. This is a fast, convenient means of making corrections in the early stages of product development. However, as the board moves to the production environment, the cost of the highly programmable FPGA no longer can be justified as the design becomes more stable and higher volumes are desired.

But jumping to a mask-programmed gate array or an ASIC requires a more intimate relationship between the vendor and the designer and a delay measured in many weeks for production of the customized ASICs. ATS has dramatically shortened this time. Rather than having large minimum quantities for mask ASIC orders, ATS can take orders for very small quantities (under 1,000) of a customer's pattern and run it through wafer fab. Rather than having an entire lot of wafers dedicated to a single pattern, ATS can put the patterns of many different customers or many different designs on each wafer, greatly reducing the volume needed for any one by itself. As a fabless company, San Jose, California-based ATS used to go to overseas foundries to fabricate the wafers.

Microchip Technology will be a boon to the QuickASIC technique in two key ways. Microchip is a U.S.-based semiconductor house with (fairly inexpensive) fabs in the Phoenix area. The old ATS built its business with a six-week turnaround time for the QuickASICs, which could be half of what most ASIC vendors can do. As Microchip, with its own in-house, motivated fabs and contending only with other Microchip products for fab space, QuickASICs are expected to be cranked out in as little as three weeks, making QuickASIC even quicker. Also, with Microchip Technology's greater resources and recognition, QuickASIC should enjoy a wider audience and resulting higher-volume business, which in turn generates lower costs.

Add One Part Micro—Step 2

Now, what if an MCU core processor were available in the ASIC? A designer could assemble a prototype product with an off-the-shelf Microchip OTP MCU and use an FPGA to build additional interfaces and a unique peripheral circuit. Through the development stages, there will be a few FPGAs blown and trashed as the hardware is shaken down and a few OTP MCUs burned and tossed as the software settles in. All of this can take place while the customer deals only with a distributor, having essentially no relationship with the vendor. Then, as the boss insists on putting a product into dealers' hands, the hardware may have stabilized enough to move the FPGA to a QuickASIC. Since the QuickASIC can be turned around in less than a month, it will not take too many of the expensive FPGAs in the initial production of the product before the lower-cost ASIC can supplant it. The software seems to take more time to debug and can continue for quite some time with OTP-based MCU programming, giving plenty of flexibility for minor modifications of the code at a moderate cost premium.

At some point, as the MCU code stabilizes, the logic in the FPGA-ASIC can be combined with the MCU, and a QuickASIC can be produced that is composed of the custom logic as well as the MCU. This might have OTP ROM or mask ROM, again depending on the stability of the program code. Here, the customer moves closer to the vendor to assure that the customized ASICs have the right patterns and are delivered to the desired schedule. The resulting ASIC should cost less, occupy less space, have fewer solder joints, and be more reliable than a separate MCU and an ASIC or, certainly, an MCU and a cupful of TTL.

Where Will This Take Microchip?

Microchip Technology's PIC families of microcontrollers have quietly established themselves as serious contenders in the MCU business, moving up to No. 10 in terms of revenue in the hotly contested 8-bit MCU market, the largest segment of MCUs. Microchip's foray into OTP microcontrollers has set more than a few vendors reeling from mask ROM or flash MCU sales. Microchip has established itself in MCUs as a very low-cost 8-bit vendor, addressing a piece of the market in which traditional 8-bit vendors have difficulty making money and in which the 4-bit architectures cannot measure up.

The availability of a core microprocessor that can be used in a lower-cost ASIC can be a significant factor in the selection of the processor architecture. This effectively weds the designer to the vendor of the architecture, which gives some additional leverage for added value and a higher price and provides incentive to remain with the same vendor. It can add noticeably to the acceptance of the processor architecture, a critical factor in the long-term success of the architecture. Because an MCU typically uses a fairly small quantity of program code, it might be easier to change the design to another architecture under pressure from another, aggressive vendor, than it is for a microprocessor-based system. Combining the core controller with a customized ASIC is one more handle with which a vendor can hold onto its customers.

Acquiring an ASIC technology is one thing. If the processes are fairly easily transferable to Microchip's fabs, there should be few start-up problems. Having an MCU process, with its inherent analog component, plus having an EPROM technology and getting both of those onto the same process with an ASIC is not necessarily simple. However, ASICs of this size (under 100,000 gates) are not in the tiniest geometry and so have a better chance of accepting EPROM, MCU, and analog processing steps than a shiny new Pentium might. Certainly, Microchip carefully reviewed the technology match before embarking down this path. And, indeed, the QuickASIC acquisition should be considered a success even without the MCU angle, although the possibilities are not as interesting.

But technology is only part of the equation. The ASIC business is new and different for Microchip Technology. It is hazardous when a company sees some green grass in a pasture sowed with a different crop. There can be pitfalls and unforeseen challenges in the new product area that may be discovered only when the company is in the thick of it. Many companies fail altogether under these circumstances. IBM got out of the telephone business almost as quickly as AT&T got out of the computer business. Success in one business does not assure success in another business, even a closely related one. Microchip will need to be vigilant to keep this new venture from detracting from its established businesses.

The microprocessor, microcontroller, and DSP business tends toward more customization—where the customer defines the product. An ASIC is completely defined by the customer. For its future, Microchip is going to need ASIC technology. Now is a good time for Microchip to get a foot in this door, learn the ropes, and set a plan in motion. This appears to be what it is doing.

ATS had sales of just under $4 million in 1995, primarily from the sale of QuickASICs. Microchip expects to ramp this business up to $15 million by 1998, with revenue doubling in subsequent years. With ATS' revenue being 2 percent of Microchip's, it will hardly be noticed on Microchip's income statement for a while, and, it is hoped, ATS will not be detrimental to Microchip's expense column. However, ATS should help give Microchip an important piece of technology that will take it into the future.

Microchip has carefully sought underserved portions of the semiconductor marketplace and brought its special expertise and its low cost structure to bear on these willing markets. The concept of using a one-time programmable MCU rather than a mask ROM MCU addresses a market that must be nimble and quick to respond to changes and does it for a price better than that of EPROM or flash, although more than that of mask ROM. This has opened up a very successful business for Microchip. The concept of moving a designer very quickly from expensive but very programmable FPGAs to a much more cost-effective ASIC, without requiring high minimum volumes and nonrecurring engineering (NRE) costs, looks as though it addresses the same nimble type of market. Putting these two products together should prove to be a very powerful combination, and may cause other chip vendors to once again rethink their strategies.

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Perspective

Embedded Microcomponents Worldwide

Product Analysis

Searching for the Best of All Possible DSP Worlds

Abstract: *Motorola has given birth to three new families of DSPs in the last nine months, all directed toward different aspects of communications. This document evaluates Motorola's unique approaches to the 56300, 56600, and 56800 architectures and provides some general comments on DSP bit sizes.*
By Tom Starnes

Motorola's New Approach to Digital Cellular and Combination MCU/DSPs

Like other digital signal processor (DSP) vendors, Motorola has separate DSPs to operate on 16 bits or 32 bits of data. But Motorola is best known for its unusual 24-bit DSPs, which are excellent for audio applications. The longer fixed-point data accommodates digital representations of fine audio signals, which permit all human-audible sound to be reproduced and manipulated with high fidelity. 16-bit data is good enough for reproducing voice, but disappointing for music. More is better, but also more expensive. So 16-bit DSPs, found in the large majority of applications, are used in voice-grade functions like telephone transmissions, answering machines, and voice recorders. Good digital musical reproduction and synthesis (for instruments) need the added resolution and range afforded in the 24-bit DSPs. Good video reproduction goes for the floating-point version of DSP, typically performed on 32-bit DSPs. Motorola is essentially the only manufacturer of 24-bit DSPs, although some 20-bit DSPs are available that provide adequate resolution for music.

Until last fall, Motorola offered its 56100 family of products performing 16-bit DSP, the 56000 family for 24-bit DSP, and the 96002 for 32-bit floating-point DSP. Since autumn, it has introduced the 56800, which is a new architecture blending 16-bit DSP with complete microcontroller (MCU)

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functionality, the 56300 family as the high-end 24-bit DSP, and the derivative 56600 family, which directs the 24-bit DSP instructions to perform strictly on 16-bit data. Table 1 illustrates the major distinctions between Motorola's DSP families. Each of these families typically has only a few parts in it (plus package and speed variations), with the original 56000 products having the most with six, and the 32-bit having only the fairly old DSP96002. The discussion that follows highlights the newer families' purpose and outlook.

Table 1

Motorola DSP Product Family Comparisons

Family	56100	56800	56000	56300	56600	96000
Type	16-bit DSP	16-bit DSP/MCU	24-bit DSP	24-bit DSP	24/16-bit DSP	32-bit DSP
ALU Operation	16 x 16 + 40 → 40 bits	16 x 16 + 40 → 40 bits MCU instructions (68HC11-like)	24 x 24 + 56 → 56 bits	24 x 24 + 56 → 56 bits	16 x 16 + 40 → 40 bits	32 x 32 + 96 → 96 bits
Cycles per Instruction	2	2	2	1	1	2
Instruction Length	16 bits	16 bits	24 bits	24 bits	24 bits	32 bits
Data Type	Fixed-point	Fixed-point	Fixed-point	Fixed-point	Fixed-point	Floating-point
Data Width	16 bits	16 bits	24 bits	24 bits	16 bits	32 bits
Program Memory	Large ROM[1]	Small RAM	Small RAM[2]	Small RAM	Large ROM, small cache	Small RAM
X-Data Memory	Large ROM[1]/ Large RAM	Small RAM	Small RAM	Small RAM	Small RAM	Small RAM/ Small ROM
Y-Data Memory	None	None	Small RAM	Small RAM	Small RAM	Small RAM/ Small ROM
External Address/Data Lines	16/16	16/16	24/24	24/24	24/16	32/32 and 32/32
DMA Controller	None	None	None	6 channels	None	None
Host Interface	General	General	General	General and PCI	General	General
Serial Communications	3	3	3	3	2	3
Timers	1	1	1	Triple	Triple	1
Codec	Sigma-Delta	None	None	None	None	None
Performance (DSP mips)	30 mips	30 mips	33 mips	66 mips	60 mips	20 mips
Price Range	$20	$10	$25	$50	$25	$90

Notes:
PCI = Peripheral Component Interconnect
Large refers to >7K words of ROM or >3K words of RAM
[1]Small Program RAM and Large Data RAM version also available
[2]Large Program ROM and Large Data ROM versions also available
Source: Dataquest (May 1996)

A Merging of the MCU with the DSP

Late in February, Motorola announced a new DSP chip family targeted for low-end areas of the communications market: digital messaging (pagers), radio frequency (RF) modems, and digital answering machines, as well as AC motor and servo controllers. The new 16-bit 56800 architecture runs traditional DSP instructions as well as MCU instructions. Voltaire might refer to this new family as the best of both worlds, the very high speed, real-time DSP world and the bit-manipulating, I/O-focused MCU world. In fact, in typical applications, most DSP chips sit alongside master MCUs. A single chip to do both functions will permit the elimination of one of these components, greatly reducing board space, power consumption, cost, and interconnects. The new architecture was designed from the ground up with a full complement of DSP instructions, as well as the system management, control, and bit-manipulation instructions that MCUs excel in, plus a few tricks borrowed from full microprocessor architectures.

The 56800 DSPs are a combination of Motorola's 56100 DSP family, the 68HC11 microcontroller family, and some 68000 microprocessor ideas—each a well-proven architecture in its own right. This is not just a slap-on-a-few-MCU-functions approach. Rather, new instructions, addressing modes, register handling, stack manipulation, and barrel shifters are built right in to the basic arithmetic logic unit (ALU), address generator, and bus interface. Significant evaluation of the execution of both DSP and MCU code was used, along with careful analysis of C language compilers, to tailor the architecture so that C programs, DSP algorithms, and assembly-language control routines all run very efficiently on the chips, compelling Motorola to proclaim that a mips-to-mips comparison will not properly benchmark the architecture the way an application-to-application comparison would. Careful attention to transistors wasting electricity and lower 3V supply voltage allows the completely new design to drop power consumption significantly. This, along with the higher efficiency of the architecture, should allow applications to run a long time on only a few batteries.

The 56800 architecture comes out of Motorola's DSP Division, so it will look and act most like a DSP and in fact would be an unlikely candidate for applications not running DSP algorithms. But by including the MCU operations in the original concept for the architecture, the MCU functionality should rival most general MCU processors. This is a far more integrated, and therefore more effective, approach than that of many MCUs that profess DSP capability by simply adding a multiply-accumulate (MAC) instruction or accelerator. Similarly, the poorly named Native Signal Processing (NSP) concepts (use the regular MPU to do DSP operations in its ample spare time) is like hammering in a nail with a screwdriver. The big RISC machines strap on a separate processing element to do DSP or image processing, consuming many transistors, dollars, and amps or providing limited DSP functionality.

Motorola has enough experience in processor, controller, and digital signal processing architectures to know the right things to put into a good, efficient combination chip. The greater Motorola certainly knows a few things about cellular telephony and paging, which are highly dependent on DSPs, MCUs, and batteries. Thus, the lineage of the 56800 DSP family couldn't be any better. For applications where good controller capability is needed with true DSP functionality and performance, the 56800 could be a really good fit and run off a battery.

A RAM and a ROM-based part should be available in 1996 with a complement of memory, two serial peripheral interfaces, a serial synchronous interface, three 16-bit timers, and 16 to 32 I/O lines. The first 3V part was to sample in the first quarter, and volume quantities will be available later for under $10, delivering up to 20 DSP mips and consuming down to 1 mA/mips.

For Telephony: A 24-Bit DSP Doing the Work of a 16-Bit DSP, and a More Powerful 24-Bit DSP

Late in May, Motorola announced a new DSP that performs processing on 16 bits of data while using instruction words that are 24 bits wide. The new 56600 family is a modification of the fully 24-bit 56300 product family introduced in September 1995. The 56600 family is a "1x" DSP, executing one DSP instruction for every clock cycle, which puts it in the class with the highest single-ALU DSP. The data ALU is 16 bits wide with two 40-bit accumulators. A 40-bit barrel shifter can reduce time for parsing data streams. The DSP can access 64K words of program, X-data, and Y-data memory space (each) over separate buses when the memory is on-chip. A variety of typical DSP peripherals make up the balance of the single-chip DSPs.

The first part in the family is a predominantly ROM-based DSP56602 with sizable quantities of program and X- and Y-data memory, as shown in Table 2. A small piece of program RAM is handy for patch code or branch tables to more extensive program modifications. The peripherals on the DSP56602 are the same as the DSP56301, but without the direct memory access (DMA) controller and a couple of serial interfaces. The DSP56602 is a static design and can be clocked by its PLL at 60 MHz running at its 2.7V rating, delivering 60 mips (DSP mips) of performance.

In telephony, where the network was designed to transmit only voices, 16-bit DSPs are all that is needed to make the conversation intelligible and allow the listener to identify the party at the other end of the line. Motorola has some 16-bit DSPs, but the primary ones for the telephone industry (56100) are based on the now 10-year-old 56000 architecture. The new 56300 architecture runs much the same instruction set as the previous 24-bit 56000 architecture; it just does it twice as fast with a lot less current. High-end fixed-point DSPs like the DSP56301 have twice the performance of their predecessors, primarily because of the newer execution unit that can complete each instruction, especially the MAC operation, in a single clock, rather than the previous two. Plus, the 56300 instructions are very powerful, taking advantage of the variety afforded by their encoding into 24-bit instruction words rather than the 16-bit instruction words typically found in "16-bit" DSPs. Motorola believes its DSP instructions do

Table 2

Feature Comparison of Motorola DSPs for Telecommunications

Product	DSP56166	DSP56301	DSP56602
Type	16-bit DSP	24-bit DSP	24/16-bit DSP
ALU Operation	16 x 16 + 40 → 40 bits	24 x 24 + 56 → 56 bits	16 x 16 + 40 → 40 bits
Cycles per Instruction	2	1	1
Instruction Length	16 bits	24 bits	24 bits
Data Type	Fixed-point	Fixed-point	Fixed-point
Data Width	16 bits	24 bits	16 bits
Program Memory	8K[1] x 16 ROM 256 x 16 RAM	2.5K x 24 RAM 1K x 24 cache	24K x 24 ROM 512 x 24 RAM
X-Data Memory	4K x 16 ROM 4K x 16 RAM	2K x 24 RAM	6K x 16 ROM 4K x 16 RAM
Y-Data Memory	None	2K x 24 RAM	6K x 16 ROM 4K x 16 RAM
External Address/ Data Lines	16/16	24/24	24/16
DMA Controller	None	6 channels	None
Host Interface	General	General and PCI	General
Serial Communications Interface	1	1	None
Synchronous Serial Interface	2 reduced	2 enhanced	2 reduced
Timers	1	Triple	Triple
Codec	Sigma-Delta	None	None
Debug Port	Yes	Yes	Yes
Oscillator	PLL	PLL	PLL
Performance (DSP mips)	30 mips	66 mips	60 mips
Price Range	~$20	$48 (100K units)	$25 (100K units)
Frequency	60 MHz	66 MHz (80 coming)	60 MHz
Voltage	5V	3.3V (1.8 coming)	2.7V (1.8 coming)
Power Consumption	3.5 mA/mips	1.4 mA/mips	0.85 mA/mips
Package	80-pin TQFP	208-pin TQFP	144-pin TQFP
Available	1992?	Q4/95	Q2/96

Notes:
PCI = Peripheral Component Interconnect
PLL = Phase-Locked Loop Oscillator
[1]2K Program RAM with 4K data RAM version also available
Source: Dataquest (May 1996)

up to 40 percent more work than other DSPs and that the "mips rating" underrates its product.

DSP mips cannot be correlated well with VAX mips or other more familiar microprocessor ratings. With a single-DSP instruction, as many as six operations can take place, including fetching an instruction, fetching two pieces of data, multiplying them, adding the product to an accumulator, incrementing three pointers, testing a condition, and branching. No Pentium can do as much. DSP mips typically refer to the number of DSP instructions that can execute in a microsecond. Essentially all instructions in a DSP execute in the same amount of time (which is very RISC-like.)

But the 56300 uses 24-bit-wide data—8 bits more than needed in telecommunications. In fact, the extra bits add perceptible error into standard algorithms that are fine-tuned for 16-bit data, because they do not round to numbers with the same result. The 56300 designers added a "16-bit exact" rounding option to their 24-bit arithmetic operations to provide results identical to a normal 16-bit machine, making operation precise in the critical 16-bit-oriented telephony algorithms. Very clever. So now, the fast, efficient 24-bit DSP machine can handle the cellular base station requirements.

The DSP56301 is a top-of-the-line DSP from Motorola, bringing the highest level of performance to bear on applications such as digital cellular base stations, where dozens of cellular transmissions must be maintained at once. High performance at an attractive cost is the key factor in these designs. Nestled in a building or, in some cases, a good-size box, base stations have the luxury of being plugged into the wall. Power consumption is important from the aspect of the associated heat dissipation, which can burden enclosed boxes or rooms, more than on actual current draw.

The 56600 family is made from the new 56300 family, but tailored for the subscriber end of digital cellular: the cellular phone. The handset has only itself to be concerned with, but it must run as long as possible from a battery, and the overall size and weight of the phone should be minimized. In the GSM handsets popular in Europe, there is only one channel transmission to work on, but there is also the voice encoding and decoding to handle. Earlier versions of digital handsets used separate DSPs for the channel modem and the vocoder, plus an MCU for the system management and call processing. These two 30-ish mips DSPs can now be replaced with a single DSP like the DSP56602, with its very high performance.

But the whole reason for using a cellular is to be "untethered" and portable, so the smallest battery possible is desired, and the power consumption of key components like the DSP is critical. This flies in the face of performance, but the ever-amazing electronics prevails. On a clock-by-clock basis, only those portions of the 56300 and 56600's execution unit, memory, and peripherals that are needed are powered, conserving precious battery power. On the DSP56602, removing unnecessary peripheral circuits and trimming out circuitry associated with the additional 8 data bits coupled with the low supply voltage bring the power rating of the DSP56602 well below the 1mA-per-mips mark. (In some ways the DSP zealots have a jump on the processor folks. Rather than just quoting a wattage rating, they focus more on how much battery juice is needed to get a measured amount of work done, with mA/mips.) The lower supply voltage also reduces the requirements of the battery, with the DSP56602 destined for a 1.8V version.

Pros and Cons of Mixing 24 Bits and 16 Bits

But why use 24-bit-wide instructions on 16-bit data? Other implementations use 16-bit instructions for 16-bit data and happen to be very convenient for most microprocessor architectures. DSP designs like Motorola's, however, use a triple Harvard architecture. This uses three separate buses to access three separate memory spaces (one for instructions and two for data) simultaneously to speed the DSP operations for their critical real-time performance. (Motorola's original 16-bit architecture, the 56100, had a program memory space and only one data space.) With this layout, the bit width of the program and the data is immaterial. There is no added efficiency for having all buses the same width.

On the other hand, what are the advantages of the wider instruction width? The more bits in the instruction, the more variety available to each instruction. The greater the variety, the more efficiently the program can do its work, timewise. The cost? Wider instructions take up more space (horizontally) in memory. It is difficult to really pin down how much more this costs, but at least there is a perception that it must cost more to have all those other bits around. In reality, it may only add a few hundred mils to a ten-thousand-square-mil die, which becomes indistinguishable from differences because of other features in the part.

Why did Motorola take this approach? Because its 56300 architecture was the one that was closest to delivering the performance and 75 percent of the other desirable features for digital cellular handset applications. The modifications to come up with the 56600 were far easier to make than the effort to start from the ground up or to modify the 56100 or 56800 parts.

Will the 16-bit data with 24-bit instructions work? There is no fundamental reason why it will not. It's unusual, but if the price is low enough ($25 is close, but not a shoe-in), and the other features are right, this part will have success in the very active digital cellular market, as well as other applications looking for very high DSP performance with 16-bit resolution and a tight power budget.

Motorola still sets the pace on tiny feature-packed cellular phones, but Nokia, Ericsson, and others took a bite out of its market share in 1995. Motorola's DSPs also face heavy competition in the cellular phone market from Texas Instruments and AT&T. Innovative DSPs, working closely with potential customers, and aggressive marketing will be required to maintain a significant presence in this highly competitive marketplace. Now with the DSP56301, Motorola has a very powerful DSP to handle more channels in the cellular base station. With the DSP56602, it has a 16-bit DSP with the performance to accommodate the entire DSP function of a digital cellular handset in a compact size and to do it while extending the battery life—all at an attractive price.

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Perspective

Embedded Microcomponents Worldwide

Market Analysis

"Digital" Dominates the News at the 1996 Winter Consumer Electronics Show

Abstract: *Solid sales of multimedia PCs into the U.S. home market made the statistics on consumer electronics sale reported by the Consumer Electronics Manufacturers Association look good for the 1995 holiday season, but, otherwise, consumer electronics sales were slow. Retailers came to the 1996 Winter Consumer Electronics Show eager for new products that hold the potential to draw customers back to their stores in 1996. Manufacturers rolled out products and promotions that conveyed a clear message: The key for increasing sales is spelled D-I-G-I-T-A-L. This document provides information and analysis on the most significant product announcements and demonstrations at the 1996 Winter Consumer Electronics Show.*

By Tom Starnes and Dale Ford

Consumer Electronics Manufacturers Present a Vision of a Digital Future

More than 97,000 attended the 1996 International Winter Consumer Electronics Show (CES), held in Las Vegas from January 5 through 8. The Winter CES is the premier event for the consumer electronics industry's largest annual consumer electronics trade show, bringing together the highest concentration of manufacturers of consumer electronics with buyers, retailers, and other decision makers. This year, more than 1,800 exhibitors showed their products on over 1 million square feet of floor space.

Attendance at the 1996 Winter CES was significantly lower than in 1995 because of the withdrawal from the show of the major video game companies like Sega and Nintendo. The most visible video game company at the show was Fox Interactive, and it does not intend to return for the 1997

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show. The video game companies launched their own show in Los Angeles during 1995. This new trade show, called Electronics Entertainment Expo (E3), is dedicated to the video game industry and will be held again May 16 through 18 at the Los Angeles Convention Center.

The CES is sponsored by the Consumer Electronics Manufacturers Association (CEMA), a sector of the Electronic Industries Association (EIA). According to CEMA, an estimated 750 facilities in the United States manufacture or assemble consumer electronics products, employing an estimated 180,000 people. Another 3.4 million people, with total wages estimated at $56 billion, are employed in the more than 130,000 stores that sell these products to the consumer. However, CEMA casts a wide net in defining consumer electronics. Its definition includes products such as PCs and cellular phones sold into the home, along with traditional consumer products such as TVs, VCRs, boom boxes, and cameras.

Solid sales of multimedia PCs into the U.S. home market made the U.S. statistics look good for the 1995 holiday season, but, otherwise, consumer electronics sales were slow. Retailers came to the show eager for new products that hold the potential to draw customers back to their stores in 1996. Consumer electronics manufacturers came to the show with products and promotions that conveyed a clear message: The key for increasing future sales is spelled d-i-g-i-t-a-l.

DVD Steals the Spotlight (Just Don't Ask What It Stands For)

So what was the hottest consumer electronics products at this year's CES? Without a doubt, digital video disc (DVD) players stole the show as almost a dozen of the world's major consumer electronics companies introduced, with a lot of fanfare, energy, and expense, either prototypes or plans to produce DVD players. The activity at the show surrounding DVD players, by both the manufacturers and the buyers, was truly astounding. After a disappointing Christmas season for retailers of traditional consumer electronics products, many hopes are being placed on this product. With the promotional efforts that are planned, consumers will soon be adding "DVD" to their household vocabulary. The following companies have jumped on the DVD bandwagon:

- Toshiba
- Sony
- Philips
- Matsushita
- Pioneer
- Samsung
- LG Electronics
- Thomson
- Onkyo
- Zenith
- Mitsubishi

It should be remembered that both Sony and Toshiba were demonstrating DVD technology at the 1995 Winter CES. (Toshiba's demonstrations were behind closed doors.) Throughout 1995, the industry watched closely as intense competition was played out between two formats, Super Density (SD) and Multimedia CD (MMCD). Nobody wanted to see a repeat of the format wars that had hindered the early growth of other consumer electronics markets, and the two camps were finally pushed into negotiations on a common standard. The announcement of a final DVD specification allowed manufacturers to roll out their products with confidence at the 1996 Winter CES. If agreement had not been reached it could have been a gloomy show. However, the groundwork has been laid, and now the race to the market is on.

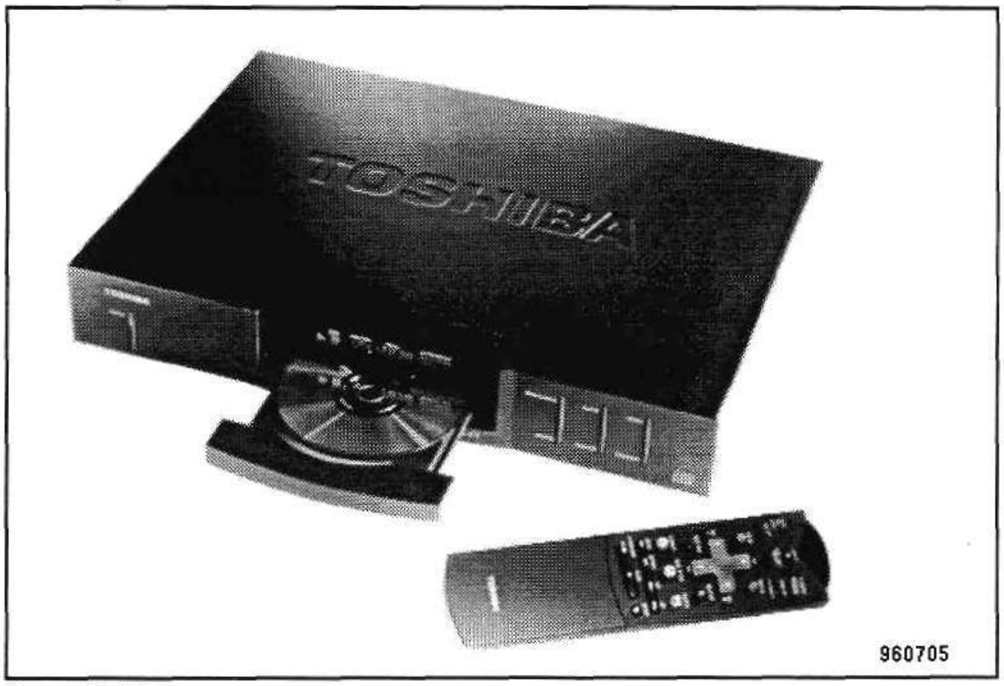
An interesting side note to the final DVD specification is that the term "DVD" was left undefined in the final agreement. Because of the potential application of DVD technology in products targeted at multiple markets, including the video playback market and the PC market, the major companies decided they did not want to define DVD as "digital video disc." Left with a term begging for a definition, the industry appears to be adopting the name "digital versatile disc."

Toshiba led the pack with the earliest announcements of product plans. It intends to bring its SD-1006 and SD-3006 to market by early September at prices of $599 and $699. (All prices given in this document are manufacturers' suggested retail prices.) Figure 1 shows the SD-3006 player. These players are targeted at the video playback market. A version of DVD has also been developed for PC storage called DVD-ROM, but the focus of the Winter CES was on the video playback market. Sony, Thomson, and Philips were other major players outlining product introductions for the fourth quarter of 1996. Matsushita/Panasonic was holding only closed-door discussions with selected retailers about their plans. Pioneer, which has been the standard bearer for Laser Disc (LD) technology, was showing a hybrid product that could play both LD and DVD. The best prospect for the success of this type of product is in the Asia/Pacific and Japanese markets, where LD has experienced stronger acceptance. It is also notable that Korean companies such as LG Electronics and Samsung were promoting plans for product introductions in late 1996 or early 1997.

Although early promises were made of introducing DVD players at a $499 price point, it was also expected that this target would be difficult to reach, so Toshiba's prices were not a surprise. However, Thomson still vows to reach $499 with its introductory product. It is not clear how it will do this in light of its manufacturing agreement with Matsushita. It was announced at the show that Matsushita will supply DVD players to Thomson for sale around the world and, in return, Thomson will provide Matsushita with DSS home satellite systems for sale under the Panasonic brand in the United States. Sometime after 1996, both companies will begin to manufacture their own products in each of these categories.

Some of the early predictions by manufacturers for the success of DVD might be called optimistic. In fact, some of them might be called wildly optimistic. Their projections of 2.5 million to 3 million shipments in the first year would make the early shipments of the highly successful Direct Broadcast Satellite (DBS) systems look small in comparison. Other manufacturers were trying to be more cautious in their forecasts, not wanting to let the

Figure 1
DVD System



Source: Toshiba

hype set unrealistic expectations that, if unmet, could lead to a major letdown and fallout among critical supporters. A coordinated launch of this product is being orchestrated. Major Hollywood studios are preparing to release between 250 and 400 movie titles in the DVD format this fall. Dataquest does expect the DVD to be a highly successful product that will benefit from the combined support of manufacturers, retailers, and software providers. Preliminary projections of DVD unit shipments into the video playback market call for 60,000 units to be shipped in 1996, with sales accelerating rapidly to 2.5 million units in 1998. Dataquest's Consumer Multimedia Semiconductors and Applications Worldwide program will be publishing an in-depth analysis of DVD in the first quarter of 1996 that will provide more detailed information and a final forecast on this exciting product.

DBS Systems Celebrate the Past and Look to the Future

In second place in the hot product race were direct broadcast satellite (DBS) systems introduced by several manufacturers.

DSS

At the show, Thomson Consumer Electronics announced that it has shipped a total of 1.8 million Digital Satellite Systems (DSS) to dealers in its first 18 months of production. There were 600,000 units shipped in 1994, and an additional 1.2 million units shipped in 1995 under both the RCA and GE brand names. In December 1995, sales of DSS averaged 5,000 units per day. About 25 percent of DBS subscribers dropped their cable TV subscription in favor of DBS services. Thomson also announced that its factory inventory stands at less than one week. Its total manufacturing capacity is now 2 million units annually.

Thomson unveiled its second-generation DSS receivers at the Winter CES. Thomson now has three systems with the RCA brand: the DS7430RA top-of-the-line system for multiroom operation, the DS4430RA deluxe single-room system, and the entry-level DS3330RA system. These new models will begin shipping to dealers on January 15, 1996. At the end of January, Thomson will also have a DSS with its ProScan brand on it. Thomson plans to design a DSS receiver as a PC add-in card sometime in 1996.

Pay TV services for DSS are split between two different program suppliers, DirecTV and U.S. Satellite Broadcasting (USSB). DirecTV is owned by GM Hughes Electronics. USSB is owned by Hubbard Broadcasting Inc. News Datacom provides the conditional access service for both DirecTV and USSB.

During the Winter CES keynote speeches, Joe Clayton, executive vice president of Thomson Consumer Electronics, said that there would be 11 different brands of DSS by the end of 1996 and two completely new DBS systems (AlphaStar by Tee-Comm and Digital Sky Highway—DISH—Network by EchoStar). At the Winter CES, Uniden unveiled its DSS receiver, the Uniden UDS 200. Uniden has been a leader in integrated receiver-decoders (IRDs) for the C-band satellite market. Table 1 shows manufacturers that have or plan to have DSS-compatible receivers. Figure 2 shows Sony's DSS system. DSS is now available at over 20,000 retail points of sale. Best Western plans to begin offering DirecTV in its hotel rooms in January 1996.

Table 1
Manufacturers of DSS-Compatible Receivers

Manufacturer	Introduction Date
Thomson Consumer Electronics (RCA)	June 1994
Sony Electronics Inc.	June 1995
Thomson (GE Brand)	September 1995
Hughes Network Systems	Early 1996
Uniden America Corporation	Mid-1996
Toshiba America Consumer Products Inc.	Mid-1996
Samsung Electronics Co. Ltd.	June 1996
Sanyo Electric Co. Ltd.	June 1996
Daewoo Electronics Co.	June 1996
Matsushita (Panasonic and Quasar Brands)	June 1996
Thomson (RCA ProScan Brand)	1996

Source: Dataquest (January 1996)

Figure 2
The Sony DSS System

Source: Sony

Primestar at the Winter CES

On January 5, 1996, Primestar Partners L.P. announced its 1 millionth subscriber. This milestone occurred 17 months after its national launch. Primestar claims to have a 45 percent share of the DBS market, which, by its estimates, would put the total number of DBS subscribers at just over 2 million. Primestar is owned by a consortium of cable operators, led by Tele-Communications Inc. with a 22 percent share. General Instrument manufactures the hardware for Primestar. The Digicipher-I video decoder and the audio chip for the Primestar receiver are made by Motorola.

Primestar plans to spend $150 million in advertising in 1996. The highlight of the campaign is two TV spots airing during the Super Bowl on January 28—one during the pregame show and the other during the game itself. Primestar is also sponsoring the American Red Cross with a donation of $1 million and has announced its intention of serving hotels through an alliance with LodgeNet Entertainment Corporation.

Comparing Primestar and DSS

The street price for DSS has dropped to $499. This is for the first-generation RCA or GE brand with a $100 manufacturer's rebate from Thomson Consumer Electronics. The first-generation standalone receiver (without a dish) has dropped to a street price of $405 (including Thomson's $50 manufacturer's rebate). Primestar's customer-premises equipment remains the property of Primestar. With DSS, customers can choose to install the equipment themselves with a kit costing $70 or choose professional installation costing $150 to $200. Primestar offers no choice—professional installation is required at a rate of $150 to $200.

Pay TV services for DSS are split between two program suppliers, DirecTV and USSB, whereas Primestar is the sole programming supplier for its system. DirecTV has more channel capacity than Primestar. Primestar has 10 pay-per-view channels and DirecTV has 60. Also, DirecTV has 28 digital music channels and Primestar has only 14.

EchoStar's New DISH Network

EchoStar Communications Corporation of Englewood, Colorado, successfully launched its first direct broadcast satellite, EchoStar-I, on December 28, 1995. The satellite, a series 7000 satellite from Lockheed Martin Corporation, was launched from China Great Wall Industry Corporation's launch facility in Xichang, China. The satellite's final location will be at 119 degrees west longitude to provide 75 channels of programming for EchoStar's DISH Television Network by mid-February. EchoStar plans to launch a second satellite next year that will increase its capacity to 150 channels.

EchoStar's DBS system uses an 18-inch dish just like the RCA system. The basic receiver and dish system has a price of $599. However, consumers also have the option of renting the hardware for $10 per month, added to the cost of the programming package. EchoStar hopes to become the low-cost DBS service provider, with 40 basic channels starting at $19.99 per month. The EchoStar receiver uses MPEG-2 compression and is fully compatible with the Digital Video Broadcast (DVB) standard. EchoStar has chosen Electronic Data Systems of Plano, Texas, to provide customer service and sales support.

EchoStar began making C-band satellite dishes in 1980. In 1995, the company's financial results suffered from the decline of the bigger dishes.

AlphaStar

AlphaStar Digital Television is a new home satellite system scheduled to begin late in the first quarter of 1996 for the U.S. and Canadian markets. The programming services are provided by AlphaStar Television Network Inc. in the United States and ExpressVu Inc. in Canada. The hardware is available now from Tee-Comm Electronics Inc. On August 21, 1995, AlphaStar announced that Samsung Electro-Mechanics Company would also be manufacturing hardware systems.

The AlphaStar system uses a dish that is either 24 inches, 30 inches, or 39 inches in diameter. The Star Trak 1000 digital receiver uses TV/Com International's Compression NetWORKS system architecture, which is fully DVB-compliant and uses MPEG-2 compression and Viterbi forward error correction. Similar to DSS, the Star Trak receiver has a built-in 2400-baud telephone modem for ordering programming and an ISO 7816 smart card with three levels of security. The receiver can accept satellite signals in either the C-band or the Ku-band. Unlike DSS, the Star Trak receiver does not allow for S-video output. The DirectStar satellite dish is being made by Winegard Company of Burlington, Iowa. The system costs $1,099 in Canada. There will also be a lease-to-own option available.

ExpressVu received a service license from the Canadian Radio-Television and Telecommunications Commission on December 20, 1995. To serve Canada with almost 100 channels of video and audio programming, ExpressVu has reserved transponder space on Telesat's Anik E1 satellite. ExpressVu plans to provide an entry-level service for as little as $7.95 per month. For the U.S. market, AlphaStar Television Network will use 14 transponders on AT&T's Telstar 402R satellite, which was launched on September 24, 1995. AlphaStar has chosen Turner Vision in Bluefield, West Virginia, to provide call center services.

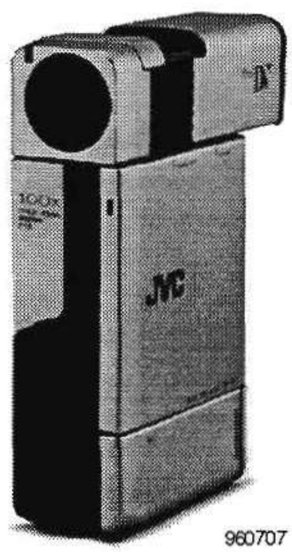
Camcorders

Common Digital Format Paves the Way for a New Generation

JVC introduced the world's smallest and lightest camcorder at the Winter CES, perfect for James Bond. JVC's GR-DV1 digital camcorder uses the new digital video cassette (DVC) format, which is now apparently going by just "DV." RCA debuted an identical model that it is sourcing from JVC. The RCA model number is CC900D. The JVC and RCA DVC camcorders will be available in the spring. Figure 3 shows the new JVC GR-DV1 digital camcorder.

It looks as if standards may still be in flux with these cameras, but the JVC/RCA models used a mini-DV cassette containing 30 minutes or 60 minutes of 1/4-inch tape. The cassette is about half the size of an 8mm tape. With a weight of only a pound (0.45 kg) and a very rectangular form of 1-3/4 x 3-1/2 x 5 3/4 inches (43 x 148 x 88mm), the camcorder is significantly smaller than its smallest analog cousins. A 3.6v lithium ion battery about the size of an AA battery runs the camcorder.

Figure 3
The JVC GR-DV1 Digital Camcorder



Source: JVC

The GR-DV1 has one 570,000-pixel, 1/3-inch charge-coupled device (CCD) that can pick out images in 1 lux of light. It has a digital image stabilizer that works extremely well, even when the 10x optical zoom and the 100x digital zoom are enabled. The DV format allows for a 500-line image, which betters S-VHS and Hi-8 by 20 percent and can produce a 16:9 or standard ratio image. However, the camcorder does not have a digital output and can transmit images only at S-video resolution.

So what's really digital? The image is digitized and compressed using discrete cosine transforms and variable length coding with an in-frame compression rate of 25 Mbps. The audio is pulse code modulated digital stereo, sampled at 48 kHz in a two-channel, 16-bit mode, or at 32 kHz in a four-channel, 12-bit mode. Each frame is incredibly sharp and can be edited, spliced, dubbed, and cut many times without sound or picture degradation.

The camcorder can be used to take digital still photographs, too, even in a timed sequence, and stores over 4,000 images on a tape, each digitally pure. The camera can be connected directly to a TV for playback. It also comes with a docking station for fancy editing. Besides the 12 digital special effects and 18 scene transitions available in the camera, the docking station brings editing capabilities up to professional standards. It adds time-code stamping, audio dubbing, and the ability to rearrange up to eight scenes at a time, along with a selection of effects and transitions. A Joint Level Interface Protocol (JLIP) in the docking station allows for sophisticated linking and control of the camcorder with a variety of audiovisual equipment and computers.

Although these digital camcorders are not an everyday consumer item, for the low-budget professional, serious amateur, or the gadget whiz with a little extra cash and some imagination, they are an impressive marvel. The size and weight are small enough to make it easy to leave this camcorder behind on a bus. But they are expensive. According to the EIA, the average selling price (ASP) for consumer camcorders in 1995 was $610. In Japan, the Ministry of Finance pegs that ASP at $482. Of course, these ASPs are the selling prices from manufacturers to dealers. An additional 33 percent can be added for the retailers' margin. Dataquest conducted a retail price survey in February 1995 and found name brand camcorders as low as $450 street price. The upper limit for the consumer market is $1,500. Prosumers will typically choose a Hi-8, S-VHS, or S-VHS-C model with one CCD for anywhere between $1,200 and $2,500. The industrial and broadcast markets choose cameras and camcorders in the $2,500-to-$100,000 range.

In addition to the JVC/RCA introduction, Sony, Panasonic, and Sharp digital camcorders were also presented at the show. Table 2 summarizes some of the information presented on these products. Hitachi also revealed its plans to introduce a digital camcorder that would not use DV cassettes but instead would use an entirely tapeless format. This pocket-size camcorder will be able to store 3,000 still frames and interface with a PC for editing and storage. Introduction is planned for the second half of 1996.

Table 2
Digital Camcorder Introductions

Model	Features	Price ($)	Availability
JVC GR-DV1	Single 570,000-pixel CCD, digital image stabilizer, editing functions	2,995	April 1996
RCA CC-900B	Single-CCD, editing functions	2,999	March or April 1996
Sony DCR-VX1000	Three-CCD imaging with 410,000 pixels per CCD, Super SteadyShot stabilization, and IEEE 1394 interface for editing/dubbing	4,199	Now
Sony DCR-VX700	Similar to DCR-VX1000, except for single 410,000-pixel CCD	2,999	Now
Panasonic PV-DV1000	Three-CCD imaging with 270,000 pixels per CCD, Digital Electronic Image Stabilizer, Digital Photo-Shot for still frames, and 16:9 recording mode	4,199	Now
Sharp VL-DH-5000	Three-CCD imaging with 410,000 pixels per CCD; 5-inch LCD color monitor	4,595	May 1996

Source: Dataquest (January 1996)

An Eye on Canon's Camcorder

Canon's feature products were its latest analog camcorders, with sophisticated eye-tracking circuitry. In these, an infrared light shines at the retina of the eye pressed against the viewfinder. After two calibration tests, the circuitry can then do an excellent job of following the eye's movements. This is most useful for identifying the object in the picture most critical to the focus, lighting, and color. This technique results in a very precise focusing in spite of the fact that nearer, farther, or larger objects appear in the viewfinder or that a chain link fence, net, window, or cable appears in front of the desirable image. The desired focal point does not have to be in the center of the picture, nor does it have to be motionless. The result is quite impressive. However, too long a glance at a less-desirable portion of the viewfinder image will cause refocusing on the new object. Of course, Canon then went wild and made it so that the eye movement could be used to select features within the camera, such as zoom and fade. This resulted in significant distraction from the primary purpose of having the eye in the eyepiece: following the objects in motion. It also tends to cause unnecessary strain on eyes being asked to do fairly unnatural things. A little more dexterity in the fingertips would provide the same functionality in a normal camcorder. The eye-movement-tracking capability has possibilities in many other applications, such as computer input alternatives. Some lessons in human behavior could be gained from such a device.

Say "Cheese" to Digital Cameras

Casio leads the developing digital camera field. The strength of the Casio brand, access through Casio sales channels, handy camera size, and selection meant that Casio's QV-10 model stayed in high demand and limited supply from its U.S. initial shipping date of September 1995. Casio started producing 3,000 cameras per month in March 1995 and boosted its monthly output to 10,000 units per month in September as its camera became one of the most popular models on the market. By the end of 1995, the company had invested another ¥300 million to expand production capacity to 30,000 units per month.

The 96 images that can be stored, the 1.3-inch color LCD monitor, and the ability to delete undesired shots in the camera add up to valuable in-the-field efficiencies offered by Casio's original QV-10 digital camera. Connected to a PC or Mac, the QV-10 allows photographs and computer-generated graphics to be downloaded into the camera for a small, portable presentation system. Electronic images can be output to PCs or directly to a TV. An ink jet color printer produces acceptable hard copies of the photos, although these are not "suitable for framing." In fall 1996, a color printer, the QG-100, will produce higher-density, color, 2-inch-to-3-inch hard copies that look a little more like a Polaroid. But, for $350, the QG-100 has a far more limited use than a similarly priced Hewlett-Packard ink jet printer.

Casio showed an improved model of the camera, dubbed the QV-30, at the Winter CES (see Figure 4). It expects to begin shipping this $1,000 camera in April 1996. Slightly larger than the QV-10, the lens can be made 46mm wide-angle or 105mm telephoto for more versatility. The resolution of the image is 300 lines, compared with the 200 lines of the QV-10, and the new model has a larger, 2.5-inch TFT LCD. An agreement with Adobe will make available a consumerized version of Photoshop called PhotoDeluxe, which will allow images transferred to a PC to be enhanced, manipulated, and cropped. The images can then be integrated with greeting cards, calendars, and other personal items.

Figure 4
Casio's New Model QV-30 Digital Camera

Source: Casio

Ricoh also showed its entry into the digital camera business. Although the Ricoh camera offers impressive features, it appeared that its designers had not seen the Casio model before putting this product together. The Ricoh RDC-1 will hold up to 492 still images in the biggest flash EPROM, but requires a PC to delete pictures. Some additional capabilities were available in the camera, such as a protocol to upload images to a remote PC over an add-on modem. The lens is equivalent to a 50mm-to-150mm lens, but the LCD screen was a cumbersome add-on rather than being molded into the back of the unit, as is Casio's. It, too, will have a small printer accessory and Photoshop-type PC software, perhaps included. Ricoh does have the ability to capture 10 seconds of audio with each photo, or to record up to 20 seconds of motion with sound, with each frame a complete compressed image. However, with U.S. availability in the spring and a big $1,800 price, Ricoh seems to be going for a higher-end, some-assembly-required market, and it is not likely to have Casio on the ropes soon.

The Casio cameras and the Ricoh have similar internal designs. Each uses a Hitachi SH-1 microcontroller in the camera, running 14 MHz out of code in the 64KB on-chip ROM, with 0.5MB DRAM for working space. The processor is aided by an individually developed ASIC that performs digital image compression. Ricoh uses JPEG as its image compression definition and consumes twice as much memory to store the data as Casio. However, the Ricoh can perform its compression fast enough to store 30 images per second continuously. Little real image enhancement takes place in the camera, as the processors primarily take what comes in off the CCD, set up the compression, and organize the bits in the flash EPROM. A digital camera by Sierra uses a MIPS microprocessor and actually performs digital signal processing (DSP) functions on the image to balance, correct, and enhance the image in the camera. Casio uses 2MB flash memory to hold 96 images, while Ricoh uses 2MB, 8MB, or 24MB of flash in a PCMCIA-type removable cartridge to store up to 492 stills.

Chinon has also been a major manufacturer of digital cameras, producing digital still cameras for U.S. makers on an OEM basis since 1992. It manufactures cameras for Apple, Kodak, and Logitech. In December 1995, it announced two new cameras under its own brand name, the ES-1000 and ES-3000. The ES-1000 is priced at $499 and will begin U.S. shipments in February 1996. The higher-end ES-3000 model is similar in size to a palmcorder and offers 3x zoom, with the highest-resolution image being 640 x 480 pixels. Storage capacity ranges from five images at 640 x 480 resolution to 40 images at 320 x 240 resolution in the internal 1MB of memory. Capacity can be increased with an optional flash memory card of 2MB, 4MB, 8MB, and 16MB. The 16MB card allows 689 images to be stored at 320 x 240 resolution. One of the main disadvantages of this product is the absence of a built-in or add-on display module. Images must be ported to a PC for viewing. Chinon has announced that it will triple its monthly production capacity from the 20,000 units per month it is estimated to have reached in December 1995.

Today, digital cameras are most popular with professionals such as insurance companies and real estate agents (who apparently are also besieged as the target markets for personal digital assistants), who may prefer the instant image and easy integration with a computer file or simply want an easy way to show a house. However, to the pleasant surprise of manufacturers, consumers are also beginning to purchase digital cameras and driving a stronger-than-expected market. The merger of the camera and a computer represents the easiest way to get photographs into a PC. Images can be transferred to the hard drive of a computer, where they can be viewed, edited, or added to documents. While the images created by digital cameras are inferior to the quality achieved by traditional film cameras, the image that can be captured in a PC through a digital camera is superior to the method of using a scanner to transfer a photo into a computer. The picture quality of the latest digital cameras is comparable to S-VHS or Hi-8 video images. Even with prices ranging from $500 to $1,800, Casio expects overall market sales of digital cameras to be four times higher in 1996 than in 1995.

What's on the Tube Tonight?

From the first day of television programming, viewers have been asking what there is to watch. TV listings in local papers satisfied some people's needs, and, in the United States, *TV Guide*, a separate magazine including listings, satisfied others. But television has changed drastically in the last decade, and the means of keeping up with programming is changing, as well. The VCR changed the viewing habits of the public, but a recent U.S. survey showed that one-third of VCR owners did not know how to record a TV show when they were not home. Now the program listings can be found on the TV itself, and recording a program on the VCR is finally easy.

There are many systems on the market in the United States that provide television program information electronically and simplify the use of the TV and VCR. VCR Plus started the process five years ago by giving users a means of programming their VCRs with a single six-digit code found in the printed TV listings, without having to program the channel, date, time, and duration separately. A VCR that supports VCR Plus will then record the right channel at the right time. A normal VCR can also take advantage of VCR Plus using a special remote control unit that will send the right signals to the VCR to perform the recording designated by the six-digit code. But that is now old hat.

Video Guide

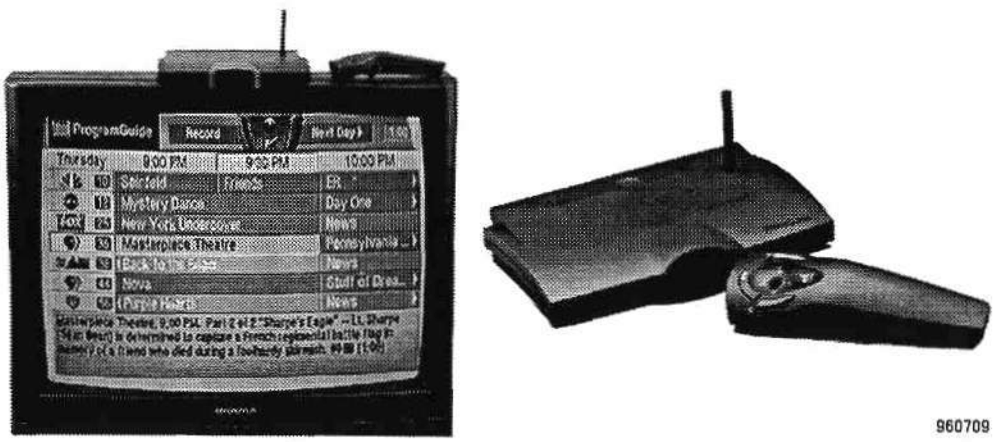
Radio Shack has been advertising the Video Guide, which is provided by a company called Video Guide. The system is available at other major retailers. Video Guide is interested in the installed base of already-purchased TVs and VCRs. As the latest entry into the market, it may want to provide the best set of features. It uses a small $100 unit near the TV/VCR in conjunction with an extremely simple remote control, which essentially can replace the remote control for most TVs and VCRs. For $50 a year, Video Guide distributes one week's worth of TV programming over a paging network in each region. The receiver intercepts the TV signal (on channel three) and can display upcoming programming on the screen.

Video Guide has the nicest-looking display of the three approaches (see Figure 5), with its fancy graphics even looking good on smaller TV screens. Browsing the on-screen programming guide is helped by alphabetical listings and some search capability. It is easy to find all of the showings of "The Outer Limits" for the next week to be sure none are missed or to find all programs in the sports category. Video Guide even keeps up with a subscriber's most watched channels and prioritizes them in the listings. Once the wanted program is highlighted, pushing a button will cause the TV to tune it in if it is being shown at the time. If it is not being shown, pushing another button will schedule it to be recorded later by the VCR. A tiny wired "repeater" infrared link placed on the VCR assures that a desired program will be recorded properly.

Through Video Guide, not only is TV programming available over the airwaves, but for up to $50 a year more, a sports newswire and a news and weather listing can be obtained. These text-based services are quite handy, allowing the subscriber to scan headlines and get more detail and even to jump to the ball game in progress if it is showing on one of the available channels. The sports information keeps up with the score, quarter, and events—an advantage of using a paging transmission rather than TV channel space. With the public's ever-increasing appetite for sports and news (baseball strikes and politics notwithstanding, and with Olympic games and the O.J. Simpson trial whetting appetites), these extra services could offer a significant edge over other systems.

The Video Guide system uses a Motorola 68EC000 processor in the main chassis and a Microchip Technology microcontroller in the remote control. The services are provided by Video Guide over the paging network, and regional information is included in the TV, news, and sports data provided. Since its release in early November, an average of 1,000 systems a day have been sold, with a nice boost from holiday sales. With a little more word-of-mouth advertising and promotion, this number should grow substantially.

Figure 5
Video Guide Unit



Source: Video Guide

StarSight

An earlier version of the TV program guide came from StarSight. StarSight focused its attention on the new-TV and new-VCR markets, although Magnavox has a standalone StarSight receiver for aftermarket opportunities. A StarSight receiver could add $35 to the cost of a TV or VCR and add $100 to the unit's selling price, plus a $50 annual subscription. When included with the TV or VCR, the only evidence of the circuit is a few extra buttons on the remote control. StarSight taps into the listings of *TV Guide* magazine, bringing that extra edge to its service. However, only TV program listings are provided, without the news and sports information available from Video Guide. Also, the receiver gets its data in the background of the local PBS affiliate broadcast, so for up-to-the-minute updates of news, sports, or weather, the PBS channel must be tuned in. StarSight does provide seven days of programming, expanded descriptions, category selection, and highlight-and-see/record capabilities.

StarSight's text on the TV screen has all the appeal of the Courier typewriter typeface with a little color highlighting, but it should be legible on any TV screen. The StarSight system does overlay the text on the TV program being watched—a benefit for the viewer who just can't stand missing a second of the program.

StarSight has been on the market for about a year. It has support from 14 major TV/VCR manufacturers, although relatively few TVs or VCRs today are shipped with StarSight. Thomson, with its GE, RCA, and ProScan brands in the United States, has invested $25 million in the company, so it is backing StarSight at a different level. The StarSight system uses specially designed chips from Zilog to receive the listings and place them on the TV screen.

A Baby Brother?

Gemstar, maker of VCR Plus+, has now introduced TV Guide Plus+. TV Guide Plus+ is offered as a free service after a properly equipped television or VCR is purchased. American Broadcasting Company (ABC) affiliates broadcast the electronic program guide to local broadcast areas, possibly covering a greater range than PBS or paging systems. The service also taps directly into listings of the "trusted" printed *TV Guide*. The simple dot matrix text display on the screen shows only two days of complete programming, although some listings show a longer period. A video window allows viewing of the current channel, some real-time information is possible, and VCR Plus+ has been turned into a one-button recording feature, but TV Guide Plus+ looks like the simplest form of electronic program listing. TV Guide Plus+ is primarily designed for inclusion in the TV or VCR. Magnavox is promoting TV Guide Plus+ in some of its TVs and VCRs, although other models sport StarSight.

Historical Reference

These systems for distributing TV programming, news, weather, sports, and information are reminiscent of the Teletext service that has been available in Great Britain since the early 1980s. This system started as an accessory to the TV but soon was incorporated into the set. An extra £100 (about

$100 in the early 1980s, now about $75) would buy a TV fitted with Teletext circuitry. The service was free in Great Britain, where advertising was found on only two of the four available channels and was generally regarded with disdain. Hundreds of "pages" of text were available to the user, providing news stories, weather, sports, air traffic information, and listings for programs. Subtitles for the hearing-impaired viewer were also transmitted over Teletext.

The British eagerly accepted this information system when only four TV channels were broadcast with almost no variation across the country and a hundred quid was a lot of money to most people. The textual information came over the transmission during the vertical blanking interval (as is done in many current systems), but this means the subtitles for the hearing-impaired do not record on a VCR. The desired information was brought up on the TV screen by entering the page number on the remote control. The system is still in place, and approximately 70 percent of TVs in Great Britain have Teletext. Some advances have been made in the service, simplifying navigation through the pages, but it does not provide a simplified link to the VCR.

It is not clear why a Teletext-type system never took hold earlier in the United States. Perhaps one of these new systems will have long-term success. Whether more than one will survive may be a test of standards, features, and marketing. Table 3 shows a comparison of TV program listing systems.

Table 3
Comparison of Electronic TV Program Listing Systems

System	Number of Days of Listings	Added Price ($)	Annual Service Charge ($)	Broadcast Medium	Integration With TV or VCR	Notes
Video Guide	7	100	50	Paging	External	Modem display, real-time sports and news available
StarSight	7	100	50	PBS	Internal/ external	Shows video
TV Guide Plus+	2	50	Free	ABC	Internal	No charge for service
VCR Plus+	7	40	Free	Newspaper	Internal/ external	Requires print media six-digit code
Teletext	1	75	Free	BBC	Internal	Closed captioning

Source: Dataquest (January 1996)

Voice Recording Systems

There were plenty of exhibitors showing voice recording systems, such as digital answering machines, digital voice recorders, and novelty recorders. For instance, Motorola was showing its new Tenor voice pager, which is capable of receiving voice messages through a pager network. The device can record up to four minutes of messages.

Parrot RCS S.A., a French company headquartered in Paris, was showing its new Parrot Speech Recognition Organizer. The Parrot Organizer combines a voice recorder and a phone directory that can be accessed with speech recognition. The product also features an automatic phone dialer and an optional interface to either a Macintosh or PC-compatible computer. The Organizer is assembled by IBM and retails for $279 in the United States.

The heart of the Parrot Organizer is a customized Texas Instruments TMS 320 C52 DSP at 40 MHz, capable of 20 mips. The DSP integrates Parrot's proprietary speech recognition software. The Organizer has 256KB of RAM and 256KB of ROM for voice prompts in five different languages. With compression, the Parrot Organizer is capable of 14 minutes of recording time at 2,400 bps. The Organizer also includes an ASIC for managing the energy and real-time clock that was designed and developed by Parrot and manufactured by Fujitsu. The Parrot Organizer is completely designed in 3.3V CMOS technology and runs on four AAA batteries.

Voice It Worldwide Inc. was showing its new Family Message Center, a digital note recorder with four separate channels for multiple users. The Message Center has a suggested retail price of $119. Voice It was also showing its extended line of Personal Note Recorders, the VT-40, VT-90, VT-180, and VT-240. The numbers indicate the seconds of recording time at the slowest recording speed. Voice It's Personal Note Recorders offer three different recording speeds, which allows the user a trade-off between recording time and audio quality. The recordings are always played back at the speed of normal speech. Figure 6 shows Voice It's VT-240 Personal Note Recorder.

The Flashback Digital Recorder from Norris Communications Corporation won a Popular Science Award in November of 1994. The product was featured in *Popular Science's* Best of What's New issue in the Audio and Video category. The Flashback features interchangeable memory cartridges called SoundClips that contain flash memory chips from Intel. Cartridges are available with 18 minutes or 36 minutes of recording time (a 72-minute version is also planned). The Flashback runs on two AA batteries. The product also features playback at three different speeds, with automatic pitch adjustment. The Flashback with one 36-minute cartridge lists for $249.

On November 10, 1995, Norris announced its intention to sell its Flashback technology to other OEMs. Norris also introduced its new SoundLink adapter. The SoundLink is a single-piece PCMCIA type II card that is essentially a PC docking port for Flashback SoundClips. Another product, introduced on November 13, 1995, was the Norris Flashfile System (NFS). The NFS is a development tool and file manager application program interface designed for other companies using flash memory in both primary and secondary storage applications. The NFS is a complete flash memory manager

Figure 6
The Voice It VT-240 Personal Note Recorder

Source: Voice It

with an MS-DOS redirector that takes only 13KB of ROM and 300 bytes of RAM to implement.

The 18-minute SoundClip contains 1MB of flash from Intel; the 36-minute version contains 2MB. The Flashback Digital Recorder also contains 512KB of DRAM used as a temporary buffer for compression and pitch adjustment during playback. The DRAM part used is a Micron 70ns 1Mx4. Other identifiable parts inside the Flashback included a 32Kx8 EPROM from Atmel, a codec from Oki, and a shift register from Harris.

Voice Recording Chips

The following five chip companies exhibited at this year's Winter CES:

- AT&T Microelectronics
- DSP Group Inc.
- Integrated Storage Devices
- National Semiconductor
- Zilog

All of these companies were showing chips designed for voice recording applications. National Semiconductor was previewing a 4MB serial flash part and voice processor chipset that it plans to introduce in the first quarter of 1996. The remaining four companies will be reviewed in detail in an upcoming Dataquest document.

Additional Show Highlights and Notes

An exhaustive report of all the new product introductions and developments at the Winter CES is not possible here. However, the following items demand at least a brief description.

Compaq and Fisher Price Invent the $2,000 Toy

Although the PC may have been accused of being nothing more than an expensive toy in the past, Compaq and Fisher Price have teamed up to create an innovative product that truly does turn a multimedia PC into a toy. This new product has drawn on the strengths of both companies to produce one of the more creative approaches to the home education/entertainment market. The Wonder Tools product line was designed for children from ages 3 to 7 and includes three categories: interactive computer toys, preschool-appropriate peripherals, and standalone software titles for children and families. The first products introduced at the Winter CES were the Wonder Tools Cruiser and Software, an innovative driving console and CD-ROM software that create an interactive experience for children (see Figure 7), and The Wonder Tools Keyboard, a keyboard with oversized keys, a mouse, and activity software that makes the computer easier and more fun to use for children. These products are designed to be used with any Windows-based PC and are scheduled to be available in the United States during the second half of 1996.

Figure 7
The Compaq/Fisher Price Wonder Tools System

Source: Compaq/Fisher Price

Binaura Steps Up to Challenge Spatializer and Q-Sound

Spatializer Audio Laboratories and Q-Sound have been among the most recognized names in the world of 3-D or enhanced audio products for the multimedia PC. Although multimedia PCs have been the platform for early applications of this technology, the market for this type of product is much larger than just PCs. In theory, any electronics product that reproduces sound is a target for enhanced audio technology. At the Winter CES, Spatializer introduced its HTMS-2510 stereo surround sound system for the consumer market. By plugging an HTMS-2510 in line with TVs, stereos, and VCRs, consumers can bring 3-D surround sound capability into their homes. However, a more significant development in this area may have come from a company called Binaura that demonstrated its technology in a motor home outside the convention center.

Binaura has already announced major design-wins for its patented audio enhancement technology with Creative Labs and Diamond Multimedia. The Soundblaster and 3-D multimedia accelerator products introduced by Creative Labs and Diamond Multimedia in 1995 incorporated its technology. Binaura claims that it already has five licensees of its technology and expects the total to increase to 13 or 15 soon. Discussions with company executives indicate that Binaura is positioned to capture over 70 percent of the multimedia upgrade kit market in 1996.

At the Winter CES, the company was demonstrating a very simple, inexpensive box with a pair of speakers driven by a portable CD player. The sound enhancement was impressive when applied to both stereophonic and monophonic signals. The Binaura system is implemented with discrete components: one quadraphonic operational amplifier, one quadraphonic multiplexer, 20 resistors, and four capacitors. It plans to offer an ASIC version of the circuit in the first half of 1996. Its goal is to be a leader in audio enhancement technologies for consumer electronics, video games, automotive sound, home entertainment, and multimedia computing markets. Look for significant market developments from this small, aggressive company during 1996.

Sony Hopes Price Cuts Will Stimulate U.S. MiniDisc Sales

Sony announced a reduction in the price of its play-only MiniDisc (MD) portable to $199 with the introduction of its MZ-E40. This model is scheduled to begin U.S. shipments in July and would replace an earlier model with a suggested retail price of $349 (an average street price of $299). Sony claims to have sold 1.5 million car, home, and portable MD players worldwide, but the steep price has created a major barrier to its success in the U.S. market. The new model features a 10-second memory buffer and seven hours of playback on two AA batteries, compared with a three-second buffer and five hours of playing time on the previous model. Sharp has also begun to manufacture MiniDisc products, which it was showing at CES.

IEEE 1394 Begins to Make Inroads into the Consumer World

For over a year, the proponents of the IEEE 1394 standard have been promoting it as the future consumer electronics network. Evidence of progress in penetrating the consumer electronics world was seen at the Winter CES. The most notable products that included IEEE 1394 communications capability were Sony's digital camcorders. However, the marketing of IEEE 1394 appears to be an uphill battle still. The most frequent response when various representatives were asked if their product included an IEEE 1394 port was a blank stare. When pressed on the issue, most representatives were either uninformed or unconvinced of the merits of an IEEE 1394 port. Although Sony's incorporation of this port in its camcorders is encouraging, the day when this capability is a standard feature would appear to be distant.

Afraid of the Dark?

Although ITT's Night Quest product line has essentially no semiconductor content, the company did have one of the more intriguing products in the consumer's price range. ITT was showing its night vision monoculars and binoculars for the consumer market at the Winter CES. With technology developed (and paid for) for the military, these second- and third-generation viewers turn complete darkness into green daylight. Indoors, with imperceptible light, or outdoors, in starlight (not moonlight), these viewers show detail of everything, with nothing hiding in the shadows.

Night vision glasses such as these have been seen in spy movies and military exercises, but now are available for as little as $800, not the $5,000-to-$10,000 price range seen in military surplus catalogs. The company claims that these are far more sensitive than those used by the Russian military.

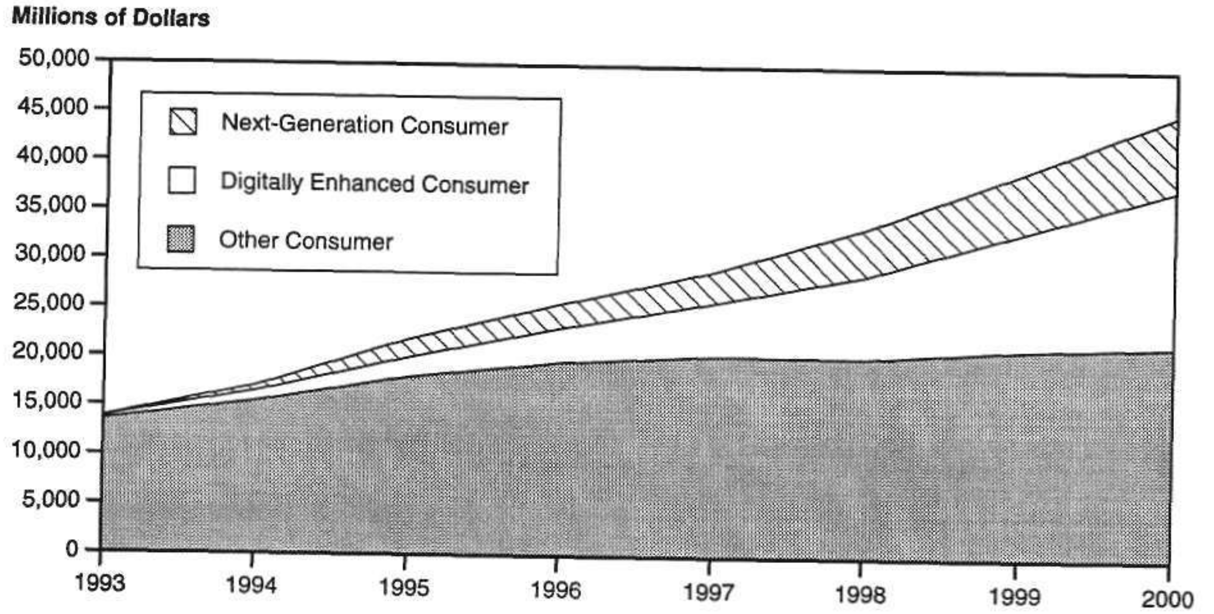
Last year, ITT sold these monoculars/binoculars successfully to the marine market, where they aid significantly in night boating. ITT is now bringing the glasses to a broader sporting goods market for use by hunters, campers, hikers, and others to see prowlers, animals, trails, lost people, and things that go bump in the night. These are slightly infrared-sensitive but do not depend on infrared for imaging (an infrared flashlight is offered for supplemental lighting).

The image on all models is amazingly clear and detailed. There is basically no magnification, so the field of view is maximized (52 degrees), and 2x and 3x lens attachments are available. Most models even float, so consumers won't lose their investment overboard, although another Night Viewer might be needed to see the first one bobbing along in the dark. The lowest cost model, the Night Quest 100, is a monocular weighing only 10 oz.

Summary

With DBS, MD, DVC, and DVD, the home digital revolution is in full swing. With the transition to digital, Dataquest expects that the value of semiconductors going into consumer electronics will grow from $22 billion in 1995 to $46 billion by 2000. (Note that this does not include the semiconductor market opportunity in home appliance/convenience products.) As shown in Figure 8, new digital products and digital enhancements to current consumer products will drive the growth in the consumer semiconductor market in the future. The digital products introduced at the 1996 Winter CES give added credence to this forecast.

Figure 8
Consumer Semiconductor Market Forecast: Digital Will Drive the Growth in Chips



Source: Dataquest (January 1996)

Dataquest has launched a new program, Consumer Multimedia Semiconductors and Applications Worldwide, that will provide in-depth, detailed market research and analysis on the consumer electronics market and the semiconductor market driven by products and technologies such as those described in this document. Also watch the Embedded Microcomponents Service for more on the impact of consumer electronics on microcomponents.

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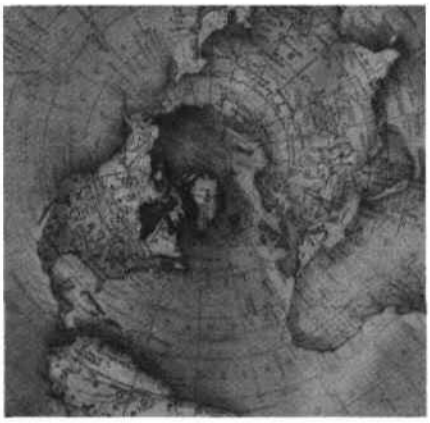

Dataquest

Regional Microcomponent Revenue Forecast through the Millennium: A Cool Front Passing

Market Trends

Program: Embedded Microcomponents Worldwide
Product Code: MCRO-WW-MT-9604
Publication Date: December 16, 1996
Filing: Market Trends

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Chapter 1
Overview

Microcomponents comprise four categories of metal-oxide semiconductors (MOS): microprocessors (MPUs), microcontrollers (MCUs), programmable digital signal processors (DSPs), and microperipherals (MPRs). This report presents Dataquest's forecast for this very important market over the next five years. The forecast is backed by extensive research and in-depth analysis of product characteristics, market dynamics, and end equipment. Forecasts of revenue through the year 2000 are given for the categories of MPUs, MCUs, DSPs, and microperipherals. Projections for the Americas, Japan, Europe, and Asia/Pacific regions are presented by category.

Greater detail of the microprocessor forecast is available in Dataquest's document *Microprocessor Forecast and Embedded Microprocessor Trends through the Year 2000* (MCRO-WW-MT-9602, September 23, 1996), with more on the computational portion detailed in Dataquest's document *Compute Microprocessor Market Trends and Forecast* (PSAM-WW-MT-9604, September 2, 1996). Greater detail of the microcontroller forecast is available in Dataquest's document *The Microcontroller Forecast—A Mixed Bag and Then Back on the Track* (MCRO-WW-MT-9603, September 23, 1996). Additional information on the DSP market can be found in "Digital Signal Processors—A Brilliant Light in an Overcast Year" (MCRO-WW-DP-9608, December 16, 1996).

Definitions of terms are in Appendix A, and exchange rates used for this document can be found in Appendix B.

Highlights of the Forecast

Microcomponents perform complex functions that are vital to the application into which they are designed. Although similar functions could be performed by somewhat similar circuits, there is usually quite a bit of investment tied up in the original microcomponent chosen for the application, and this is not quickly disposed of. Because microcomponents are not, therefore, commodities, they are less influenced by some of the dramatic swings in the general semiconductor marketplace and especially in those semiconductors that are true commodities.

Dataquest is forecasting semiconductors overall to lose more than 9 percent of their 1995 revenue in 1996, led by the dramatic decline in DRAM pricing. On the contrary, worldwide revenue for microcomponents should close out 1996 at over $39 billion, 13 percent higher than 1995, driven mostly by the x86 processors going into personal computers. Microprocessors lead the category with 13.8 percent growth over 1995.

Embedded MPUs and MCUs are having a fairly flat year in 1996 but are on the positive side for growth and should improve in 1997, with full-strength growth returning in 1998 and beyond. DSPs will defy the trend and show the greatest growth rate (36 percent) in semiconductors in 1996. Unit volume and revenue stayed strong in 1996 for DSPs because of the increasing use of DSPs, the unique makeup of the primary vendors of DSPs, and the strong demand for DSP end products that went unfulfilled in previous years because of chip shortages. MPRs will also show a respectable growth in 1996, being bolstered by the continued good demand for PCs and therefore the chipsets that go into them.

Overall, the long-term outlook for all microcomponents is very rosy, with a 20 percent compound annual growth rate (CAGR) anticipated for the last three years of the forecast period. Intel is expected to maintain its commanding lead with the main PC processor, but the rest of the vast embedded marketplace will see many new applications, architectures, standards, chips, combinations, and speeds appear to keep the industry fresh, vibrant, and full of opportunity.

Weathering the Present

Semiconductors in general surprised everyone in 1996. The weather had been so nice for so long that most of the industry had come to believe that the sunny skies would just never end. But the sun spots flared up in earnest, the semiconductor El Niño eventually changed its mood, the PC jet stream eased up and altered its course, and a nasty cold front swept over the landscape. The memory business took the brunt of the storm, with temperatures plunging 100 degrees in the process. Microcomponents took a chill but have been one of the more pleasant locales this fall. Yes, even Hawaii has its weather. Most semiconductors fell somewhere in between, with the larger-die products generally on the warmer side (except for the DRAMs, and DRAM seems to be being forced to the levels where it should have been all along).

It seems the more one delves into the detail of the environment, the more one finds that nobody completely missed the microcomponent storm. Some took a direct hit from a hurricane. Some have to face a long drought, while others had so much rain as to flood the rivers. The rain below means that there's heavy snowfall in the mountains, which can be good for those who run the ski resorts. But come spring, the melt is likely to flood the valleys below—better reassess the dams. Some of the warmest climates aren't used to the cold, no matter how brief, and discover many accidents caused by unskilled drivers maneuvering on the icy roads that the city is ill-equipped to clear. And for those who seem to have missed all the weather, beware. There are still earthquakes, insect infestations, and range fires to disturb a peaceful existence. Each vendor can expect its own unique form of weather, as determined by the applications and regions it services, the products and prices it offers, the manufacturing and organizations it manages, and the people and finances it has.

Mind you, this is not destruction, it is only some unpleasantness. If the autumn turns to winter or lasts too long, it will wear on the nerves, the spirit, and the pocketbook. Changes have to be made to deal with the weather. Pull out the heavy coats, put an extra blanket on the bed, put up the storm windows, and batten down the hatches. Keep a keen eye on that budget. Hail, constant rains, and freezes that occur out of season can minimize yields of the crops that have taken all year to nurture. The fixed assets have to be paid for, come rain or shine.

There is naturally quite a bit of turbulence during such dramatic changes. Each company, market, and product family has its own weather to contend with. The best-prepared vendors are faring the best during the storms. Some vendors that are tightly coupled to the PC industry are doing quite well. Intel has a death grip on the CPU slot and has expertly managed its product mix and maximized its demand. Others are suffering badly when their products do not make the grade, are poorly timed, or depend on a weak OEM or end product. Zip drives are booming; 9600-baud modems are sold in garage sales (jumble sales). But there are other good industries, too. Automobiles continue to sell at a fairly steady pace and yet use more microcontrollers with each passing year. Cellular phones can be good business, but there are many changes under way and constant price pressure.

When this period of turbulence is past, the vendors and OEMs in the electronics industry should have a renewed dedication of purpose and more clearly focused goals.

A Rosy Long-Term Outlook

Microcomponents are actually faring rather well in the 1996 climate. Dataquest is forecasting semiconductors overall to lose over 9 percent of their 1995 revenue in 1996, led by the dramatic decline in DRAM pricing. DRAMs alone are forecast to drop $20 billion (46 percent) from their annual high in 1995. Revenue for microcomponents should close out 1996 at 13 percent higher than 1995, driven most by the x86 processors going into personal computers. The Pentium seems to be a pretty hardy crop when sown in the PC fields. Most laboratory-grown varieties appear to be inferior when the going gets tough, and these crops seem to wither more quickly than the pure-bred version. Although it looks as if there is a slowing of the number of new people getting their hands on a PC (first-time buyers), there is a significant business in putting more PCs into the hands of those who already use them (additional computers for the home to supplement the office/original computer). The previous computers are being handed down to the children or relegated to more dedicated roles (World Wide Web, games, or finances). The upgrade market for the older computers keeps a brisk industry going for memory, disk drives, modems, and sound cards, as well as software.

The embedded microcomponent market comprises a tremendous variety of applications, from television remote controls to magnetic resonance imaging equipment. These markets are served by dozens of vendors of thousands of MPUs, MCUs, and DSPs, which are coded by millions of programmers to perform each individual application, with billions of units shipped every year. The broad base of embedded applications insulates the microcomponent industry from some of the drastic ups and downs of specific markets, while the number of new applications emerging that use these programmable devices is constantly expanding. More and more applications use embedded MPUs, MCUs, and DSPs because of the need for better monitoring of processes, greater sophistication in the control of systems, simpler and more intuitive interfaces between man and machine, adaptation of constantly changing standards, and the drive to do more (that is, channels) with less (that is, bandwidth).

The mix between off-the-shelf programmable devices (MPUs, MCUs, and DSPs), custom programmable devices, application-specific ICs (ASICs), and fixed-function peripheral circuits continues to churn. With every opportunity for the cost of a programmable device to be reduced by moving to a dedicated microperipheral, there appear more new applications that are just crawling out of the laboratories where the protocols, usage, interfaces, and form factors are in such a state of change as to require a very flexible and therefore programmable device at the helm. Some OEMs will use standard processors and controllers. Others prefer to "roll their own" and develop ASIC-based solutions. Still others have high enough volume to command uniquely integrated MPUs to perform the precise functions needed at a better price point. In digital electronics, there is definitely more than one way to "skin a cat."

Over time, as a new product settles down and the market matures, the functions are common enough and in high enough volume that they can be manufactured most inexpensively as microperipherals. Fax-modem chips and some cellular phone chips are examples of these. The personal computer industry has taken a bit of a different tack: PC chipsets, graphics chips, and audio chips are MPRs that emerged more as a collection of glue logic and dedicated functions to perform a set of operations according to some rapidly established standards and processor interfaces. These replace an ASIC or a "bag of parts" of transistor-transistor logic (TTL), rather than a programmable device. With the growth of the PC market, these PC peripherals have seen substantial activity and growth. MPEG decoder chips also fit in this profile, even though MPEG can be well accommodated in programmable devices; but the standard is fixed and the overhead of general programmable processors implementing the dedicated function is too wasteful to be justified in many circumstances.

The distinction between MPUs, MCUs, DSPs, ASICs, MPRs, and memory continues to blur. Processors may be buried inside an MPR to ease the design of the MPR. Digital signal processing may be an integral part of an MPR's function. Some MPUs can be placed in the corner of a large memory device like a DRAM. MPU and MCU cores may be available as macros or hard blocks in an ASIC library. Multiply-accumulate (MAC) accelerators can be found on some MCUs and MPUs and in ASIC libraries. Peripherals integrated onto processors can look a lot like an MCU, but without the ROM. Dataquest is careful to distinguish among these components according to specific definitions that reflect generally accepted views, although they may differ from a particular vendor's product definition. Dataquest's microcomponent definitions are detailed in Appendix A. Some examples of microcomponents and other semiconductors are illustrated in Figure 1-1.

Overall Forecast

An overview of Dataquest's forecast of microcomponents by product type is given in Table 1-1. The market for all semiconductors in 1995 was $151.3 billion. This is expected to shrink in 1996 to just under $137 billion. The CAGR for the next five years should be 13.9 percent for all semiconductors. However, for the last three years of the millennium, semiconductors are forecast to have a 23.4 percent CAGR. Microcomponents made up 22.8 percent of all semiconductors sold in 1995, and this proportion will grow to over 27 percent by late 2000 (see Figure 1-2). Over $34.5 billion of microcomponents were sold in 1995, with growth tapering off a bit before rising at a CAGR of 19.8 percent starting in 1997, to reach $78.6 billion in the year 2000. Figure 1-3 compares the strong five-year CAGR for microcomponent families with all semiconductor products.

Figure 1-1
Categorization of Microcomponents

Semiconductors							
Microcomponents					Memories	ASIC	Others
	Embedded Microcomponents						
Computational MPU	Embedded MPU	MCU	DSP	MPR			
x86 (most)	x86 (some)	(Many)	(Many)	(Many)			
68K (few)	68K (most)						
PowerPC	PowerPC (some)						
MIPS	MIPS (some)						
Others	SH-series						
	Others						

Dataquest's Embedded Microcomponents Worldwide Service Coverage

968369

Note: Compute microprocessors perform the central processing unit function of personal computers, workstations, and servers. Embedded microprocessors perform dedicated processing and controlling tasks as programmed by the OEM.
Source: Dataquest (November 1996)

Embedded microcomponents include those MPUs used in embedded systems and all MCUs, DSPs, and MPRs. Embedded microcomponents sell at one-tenth the price of computational processors but ship almost two orders of magnitude more units to attain 60 percent of the microcomponent market revenue.

The forecast of microcomponents going into the four regions, the Americas, Japan, Europe, and Asia/Pacific, can be found in Table 1-2. The Americas is the largest microcomponent market and is expected to grow faster than the average, as shown in Figure 1-4. Asia/Pacific should have the highest overall growth rate (see Figure 1-5), fueled by OEMs, including Japanese companies building their products in lower-cost plants and with lower-cost labor in the Far East, as well as by growth in electronics in Asian and Pacific rim countries.

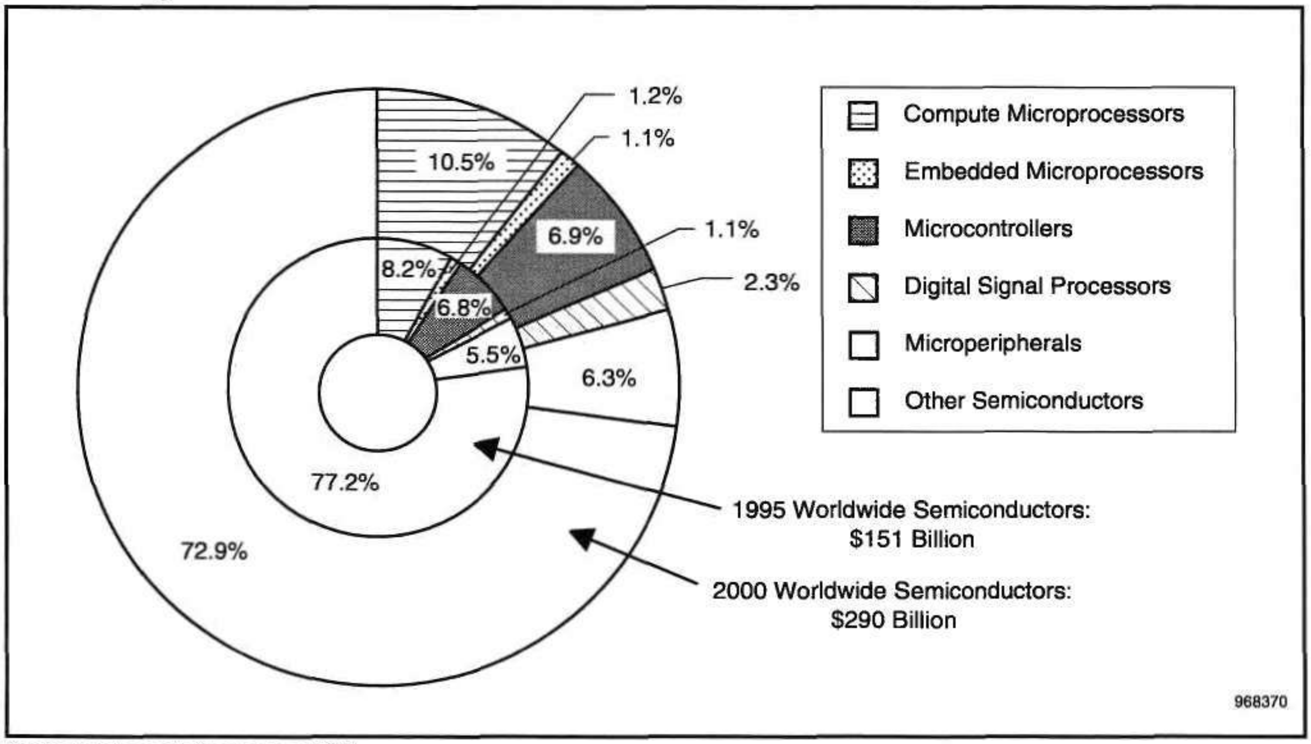
Further divisions of the revenue of microprocessors, microcontrollers, digital signal processors, and microperipherals for the Americas, Japan, Europe, and Asia/Pacific regions and the rest of the world are forecast in later chapters of this document.

Table 1-1
Worldwide Forecast of Microcomponent Revenue, by Product Family
(Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Total Worldwide Semiconductors	85,514	110,513	151,272	136,977	154,605	188,922	234,916	290,219	
Growth (%)		29.2	36.9	-9.4	12.9	22.2	24.3	23.5	13.9
Total Worldwide Microcomponents	19,947	26,408	34,513	39,283	45,674	55,088	65,947	78,640	
Growth (%)		32.4	30.7	13.8	16.3	20.6	19.7	19.2	17.9
Percentage of Worldwide Semiconductors	23.3	23.9	22.8	28.7	29.5	29.2	28.1	27.1	
Embedded Microcomponents	12,287	16,320	22,052	24,023	27,124	32,818	39,667	48,180	
Growth (%)		32.8	35.1	8.9	12.9	21.0	20.9	21.5	16.9
Percentage of Worldwide Microcomponents	61.6	61.8	63.9	61.2	59.4	59.6	60.1	61.3	
Percentage of Worldwide Semiconductors	14.4	14.8	14.6	17.5	17.5	17.4	16.9	16.6	
Microprocessors	8,783	11,437	14,279	17,130	20,640	24,650	29,000	33,590	
Growth (%)		30.2	24.8	20.0	20.5	19.4	17.6	15.8	18.7
Percentage of Worldwide Microcomponents	44.0	43.3	41.4	43.6	45.2	44.7	44.0	42.7	
Percentage of Worldwide Semiconductors	10.3	10.3	9.4	12.5	13.4	13.0	12.3	11.6	
Microcontrollers	5,904	7,517	10,249	10,640	11,450	13,810	16,510	20,040	
Growth (%)		27.3	36.3	3.8	7.6	20.6	19.6	21.4	14.4
Percentage of Worldwide Microcomponents	29.6	28.5	29.7	27.1	25.1	25.1	25.0	25.5	
Percentage of Worldwide Semiconductors	6.9	6.8	6.8	7.8	7.4	7.3	7.0	6.9	
Digital Signal Processors	679	1,030	1,669	2,223	3,004	3,978	5,187	6,700	
Growth (%)		51.7	62.0	33.2	35.1	32.4	30.4	29.2	32.0
Percentage of Worldwide Microcomponents	3.4	3.9	4.8	5.7	6.6	7.2	7.9	8.5	
Percentage of Worldwide Semiconductors	0.8	0.9	1.1	1.6	1.9	2.1	2.2	2.3	
Microperipherals	4,581	6,424	8,316	9,290	10,580	12,650	15,250	18,310	
Growth (%)		40.2	29.5	11.7	13.9	19.6	20.6	20.1	17.1
Percentage of Worldwide Microcomponents	23.0	24.3	24.1	23.6	23.2	23.0	23.1	23.3	
Percentage of Worldwide Semiconductors	5.4	5.8	5.5	6.8	6.8	6.7	6.5	6.3	

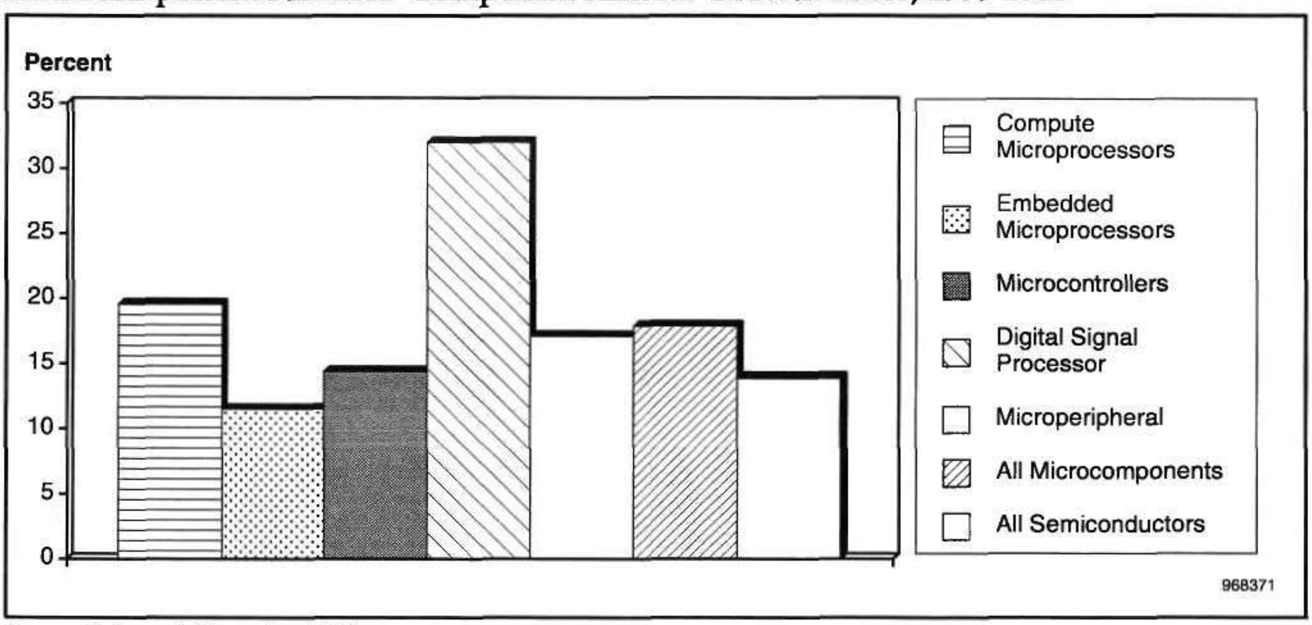
Source: Dataquest (November 1996)

Figure 1-2
Microcomponents as a Portion of All Semiconductor Revenue, 1995 and 2000



Source: Dataquest (November 1996)

Figure 1-3
Microcomponent Families' Compound Annual Growth Rates, 1995-2000



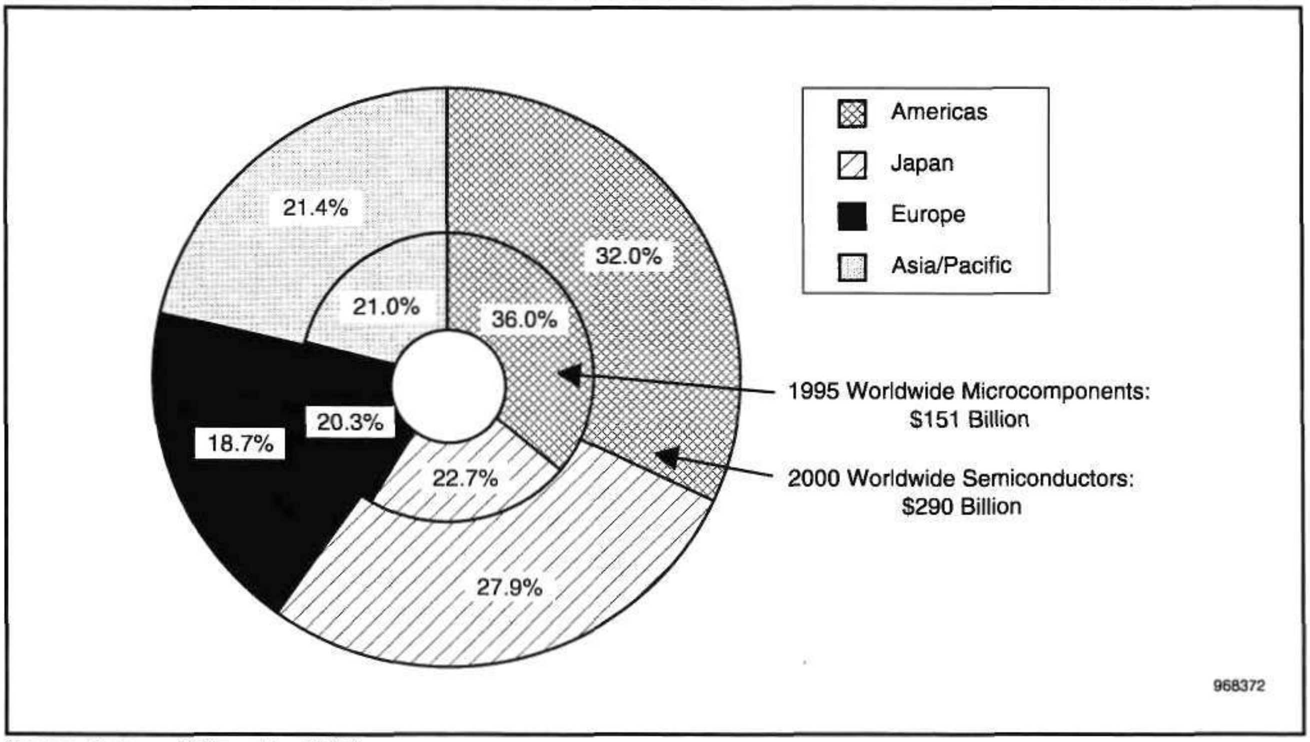
Source: Dataquest (November 1996)

Table 1-2
Revenue Forecast from Microcomponent Consumption in Each Region
(Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Total Worldwide Semiconductors	85,514	110,513	151,272	136,977	154,605	188,922	234,916	290,219	
Growth (%)		29.2	36.9	-9.4	12.9	22.2	24.3	23.5	13.9
Total Worldwide Microcomponents	19,947	26,408	34,513	39,283	45,674	55,088	65,947	78,640	
Growth (%)		32.4	30.7	13.8	16.3	20.6	19.7	19.2	17.9
Percentage of Worldwide Semiconductors	23.3	23.9	22.8	28.7	29.5	29.2	28.1	27.1	
Americas	7,620	9,839	12,430	14,353	17,270	21,130	24,900	29,110	
Growth (%)		29.1	26.3	15.5	20.3	22.4	17.8	16.9	18.6
Percentage of Worldwide Microcomponents	38.2	37.3	36.0	36.5	37.8	38.4	37.8	37.0	
Percentage of Worldwide Semiconductors	8.9	8.9	8.2	10.5	11.2	11.2	10.6	10.0	
Japan	3,987	5,603	7,830	8,260	9,369	11,470	14,050	16,970	
Growth (%)		40.5	39.7	5.5	13.4	22.4	22.5	20.8	16.7
Percentage of Worldwide Microcomponents	20.0	21.2	22.7	21.0	20.5	20.8	21.3	21.6	
Percentage of Worldwide Semiconductors	4.7	5.1	5.2	6.0	6.1	6.1	6.0	5.8	
Europe, Africa, and Middle East	4,037	5,408	7,001	8,055	8,924	10,260	12,260	14,970	
Growth (%)		34.0	29.5	15.1	10.8	15.0	19.5	22.1	16.4
Percentage of Worldwide Microcomponents	20.2	20.5	20.3	20.5	19.5	18.6	18.6	19.0	
Percentage of Worldwide Semiconductors	4.7	4.9	4.6	5.9	5.8	5.4	5.2	5.2	
Asia/Pacific	4,303	5,558	7,252	8,615	10,111	12,228	14,737	17,590	
Growth (%)		29.2	30.5	18.8	17.4	20.9	20.5	19.4	19.4
Percentage of Worldwide Microcomponents	21.6	21.0	21.0	21.9	22.1	22.2	22.3	22.4	
Percentage of Worldwide Semiconductors	5.0	5.0	4.8	6.3	6.5	6.5	6.3	6.1	

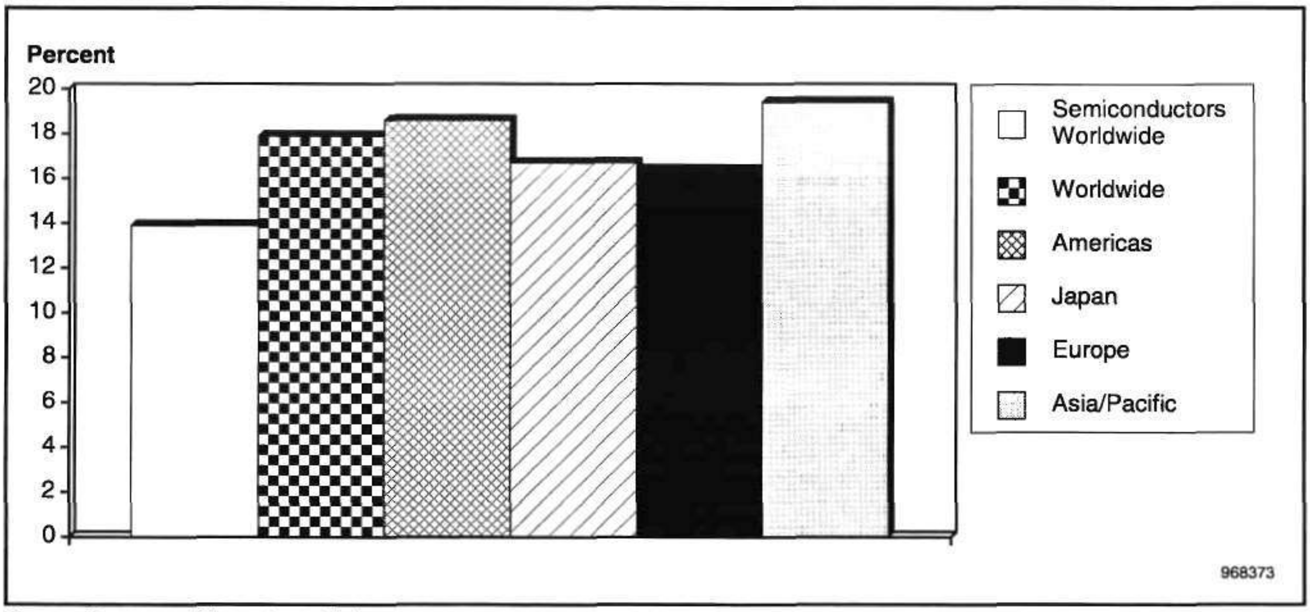
Source: Dataquest (November 1996)

Figure 1-4
Regional Distribution of Microcomponent and All Semiconductor Consumption, 1995



Source: Dataquest (November 1996)

Figure 1-5
Regional Microcomponent and Semiconductor Compound Annual Growth Rates, 1995-2000



Source: Dataquest (November 1996)

Chapter 2
A Closer Look at the Microcomponent Product Families

In this chapter, the forecast of microcomponents is broken into microprocessors, microcontrollers, programmable digital signal processors, and microperipherals, showing their distribution into the Americas, Japan, Europe, and Asia/Pacific regions. A section is dedicated to each product family: all microcomponents, microprocessors, microcontrollers, programmable digital signal processors, and microperipherals. Within each section, the revenue forecast for the product family is given in tables and related figures contrasting the Americas, Japan, Europe, and Asia/Pacific.

All numbers attributed to a region represent the revenue resulting from consumption of the specified microcomponents in that region.

Microcomponents

The forecast of all microcomponent revenue (see Table 2-1) shows how microcomponents are expected to ship into each of the four geographic regions for the next five years. (Table 2-1 is a subset of Table 1-2.) Percentages are given for each region's microcomponent revenue as a portion of the worldwide revenue for all microcomponents and for total semiconductors.

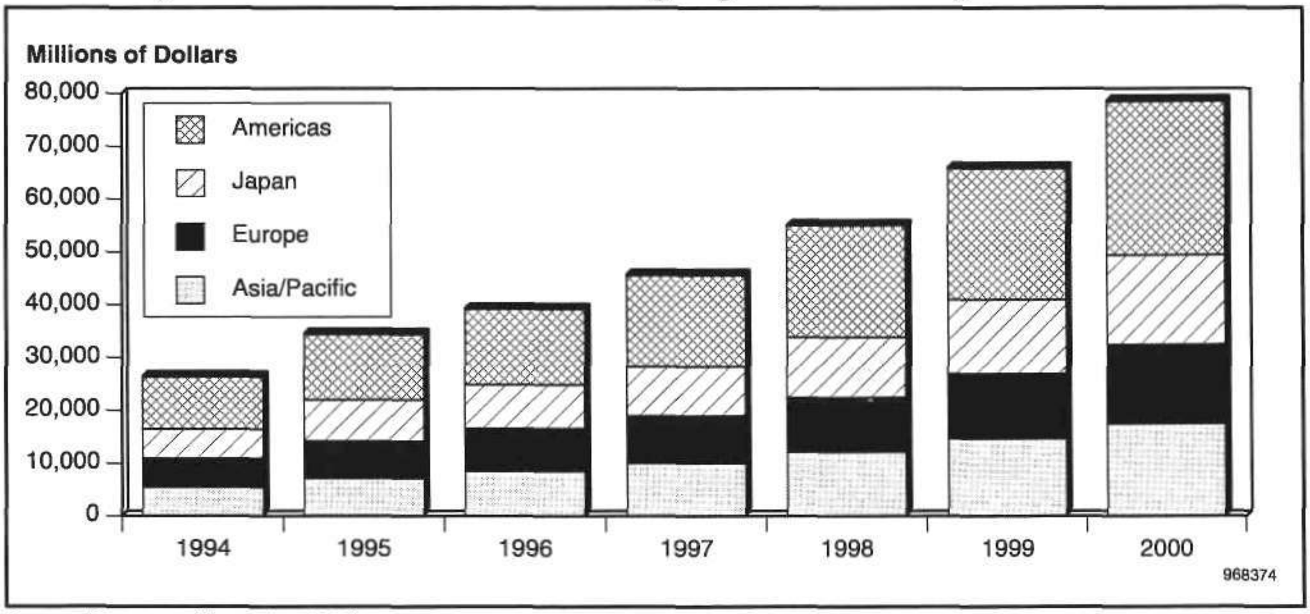
Figure 2-1 shows each region's microcomponent revenue as a portion of the worldwide microcomponent revenue. Figure 2-2 illustrates each region's microcomponent revenue. Figure 2-3 shows the change expected in the distribution of microcomponent revenue among the regions in 1995 and the year 2000. Figure 2-4 compares the CAGR of microcomponent revenue for each region.

Table 2-1
Revenue Forecast from Microcomponent Consumption in Each Region (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Total Worldwide Semiconductors	110,513	151,272	136,977	154,605	188,922	234,916	290,219	
Growth (%)		36.9	-9.4	12.9	22.2	24.3	23.5	13.9
Total Worldwide Microcomponents	26,408	34,513	39,283	45,674	55,088	65,947	78,640	
Growth (%)		30.7	13.8	16.3	20.6	19.7	19.2	17.9
Percentage of Worldwide Semiconductors	23.9	22.8	28.7	29.5	29.2	28.1	27.1	
Americas	9,839	12,430	14,353	17,270	21,130	24,900	29,110	
Growth (%)		26.3	15.5	20.3	22.4	17.8	16.9	18.6
Percentage of Worldwide Microcomponents	37.3	36.0	36.5	37.8	38.4	37.8	37.0	
Percentage of Worldwide Semiconductors	8.9	8.2	10.5	11.2	11.2	10.6	10.0	
Japan	5,603	7,830	8,260	9,369	11,470	14,050	16,970	
Growth (%)		39.7	5.5	13.4	22.4	22.5	20.8	16.7
Percentage of Worldwide Microcomponents	21.2	22.7	21.0	20.5	20.8	21.3	21.6	
Percentage of Worldwide Semiconductors	5.1	5.2	6.0	6.1	6.1	6.0	5.8	
Europe, Africa, and Middle East	5,408	7,001	8,055	8,924	10,260	12,260	14,970	
Growth (%)		29.5	15.1	10.8	15.0	19.5	22.1	16.4
Percentage of Worldwide Microcomponents	20.5	20.3	20.5	19.5	18.6	18.6	19.0	
Percentage of Worldwide Semiconductors	4.9	4.6	5.9	5.8	5.4	5.2	5.2	
Asia/Pacific	5,558	7,252	8,615	10,111	12,228	14,737	17,590	
Growth (%)		30.5	18.8	17.4	20.9	20.5	19.4	19.4
Percentage of Worldwide Microcomponents	21.0	21.0	21.9	22.1	22.2	22.3	22.4	
Percentage of Worldwide Semiconductors	5.0	4.8	6.3	6.5	6.5	6.3	6.1	

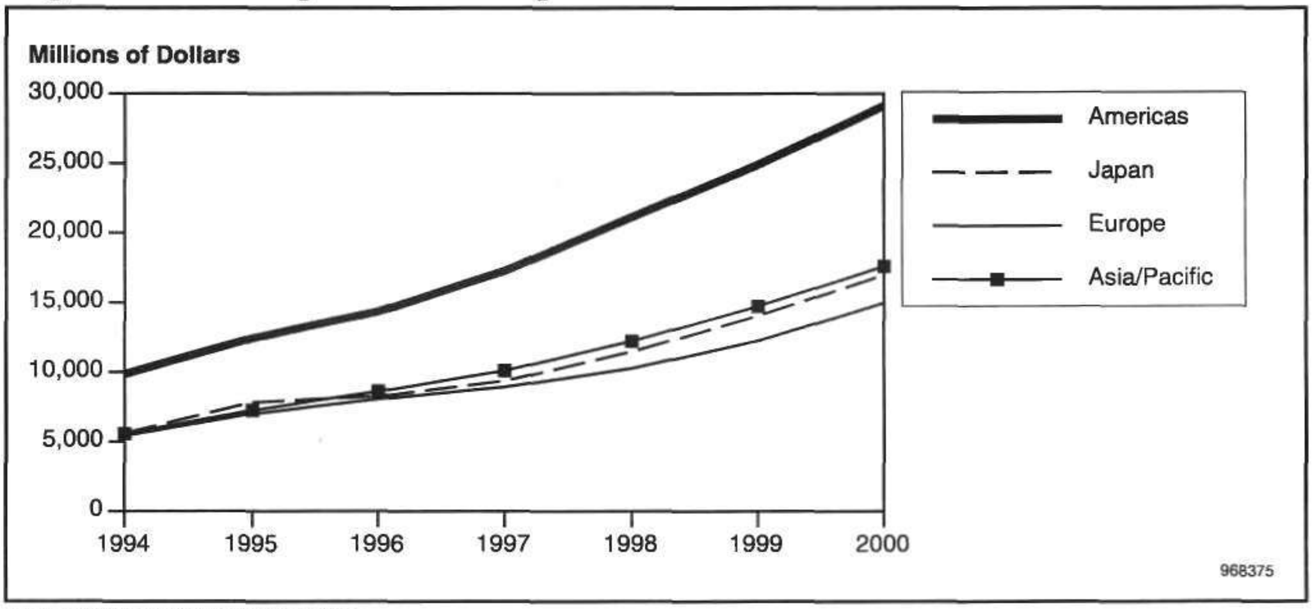
Source: Dataquest (November 1996)

Figure 2-1
Microcomponent Revenue Forecast Showing Region of Consumption



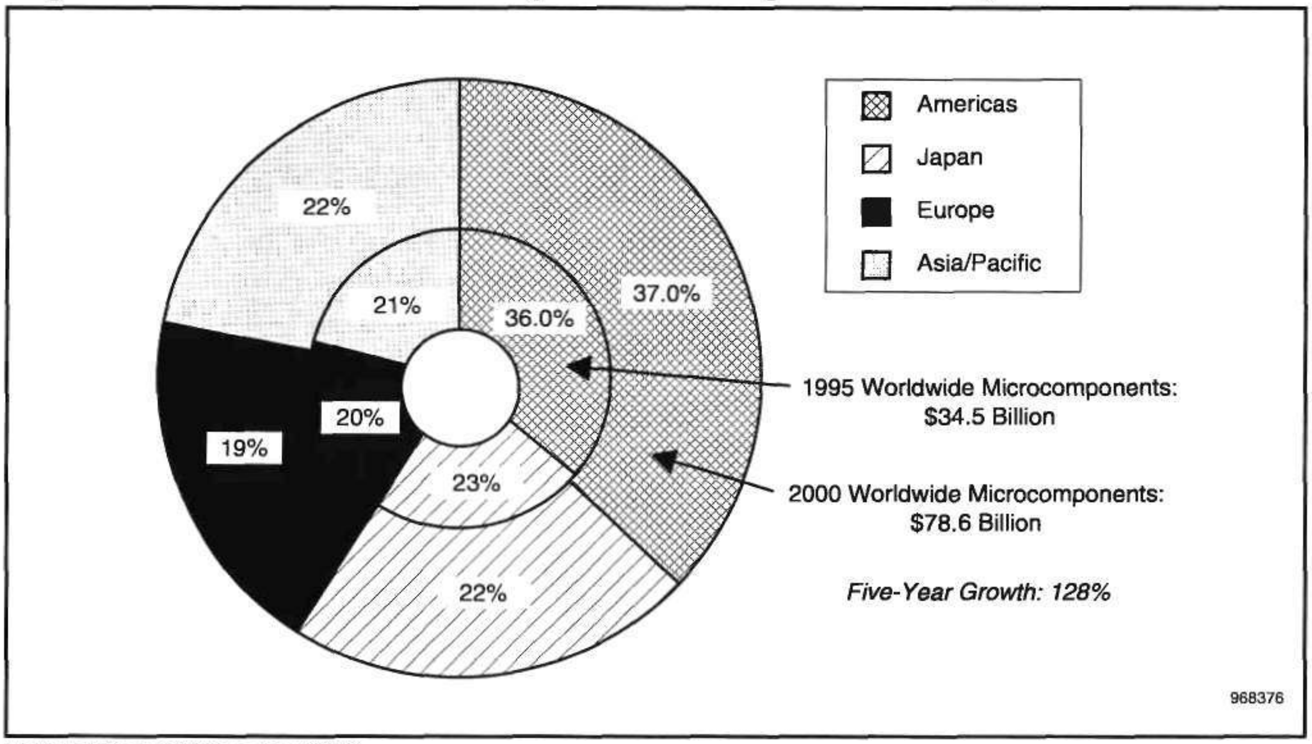
Source: Dataquest (November 1996)

Figure 2-2
Regional Microcomponent Consumption Forecast



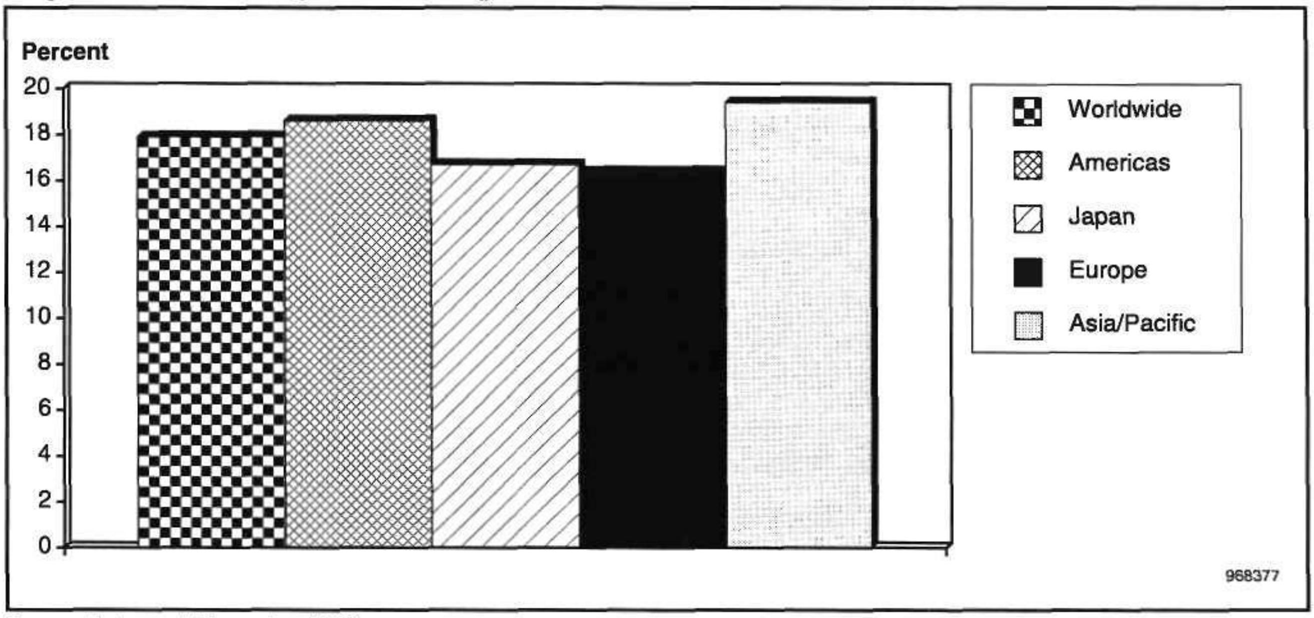
Source: Dataquest (November 1996)

Figure 2-3
Regional Distribution of Microcomponent Consumption Revenue, 1995 and 2000



Source: Dataquest (November 1996)

Figure 2-4
Regional Microcomponent Compound Annual Growth Rates, 1995-2000



Source: Dataquest (November 1996)

Microprocessors

The forecast of all microprocessor revenue is shown in Table 2-2 as microprocessors are expected to be consumed in each of the four geographic regions for the next five years. Percentages are given for each region's microprocessor revenue as a portion of the worldwide revenue from microprocessors, from microcomponents, and from all semiconductors. All figures are for microprocessors destined for both computational and embedded systems, RISC or CISC.

Figure 2-5 shows each region's microprocessor revenue as a portion of the worldwide microprocessor revenue. Figure 2-6 illustrates each region's microprocessor revenue. Figure 2-7 shows the change expected in the distribution of microprocessor revenue among the regions in 1995 and the year 2000. Figure 2-8 compares the CAGR of microprocessor revenue for each region.

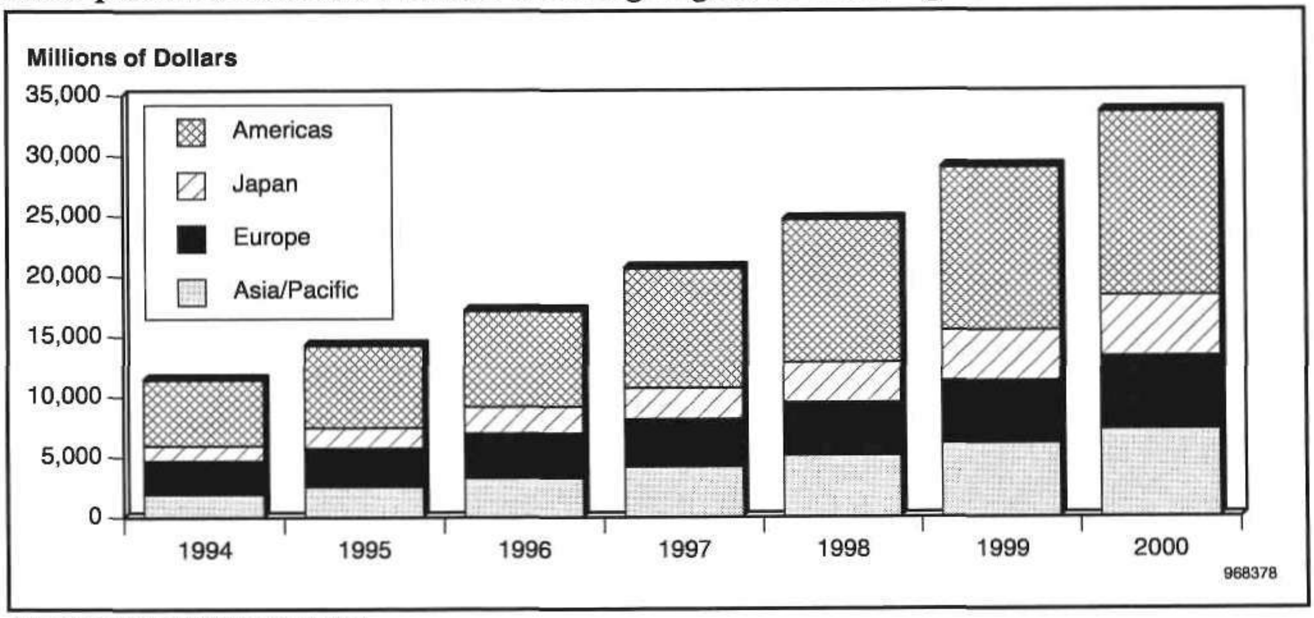
Greater detail of the microprocessor forecast is available in the Dataquest's documents *Microprocessor Forecast and Embedded Microprocessor Trends through the Year 2000* (MCRO-WW-MT-9602, September 23, 1996) and *Compute Microprocessor Market Trends and Forecast* (PSAM-WW-MT-9604, September 2, 1996). They present forecasts and analysis of RISC and CISC and 8-bit, 16-bit, and 32-bit MPUs, as well as embedded and computational applications. Processor architectures popular in embedded and computational applications are also reviewed.

Table 2-2
Revenue Forecast from Microprocessor Consumption in Each Region (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Total Worldwide Microprocessors	11,437	14,279	17,130	20,640	24,650	29,000	33,590	
Growth (%)		24.8	20.0	20.5	19.4	17.6	15.8	18.7
Percentage of Worldwide Microcomponents	43.3	41.4	43.6	45.2	44.7	44.0	42.7	
Percentage of Worldwide Semiconductors	10.3	9.4	12.5	13.4	13.0	12.3	11.6	
Americas	5,446	6,806	7,930	9,880	11,800	13,500	15,200	
Growth (%)		25.0	16.5	24.6	19.4	14.4	12.6	17.4
Percentage of Worldwide Microprocessors	47.6	47.7	46.3	47.9	47.9	46.6	45.3	
Percentage of Worldwide Microcomponents	20.6	19.7	20.2	21.6	21.4	20.5	19.3	
Percentage of Worldwide Semiconductors	4.9	4.5	5.8	6.4	6.2	5.7	5.2	
Japan	1,247	1,690	2,200	2,580	3,310	4,200	5,060	
Growth (%)		35.5	30.2	17.3	28.3	26.9	20.5	24.5
Percentage of Worldwide Microprocessors	10.9	11.8	12.8	12.5	13.4	14.5	15.1	
Percentage of Worldwide Microcomponents	4.7	4.9	5.6	5.6	6.0	6.4	6.4	
Percentage of Worldwide Semiconductors	1.1	1.1	1.6	1.7	1.8	1.8	1.7	
Europe, Africa, and Middle East	2,775	3,197	3,700	3,950	4,410	5,140	6,030	
Growth (%)		15.2	15.7	6.8	11.6	16.6	17.3	13.5
Percentage of Worldwide Microprocessors	24.3	22.4	21.6	19.1	17.9	17.7	18.0	
Percentage of Worldwide Microcomponents	10.5	9.3	9.4	8.6	8.0	7.8	7.7	
Percentage of Worldwide Semiconductors	2.5	2.1	2.7	2.6	2.3	2.2	2.1	
Asia/Pacific	1,969	2,586	3,300	4,230	5,130	6,160	7,300	
Growth (%)		31.3	27.6	28.2	21.3	20.1	18.5	23.1
Percentage of Worldwide Microprocessors	17.2	18.1	19.3	20.5	20.8	21.2	21.7	
Percentage of Worldwide Microcomponents	7.5	7.5	8.4	9.3	9.3	9.3	9.3	
Percentage of Worldwide Semiconductors	1.8	1.7	2.4	2.7	2.7	2.6	2.5	

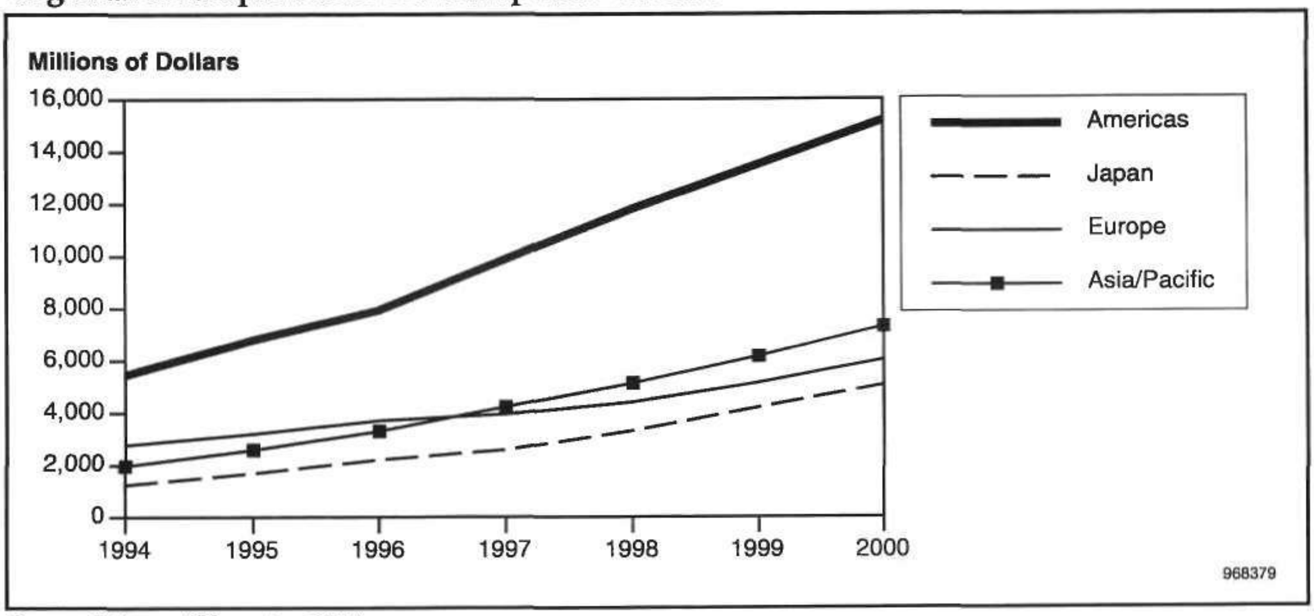
Source: Dataquest (November 1996)

Figure 2-5
Microprocessor Revenue Forecast Showing Region of Consumption



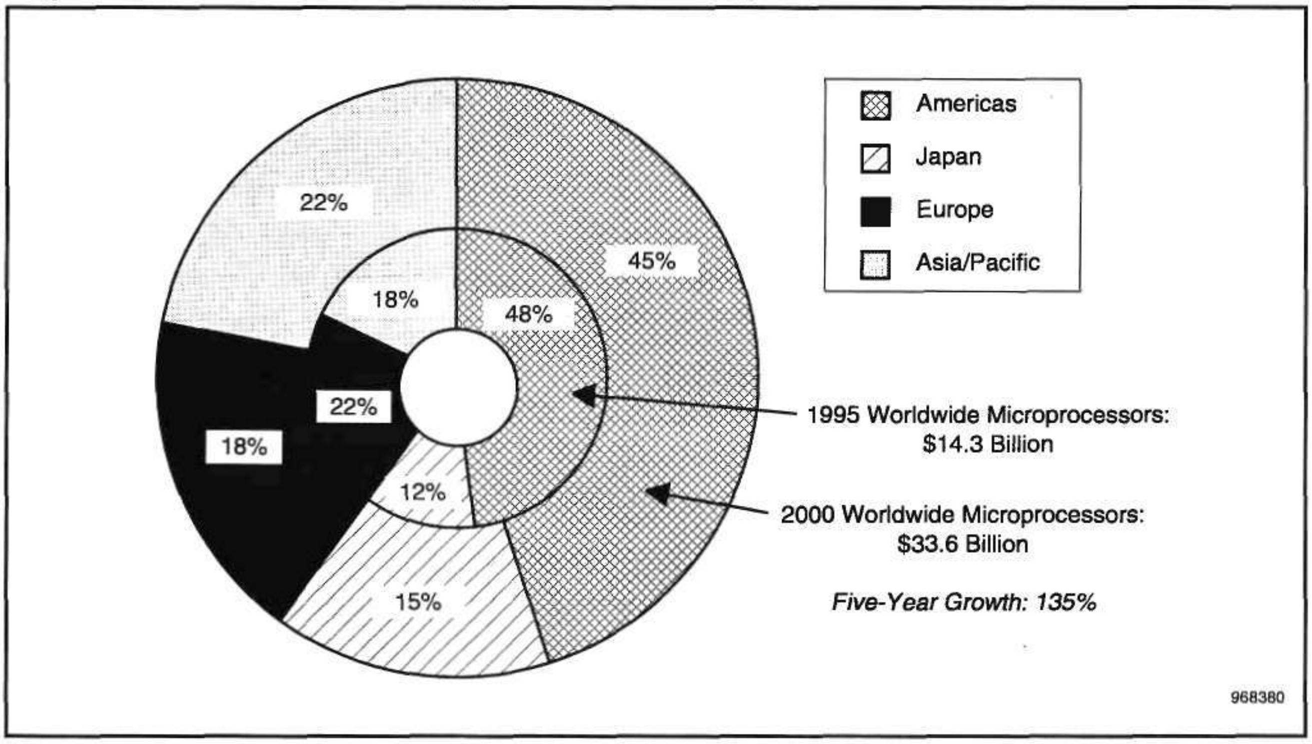
Source: Dataquest (November 1996)

Figure 2-6
Regional Microprocessor Consumption Forecast



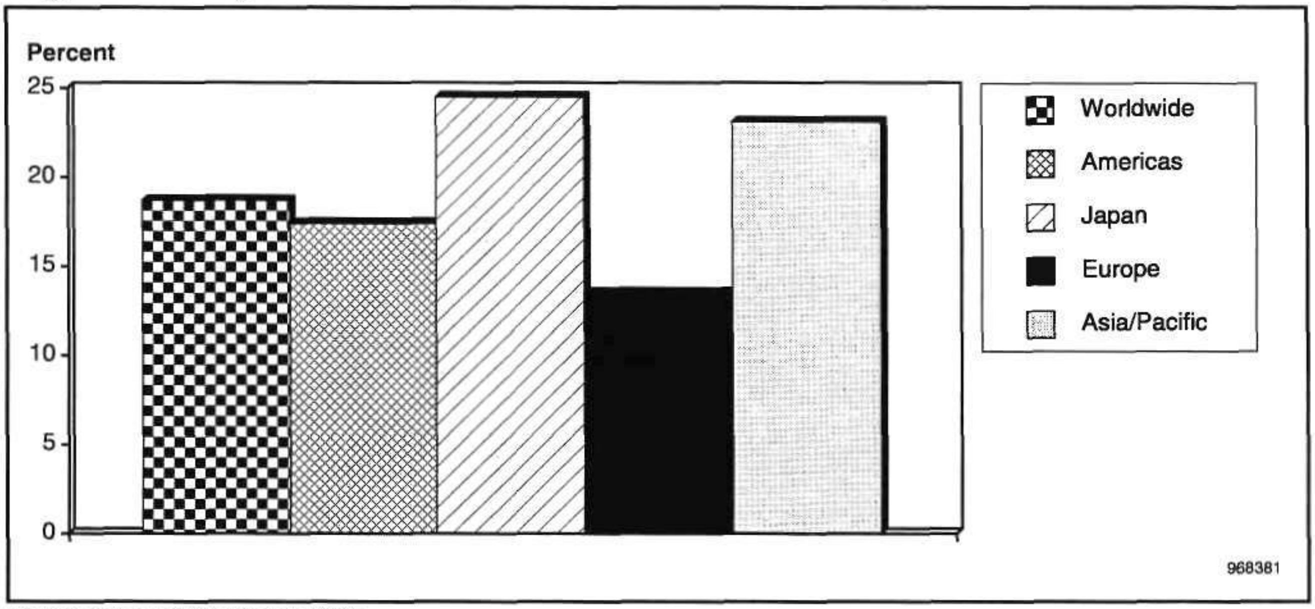
Source: Dataquest (November 1996)

Figure 2-7
Regional Distribution of Microprocessor Consumption Revenue, 1995 and 2000



Source: Dataquest (November 1996)

Figure 2-8
Regional Microprocessor Compound Annual Growth Rates, 1995-2000



Source: Dataquest (November 1996)

Microcontrollers

The forecast of all microcontroller revenue (see Table 2-3) shows how microcontrollers are expected to be consumed in each of the four geographic regions for the next five years. Each region's microcontroller revenue is given as a percentage of the worldwide revenue for microcontrollers, all microcomponents, and total semiconductors.

Figure 2-9 shows each region's microcontroller revenue as a portion of worldwide microcontroller revenue. Figure 2-10 illustrates each region's microcontroller revenue. Figure 2-11 shows the change expected in the distribution of microcontroller revenue among the regions in 1995 and the year 2000. Figure 2-12 compares the CAGR of microcontroller revenue for each region.

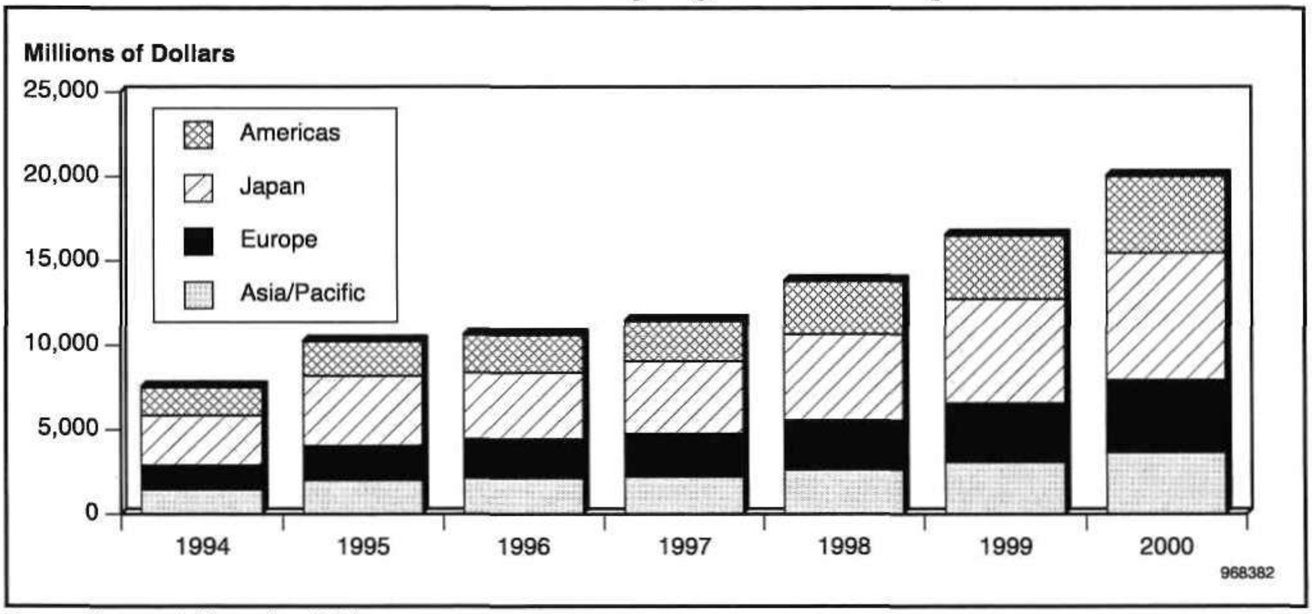
Greater detail on the microcontroller forecast is available in Dataquest's document *The Microcontroller Forecast—A Mixed Bag, Then Back on the Track* (MCRO-WW-MT-9603, September 23, 1996). It gives trends for 4-bit, 8-bit, and 16-bit and greater MCUs, as well as forecasts for MCUs in data processing, communications, industrial, consumer, civil aerospace, and transportation applications.

Table 2-3
Revenue Forecast from Microcontroller Consumption in Each Region (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Total Worldwide Microcontrollers	7,517	10,249	10,640	11,450	13,810	16,510	20,040	
Growth (%)		36.3	3.8	7.6	20.6	19.6	21.4	14.4
Percentage of Worldwide Microcomponents	28.5	29.7	27.1	25.1	25.1	25.0	25.5	
Percentage of Worldwide Semiconductors	6.8	6.8	7.8	7.4	7.3	7.0	6.9	
Americas	1,652	2,047	2,240	2,380	3,120	3,740	4,540	
Growth (%)		23.9	9.4	6.3	31.1	19.9	21.4	17.3
Percentage of Worldwide Microcontrollers	22.0	20.0	21.1	20.8	22.6	22.7	22.7	
Percentage of Worldwide Microcomponents	6.3	5.9	5.7	5.2	5.7	5.7	5.8	
Percentage of Worldwide Semiconductors	1.5	1.4	1.6	1.5	1.7	1.6	1.6	
Japan	2,964	4,140	3,930	4,280	5,110	6,180	7,550	
Growth (%)		39.7	-5.1	8.9	19.4	20.9	22.2	12.8
Percentage of Worldwide Microcontrollers	39.4	40.4	36.9	37.4	37.0	37.4	37.7	
Percentage of Worldwide Microcomponents	11.2	12.0	10.0	9.4	9.3	9.4	9.6	
Percentage of Worldwide Semiconductors	2.7	2.7	2.9	2.8	2.7	2.6	2.6	
Europe, Africa, and Middle East	1,431	2,030	2,300	2,550	2,920	3,480	4,260	
Growth (%)		41.9	13.3	10.9	14.5	19.2	22.4	16.0
Percentage of Worldwide Microcontrollers	19.0	19.8	21.6	22.3	21.1	21.1	21.3	
Percentage of Worldwide Microcomponents	5.4	5.9	5.9	5.6	5.3	5.3	5.4	
Percentage of Worldwide Semiconductors	1.3	1.3	1.7	1.6	1.5	1.5	1.5	
Asia/Pacific	1,470	2,032	2,170	2,240	2,660	3,110	3,690	
Growth (%)		38.2	6.8	3.2	18.8	16.9	18.6	12.7
Percentage of Worldwide Microcontrollers	19.6	19.8	20.4	19.6	19.3	18.8	18.4	
Percentage of Worldwide Microcomponents	5.6	5.9	5.5	4.9	4.8	4.7	4.7	
Percentage of Worldwide Semiconductors	1.3	1.3	1.6	1.4	1.4	1.3	1.3	

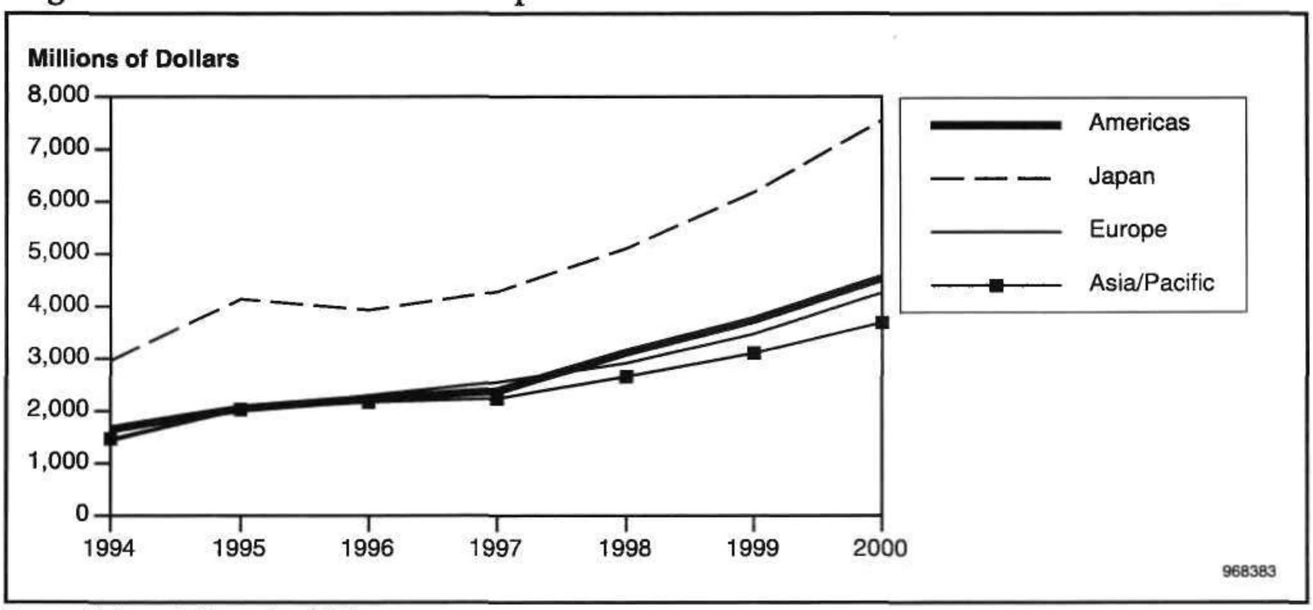
Source: Dataquest (November 1996)

Figure 2-9
Microcontroller Revenue Forecast Showing Region of Consumption



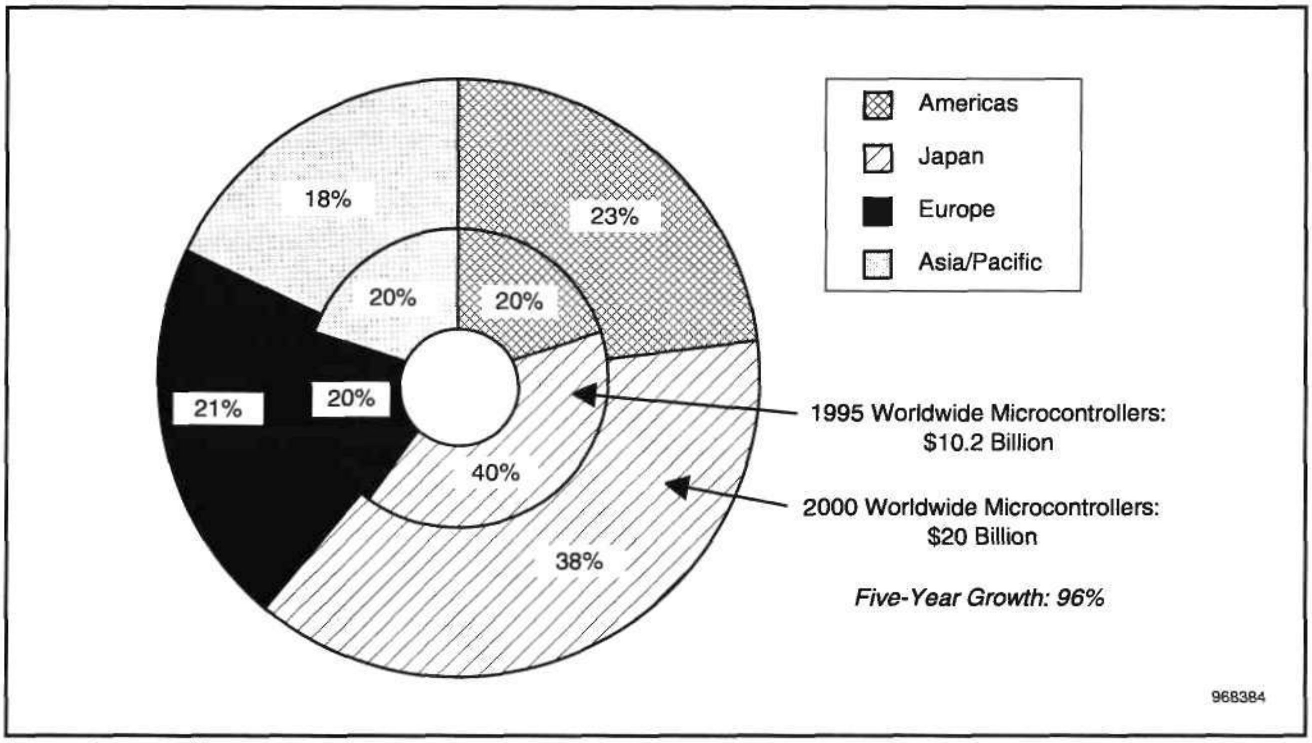
Source: Dataquest (November 1996)

Figure 2-10
Regional Microcontroller Consumption Forecast



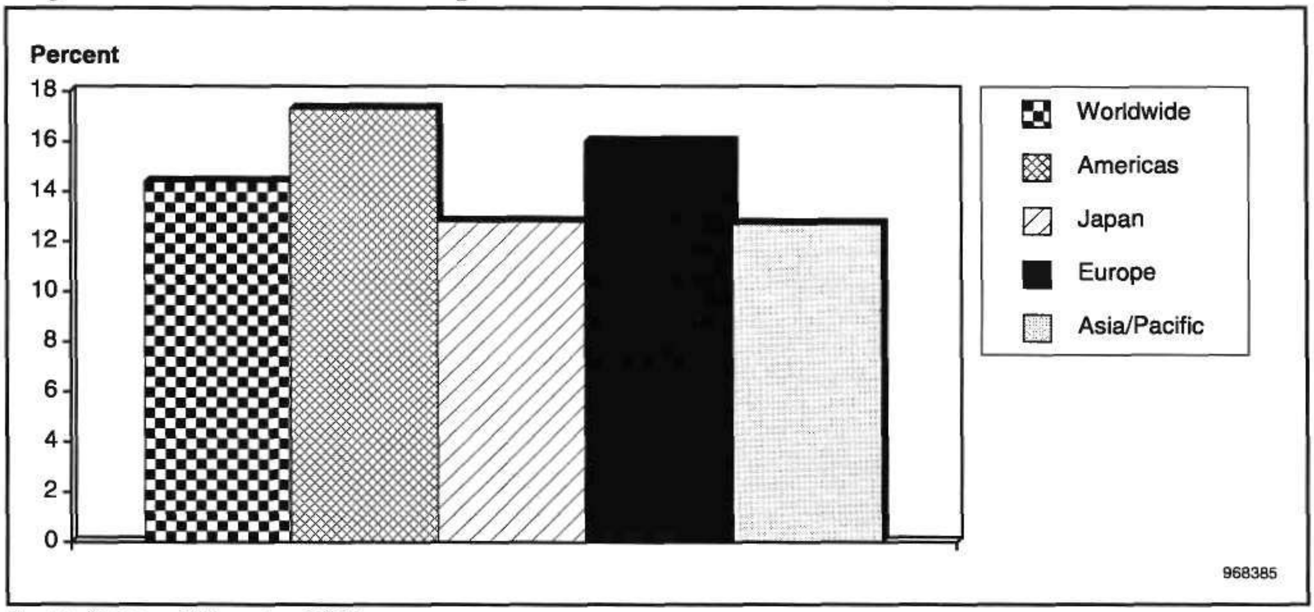
Source: Dataquest (November 1996)

Figure 2-11
Regional Distribution of Microcontroller Consumption Revenue, 1995 and 2000



Source: Dataquest (November 1996)

Figure 2-12
Regional Microcontroller Compound Annual Growth Rates, 1995-2000



Source: Dataquest (November 1996)

Digital Signal Processors

The forecast of all programmable digital signal processor revenue (see Table 2-4) shows how DSPs are expected to be consumed in each of the four geographic regions for the next five years. Percentages are given for each region's digital signal processor revenue as a portion of the worldwide revenue for digital signal processors, all microcomponents, and total semiconductors.

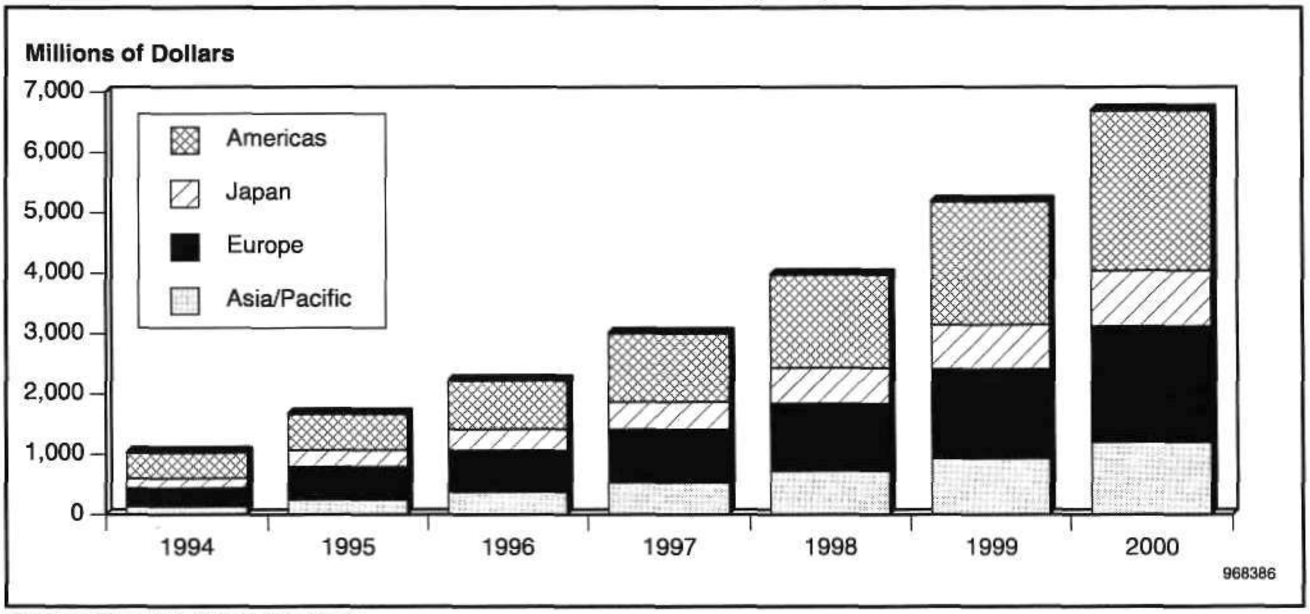
Figure 2-13 shows each region's programmable digital signal processor revenue as a portion of worldwide DSP revenue. Figure 2-14 illustrates each region's DSP revenue. Figure 2-15 shows the change expected in the distribution of DSP revenue among the regions in 1995 and the year 2000. Figure 2-16 compares the CAGR of DSP revenue for each region. The primary contributors to DSP revenue continue to be the general-purpose DSPs from Texas Instruments, Lucent Technologies (formerly AT&T), Analog Devices, and Motorola. Additional information on the DSP market can be found in "Digital Signal Processors—A Brilliant Light in an Overcast Year" (MCRO-WW-DP-9608, December 16, 1996).

Table 2-4
Revenue Forecast from Digital Signal Processor Consumption in Each Region (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Total Worldwide Digital Signal Processors	1,030	1,669	2,223	3,004	3,978	5,187	6,700	
Growth (%)		62.0	33.2	35.1	32.4	30.4	29.2	32.0
Percentage of Worldwide Microcomponents	3.9	4.8	5.7	6.6	7.2	7.9	8.5	
Percentage of Worldwide Semiconductors	0.9	1.1	1.6	1.9	2.1	2.2	2.3	
Americas	421	595	803	1,130	1,540	2,030	2,650	
Growth (%)		41.3	35.0	40.7	36.3	31.8	30.5	34.8
Percentage of Worldwide Digital Signal Processors	40.9	35.7	36.1	37.6	38.7	39.1	39.6	
Percentage of Worldwide Microcomponents	1.6	1.7	2.0	2.5	2.8	3.1	3.4	
Percentage of Worldwide Semiconductors	0.4	0.4	0.6	0.7	0.8	0.9	0.9	
Japan	166	274	350	459	590	740	920	
Growth (%)		65.1	27.7	31.1	28.5	25.4	24.3	27.4
Percentage of Worldwide Digital Signal Processors	16.1	16.4	15.7	15.3	14.8	14.3	13.7	
Percentage of Worldwide Microcomponents	0.6	0.8	0.9	1.0	1.1	1.1	1.2	
Percentage of Worldwide Semiconductors	0.2	0.2	0.3	0.3	0.3	0.3	0.3	
Europe, Africa, and Middle East	305	548	685	874	1,120	1,480	1,920	
Growth (%)		79.7	25.0	27.6	28.1	32.1	29.7	28.5
Percentage of Worldwide Digital Signal Processors	29.6	32.8	30.8	29.1	28.2	28.5	28.7	
Percentage of Worldwide Microcomponents	1.2	1.6	1.7	1.9	2.0	2.2	2.4	
Percentage of Worldwide Semiconductors	0.3	0.4	0.5	0.6	0.6	0.6	0.7	
Asia/Pacific	138	252	385	541	728	937	1,210	
Growth (%)		82.6	52.8	40.5	34.6	28.7	29.1	36.9
Percentage of Worldwide Digital Signal Processors	13.4	15.1	17.3	18.0	18.3	18.1	18.1	
Percentage of Worldwide Microcomponents	0.5	0.7	1.0	1.2	1.3	1.4	1.5	
Percentage of Worldwide Semiconductors	0.1	0.2	0.3	0.3	0.4	0.4	0.4	

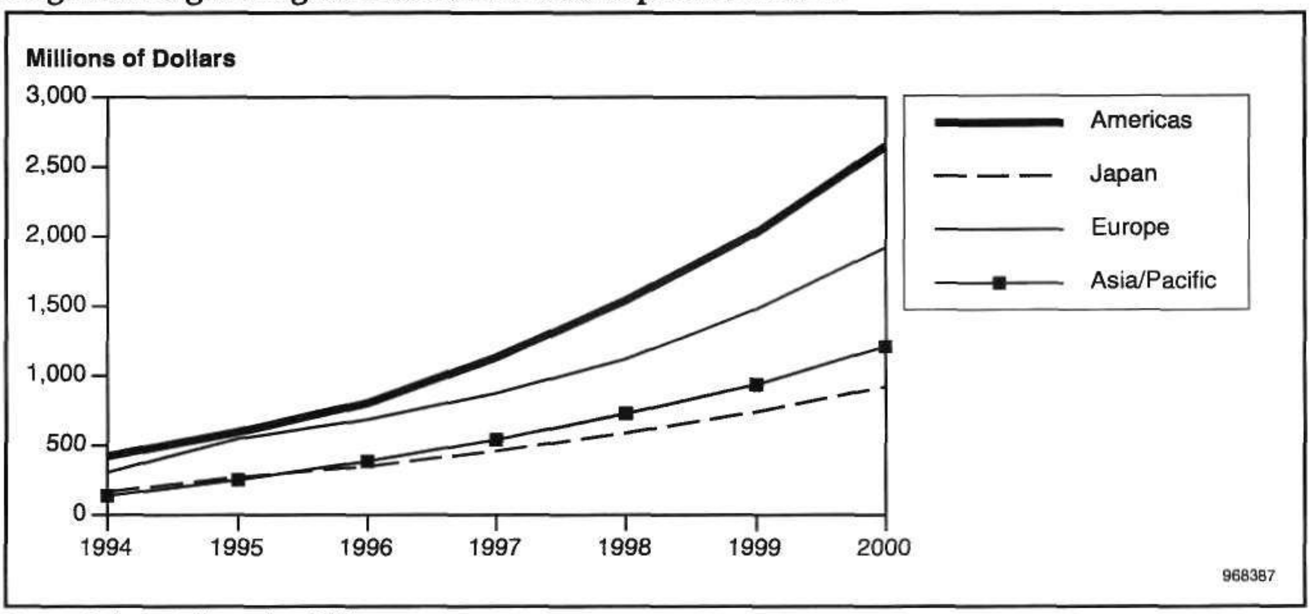
Source: Dataquest (November 1996)

Figure 2-13
Digital Signal Processor Revenue Forecast Showing Region of Consumption



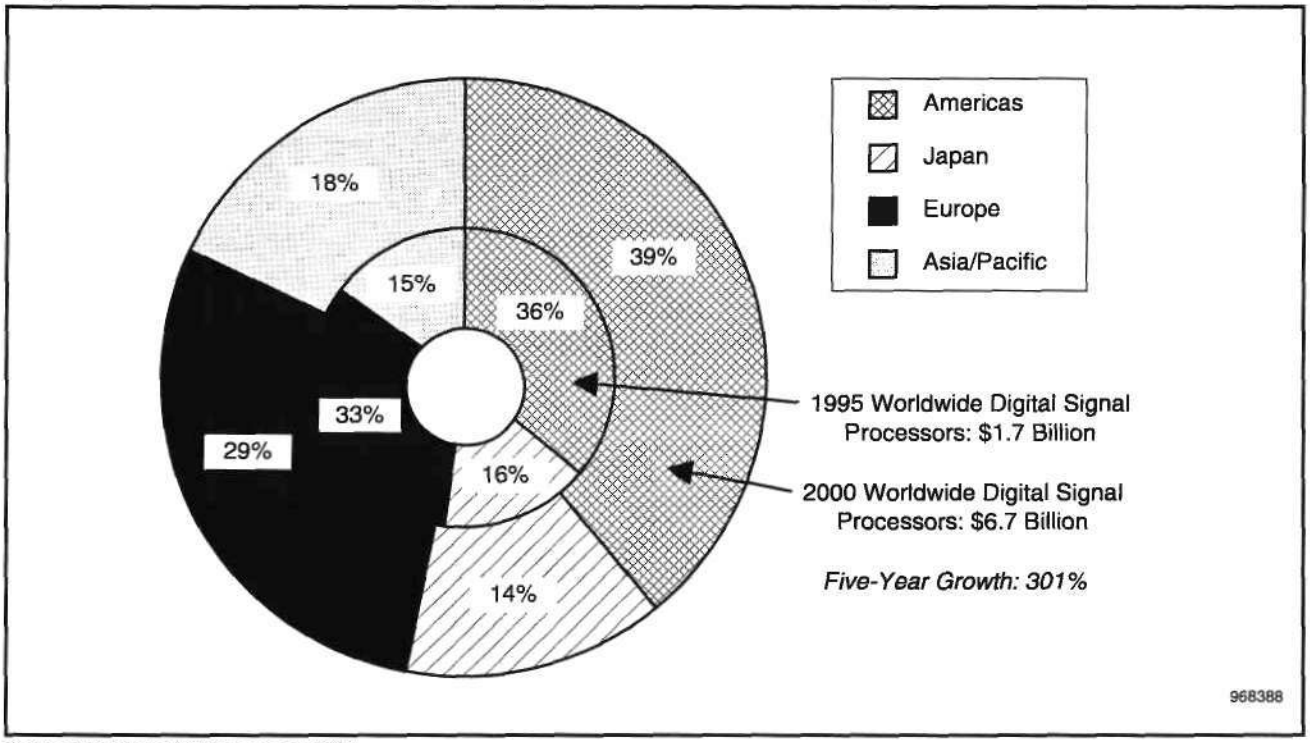
Source: Dataquest (November 1996)

Figure 2-14
Regional Digital Signal Processor Consumption Forecast



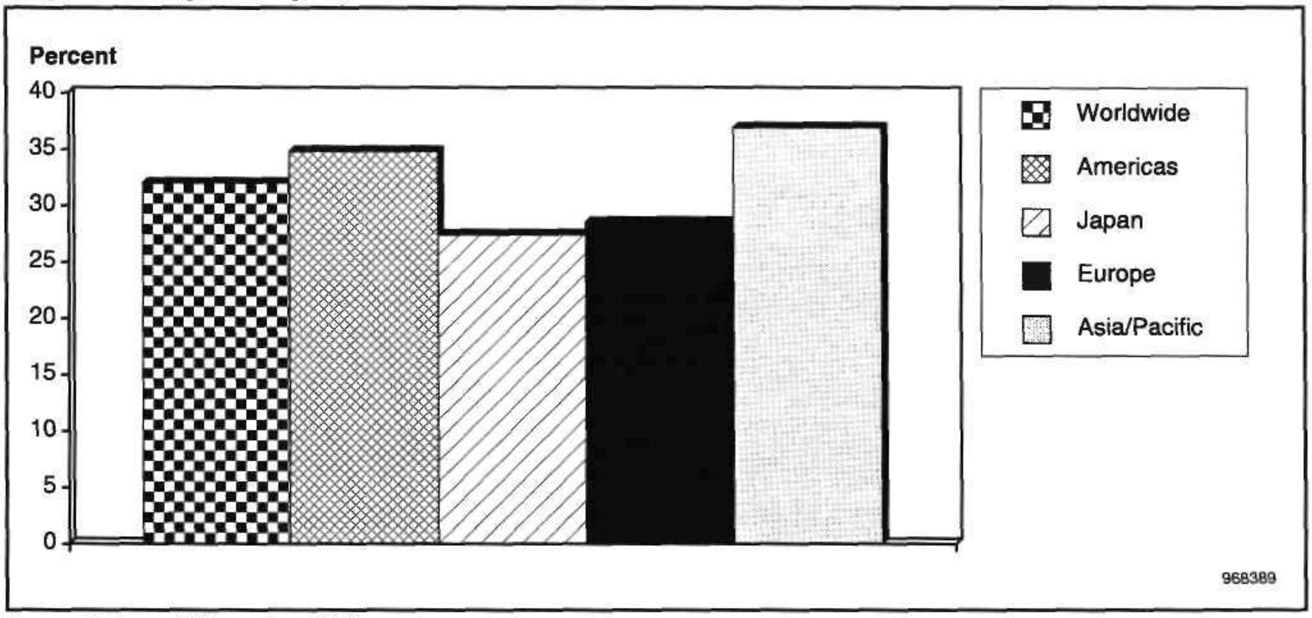
Source: Dataquest (November 1996)

Figure 2-15
Regional Distribution of Digital Signal Processor Consumption Revenue, 1995 and 2000



Source: Dataquest (November 1996)

Figure 2-16
Regional Digital Signal Processor Compound Annual Growth Rates, 1995-2000



Source: Dataquest (November 1996)

Microperipherals

The forecast of all microperipheral revenue (see Table 2-5) shows how microperipherals are expected to be consumed in each of the four geographic regions for the next five years. Percentages are given for each region's MPR revenue as a portion of the worldwide revenue for MPRs, all microcomponents, and total semiconductors.

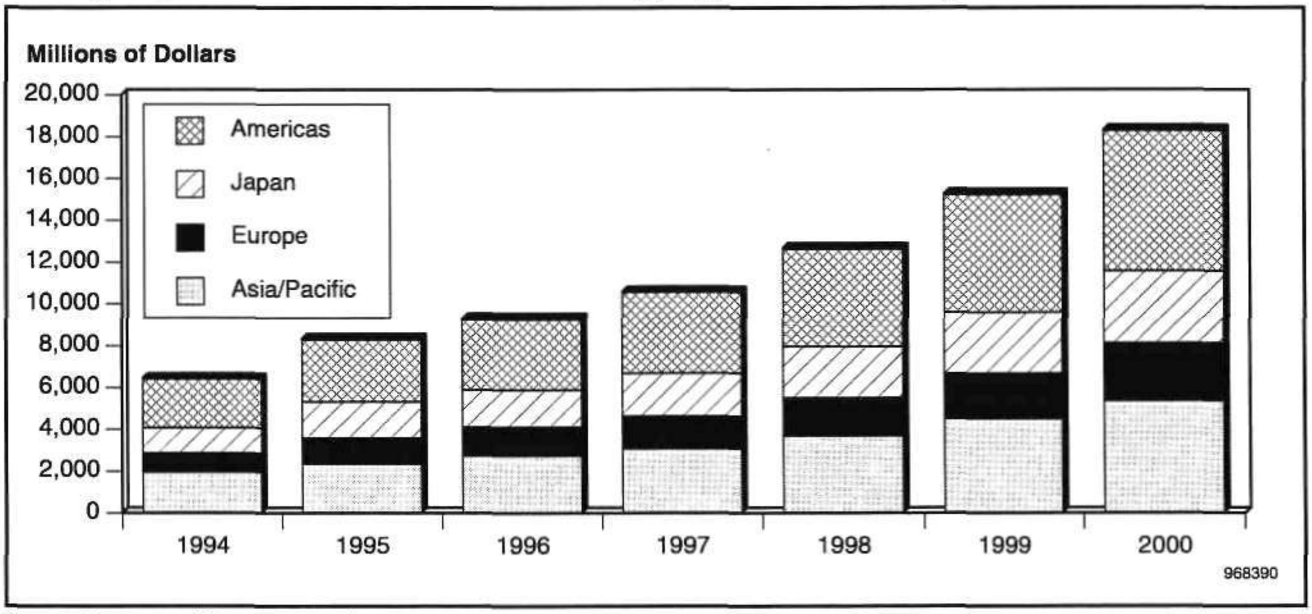
Figure 2-17 shows each region's microperipheral revenue as a portion of worldwide microcontroller revenue. Figure 2-18 illustrates each region's MPR revenue. Figure 2-19 shows the change expected in the distribution of MPR revenue among the regions in 1995 and the year 2000. Figure 2-20 compares the CAGR of MPR revenue for each region.

Table 2-5
Revenue Forecast from Microperipheral Consumption in Each Region (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Total Worldwide Microperipherals	6,424	8,316	9,290	10,580	12,650	15,250	18,310	17.1
Growth (%)		29.5	11.7	13.9	19.6	20.6	20.1	17.1
Percentage of Worldwide Microcomponents	24.3	24.1	23.6	23.2	23.0	23.1	23.3	
Percentage of Worldwide Semiconductors	5.8	5.5	6.8	6.8	6.7	6.5	6.3	
Americas	2,320	2,982	3,380	3,880	4,670	5,630	6,720	17.6
Growth (%)		28.5	13.3	14.8	20.4	20.6	19.4	17.6
Percentage of Worldwide Microperipherals	36.1	35.9	36.4	36.7	36.9	36.9	36.7	
Percentage of Worldwide Microcomponents	8.8	8.6	8.6	8.5	8.5	8.5	8.5	
Percentage of Worldwide Semiconductors	2.1	2.0	2.5	2.5	2.5	2.4	2.3	
Japan	1,226	1,726	1,780	2,050	2,460	2,930	3,440	14.8
Growth (%)		40.8	3.1	15.2	20.0	19.1	17.4	14.8
Percentage of Worldwide Microperipherals	19.1	20.8	19.2	19.4	19.4	19.2	18.8	
Percentage of Worldwide Microcomponents	4.6	5.0	4.5	4.5	4.5	4.4	4.4	
Percentage of Worldwide Semiconductors	1.1	1.1	1.3	1.3	1.3	1.2	1.2	
Europe, Africa, and Middle East	897	1,226	1,370	1,550	1,810	2,160	2,760	17.6
Growth (%)		36.7	11.7	13.1	16.8	19.3	27.8	17.6
Percentage of Worldwide Microperipherals	14.0	14.7	14.7	14.7	14.3	14.2	15.1	
Percentage of Worldwide Microcomponents	3.4	3.6	3.5	3.4	3.3	3.3	3.5	
Percentage of Worldwide Semiconductors	0.8	0.8	1.0	1.0	1.0	0.9	1.0	
Asia/Pacific	1,981	2,382	2,760	3,100	3,710	4,530	5,390	17.7
Growth (%)		20.2	15.9	12.3	19.7	22.1	19.0	17.7
Percentage of Worldwide Microperipherals	30.8	28.6	29.7	29.3	29.3	29.7	29.4	
Percentage of Worldwide Microcomponents	7.5	6.9	7.0	6.8	6.7	6.9	6.9	
Percentage of Worldwide Semiconductors	1.8	1.6	2.0	2.0	2.0	1.9	1.9	

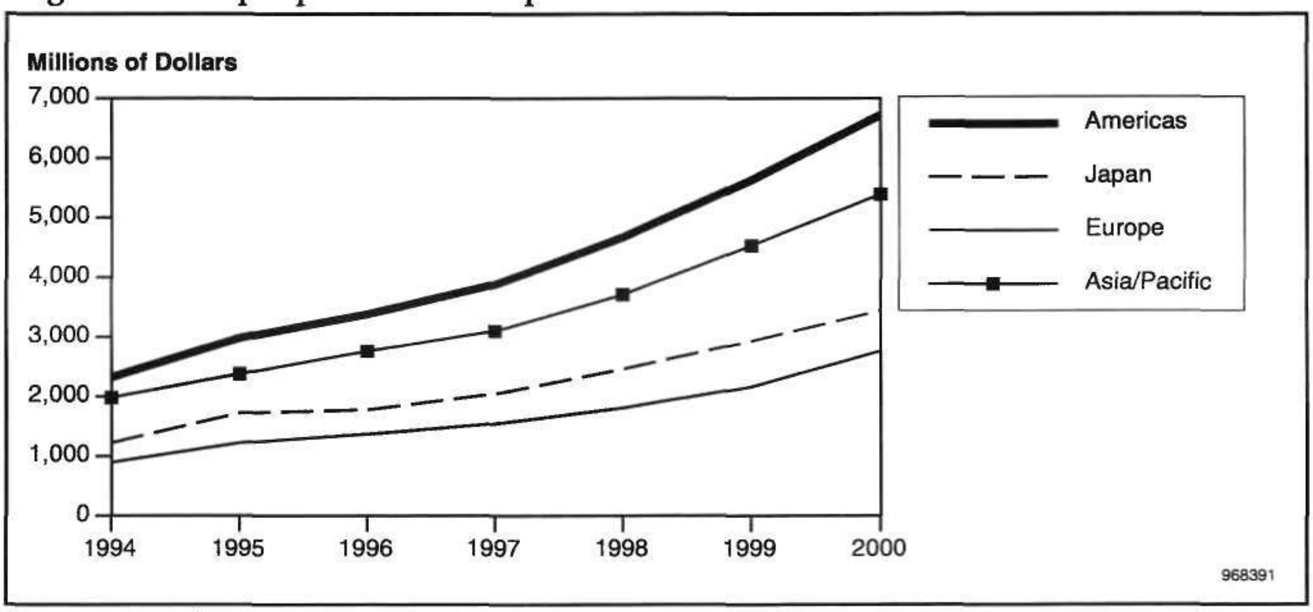
Source: Dataquest (November 1996)

Figure 2-17
Microperipheral Revenue Forecast Showing Region of Consumption



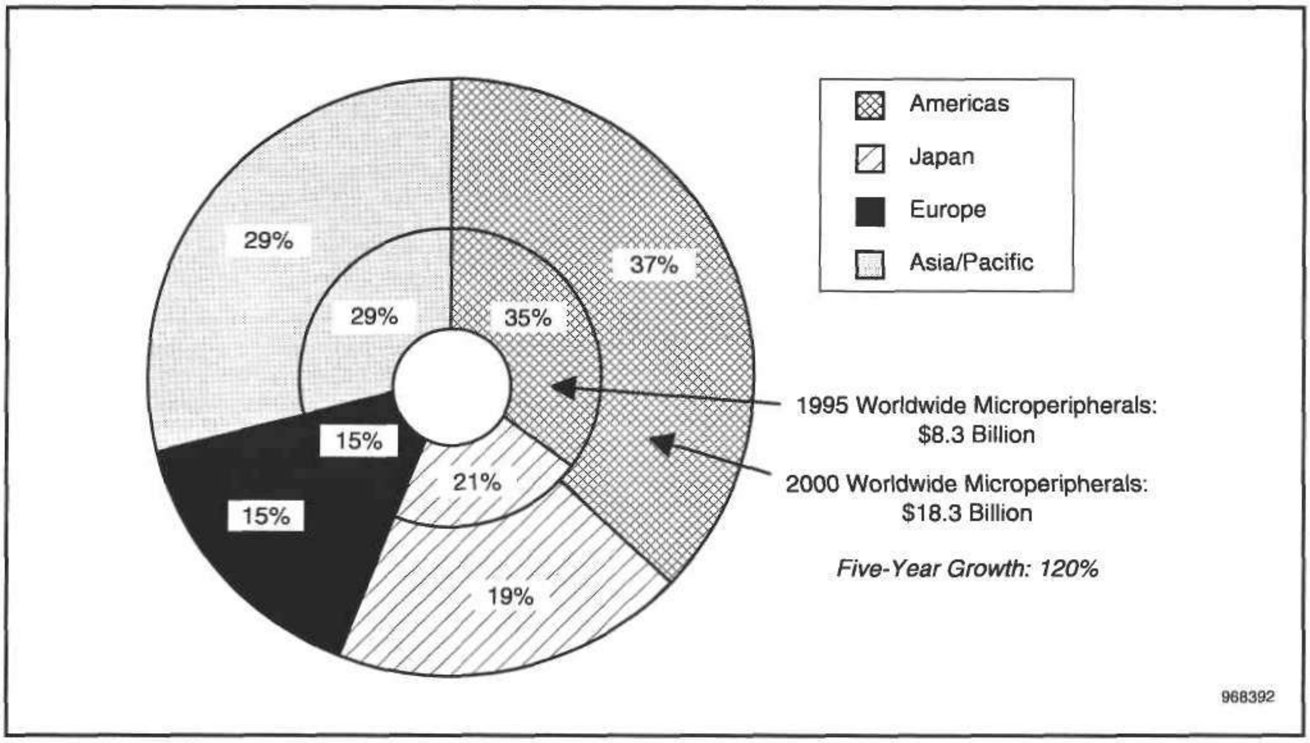
Source: Dataquest (November 1996)

Figure 2-18
Regional Microperipheral Consumption Forecast



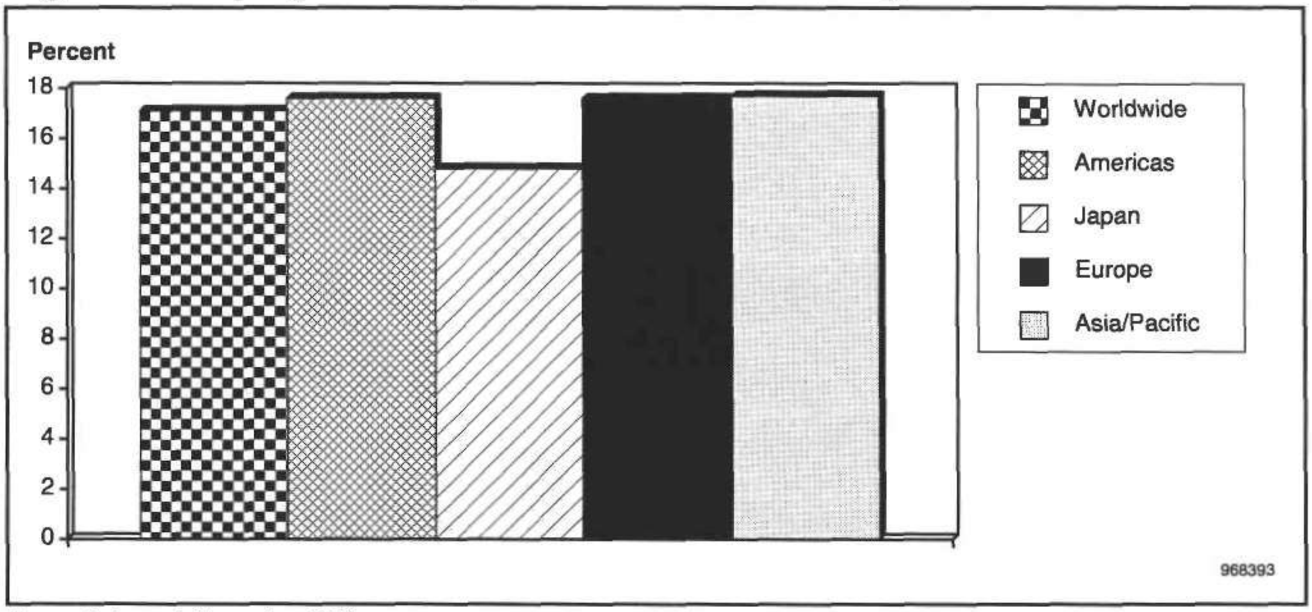
Source: Dataquest (November 1996)

Figure 2-19
Regional Distribution of Microperipheral Consumption Revenue, 1995 and 2000



Source: Dataquest (November 1996)

Figure 2-20
Regional Microperipheral Compound Annual Growth Rates, 1995-2000



Source: Dataquest (November 1996)

Chapter 3

The Growth of Microcomponents in Each Geographic Region

Microcomponents comprise microprocessors, microcontrollers, programmable digital signal processors, and microperipherals. In this chapter, Dataquest forecasts through the end of this millennium how each geographic region—the Americas, Japan, Europe, and Asia/Pacific—will consume microcomponents by product family. Within each section, the region's revenue forecast is given in tables and related figures highlighting MPUs, MCUs, programmable DSPs, and microperipherals. Numbers for microprocessors include both computational and embedded products.

All numbers attributed to a region represent the revenue resulting from consumption of the specified microcomponent in that region.

Worldwide Microcomponents

The revenue forecast for microcomponents sold throughout the world for the next five years is shown in Table 3-1 according to the product family: all microprocessors, microcontrollers, programmable digital signal processors, and microperipherals. (Table 3-1 is a subset of Table 1-1.) Percentages are given for each product family's worldwide revenue as a portion of the total semiconductor worldwide revenue.

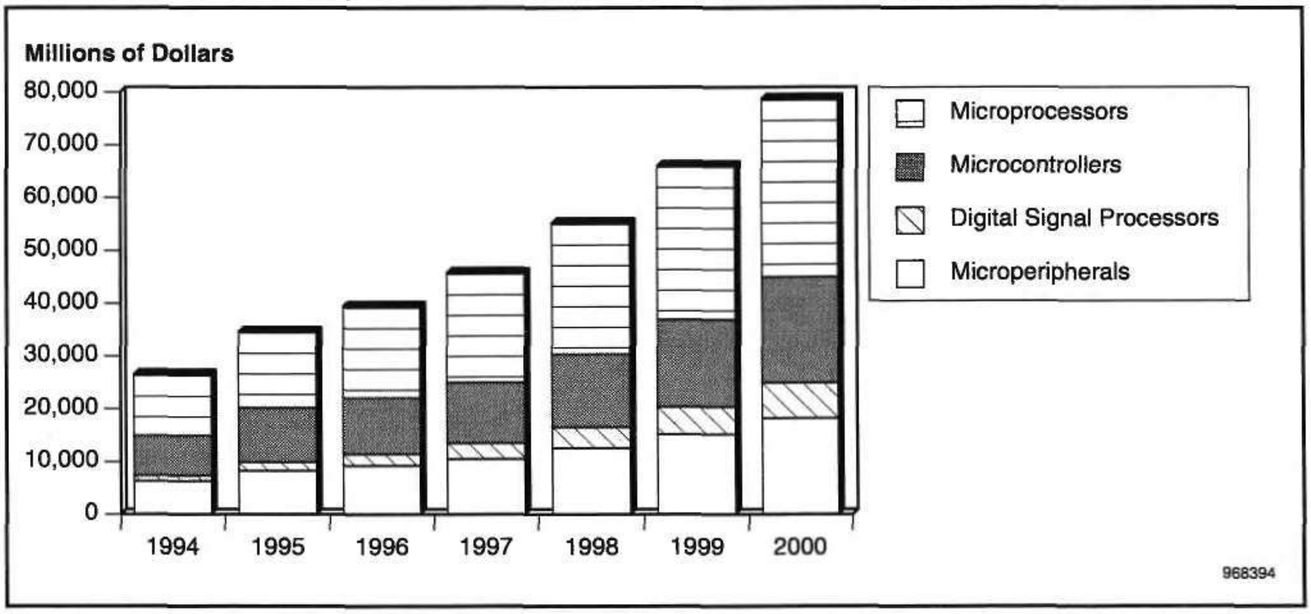
Figure 3-1 shows each product family's revenue as a portion of the entire microcomponent global revenue. Figure 3-2 shows each product family's revenue worldwide. Figure 3-3 illustrates how the microcomponent product mix will change worldwide from 1995 to the year 2000. Figure 3-4 compares the CAGR expected from 1995 through 2000 for sales of each product family globally.

Table 3-1
Revenue Forecast of Microcomponents Consumed in the World, by Product Family (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Total Semiconductors in the World	110,513	151,272	136,977	154,605	188,922	234,916	290,219	
Growth (%)		36.9	-9.4	12.9	22.2	24.3	23.5	13.9
Total Microcomponents in the World	26,408	34,513	39,283	45,674	55,088	65,947	78,640	
Growth (%)		30.7	13.8	16.3	20.6	19.7	19.2	17.9
Percentage of Semiconductors in the World	23.9	22.8	28.7	29.5	29.2	28.1	27.1	
Microprocessors	11,437	14,279	17,130	20,640	24,650	29,000	33,590	
Growth (%)		24.8	20.0	20.5	19.4	17.6	15.8	18.7
Percentage of Microcomponents in the World	43.3	41.4	43.6	45.2	44.7	44.0	42.7	
Percentage of Semiconductors in the World	10.3	9.4	12.5	13.4	13.0	12.3	11.6	
Microcontrollers	7,517	10,249	10,640	11,450	13,810	16,510	20,040	
Growth (%)		36.3	3.8	7.6	20.6	19.6	21.4	14.4
Percentage of Microcomponents in the World	28.5	29.7	27.1	25.1	25.1	25.0	25.5	
Percentage of Semiconductors in the World	6.8	6.8	7.8	7.4	7.3	7.0	6.9	
Digital Signal Processors	1,030	1,669	2,223	3,004	3,978	5,187	6,700	
Growth (%)		62.0	33.2	35.1	32.4	30.4	29.2	32.0
Percentage of Microcomponents in the World	3.9	4.8	5.7	6.6	7.2	7.9	8.5	
Percentage of Semiconductors in the World	0.9	1.1	1.6	1.9	2.1	2.2	2.3	
Microperipherals	6,424	8,316	9,290	10,580	12,650	15,250	18,310	
Growth (%)		29.5	11.7	13.9	19.6	20.6	20.1	17.1
Percentage of Microcomponents in the World	24.3	24.1	23.6	23.2	23.0	23.1	23.3	
Percentage of Semiconductors in the World	5.8	5.5	6.8	6.8	6.7	6.5	6.3	

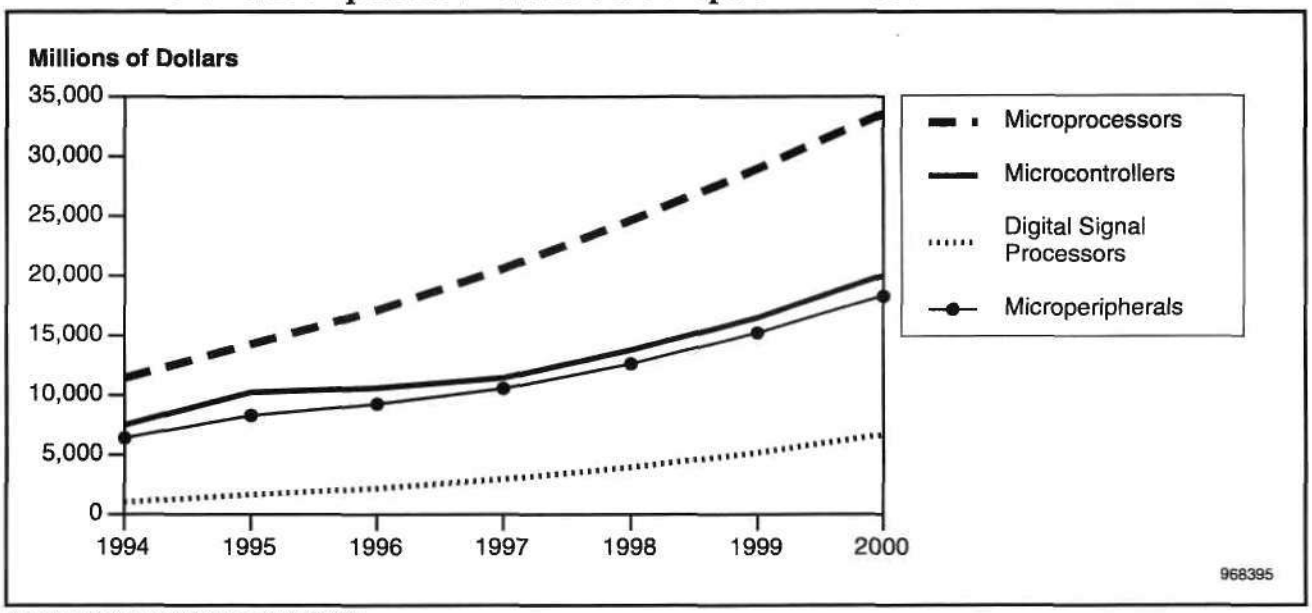
Source: Dataquest (November 1996)

Figure 3-1
The World's Microcomponent Consumption Forecast Showing Product Family Revenue



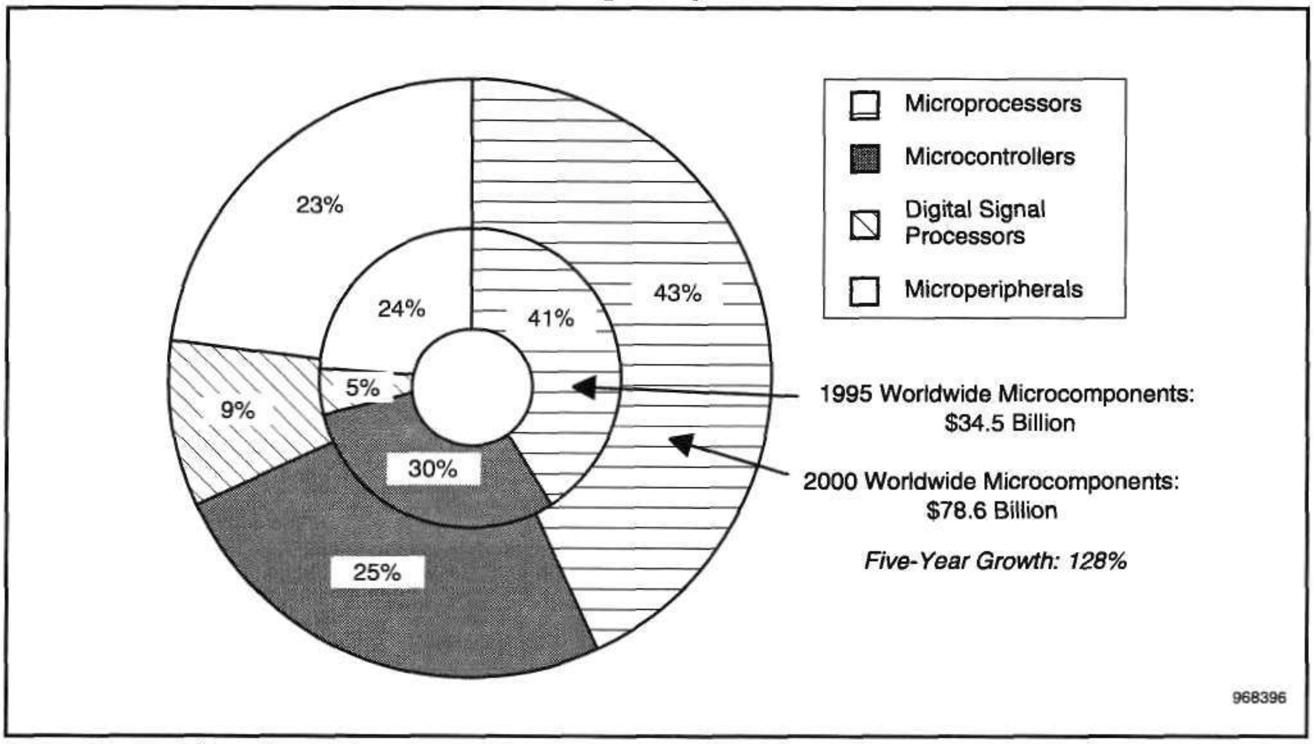
Source: Dataquest (November 1996)

Figure 3-2
The World's Microcomponent Product Consumption Forecast



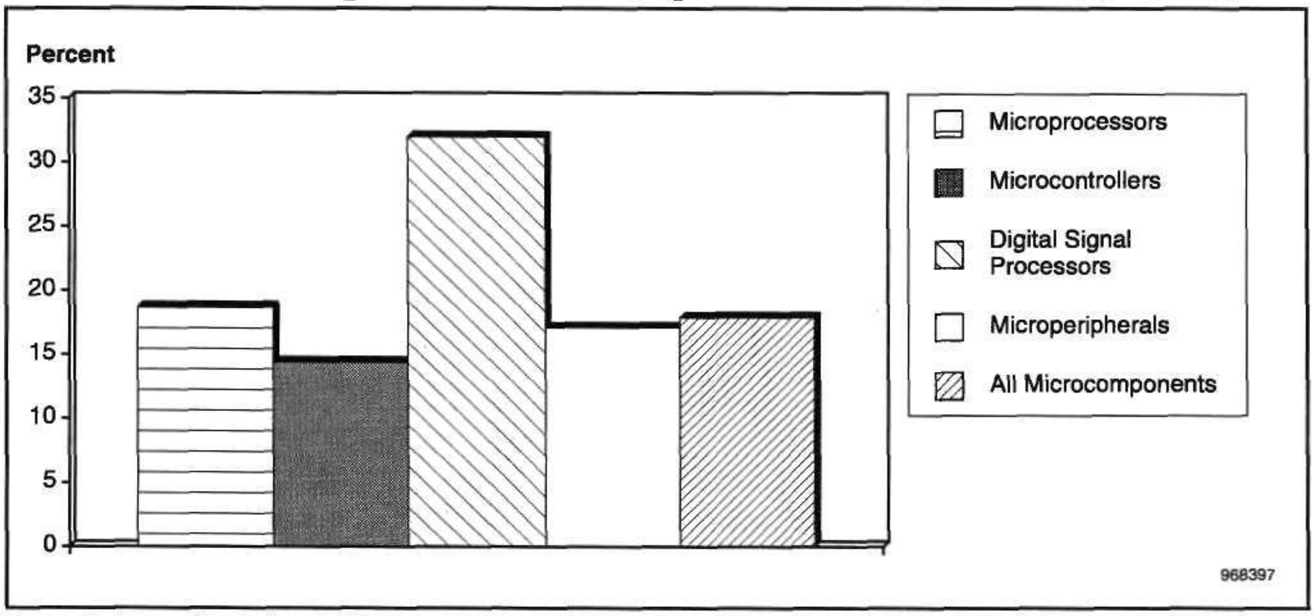
Source: Dataquest (November 1996)

Figure 3-3
The World's Microcomponent Product Split, by Revenue, 1995 and 2000



Source: Dataquest (November 1996)

Figure 3-4
The World's Microcomponent Products' Compound Annual Growth Rates, 1995-2000



Source: Dataquest (November 1996)

Americas

The revenue forecast for microcomponents consumed in the Americas for the next five years is shown in Table 3-2 by the product family: all microprocessors, microcontrollers, programmable digital signal processors, and microperipherals. Percentages are given for the product family's revenue in the Americas as a portion of all microcomponents and total semiconductor revenue in the Americas.

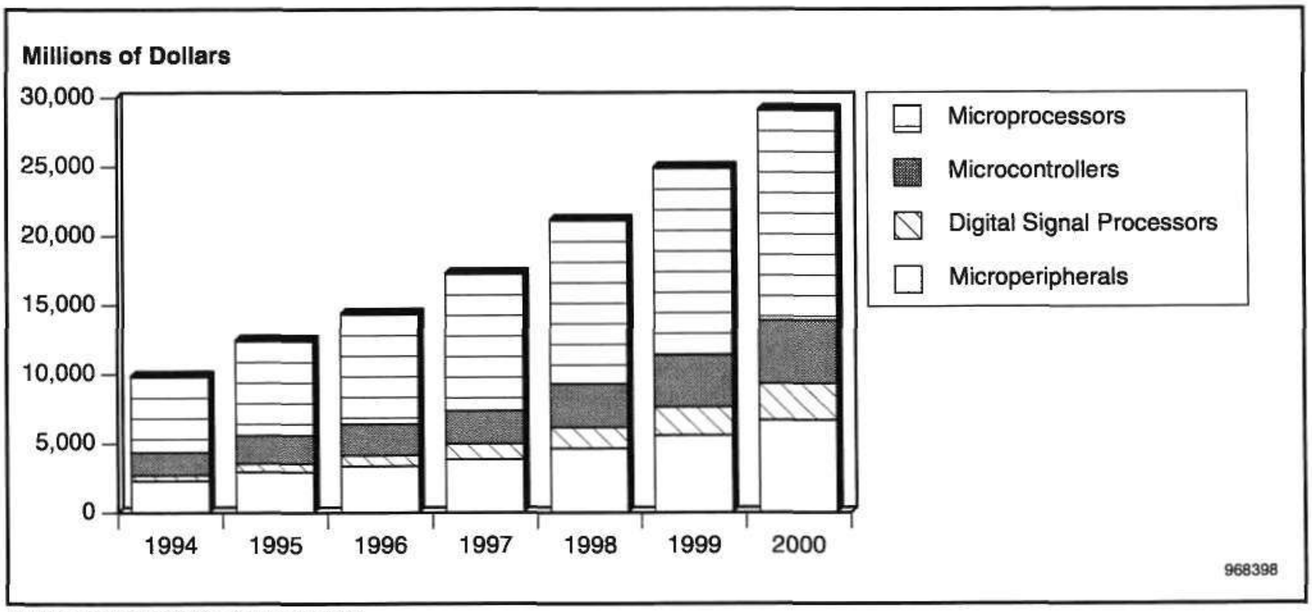
Figure 3-5 shows each product family's revenue as a portion of the entire microcomponent revenue in the Americas. Figure 3-6 shows each product family's revenue in the Americas. Figure 3-7 illustrates how the microcomponent product mix will change in the Americas from 1995 to the year 2000. Figure 3-8 compares the CAGR expected from 1995 through 2000 from consumption of each product family in the Americas.

Table 3-2
Revenue Forecast of Microcomponents Consumed in the Americas, by Product Family (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Total Semiconductors in Americas	35,773	48,354	44,177	50,440	62,330	79,222	97,714	
Growth (%)		35.2	-8.6	14.2	23.6	27.1	23.3	15.1
Percentage of Worldwide Semiconductors	32.4	32.0	32.3	32.6	33.0	33.7	33.7	
Total Microcomponents in Americas	9,839	12,430	14,353	17,270	21,130	24,900	29,110	
Growth (%)		26.3	15.5	20.3	22.4	17.8	16.9	18.6
Percentage of Semiconductors in Americas	27.5	25.7	32.5	34.2	33.9	31.4	29.8	
Percentage of Worldwide Microcomponents	37.3	36.0	36.5	37.8	38.4	37.8	37.0	
Percentage of Worldwide Semiconductors	8.9	8.2	10.5	11.2	11.2	10.6	10.0	
Microprocessors	5,446	6,806	7,930	9,880	11,800	13,500	15,200	
Growth (%)		25.0	16.5	24.6	19.4	14.4	12.6	17.4
Percentage of Microcomponents in Americas	55.4	54.8	55.2	57.2	55.8	54.2	52.2	
Percentage of Semiconductors in Americas	15.2	14.1	18.0	19.6	18.9	17.0	15.6	
Microcontrollers	1,652	2,047	2,240	2,380	3,120	3,740	4,540	
Growth (%)		23.9	9.4	6.3	31.1	19.9	21.4	17.3
Percentage of Microcomponents in Americas	16.8	16.5	15.6	13.8	14.8	15.0	15.6	
Percentage of Semiconductors in Americas	4.6	4.2	5.1	4.7	5.0	4.7	4.6	
Digital Signal Processors	421	595	803	1,130	1,540	2,030	2,650	
Growth (%)		41.3	35.0	40.7	36.3	31.8	30.5	34.8
Percentage of Microcomponents in Americas	4.3	4.8	5.6	6.5	7.3	8.2	9.1	
Percentage of Semiconductors in Americas	1.2	1.2	1.8	2.2	2.5	2.6	2.7	
Microperipherals	2,320	2,982	3,380	3,880	4,670	5,630	6,720	
Growth (%)		28.5	13.3	14.8	20.4	20.6	19.4	17.6
Percentage of Microcomponents in Americas	23.6	24.0	23.5	22.5	22.1	22.6	23.1	
Percentage of Semiconductors in Americas	6.5	6.2	7.7	7.7	7.5	7.1	6.9	

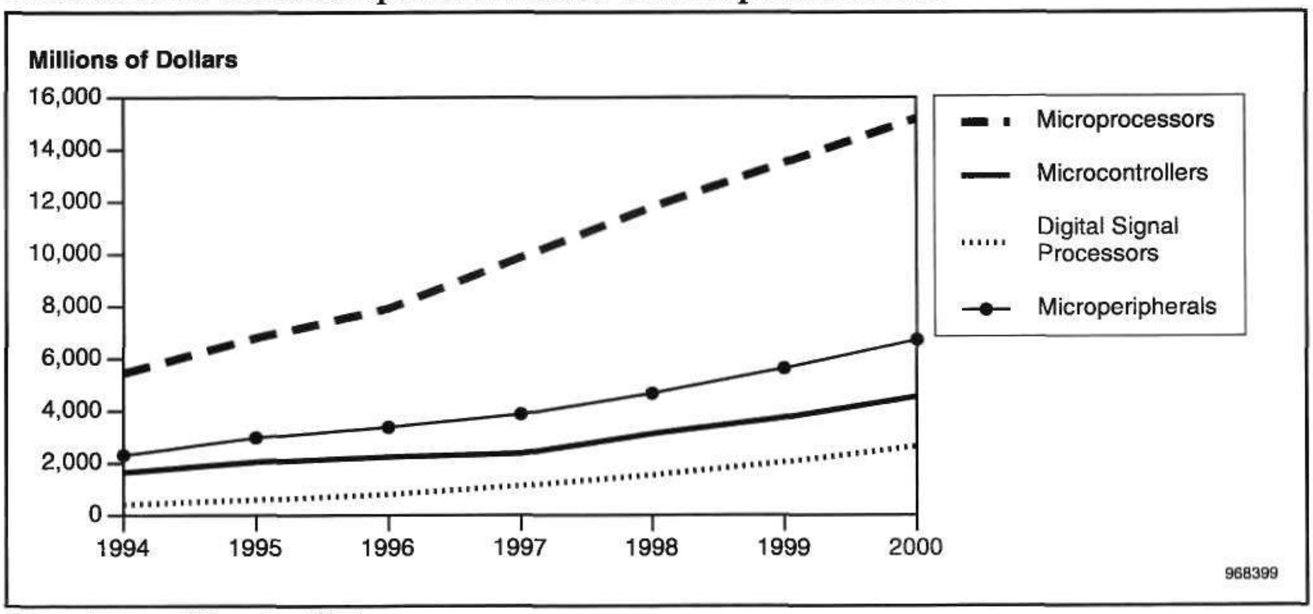
Source: Dataquest (November 1996)

Figure 3-5
The Americas' Microcomponent Consumption Forecast Showing Product Family Revenue



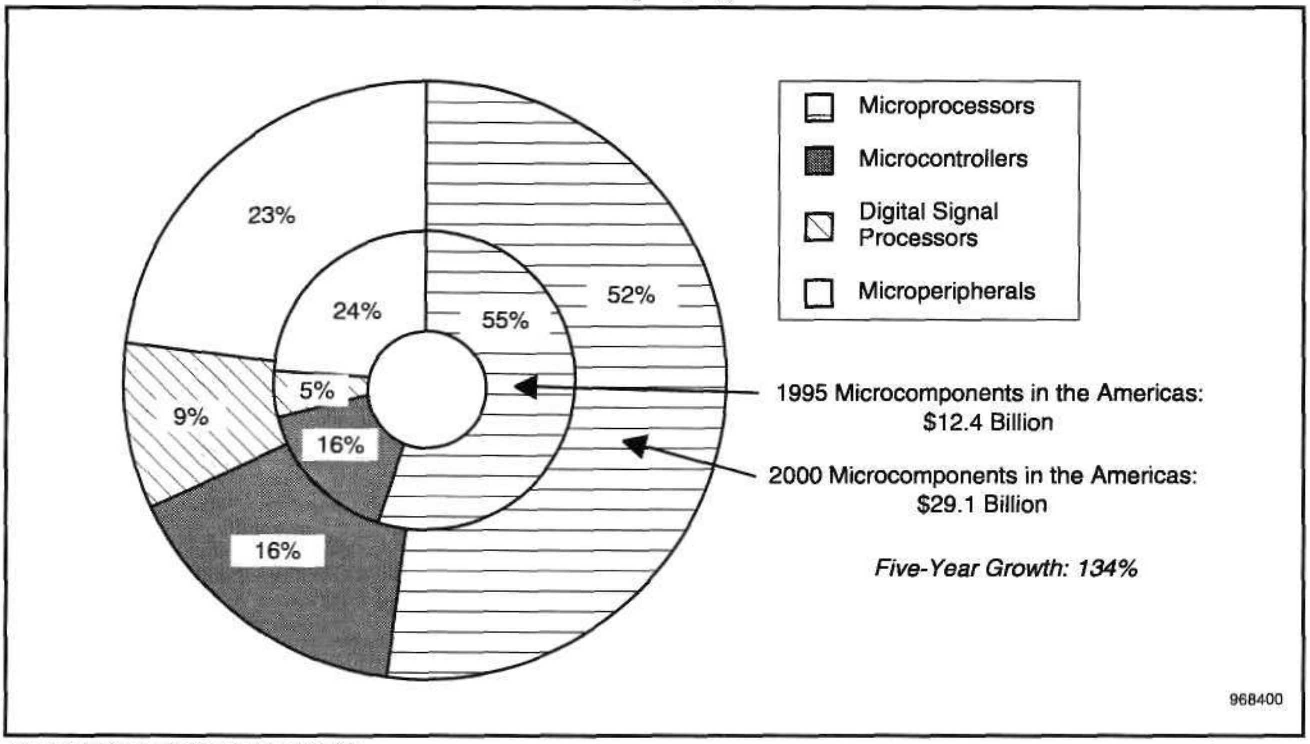
Source: Dataquest (November 1996)

Figure 3-6
The Americas' Microcomponent Product Consumption Forecast



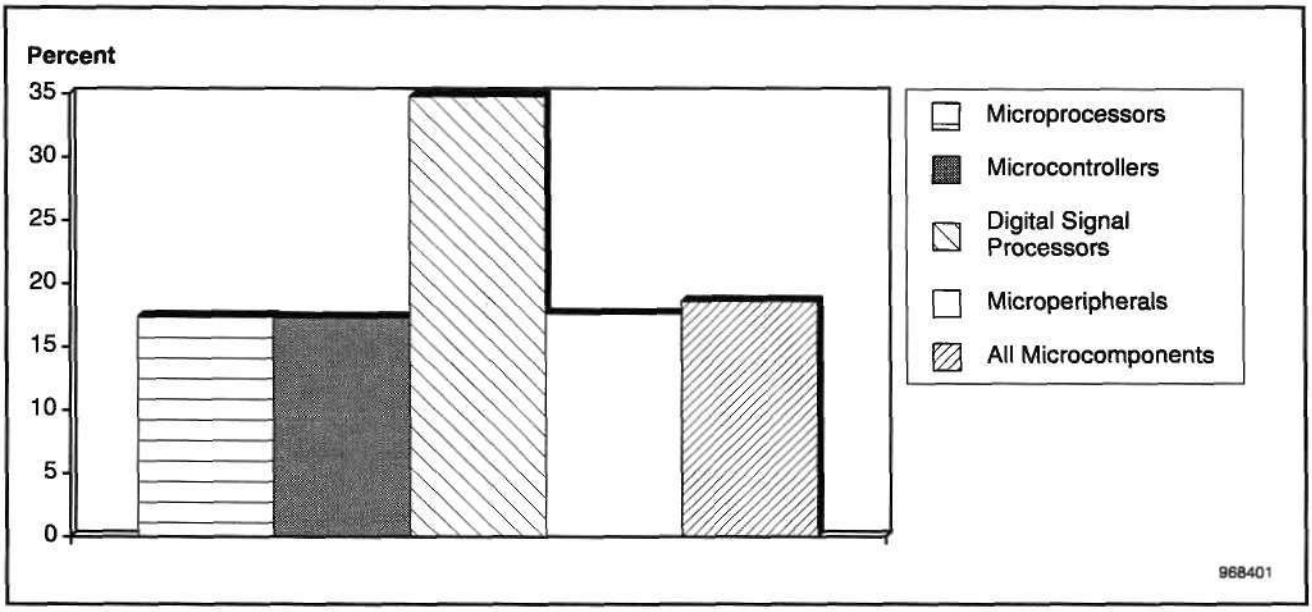
Source: Dataquest (November 1996)

Figure 3-7
The Americas' Microcomponent Product Split, by Revenue, 1995 and 2000



Source: Dataquest (November 1996)

Figure 3-8
The Americas' Microcomponent Products' Compound Annual Growth Rates, 1995-2000



Source: Dataquest (November 1996)

Japan

The revenue forecast for microcomponents consumed in Japan for the next five years is shown in Table 3-3 by the product family: all microprocessors, microcontrollers, programmable digital signal processors, and microperipherals. Percentages are given for the product family's revenue in Japan as a portion of all microcomponents and total semiconductor revenue in the region.

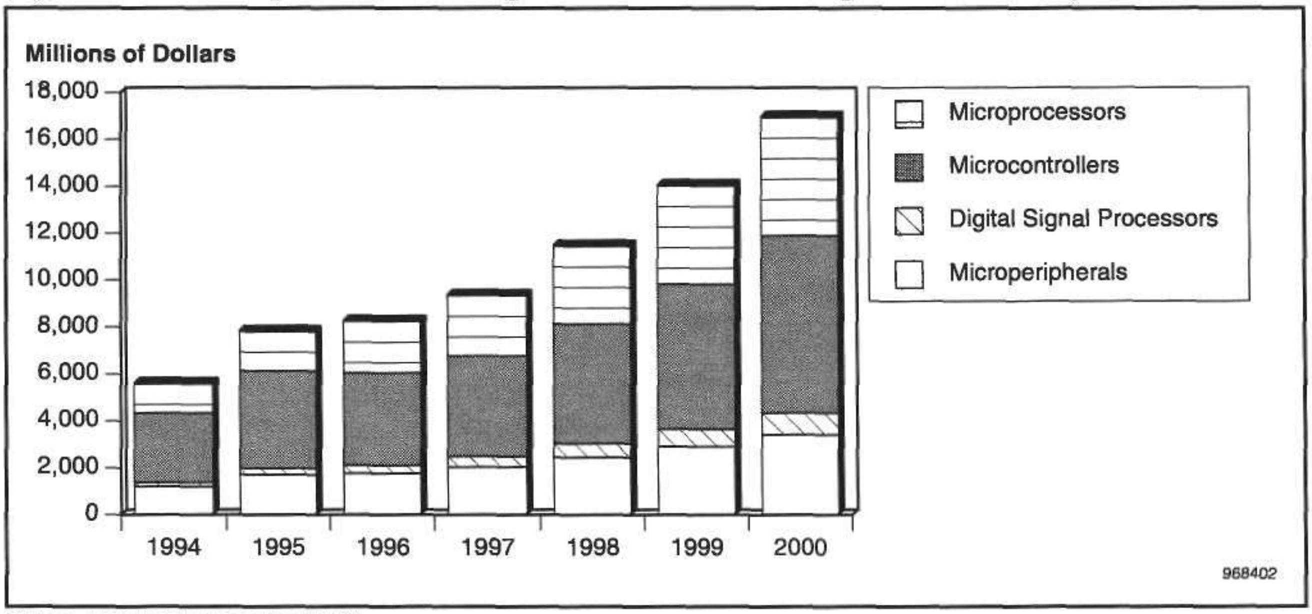
Figure 3-9 shows each product family's revenue as a portion of the entire microcomponent revenue in Japan. Figure 3-10 shows each product family's revenue in Japan. Figure 3-11 illustrates how the microcomponent product mix will change in Japan from 1995 to the year 2000. Figure 3-12 compares the CAGR expected from 1995 through 2000 from consumption of each product family in Japan.

Table 3-3
Revenue Forecast of Microcomponents Consumed in Japan, by Product Family (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Total Semiconductors in Japan	31,008	42,166	36,574	40,476	48,368	58,842	70,483	
Growth (%)		36.0	-13.3	10.7	19.5	21.7	19.8	10.8
Percentage of Worldwide Semiconductors	28.1	27.9	26.7	26.2	25.6	25.0	24.3	
Total Microcomponents in Japan	5,603	7,830	8,260	9,369	11,470	14,050	16,970	
Growth (%)		39.7	5.5	13.4	22.4	22.5	20.8	16.7
Percentage of Semiconductors in Japan	18.1	18.6	22.6	23.1	23.7	23.9	24.1	
Percentage of Worldwide Microcomponents	21.2	22.7	21.0	20.5	20.8	21.3	21.6	
Percentage of Worldwide Semiconductors	5.1	5.2	6.0	6.1	6.1	6.0	5.8	
Microprocessors	1,247	1,690	2,200	2,580	3,310	4,200	5,060	
Growth (%)		35.5	30.2	17.3	28.3	26.9	20.5	24.5
Percentage of Microcomponents in Japan	22.3	21.6	26.6	27.5	28.9	29.9	29.8	
Percentage of Semiconductors in Japan	4.0	4.0	6.0	6.4	6.8	7.1	7.2	
Microcontrollers	2,964	4,140	3,930	4,280	5,110	6,180	7,550	
Growth (%)		39.7	-5.1	8.9	19.4	20.9	22.2	12.8
Percentage of Microcomponents in Japan	52.9	52.9	47.6	45.7	44.6	44.0	44.5	
Percentage of Semiconductors in Japan	9.6	9.8	10.7	10.6	10.6	10.5	10.7	
Digital Signal Processors	166	274	350	459	590	740	920	
Growth (%)		65.1	27.7	31.1	28.5	25.4	24.3	27.4
Percentage of Microcomponents in Japan	3.0	3.5	4.2	4.9	5.1	5.3	5.4	
Percentage of Semiconductors in Japan	0.5	0.6	1.0	1.1	1.2	1.3	1.3	
Microperipherals	1,226	1,726	1,780	2,050	2,460	2,930	3,440	
Growth (%)		40.8	3.1	15.2	20.0	19.1	17.4	14.8
Percentage of Microcomponents in Japan	21.9	22.0	21.5	21.9	21.4	20.9	20.3	
Percentage of Semiconductors in Japan	4.0	4.1	4.9	5.1	5.1	5.0	4.9	

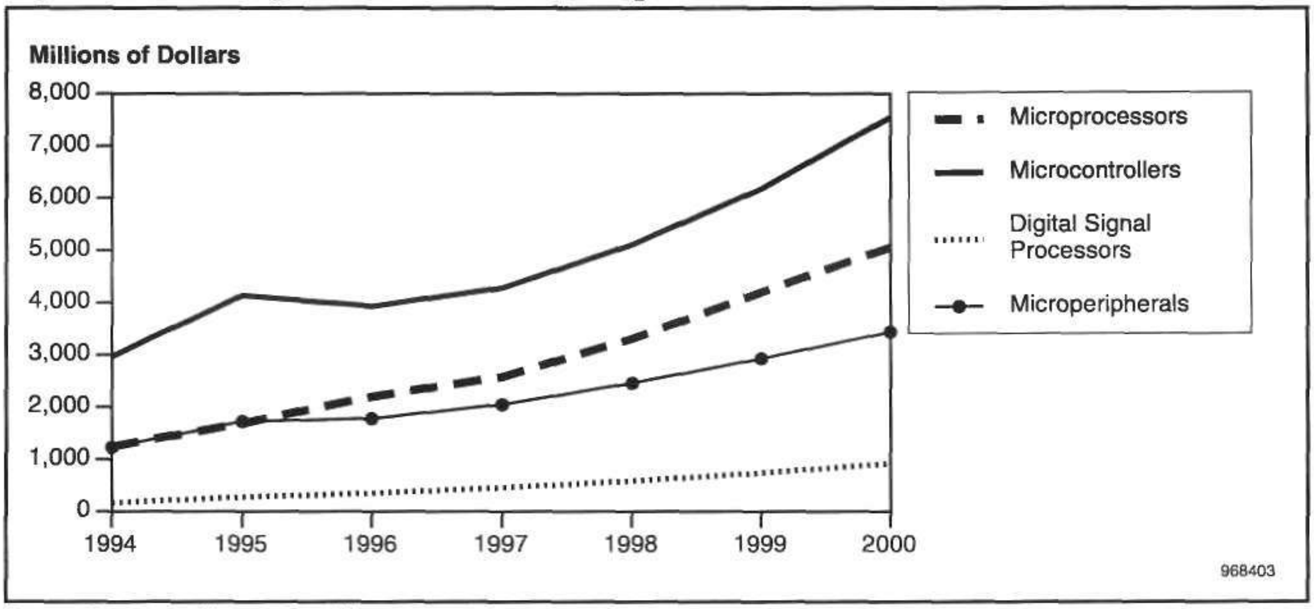
Source: Dataquest (November 1996)

Figure 3-9
Japan's Microcomponent Consumption Forecast Showing Product Family Revenue



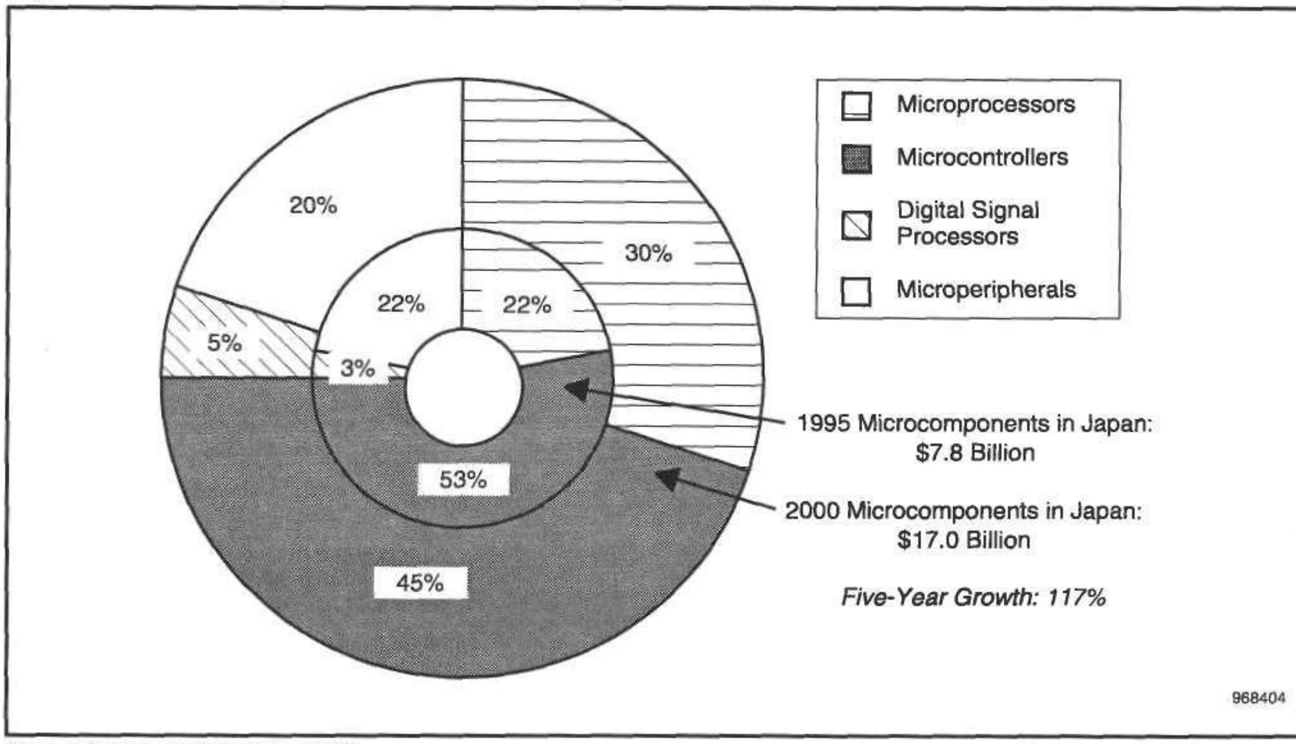
Source: Dataquest (November 1996)

Figure 3-10
Japan's Microcomponent Product Consumption Forecast



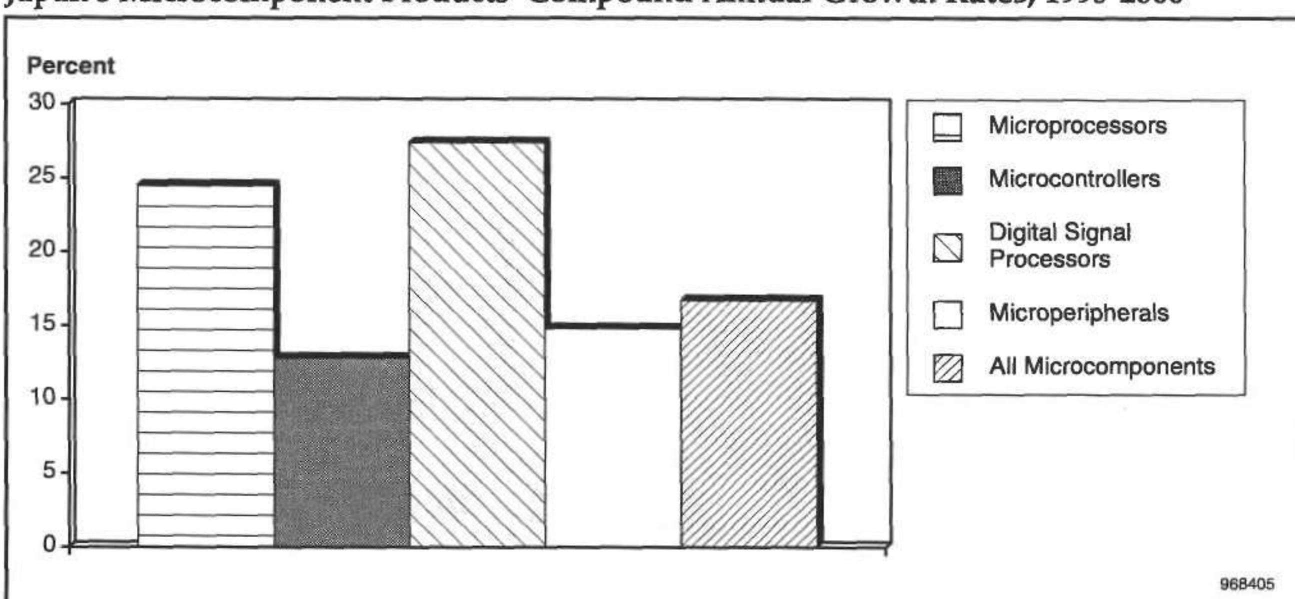
Source: Dataquest (November 1996)

Figure 3-11
Japan's Microcomponent Product Split, by Revenue, 1995 and 2000



Source: Dataquest (November 1996)

Figure 3-12
Japan's Microcomponent Products' Compound Annual Growth Rates, 1995-2000



Source: Dataquest (November 1996)

Europe, Africa, and Middle East

The revenue forecast for microcomponents consumed in the Europe, Africa, and Middle East region for the next five years is shown in Table 3-4 by the product family: all microprocessors, microcontrollers, programmable digital signal processors, and microperipherals. Percentages are given for the product family's revenue in the region as a portion of all microcomponents and total semiconductor revenue in the region.

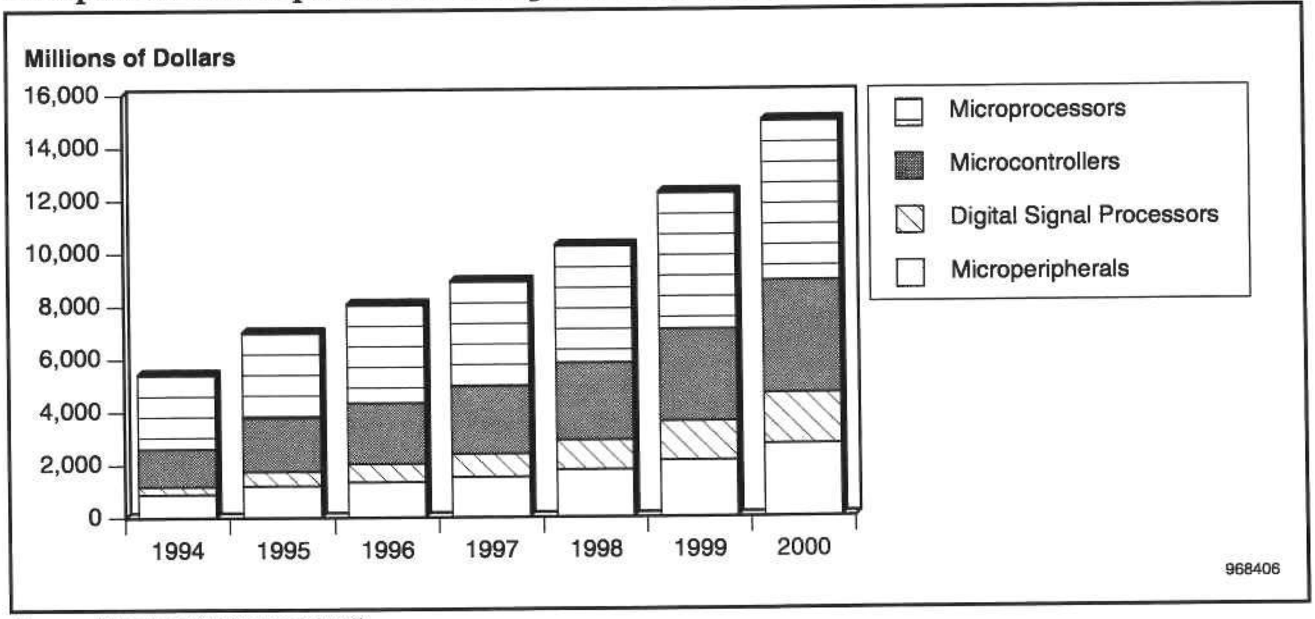
Figure 3-13 shows each product family's revenue as a portion of the entire microcomponent revenue in the Europe, Africa, and Middle East region. Figure 3-14 shows each product family's revenue in the Europe, Africa, and Middle East region. Figure 3-15 illustrates how the microcomponent product mix will change in the region from 1995 to the year 2000. Figure 3-16 compares the CAGR expected from 1995 through 2000 from consumption of each product family in the region.

Table 3-4
Revenue Forecast of Microcomponents Consumed in Europe, by Product Family (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Total Semiconductors in Europe	20,900	28,336	27,136	29,642	34,951	42,225	53,099	
Growth (%)		35.6	-4.2	9.2	17.9	20.8	25.8	13.4
Percentage of Worldwide Semiconductors	18.9	18.7	19.8	19.2	18.5	18.0	18.3	
Total Microcomponents in Europe	5,408	7,001	8,055	8,924	10,260	12,260	14,970	
Growth (%)		29.5	15.1	10.8	15.0	19.5	22.1	16.4
Percentage of Semiconductors in Europe	25.9	24.7	29.7	30.1	29.4	29.0	28.2	
Percentage of Worldwide Microcomponents	20.5	20.3	20.5	19.5	18.6	18.6	19.0	
Percentage of Worldwide Semiconductors	4.9	4.6	5.9	5.8	5.4	5.2	5.2	
Microprocessors	2,775	3,197	3,700	3,950	4,410	5,140	6,030	
Growth (%)		15.2	15.7	6.8	11.6	16.6	17.3	13.5
Percentage of Microcomponents in Europe	51.3	45.7	45.9	44.3	43.0	41.9	40.3	
Percentage of Semiconductors in Europe	13.3	11.3	13.6	13.3	12.6	12.2	11.4	
Microcontrollers	1,431	2,030	2,300	2,550	2,920	3,480	4,260	
Growth (%)		41.9	13.3	10.9	14.5	19.2	22.4	16.0
Percentage of Microcomponents in Europe	26.5	29.0	28.6	28.6	28.5	28.4	28.5	
Percentage of Semiconductors in Europe	6.8	7.2	8.5	8.6	8.4	8.2	8.0	
Digital Signal Processors	305	548	685	874	1,120	1,480	1,920	
Growth (%)		79.7	25.0	27.6	28.1	32.1	29.7	28.5
Percentage of Microcomponents in Europe	5.6	7.8	8.5	9.8	10.9	12.1	12.8	
Percentage of Semiconductors in Europe	1.5	1.9	2.5	2.9	3.2	3.5	3.6	
Microperipherals	897	1,226	1,370	1,550	1,810	2,160	2,760	
Growth (%)		36.7	11.7	13.1	16.8	19.3	27.8	17.6
Percentage of Microcomponents in Europe	16.6	17.5	17.0	17.4	17.6	17.6	18.4	
Percentage of Semiconductors in Europe	4.3	4.3	5.0	5.2	5.2	5.1	5.2	

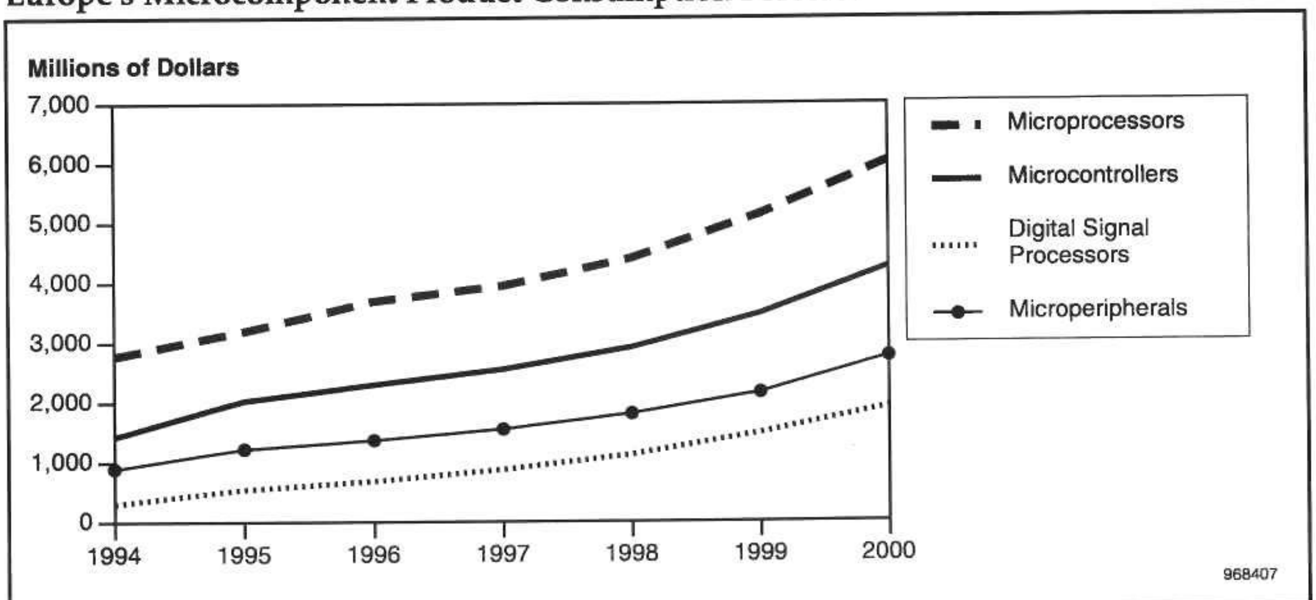
Source: Dataquest (November 1996)

Figure 3-13
Europe's Microcomponent Consumption Forecast Showing Product Family Revenue



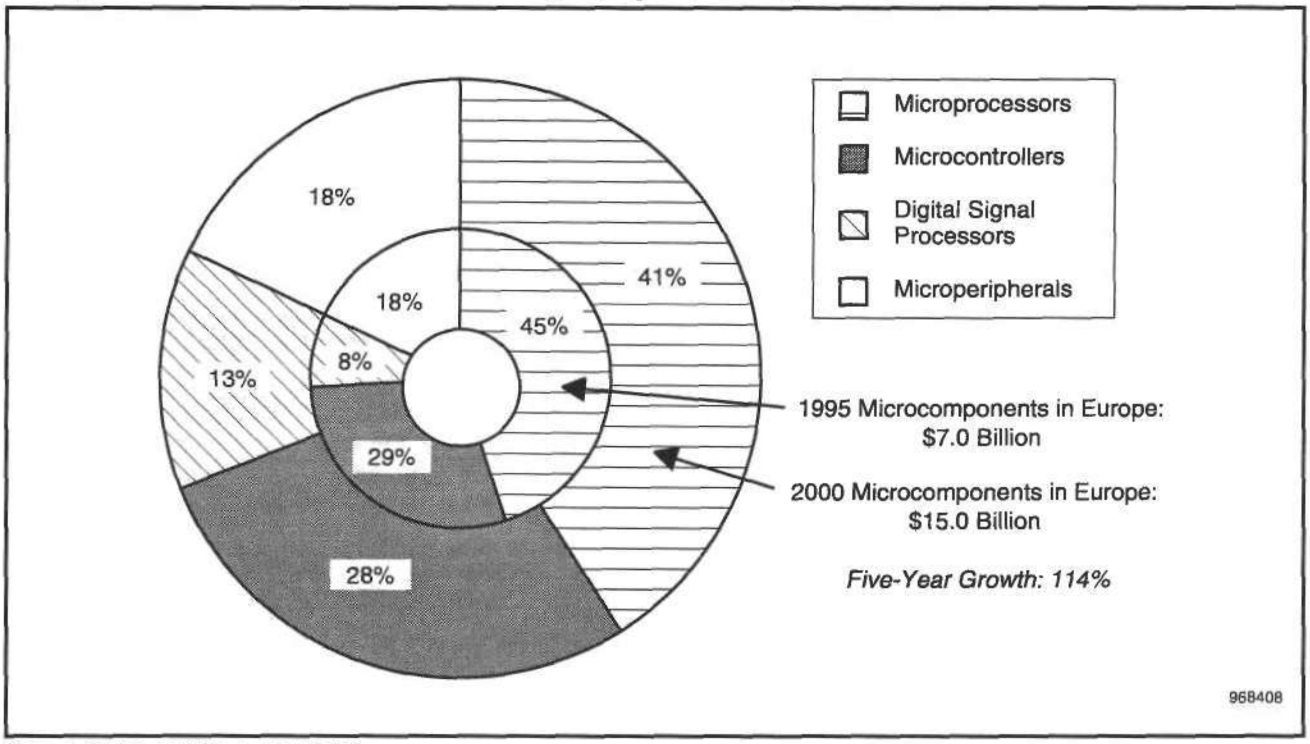
Source: Dataquest (November 1996)

Figure 3-14
Europe's Microcomponent Product Consumption Forecast



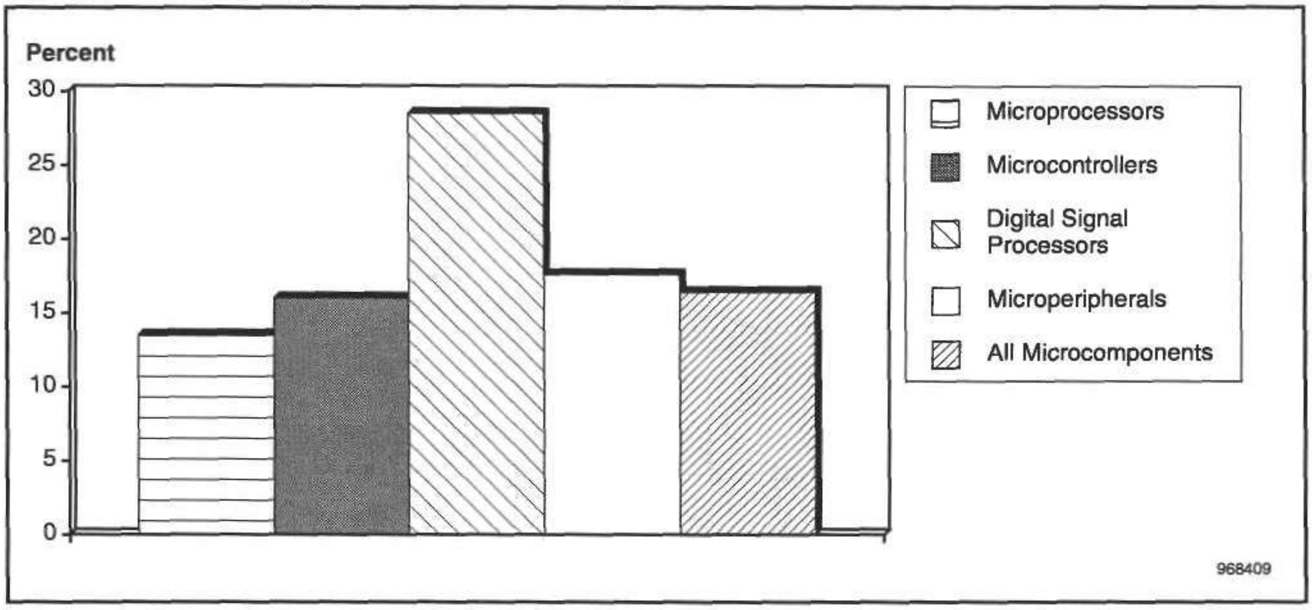
Source: Dataquest (November 1996)

Figure 3-15
Europe's Microcomponent Product Split, by Revenue, 1995 and 2000



Source: Dataquest (November 1996)

Figure 3-16
Europe's Microcomponent Products' Compound Annual Growth Rates, 1995-2000



Source: Dataquest (November 1996)

Asia/Pacific

The revenue forecast for microcomponents consumed in the Asia/Pacific region for the next five years is shown in Table 3-5 by the product family: all microprocessors, microcontrollers, programmable digital signal processors, and microperipherals. Percentages are given for the product family's revenue in Asia/Pacific as a portion of all microcomponents and total semiconductor revenue in Asia/Pacific.

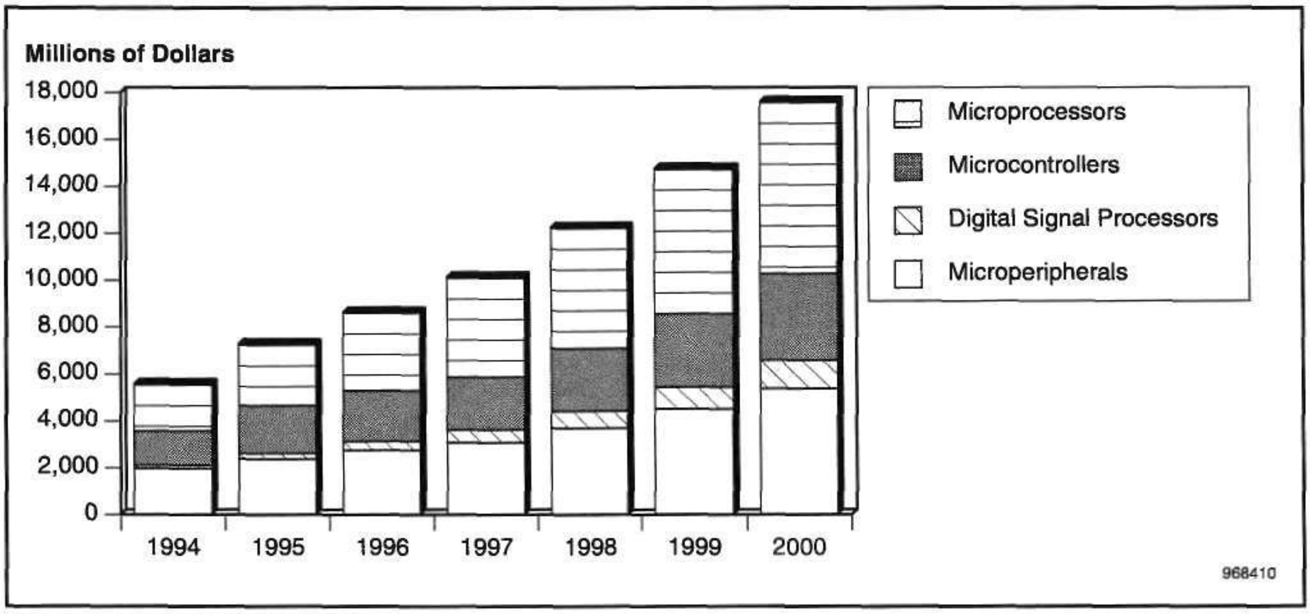
Figure 3-17 shows each product family's revenue as a portion of the entire microcomponent revenue in Asia/Pacific. Figure 3-18 shows each product family's revenue in Asia/Pacific. Figure 3-19 illustrates how the microcomponent product mix will change in Asia/Pacific from 1995 to the year 2000. Figure 3-20 compares the CAGR expected from 1995 through 2000 from consumption of each product family in the region.

Table 3-5
Revenue Forecast of Microcomponents Consumed in Asia/Pacific, by Product Family (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Total Semiconductors in Asia/Pacific	22,832	32,416	29,090	34,047	43,273	54,627	68,923	
Growth (%)		42.0	-10.3	17.0	27.1	26.2	26.2	16.3
Percentage of Worldwide Semiconductors	20.7	21.4	21.2	22.0	22.9	23.3	23.7	
Total Microcomponents in Asia/Pacific	5,558	7,252	8,615	10,111	12,228	14,737	17,590	
Growth (%)		30.5	18.8	17.4	20.9	20.5	19.4	19.4
Percentage of Semiconductors in Asia/Pacific	24.3	22.4	29.6	29.7	28.3	27.0	25.5	
Percentage of Worldwide Microcomponents	21.0	21.0	21.9	22.1	22.2	22.3	22.4	
Percentage of Worldwide Semiconductors	5.0	4.8	6.3	6.5	6.5	6.3	6.1	
Microprocessors	1,969	2,586	3,300	4,230	5,130	6,160	7,300	
Growth (%)		31.3	27.6	28.2	21.3	20.1	18.5	23.1
Percentage of Microcomponents in Asia/Pacific	35.4	35.7	38.3	41.8	42.0	41.8	41.5	
Percentage of Semiconductors in Asia/Pacific	8.6	8.0	11.3	12.4	11.9	11.3	10.6	
Microcontrollers	1,470	2,032	2,170	2,240	2,660	3,110	3,690	
Growth (%)		38.2	6.8	3.2	18.8	16.9	18.6	12.7
Percentage of Microcomponents in Asia/Pacific	26.4	28.0	25.2	22.2	21.8	21.1	21.0	
Percentage of Semiconductors in Asia/Pacific	6.4	6.3	7.5	6.6	6.1	5.7	5.4	
Digital Signal Processors	138	252	385	541	728	937	1,210	
Growth (%)		82.6	52.8	40.5	34.6	28.7	29.1	36.9
Percentage of Microcomponents in Asia/Pacific	2.5	3.5	4.5	5.4	6.0	6.4	6.9	
Percentage of Semiconductors in Asia/Pacific	0.6	0.8	1.3	1.6	1.7	1.7	1.8	
Microperipherals	1,981	2,382	2,760	3,100	3,710	4,530	5,390	
Growth (%)		20.2	15.9	12.3	19.7	22.1	19.0	17.7
Percentage of Microcomponents in Asia/Pacific	35.6	32.8	32.0	30.7	30.3	30.7	30.6	
Percentage of Semiconductors in Asia/Pacific	8.7	7.3	9.5	9.1	8.6	8.3	7.8	

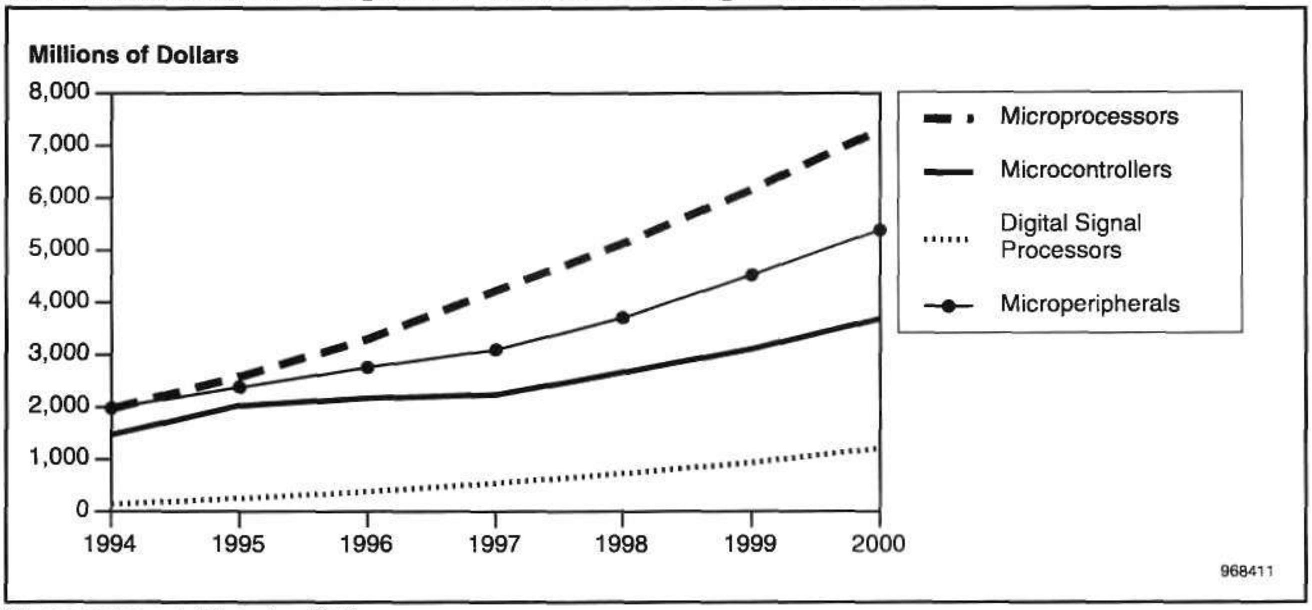
Source: Dataquest (November 1996)

Figure 3-17
Asia/Pacific's Microcomponent Consumption Forecast Showing Product Family Revenue



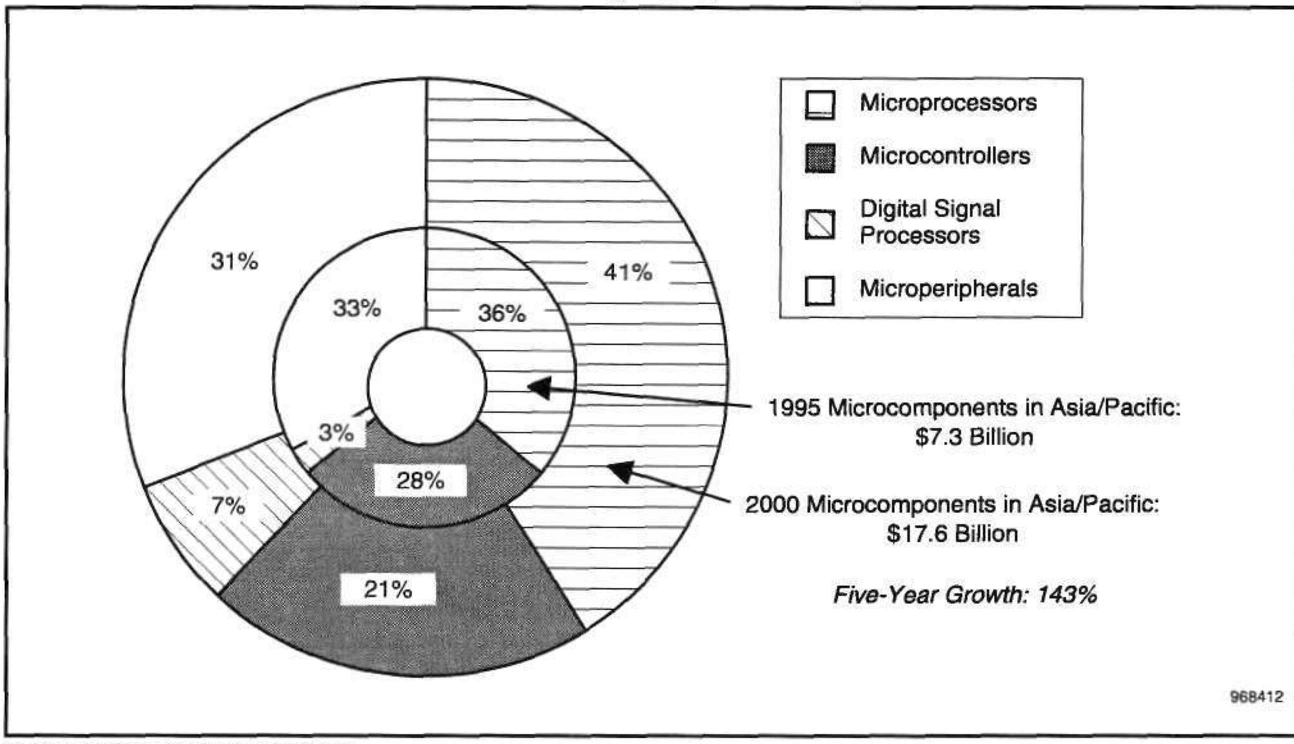
Source: Dataquest (November 1996)

Figure 3-18
Asia/Pacific's Microcomponent Product Consumption Forecast



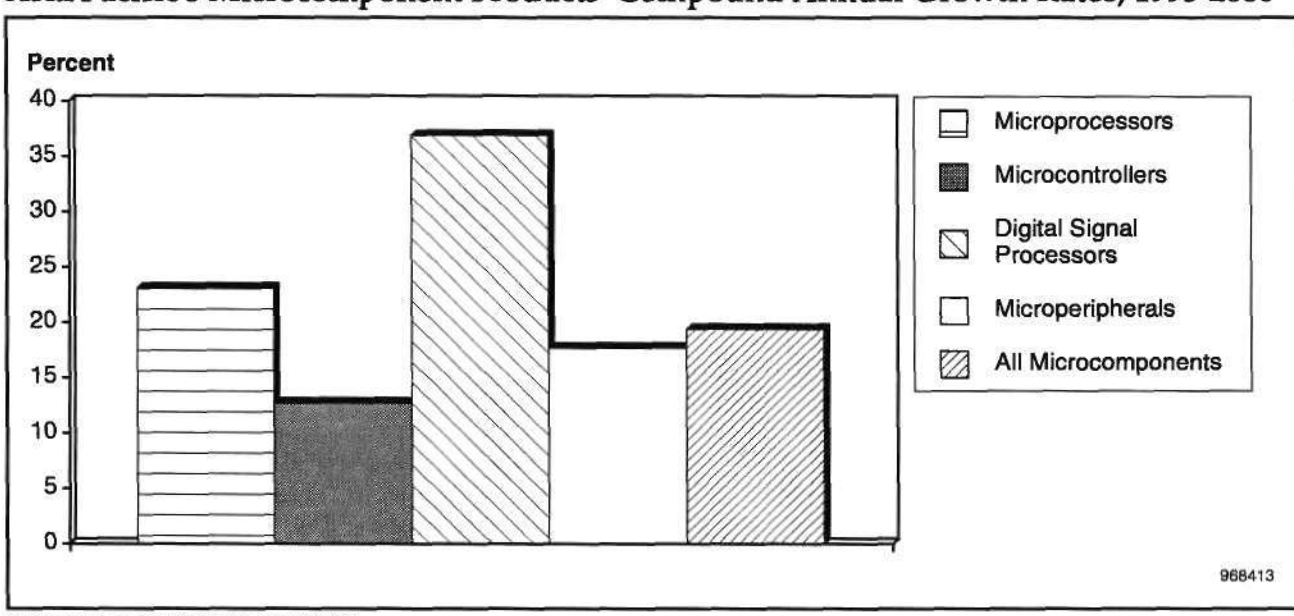
Source: Dataquest (November 1996)

Figure 3-19
Asia/Pacific's Microcomponent Product Split, by Revenue, 1995 and 2000



Source: Dataquest (November 1996)

Figure 3-20
Asia/Pacific's Microcomponent Products' Compound Annual Growth Rates, 1995-2000



Source: Dataquest (November 1996)

Appendix A
Definitions of Terms and Regions

Below are some definitions that will be helpful in understanding this document better. Note that the definitions of the regions changed somewhat in 1996.

Terms

Microcomponent

Microcomponents are a category of MOS digital integrated circuits (ICs) made up of the microprocessor (MPU), microcontroller (MCU), programmable digital signal processor (DSP), and microperipheral (MPR) product families.

Microprocessor (MPU)

An MPU is a MOS digital integrated circuit that includes an instruction decoder, arithmetic logic unit (ALU), registers, and additional logic. It may contain instruction, data, or unified caches, memory management systems, and auxiliary ALUs for floating point and other special data types. An MPU's functions are determined by fetching and executing instructions and manipulating data held in registers, internal cache, or external memory. MPUs operate out of external memory systems typically ranging from 1MB to 64MB of RAM and often backed by secondary memory systems (like disks). More highly integrated versions of MPUs may contain on-chip peripherals, interface, and support circuits. The MPU category includes MPUs incorporating or originating from an ASIC design. MPUs are divided into complex-instruction-set-computer (CISC) or reduced-instruction-set computer (RISC) implementations having 8-bit, 16-bit, or 32-bit and greater word width. MPUs are designed into computational applications or into embedded applications. A similar term is processor.

Microcontroller (MCU)

This is an IC similar to an MPU, with the primary exception being that it is designed to operate from on-chip program and data memory (not including cache memories). MCU devices must be available with on-chip program or data store. As an option, some MCU devices can be purchased without on-chip memory for use during the debug and development phase of the system. Peripherals may be included on chip to assist in sophisticated input, output, and control functions. The MCU category includes MCUs incorporating, or originating from, an ASIC design. Standalone digital signal processors are not included with MCUs. MCUs are divided into 4-bit, 8-bit, or 16-bit and greater word width. All MCUs are designed into embedded applications. A similar term is microcomputer.

Digital Signal Processor (DSP)

A DSP is a programmable MOS digital integrated circuit (IC) designed for standalone operation, consisting of a high-speed arithmetic unit (typically a multiplier-accumulator unit) designed to perform complex mathematical operations such as Fourier transforms in real time to generate, manipulate, or interpret digital representations of analog signals. Modern DSPs typically access multiple pieces of data in different locations of on-chip memory over separate data paths using specialized addressing modes. Most DSP functions, such as the multiply-and-accumulate function, complete in a single instruction clock. DSPs usually include peripherals, which may include analog circuits like analog-to-digital converters. DSPs typically operate on 16 or 24 bits of fixed point data or 32 bits of floating point data, although Dataquest does not currently subdivide DSPs into these categories. DSPs that have no version that can be reprogrammed by the user in assembly language or a higher-level language are not included but are classified as application-specific standard products (ASSP) or microperipherals. DSPs integrated on-chip with an independent microprocessor or microcontroller are classified as either an MPU or MCU, respectively. All DSPs are designed into embedded applications. A similar term is pDSP.

Microperipheral (MPR)

This is a MOS digital integrated circuit (IC) that serves as a dedicated logical support function to a microprocessor or microcontroller in a system. Microperipherals are not programmable from assembly language, although they are often highly configurable by software or electrical signals. This definition includes MPRs comprising more than one device, such as PC or core logic chipsets. The MPR category includes MPRs incorporating, or originating from, an ASIC design. MPRs might be implemented using microprocessor, microcontroller, or digital signal processing elements, although this is generally not evident to the user.

Compound Annual Growth Rate (CAGR)

This is a measure of the growth of an industry over time. A positive number indicates a growing market. It is associated with revenue unless noted as units or average selling price. A five-year span is usually reported (N = 5). The CAGR is defined as follows and usually expressed as a percentage:

$$CAGR = \sqrt[N]{\frac{Value_{t=N}}{Value_{t=0}}} - 1$$

Regions

Americas

North America

Includes Canada, Mexico, and the United States (50 states)

South America

Central America

Japan

Japan is the only single-country region.

Europe, Africa, and Middle East

Western Europe. Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of Western Europe (Andorra, Cyprus, Gibraltar, Liechtenstein, Monaco, San Marino, Vatican City, Iceland, Malta, and Turkey)

Eastern Europe. Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (Belarus, Russian Federation, Ukraine, Georgia, Moldova, Armenia, Azerbaijan, Kazakhstan, Uzbekistan, Tajikistan, Kyrgyzstan, and Turkmenistan).

Africa

Middle East

Asia/Pacific

Includes Asia/Pacific's newly industrialized economies (NIEs) and the rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, South Korea, and Taiwan. The rest of Asia/Pacific region includes Australia, Bangladesh, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.

Appendix B
Exchange Rates

Average annual exchange rates are used for revenue history as outlined in Table B-1; the 1996 "average" exchange rate is extended into the 1996-to-2000 forecast horizon. Dataquest does not forecast exchange rates. In Dataquest's worldwide services, revenue is reported in equivalent U.S. dollars.

Table B-1
Exchange Rates (Foreign Currency per U.S. Dollar)

Country	1995	1996	1996 U.S. Dollar Appreciation (%)
European Union (ECU)	0.77	0.80	3.20
France (Franc)	4.97	5.10	2.69
Germany (Mark)	1.43	1.50	4.77
Great Britain (Pound Sterling)	0.63	0.65	2.47
Japan (Yen)	93.90	108.06	15.08

Source: Dataquest (November 1996)

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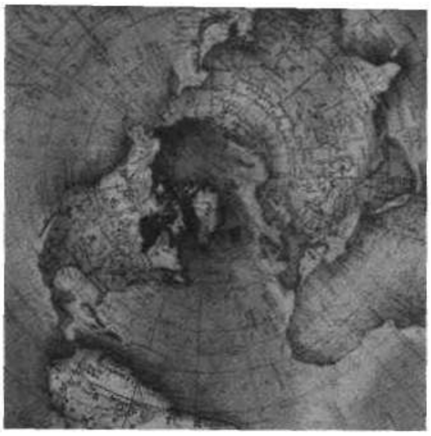

Dataquest

The Microcontroller Forecast—A Mixed Bag, Then Back on the Track

Market Trends

Program: Embedded Microcomponents Worldwide
Product Code: MCRO-WW-MT-9603
Publication Date: October 14, 1996
Filing: Market Trends

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Chapter 1
Overview

Microcontrollers (MCUs) are the second of four primary categories of microcomponent semiconductors. This report presents Dataquest's analysis of the microcontroller market of 1995 as well as Dataquest's forecast for microcontrollers over the next five years. The forecast is backed by extensive research and in-depth analysis of product characteristics, market dynamics, and end equipment. Various breakdowns of the market are given for classifications of 4-bit, 8-bit, and 16-bit microcontrollers, with tables and graphs of revenues and unit shipments given, as well as the applications of those microcontrollers. Trends in the marketplace are analyzed, along with the conditions that will influence their outcome.

In 1995, microcontrollers had a banner year, growing over 35 percent. For MCUs, 1996 has been a real mixed bag. Each vendor has its own particular challenges and timing, depending on its product mix and its markets and customers. The year should close out with a 3.4 percent revenue growth for microcontrollers, with some lagging continuing into 1997. Overall, microcontrollers are expected to remain a strong, growing part of the microcomponent product mix with a growth rate returning to well over 20 percent. In total revenue, 16-bit and larger MCUs will grow the most and show the greatest change, but 8-bit MCUs will continue to dominate the market well into the new millennium. If the players can tolerate the 1996 flatness, real prosperity will return in short order. Watch for a $20 billion business going out of the 20th century with over 20 percent growth.

What Does It Look Like?

As the groceries are being unloaded from the car, one of the bags drops and there's a crash. Inside the damp and broken bag, the contents are assessed. The canned goods are OK, but they smashed some nearby crackers. The bread got squeezed but soon regains its original shape. The jar of sauerkraut is broken and has destroyed the bottom of the sack, and the odor is starting to permeate everything else. Of course, there are the eggs, and the four that didn't break are covered with so much slop that the whole dozen is dispatched to the garbage.

In 1996, the bag of microcontrollers took a fall. We know we're worse off, but after looking around in the bag, we determine that some things are OK, while others are a mess. The condition of any particular business will depend on the application, the industry, or the region. Whether the uncrumbled crackers go into the cupboard or the unscrambled eggs get washed off will depend on the commitment of the vendor to the product, the market, and the ease with which replacement groceries can be obtained. But we're going to have a meager supper tonight.

It is not much easier to determine why certain goods survived the fall than to determine exactly how the bag got dropped. After all, it wasn't the kids carrying them in, and that loose tennis shoe has been there for a while. Perhaps it's the same reason that there's insurance. The odds are that things are going to go bad every once in a while, no matter how good they look right now.

The year 1995 was such a boom year that everyone was simply looking up. Perhaps an occasional glance down might have revealed some unexpected hazards. The phenomenal growth in the personal computer and communications industries outstripped suppliers' abilities to serve their customers' needs. Protecting their flanks and ignoring some basic business tenets, customers overordered and developed backup procedures to cover any shortages. Excess inventory was understood to be easy to burn off, and pricing didn't matter as much as supply. Vendors worked feverishly to build and reconfigure fab, assembly, and test facilities to improve capacity to supply a seemingly insatiable market.

When a flood of unused DRAM hit the market after PC sales slowed before Christmas, compound effects in the semiconductor supply and demand system turned the entire industry upside down. OEMs found too many PCs in the channel and on their docks. They stopped ordering chips to build PCs they didn't need to build. They pushed their subsystem suppliers to quit shipping the disk drives, monitors, and sound cards they didn't need. OEMs pushed their subsystem suppliers to slow down but to remain ready to ship more units on a moment's notice. Subsystem manufacturers didn't want to hold too much inventory, so they pushed back on their chip suppliers to ship fewer chips but to be ready to restart supply at any time.

Where do semiconductor suppliers have to turn? Stop turning the cranks in the fabs. Eventually they slow or stop building the new fabs. Stop ordering the new steppers and ion implanters. Delay the delivery of the testers. Rebalance the product mix in the fabs. Reestablish tight expense controls. People are affected. Applied Materials Inc. and other equipment suppliers are similarly affected. Dig in—it's going to be a tough year.

How does this affect microcontrollers? Other segments get spooked by the well-publicized events in the data processing industry and take a reality check. First, the applications in the data processing industry are affected, some severely. As the semiconductor industry goes through its shrinking pains, Wall Street and other industries take note. As supply frees up, other application segments become flush with incoming chips. But management awakens to the dominoes falling in the data processing industry and revamps its own purchasing policies. Management scrutinizes channel inventories. Makes chip inventories leaner. Matches purchase orders more closely with declining lead times. And listens carefully for vendors offering price decreases. Eventually, all the segments are affected because of fear, because of the balances of supply and demand, and because this really is a cyclical business.

However, the most perplexing aspect to understand about the business cycle of 1996 is that the global economy is still in very good health, and electronic equipment in general is still in pretty good demand. There is no global recession, no masses of unemployed workers, no inadequate supply of money to borrow. The demand for the end equipment still seems to be there. Dataquest has no magic answer tied to normal outside economic factors to describe why semiconductors, or even microcomponents specifically, are in the slump they are. But we also have no fundamental reason to radically change the long-term outlook for microcomponents.

There has been an ever-increasing number of vendors coming into the microprocessor and microcontroller business. Its high growth and reported profits have attracted the attention of the stock market, captive and specialty semiconductor manufacturers, DRAM manufacturers, RISC vendors, and total newcomers. Existing MCU vendors add architectures between former product lines to fill any cracks. Every one of these vendors targets a given piece of the pie. Although the pie grows from year to year, the targeted shares still add up to greater than 100 percent. As it is in Texas when the deer population grows unchecked, the food source is spread more thinly over the larger population, and the weak animals do not survive. Unfortunately, the stronger ones suffer, as well, until the natural thinning of the population is completed. It may be time for a thinning of the deer in microcomponents.

Care with Definitions

The words "microcontroller" and "embedded control" are used rather loosely in our industry. All too frequently they are used very inconsistently, especially from vendor to vendor. Dataquest strives to use the terms microcontroller and microprocessor (MPU) according to very specific definitions and encourages vendors, users, and spokespersons to do the same. Appendix A at the end of this document includes the definition of microcontrollers as Dataquest uses it. This document forecasts the use of microcontrollers only according to that definition. The reader should understand this definition in order to make proper use of the information included here. Note that the outlook for microprocessors is available in the Dataquest document *Microprocessor Forecast and Embedded Microprocessor Trends through the Year 2000*, MCRO-WW-MT-9602, September 23, 1996.

Chapter 2
1995—A Memorable Year for Microcontrollers

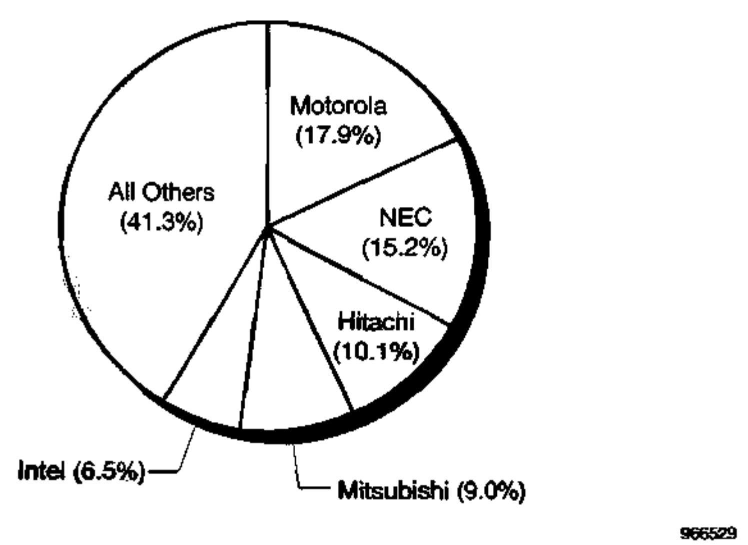
Microcontrollers had their best year ever in 1995, growing 36.4 percent in revenue and 18.7 percent in units. That may be a hard year to beat, and 1996 will not do it. Motorola Inc. held its position as the No. 1 MCU vendor, slipping slightly to just under 18 percent market share (see Table 2-1 and Figure 2-1.) NEC lost a little more ground in its second-place slot with a 15.2 percent share, dropping almost 2 percent. Hitachi Ltd. becomes a strong third-place runner in microcontrollers with big gains in its microcontroller-classed 32-bit RISC, the SH-1. Hitachi and Mitsubishi Corporation actually made the highest gains near the top of the pack, with 80 percent and 44 percent growth, respectively. Intel Corporation is in the top five MCU vendors, mostly on the strength of its 16-bit 196 product line. Further down in overall MCUs, the 8051 contingent made some significant gains in market share, outpacing the total average. Oddly, the top five vendors grew much less than the average for all MCUs, and much higher gains were found in the lower portions of the rankings.

Table 2-1
Leading Microcontroller Vendors by Revenue (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	1995 Market Share (%)
1	1	Motorola	1,424	1,838	29	17.9
2	2	NEC	1,275	1,554	22	15.2
3	5	Hitachi	577	1,038	80	10.1
4	3	Mitsubishi	637	918	44	9.0
5	4	Intel	600	670	12	6.5

Source: Dataquest (September 1996)

Figure 2-1
Leading Microcontroller Vendors' 1995 Market Share by Revenue

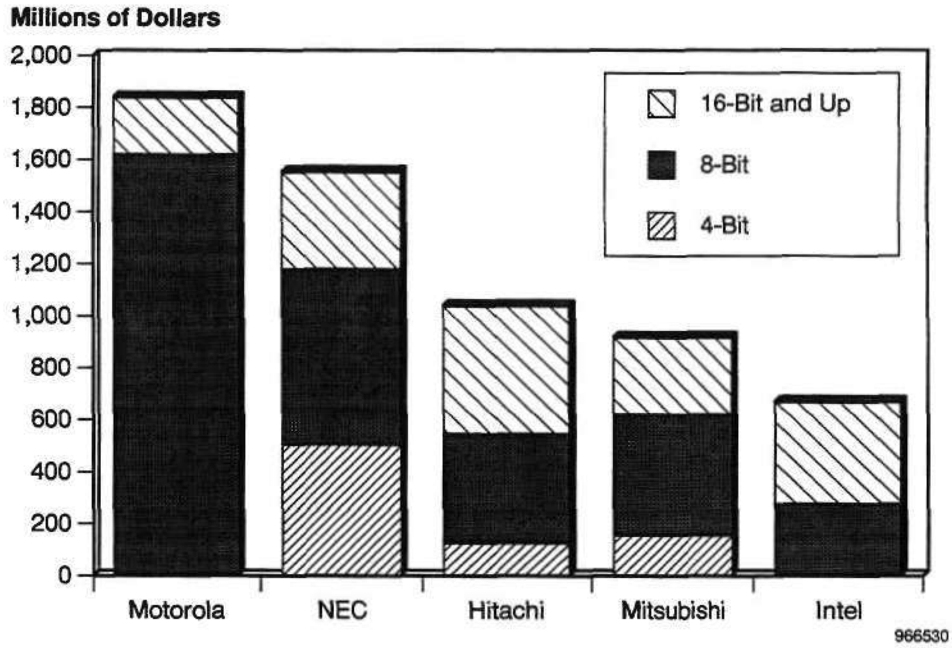


Source: Dataquest (September 1996)

There is not only one formula for becoming a successful microcontroller vendor. Figure 2-2 illustrates the makeup of the top five vendors' microcontrollers, looking at word width. Motorola clearly has a dominant role in 8-bit MCUs, and neither Motorola nor Intel has 4-bit MCUs on the market. The Japanese companies, with almost a lock on 4-bit MCUs, have products in all three categories. NEC looks to be the most balanced, but Mitsubishi actually has the closest profile to that of all the microcontrollers sold (as shown in Figure 2-3.) Figure 2-3 also shows that a greater number of lower-priced 4-bit products must be manufactured for each 4-bit dollar received. The 8-bit MCUs clearly still dominate the market in both volume and in revenue.

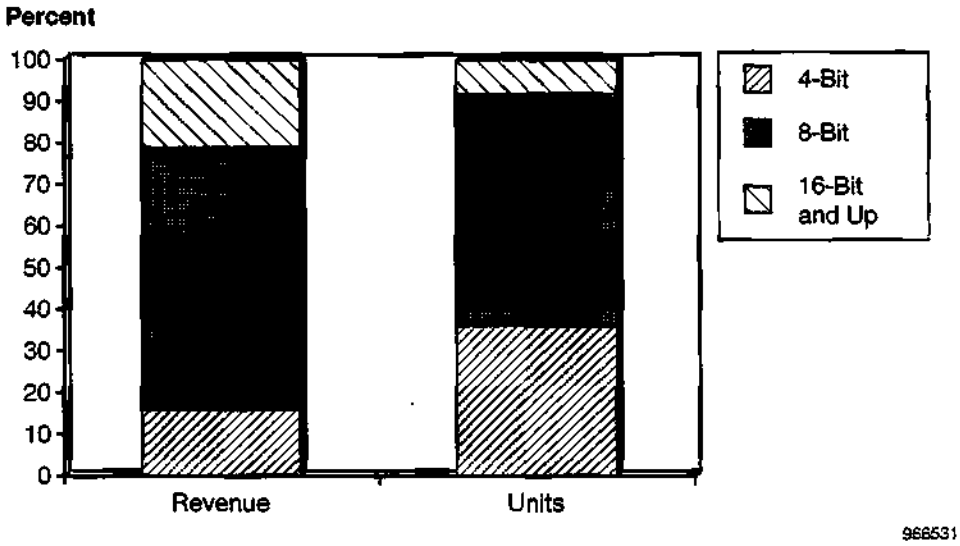
Note that data for some of the graphs in this document is found in tables in Dataquest's document *1995 Microcontroller Market Share and Shipments*, MCRO-WW-MS-9602, May 27, 1996.

Figure 2-2
Word Width of Leading Microcontroller Vendors' Product Portfolio by Revenue



Source: Dataquest (September 1996)

Figure 2-3
Word Width of All Microcontrollers



Source: Dataquest (September 1996)

The 4-Bit Microcontroller under Pressure

The 4-bit MCU, the lowest-cost, highest-volume microcomponent family, is in the throes of stagnation. Earlier, 1994 had been expected to be a peak year, but strong growth in MCUs in the mid-1990s brought 4-bit MCUs strong growth as well. Growth in 4-bit MCUs in 1995 turned out to be not as strong as anticipated but still came in at a good 14 percent. However, bad years for markets tend to precipitate change, especially for the older technologies. The market of 1996 could be just the set of conditions to send 4-bit MCUs on a permanent downward glide.

Certainly there is an abundance of applications in which minimal processing power is required, and indeed this is a necessary area for growth and feeding the bottom of the pyramid of performance and volume charts. But with most 4-bit vendors located in Japan and focusing their selling in that region, there is limited exposure of 4-bit MCUs outside that area. Also available for under $1, 8-bit MCUs tend to offer a greater performance range and better architectural compatibility, while being marketed worldwide. Some new 8-bit chips have been introduced to address lower-cost needs specifically, but Dataquest believes that more products should be marketed into this bottom end of the MCU/MPU food chain, whether they are 4-bit or 8-bit, to assure continued growth of embedded applications.

There were some shifts in vendors in the 4-bit MCU category, as Toshiba Corporation jumped from a No. 4 position in 1994 to a No. 2 position in 1995 (see Table 2-2). Mitsubishi and Hitachi dropped a position. Higher average selling prices (ASPs) kept Hitachi and Matsushita out of the top five vendors ranked by unit volume (see Table 2-3). Sanyo Electric Company and Sharp Electronics Corporation came out of their No. 6 and No. 7 revenue positions to hold No. 5 and No. 2 unit rankings in 1995. The majority of the market for 4-bit MCUs is in Japan, with Asia/Pacific as a distant second. Figure 2-4 shows the top 4-bit microcontroller vendors by revenue.

Table 2-2
Leading 4-Bit Microcontroller Vendors by Revenue (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	1995 Market Share (%)
1	1	NEC	422	506	20	30.2
2	4	Toshiba	129	208	61	12.4
3	2	Mitsubishi	192	157	-18	9.4
4	3	Hitachi	139	126	-9	7.5
5	5	Matsushita	105	111	6	6.6

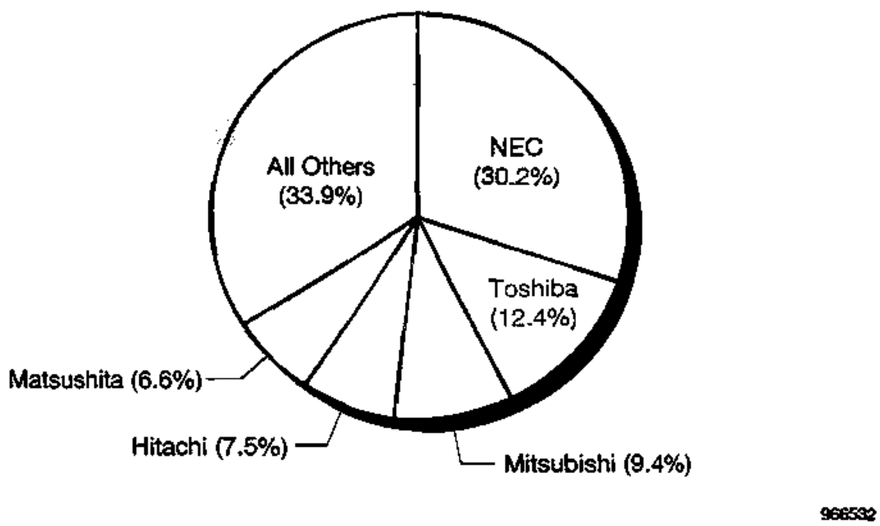
Source: Dataquest (September 1996)

Table 2-3
Leading 4-Bit Microcontroller Vendors by Units (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Change (%)	1995 Market Share (%)
1	1	NEC	308,000	331,000	7.5	31.4
2	2	Sharp	128,000	127,300	-0.5	12.1
3	3	Toshiba	114,700	109,100	-4.9	10.3
4	4	Mitsubishi	79,860	95,500	19.6	9.0
5	5	Sanyo	70,240	88,220	25.6	8.4

Source: Dataquest (September 1996)

Figure 2-4
Leading 4-Bit Microcontroller Vendors' 1995 Market Share by Revenue



Source: Dataquest (September 1996)

Mainstream 8-Bit Microcontrollers

The plethora of 8-bit microcontrollers available from 30 or more vendors makes up 62.6 percent of the revenue and 56.8 percent of the units of all microcontrollers sold. Although 16-bit and up MCUs will erode those percentages, traditional 4-bit applications will move to 8-bit, and 8-bit MCUs will continue to be the dominant category of MCUs. The variety and combinations of peripherals and memory configurations of 8-bit MCUs continue to increase, addressing more narrowly defined markets and specific customers.

Motorola continues to dominate the 8-bit MCUs, so much so that it also dominates the total microcontroller category. Its manufacturing capabilities and broad product range work well with its pervasive 6805 core architecture to make it a tough competitor (see Table 2-4 and Figure 2-5.) NEC maintained its No. 2 rating. In 1995, Europe's Philips Electronics NV showed a gain of over 50 percent in 8-bit revenue, far outpacing the average. Philips, with a jump in its 8051 products, took the No. 3 position, passing Hitachi and Mitsubishi.

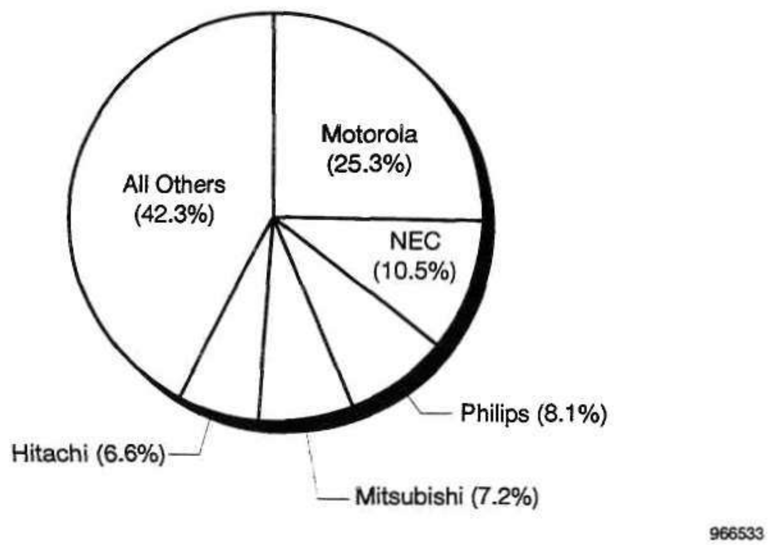
In the rankings of 8-bit units shipped (see Table 2-5) Motorola commands a huge lead. A much lower ASP lets Mitsubishi take second place from NEC. There are many vendors that hover around the 100 million units per year mark, and there are a dozen more that range between 20 million and 50 million units. Microchip Technology Inc. appeared in the top five by volume this past year with continued revenue gains and an extremely low ASP (under $2).

Table 2-4
Leading 8-Bit Microcontroller Vendors by Revenue (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	1995 Market Share (%)
1	1	Motorola	1,369	1,620	18	25.3
2	2	NEC	554	675	22	10.5
3	5	Philips	340	519	53	8.1
4	3	Mitsubishi	371	464	25	7.2
5	4	Hitachi	352	421	20	6.6

Source: Dataquest (September 1996)

Figure 2-5
Leading 8-Bit Microcontroller Vendors' 1995 Market Share by Revenue



Source: Dataquest (September 1996)

Table 2-5
Leading 8-Bit Microcontroller Vendors by Units (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Change (%)	1995 Market Share (%)
1	1	Motorola	420,286	481,595	14.6	28.5
2	2	Mitsubishi	91,552	130,452	42.5	7.7
3	3	NEC	89,800	107,500	19.7	6.4
4	4	Philips	83,000	103,051	24.2	6.1
5	6	Microchip Technology	68,023	101,900	49.8	6.0

Source: Dataquest (September 1996)

16-Bit and Larger Microcontrollers Continue to Grow

The high-end category of microcontrollers continues to grow by greater margin than the MCU category overall. A nearly 50 percent unit growth over 1994 was surpassed by a 100 percent revenue growth in 16-bit and up MCUs. The higher prices and higher margins of these high-end products entice vendors to both develop products in this category and promote them heavily for existing accounts and new markets. The emergence of some 32-bit MCUs, such as the Hitachi SH-1, also contributes to the gains in the category. Most vendors are satisfied to offer a 16-bit product that is *nearly* compatible with their 8-bit MCUs, touting the virtues of their architecture and similarities in the development tools. However, when the 16-bit parts are not object code-compatible with their 8-bit cousins, it leaves an opportunity for other vendors and architectures to serve the 16-bit and up market. Some 32-bit MPU and RISC vendors are eyeing the 16-bit and 32-bit MCU market as expansion areas and can tout their upward growth path. The 16-bit products inspired by 8-bit MCUs need a strong case for architectural compatibility to ward off those coming from above.

Hitachi has taken the prime position among the 16-bit and up MCU vendors on the success of its SH-1 in video games and digital cameras. Intel, NEC, and Mitsubishi held on with their respective 16-bit MCUs in disk drives (magnetic and optical), although this area has drawn the attention of many forms of microcomponents: MCUs, MPUs, digital signal processors (DSPs), and combinations. VCRs and cellular and similar phones have also increased the use of 16-bit MCUs. In 16-bit MCUs, Mitsubishi has grown the most in the last year, but the vendors in this category are expected to multiply, grow, and change in position regularly as the market develops further (see Tables 2-6 and 2-7 and Figure 2-6). Fujitsu Ltd. hit it big in unit volume for 16-bit MCUs, shipping a large quantity to the disk drive industry, as well.

Table 2-6
Leading 16-Bit Microcontroller Vendors by Revenue (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	1995 Market Share (%)
1	3	Hitachi	86	491	471	22.7
2	1	Intel	350	391	12	18.1
3	2	NEC	299	372	25	17.2
4	4	Mitsubishi	74	297	301	13.7
5	5	Motorola	55	218	296	10.1

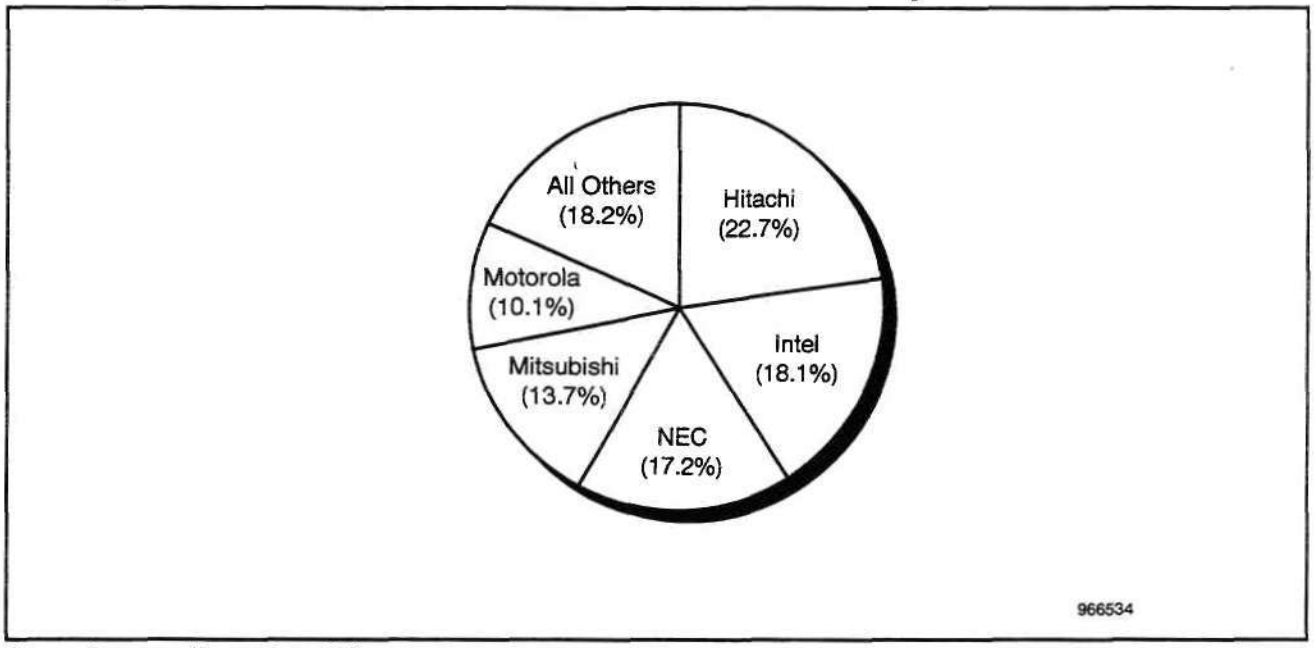
Source: Dataquest (September 1996)

Table 2-7
Leading 16-Bit Microcontroller Vendors by Units (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Change (%)	1995 Market Share (%)
1	2	Hitachi	36,600	52,513	43.5	22.8
2	4	Mitsubishi	25,200	48,450	92.3	21.1
3	1	Intel	41,000	46,500	13.4	20.2
4	3	NEC	30,880	36,800	19.2	16.0
5	7	Fujitsu	2,700	14,770	447.0	6.4

Source: Dataquest (September 1996)

Figure 2-6
Leading 16-Bit Microcontroller Vendors' 1995 Market Share by Revenue

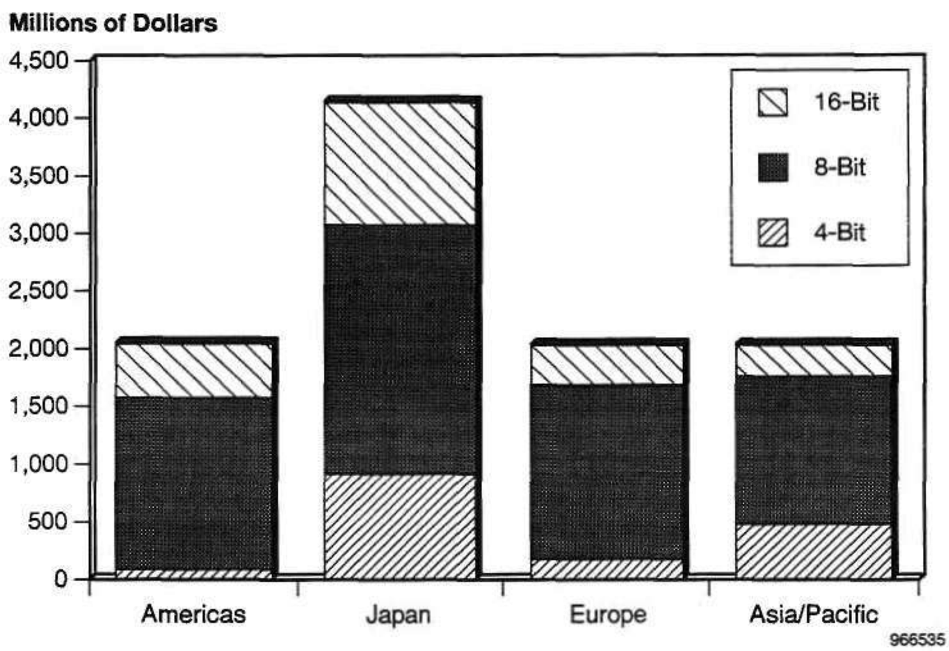


Source: Dataquest (September 1996)

Regions

The distribution of microcontroller sales over the four regions of the world show that 4-bit MCUs are primarily consumed in Japan, with Asia/Pacific being the only other region with a sizable market, as shown in Figure 2-7. However, little 4-bit product is used in Europe, and even less in the Americas; 8-bit MCUs make up the bulk of MCUs sold in every region. The greatest 16-bit and up MCU consumption occurs in Japan, with reasonable quantities shipped into the other three regions as well. The building of optical and magnetic disk/disc drives in Japan contributes to this weighting. Caution must be exercised in looking at regional distribution of microcomponents. Much of the decision-making and design activity for micro-based applications may take place in a country quite different from where the eventual product is built. Therefore, design-in resources and field applications engineers may need to be located in different regions than the countries printed on the parts shipper (as shown also in Figure 2-3).

Figure 2-7
1995 Regional Revenue of Microcontrollers by Word Width



Source: Dataquest (September 1996)

Chapter 3
Microcontrollers—The Outlook

Let's Get through 1996

For most vendors, 1996 is going to close out as a slow year. Many will see revenue lower than in 1995. Others will be over 1995. Some saw a slump early in 1996, while others have only begun to see the slowdown. Some feel that the corner has been turned, while others expect the slowdown to continue into the first quarter of 1997 before sales return to normal levels, and still others have returned to a fairly healthy business. Some will see regional variation, but others will attribute it more to certain applications. Distributors and the smaller customers they serve went very soft and have stayed there. On the other hand, some have seen their largest customers provide some reasonable stability while the smaller customers frittered away.

Automobile production has remained stable, and with increasing use of MCUs in cars, that segment has been strong for MCUs. Long design-in cycles, harsh environmental conditions, high reliability requirements (imagine an automobile grinding to a halt as frequently as the PC crashes), and some very well-entrenched vendors make it a challenge for new architectures to make inroads into the transportation segment. In the data processing segment, business is moderate in the more stable areas like keyboards, mice, and monitors, but at the cutting edge of the latest disk drive, slower MCUs have had difficulty keeping up with last year's revenue as OEMs do not want to overbuild last month's technology. The communications segment is still good. Even though the cellular and pager marketplace has become slightly saturated and highly competitive, sales are still brisk and growing.

The consumer applications are varied. Some sales in Europe and the Americas are slow for traditional consumer electronics. But the video game segment has been strong, with many new high-end games being introduced and promoted in 1996, so MCUs and MPUs in those are doing quite well. Smart cards are blossoming, especially in Europe, and should almost double in 1996. Companies like Motorola and SGS-Thomson Microelectronics, which have invested many years in this industry, should do a booming business there. (For more details, see the Dataquest document *The Exploding Market for Chip Card Semiconductors*, SAMM-WW-FR-9602, July 29, 1996.) DVD is having trouble getting started as anticipated in 1996 as all the aspects of this promising technology struggle to come together.

In these times of lower revenue, the vendors with the closest relationships with their customers will weather the storms the best. Keeping on top of the ebbs and flows of each customer's needs will allow vendors to keep their production at the right pace. Because the ups and downs in MCUs appears to be quite varied over regions, applications, and vendors, it is very likely that microcontrollers will avoid some of the start-up difficulties that plague semiconductor vendors when the market turns back on. But some caution should be exercised in this regard, or lead times could shoot back out to 26 weeks and a supply shortage could result.

Also, during 1996, additional price erosion is expected as vendors attempt to encourage sales and to elbow their way into competitors' designs. Some of these price declines may not take effect or affect shipments until 1997 but will set the pace for the next year or so. The products with the highest prices are those with the greatest opportunity for shaving margins, so flash and other nonvolatile memory-based MCUs are the most likely to drop in price. More competition in the 16-bit and up market will slim down those prices. A market going through turmoil is a ripe opportunity for repositioning and changes in the players and ranking.

The Out Years

The MCU category with the most uncertainty in the coming years is the 16-bit and up microcontrollers, because this category is still developing. Make no mistake, it is a growing marketplace. The question is how fast and in what way. The products offered (supply) influence the growth of the market as much as the applications that need (demand) the products.

More vendors are coming out with higher-performance (read: greater word width) MCUs. Some of these are 16-bit extensions of the 8-bit MCUs like the 68HC16 or the 8051XA and 251. Others are 32-bit MCUs, which often are squeezed versions of RISC processors or ASIC-like variants of microprocessors that grew some program ROM. Mitsubishi has started putting significant DRAM on a 32-bit processor (or maybe it's adding the 32-bit processor onto a sizable DRAM). Does this last product get classified as an MCU or an MPU? It is not a standalone device, so it sounds more like a microprocessor that is ultimately dependent on an external memory system.

Certainly, the price of each 16- or 32-bit MCU will decline over time, but with so many new 16-bit and even more expensive 32-bit MCUs being added to the category, the ASP could climb radically. Flash and one-time programmable ROM is not as attractive in price on the larger memory devices, so this, too, could skew ASP. Certainly, as more horsepower is available in 32-bit MCUs, some high-volume applications could appear that provide a step-function increase in the volume of this upper category. The result is that the ASP and the cumulative volume of each part is bound to cause the revenue to fluctuate in a way that is difficult to predict. Therefore, future forecasts of this market may change quite a bit from today's forecast.

After the softness that microcontrollers will see in 1996 and the beginning of 1997, the MCU market is expected to return to nearly the previously forecast growth rate. However, some of the heady optimism has been tempered. Unfortunately, a down year in year one will severely curtail the final number in year five (as any investor or retirement planner will quickly tell you). The time of low demand also hurts the ASP, which further lowers total revenue. This now delays the $20 billion microcontroller year until the year 2000. However, this will mean that microcontrollers will leave the 20th century at $20 billion—what a nice, convenient pair of numbers. (This assumes the 20th century ends on December 31, 2000, rather than December 31, 1999—a topic of some debate!)

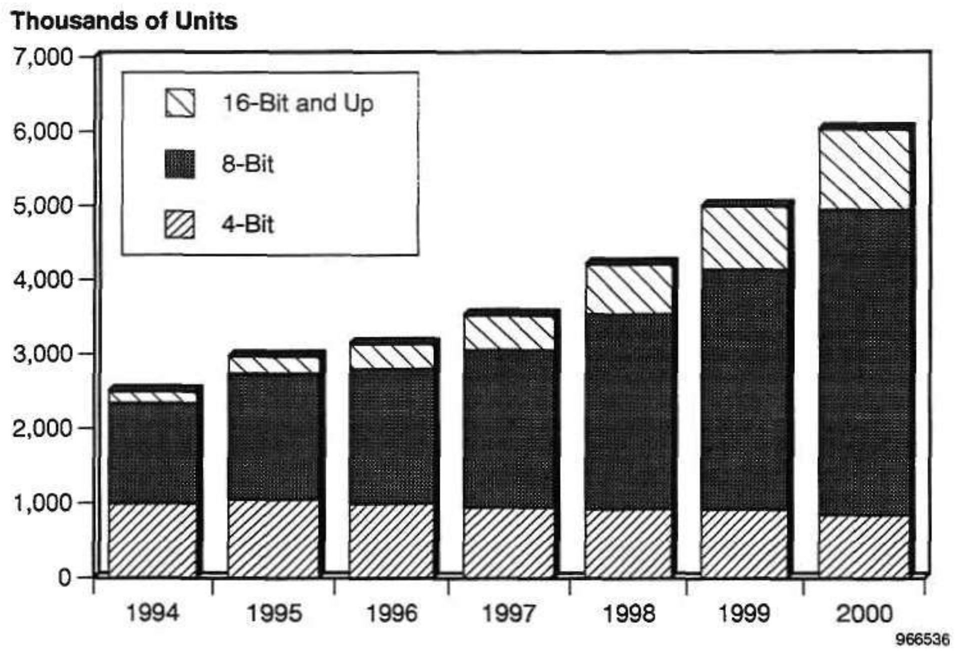
The data presented in Table 3-1 and Figure 3-1 for unit volume and in Table 3-2 and Figure 3-2 for revenue represents Dataquest's current forecast of the worldwide 4-bit, 8-bit, and 16-bit and greater microcontroller market.

Table 3-1
Microcontroller Unit Forecast by Word Width through the Year 2000 (Thousands of Units)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
All Microcontrollers								
Units	2,503,974	2,972,955	3,150,000	3,530,000	4,210,000	5,000,000	6,030,000	15.2
Growth (%)		18.7	6.0	12.1	19.3	18.8	20.6	
4-bit MCUs								
Units	999,437	1,055,674	1,000,000	953,000	931,000	927,000	853,000	-4.2
Growth (%)		5.6	-5.3	-4.7	-2.3	-0.4	-8.0	
Percentage of Total		35.5	31.7	27.0	22.1	18.5	14.1	
8-bit MCUs								
Units	1,350,048	1,687,359	1,810,000	2,110,000	2,620,000	3,220,000	4,100,000	19.4
Growth (%)		25.0	7.3	16.6	24.2	22.9	27.3	
Percentage of Total		56.8	57.5	59.8	62.2	64.4	68.0	
16-Bit and Up MCUs								
Units	154,489	229,922	335,000	470,000	664,000	857,000	1,080,000	36.4
Growth (%)		48.8	45.7	40.3	41.3	29.1	26.0	
Percentage of Total		7.7	10.6	13.3	15.8	17.1	17.9	

Source: Dataquest (September 1996)

Figure 3-1
Microcontroller Unit Forecast by Word Width through the Year 2000



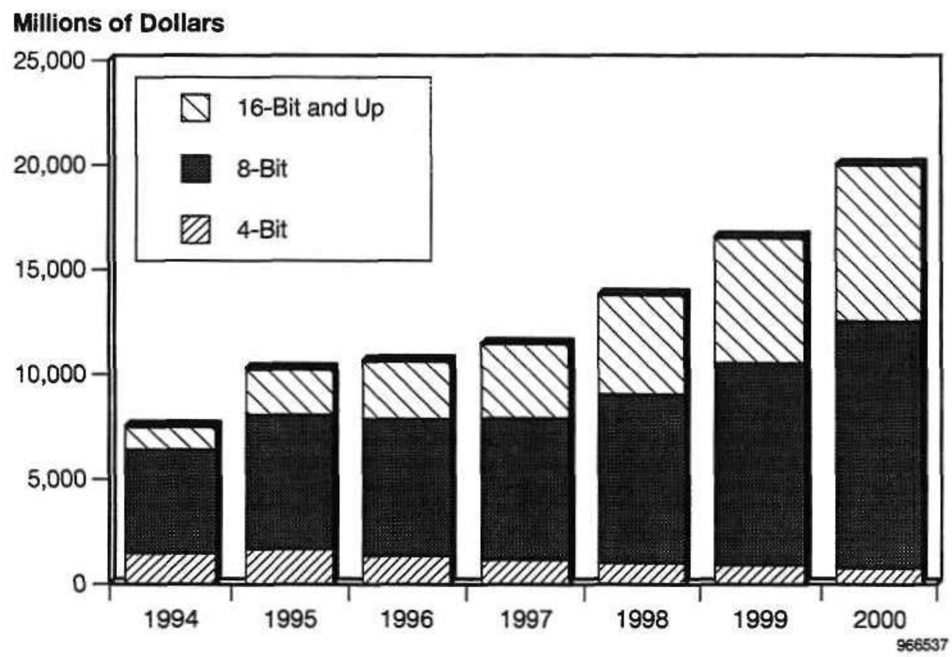
Source: Dataquest (September 1996)

Table 3-2
Microcontroller Revenue Forecast by Word Width through the Year 2000 (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
All MCUs								
Revenue	7,517	10,255	10,600	11,500	13,800	16,500	20,000	14.3
Growth (%)		36.4	3.4	8.5	20.0	19.6	21.2	
4-Bit MCUs								
Revenue	1,472	1,679	1,360	1,160	1,020	924	765	-14.5
Growth (%)		14.1	-19.0	-14.7	-12.1	-9.4	-17.2	
Percentage of Total		16.4	12.8	10.1	7.4	5.6	3.8	
8-Bit MCUs								
Revenue	4,965	6,415	6,540	6,770	8,050	9,630	11,800	13.0
Growth (%)		29.2	1.9	3.5	18.9	19.6	22.5	
Percentage of Total		62.6	61.7	58.9	58.3	58.4	59.0	
16-Bit and Up MCUs								
Revenue	1,080	2,161	2,740	3,530	4,740	5,960	7,450	28.1
Growth (%)		100.1	26.8	28.8	34.3	25.7	25.0	
Percentage of Total		21.1	25.8	30.7	34.3	36.1	37.3	

Source: Dataquest (September 1996)

Figure 3-2
Microcontroller Revenue Forecast by Word Width through the Year 2000



Source: Dataquest (September 1996)

Microcontroller Applications

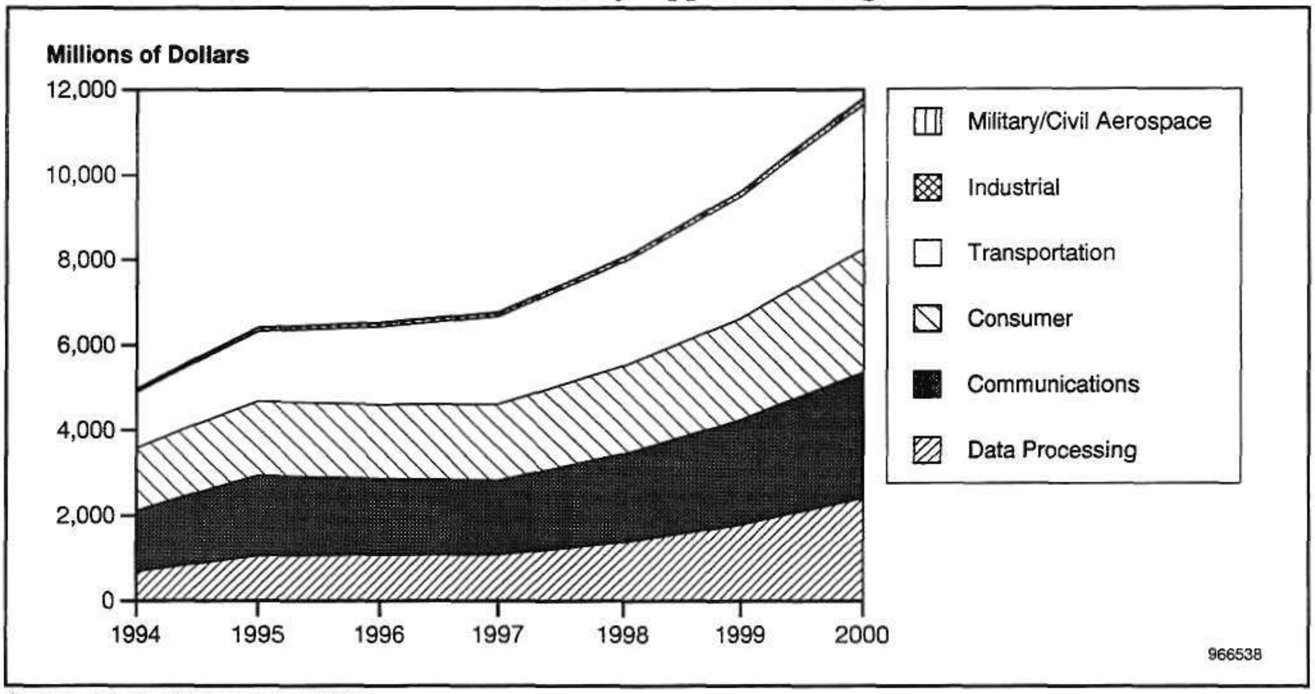
As mentioned above, the applications for microcontrollers range from TV remote controls to automotive engine control, from precision disk drive spindles to air conditioning systems, from maintenance troubleshooting ports to cellular telephone supervision and control. The forecast of the distribution of 8-bit MCU sales across the industry's application segments is presented in Table 3-3 and Figure 3-3, with information on the 16-bit segment given in Table 3-4 and Figure 3-4.

Table 3-3
8-Bit Microcontroller Revenue Forecast by Application Segment (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Data Processing	683	1,055	1,080	1,080	1,380	1,790	2,410	18.0
Communications	1,426	1,886	1,790	1,750	2,070	2,450	2,940	9.3
Consumer	1,477	1,737	1,740	1,790	2,060	2,390	2,900	10.8
Transportation	1,303	1,645	1,830	2,060	2,440	2,870	3,390	15.6
Industrial	66	81	81	83	97	115	142	11.8
Military/Civil Aerospace	9	11	11	11	12	14	17	8.4
Total	4,965	6,415	6,540	6,770	8,050	9,630	11,800	13.0

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (September 1996)

Figure 3-3
8-Bit Microcontroller Revenue Forecast by Application Segment



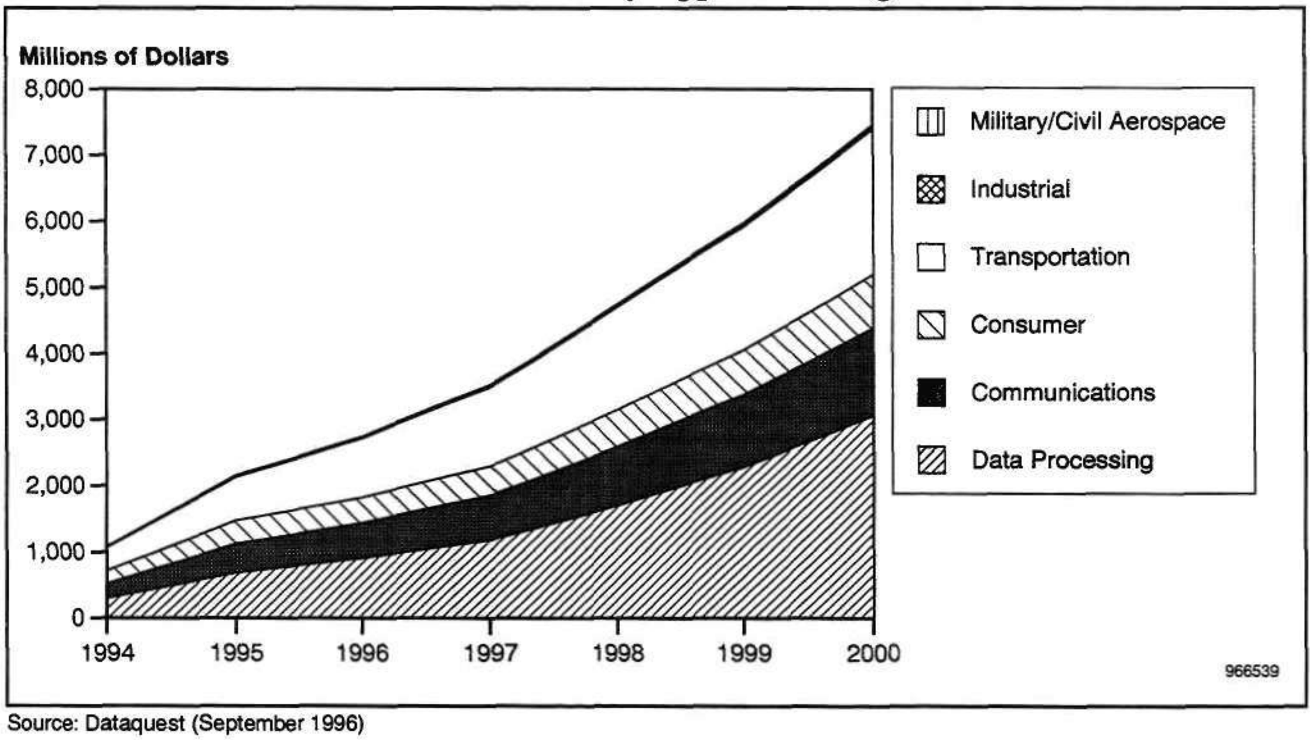
Source: Dataquest (September 1996)

Table 3-4
16-Bit Microcontroller Revenue Forecast by Application Segment (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Data Processing	299	686	905	1,180	1,700	2,280	3,060	34.8
Communications	221	442	530	671	892	1,100	1,330	24.6
Consumer	195	349	385	442	564	673	809	18.3
Transportation	348	653	889	1,200	1,550	1,860	2,190	27.4
Industrial	13	24	25	28	36	44	54	17.6
Military/Civil Aerospace	3	6	6	7	9	10	12	14.0
Total	1,080	2,161	2,740	3,530	4,740	5,960	7,450	28.1

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (September 1996)

Figure 3-4
16-Bit Microcontroller Revenue Forecast by Application Segment



Source: Dataquest (September 1996)

Appendix A
Definitions

Definitions

Below are some definitions that will be helpful in understanding this document better. Note that the definition of word width changed somewhat in 1996.

Microcontroller (MCU): An MCU is a MOS digital integrated circuit (IC) designed for standalone operation that includes a programmable processing unit, program memory, read/write data memory, and some input/output capability. The processing unit contains an instruction decoder, arithmetic logic unit (ALU), registers, and additional logic. The MCU's functions are determined by fetching and executing instructions and manipulating data held in on-chip program and data memory (not including cache memories). MCU devices must be available with on-chip program or data store. As an option, some MCU devices can be purchased without on-chip memory for use during the debug and development phase of the system. Peripherals may be included on-chip to assist in sophisticated input, output, and control functions. The MCU category includes MCUs incorporating, or originating from, an ASIC design. Standalone digital signal processors are not included with MCUs. MCUs are divided into 4-bit, 8-bit, or 16-bit and greater word width. All MCUs are designed into embedded applications. A similar term is microcomputer.

Word width: The width, in bits, of the on-chip integer unit. This measurement is independent of the data bus width or any other bus associated with the device. Wider and narrower data types might be operated on by the processor, with multiple passes through the ALU or special hardware. Most microcontrollers are 4 bits, 8 bits, or 16 bits wide. A similar term is bit size.

Embedded applications: All microcontrollers are considered to be in embedded applications. Embedded applications of microcomponents are designed to perform a fixed set of functions once the system is shipped from the manufacturer. Those functions typically define the end product. The system may be reconfigurable by the end user but cannot be reprogrammed by a high-level language such as BASIC or FORTRAN. Usually the end user would not even know what type of processor was in the equipment.

The processor will typically run a real-time operating system (though real time is not a requirement, nor is any operating system) and a set of instructions that perform functions critical to the operation of the end product. Programs run by the processor may perform system monitoring, system control, data processing, peripheral interfacing, data movement, or motion control, among other functions. Programs usually exist in ROM, although they may load from secondary storage, such as disks. Each microcontroller in the system typically has a fairly narrow range of responsibilities.

Examples of embedded applications are many and varied but include feature phones, cellular phones, cellular infrastructure, telephone switches, bridges, routers, networking cards, modems, video games, arcade games, cameras, camcorders, VCRs, satellite receivers, remote controls, audio equipment (personal, home, and professional), keyboards, disk drives, CD drives, laser printers, other computer peripherals, medical instruments, motor control, industrial process control, robotics, engine control, airbags, antilock braking systems, and global positioning systems.

Unit shipments: This is the volume or number of finished units shipped by manufacturers to users, equipment manufacturers, or distributors. The units must include operating silicon and are generally assembled into packages, tested, and shipped in protective packaging. A manufacturer's own inventory is not included. A similar term is units or volume.

Revenue: This is the total revenue value of the finished units shipped by manufacturers to users or distributors. In Dataquest's worldwide services, revenue is reported in equivalent U.S. dollars unless otherwise noted.

Compound annual growth rate (CAGR): This is a measure of the growth of an industry over time. A positive number indicates a growing market. It is associated with revenue unless noted as units or ASP. A five-year span is usually reported (N = 6). CAGR is defined as follows and usually expressed as a percentage:

$$CAGR = \sqrt[N-1]{\frac{Value_{t=N}}{Value_{t=1}}} - 1$$

Exchange rates: Average annual exchange rates are used for revenue history as outlined in Table A-1; the 1996 "average" exchange rate is extended into the 1996-2000 forecast horizon. Dataquest does not forecast exchange rates.

Table A-1
Exchange Rates (U.S. Dollars)

Country	1994 Rate	1995 Rate	1996 Rate	U.S. Dollar Appreciation (%) 1996
European Union (ECU)	0.84	0.77	0.80	2.90
France (Franc)	5.54	4.97	5.08	2.24
Germany (Mark)	1.62	1.43	1.49	4.18
Great Britain (Pound)	0.65	0.63	0.65	2.67
Japan (Yen)	101.81	93.90	107.38	14.35

Source: Dataquest (September 1996)

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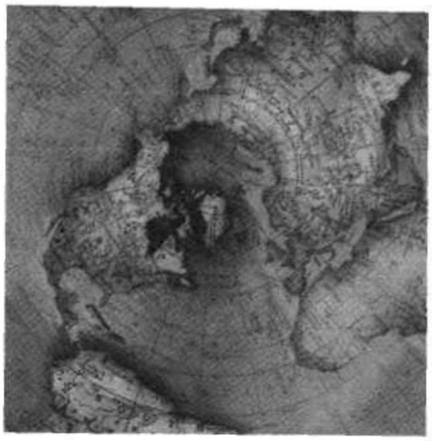

Dataquest

Microprocessor Forecast and Embedded Microprocessor Trends through the Year 2000

Market Trends

Program: Embedded Microcomponents Worldwide
Product Code: MCRO-WW-MT-9602
Publication Date: September 23, 1996
Filing: Market Trends

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Chapter 1
Overview

Microprocessors are one of four primary categories of microcomponent semiconductors. This report presents Dataquest's forecast for the microprocessor market over the next five years, with special attention on those microprocessors going into embedded application markets. This forecast is backed by extensive research and in-depth analysis of product characteristics, market dynamics, and end equipment. Various breakdowns of the market are given for classifications of 8-bit, 16-bit, 32-bit complex-instruction-set computers (CISC) and 32-bit reduced-instruction-set computers (RISC) microprocessors. Tables and graphs of revenue, unit shipments, and average selling prices (ASPs) are given for embedded as well as for the total microprocessor market. Particular microprocessor architectures are spotlighted where they are sufficiently significant, although not all architectures are itemized. Trends in the marketplace are analyzed, along with the conditions that will influence their outcome.

Highlights of the Forecast

In 1995, the microprocessor market grew 34 percent in dollars over 1994. Computational microprocessors made up 30 percent of the units and a whopping 89 percent of the revenue of all microprocessors, with the Pentium making up the lion's share. Microprocessors in embedded applications grew 41 percent in revenue in 1995.

But 1996 is going to be a tougher year for the industry. Computing microprocessors will grow 19 percent to 20 percent, while embedded microprocessors are expected to be fairly flat. The optimism that overcame the industry in the last few years caught up to it at the beginning of this year, and it will take the duration of the year for it to even out. Although the downturn is expected to reasonably short-lived, it will cause some turmoil at most vendors and will refresh the memory of its leaders about how volatile this market can be.

With a somewhat tempered optimism, the forecast is still looking very promising for embedded microprocessors, with an overall 12 percent to 15 percent growth rate for the latter four years of the forecast period, growing to over $3 billion. Some markets and products will experience growth of 20 percent and higher—much higher in emerging markets. The digital revolution in performance-demanding consumer-oriented applications such as set-top boxes, which is coming sooner than expected, could pull the overall numbers up.

Prices of embedded microprocessors are expected to increase with the trend to more highly integrated processors. Each piece of the system pulled onto the processor allows a little more money to be charged for the chip. Overall ASPs for embedded microprocessors, however, will stay in the range of $10 to $25, and price pressure will keep manufacturers on their toes.

The attraction to computing microprocessors is the overwhelming amount of money spent on PC CPUs. Unfortunately, that money has eluded almost everyone who has reached for it, other than Intel and Motorola and, now, IBM. The opportunity for failure while chasing Intel in this market is great.

From a vendor point of view, the interest in embedded microprocessors is in the opportunity for success. Although the market is smaller, it is not locked up with one primary architecture. There is a vast array of applications with healthy volumes and more high-powered applications coming. These applications may have favored architectures, but the ability to overtake the incumbent processor is not insurmountable, as it is in the PC world.

Chapter 2
The Grim Reminder—1996

Looking at 1996 from late summer, Dataquest is forecasting a year of near-zero growth in embedded processors. Overall embedded microprocessor unit shipments will be flat, as will the total revenue for embedded. This is based on the expectation that orders come back up soon enough and high enough in the second half to offset the units that were not shipped in the first half of the year.

Riding the Clutch in 1996

The year 1995 felt so good! Business was booming in semiconductors and microcomponents, with growth like never before. Even those that had been in the industry for decades had reassessed the situation and had almost concluded that the cyclical nature of semiconductors must not be an innate, natural phenomenon. Youngsters had never considered that business might go down. Wall Street was giddy but nervous. Surprise! Now 1996 is here to remind the industry that what goes up can still come down.

Early indications that a change in the business was coming may have caused a bit of indigestion with the Christmas turkey: 1996 started with companies trying to explain why their orders were not pouring in. Markets closely associated with the personal computer took the earliest hits. Excess DRAM on the market, unsold PCs, and the failure of businesses to embrace Windows 95 were the early signals. Disk drives, CD-ROMs, and printer OEMs were not ordering like before. Then some other markets showed softness. Cellular phones and pagers, which had gone very consumer in the months leading up to Christmas, went soft as the somewhat-saturated market flooded with competitors and price and marketing wars. OEMs had each predicted winning too much market share, and found they had some inventory to burn off when that market share did not materialize.

Vendors can take a little of this to get their deliveries in order. But as a couple of months turned into a quarter or two, profits suffered greatly, and quite a bit of belt tightening has taken place. Fab building has slowed down or gone on hold, contract workers have been idled, expenses and travel have been curtailed, workers have had their vacations scheduled for them, people have been laid off, and divisions have been put on the auction block. What seemed like a minor correction appears to have become a definite slowdown. Complete description of the effects is difficult.

Dataquest is still forecasting a 19 percent unit growth in PC systems, although clearly not all PC OEMs are on an even footing. This is down from previous forecasts of over 25 percent. Intel has managed to continue to grow in this environment, in part by staying absolutely ahead of the power curve while would-be competitors struggle to deliver the latest product. and in part because it simply dominates and therefore drives its primary market. Others serving the computing industry have suffered the backlash of not being No. 1.

In embedded applications, the cellular and other telecommunications infrastructure, video games, satellite receivers, and engine control remain strong. Consumer products are sluggish. Some automotive companies (Japan) are cutting prices to stimulate buying. The fundamental markets driving embedded applications actually remain strong. Few companies, aside from some in PCs, have a grim business outlook. The electronic equipment demand in the United States and worldwide remains fairly strong. There are no significant slowdowns in the U.S. or global economies. The development of formerly underdeveloped nations has not had significant setbacks (in spite of political actions). Nonetheless, orders for microprocessors, aside from the Pentium in PCs, generally languished in the first few months of 1996.

Dataquest believes that inventory of embedded microprocessors has mostly been corrected at the OEM, and orders should soon return to the levels of 1995. If these levels increase sufficiently and quickly enough, they will offset the decline of the first half of the year, which should provide a year of essentially zero growth, but with an unpleasant decline and increase within the 12-month period. The no-growth scenario could change to a rise or a fall depending on developments in the second half of the year. Unexpected delay of the rebound could cause the year to close out below 1995 levels and an unusually fast uptake of orders could make the year's shipments a few percent higher than 1995, if vendors can respond quickly enough to ship. August and September will be critical months in this determination.

Proceed with Caution

It can easily take 13 weeks for a vendor to make an IC, from silicon to chip. With enough capacity, raw materials, and labor, a customer placing an order could initiate manufacturing of an IC that would make it into its dry-pack shipper in 13 weeks. But that would be ideal (rare in the semiconductor business).

A scenario like that experienced in January 1996 swings business to a downside. OEMs discover that they have too much product in inventory (both end equipment and ICs). Maybe they placed orders that were greater than their needs, hoping to improve their access to a limited supply of chips. As excess inventory at the OEM burns off, existing orders for more chips are pushed out for later delivery. Vendors and distributors acquire some inventory. As certain major products (like DRAM) free up fab and tester space, other product types are shuffled to fill the new vacancies. But those products no longer needed the capacity, either. As vendor inventory builds up and availability improves, lead times are shortened. As lead times shorten, just-in-time delivery and economics cause OEMs to delay placing additional orders until the lead time matches their projected needs. Vendors get nervous, slowing and controlling needless product buildup. A tricky balancing act ensues. This is mid-1996.

But the demand for the end equipment is still there, and at some point orders start to be placed at levels commensurate with that demand. This often happens all at once. Because the vendor has slowed production and eased inventory, including raw materials, labor, and capacity, a sudden return to normal buying levels can wreak havoc. Lead times can suddenly lengthen to 20 weeks, which in turn wreaks havoc on the OEM, which now finds a chip shortfall. This is the exciting world of semiconductors, which can be very digital—full on or full off.

The only cost-effective means of minimizing the jerky start-stop action is to monitor customer demand and inventory very closely, and, secondarily, to monitor the customer's product success. This is a complex task that is possible only with very close, trusting customer-vendor relationships. A watchful eye on the inflection points should limit a company's exposure.

Chapter 3
The Long-Term Outlook

Although the personal computer dominates the overall microprocessor market, it is difficult for MPU vendors other than Intel, AMD, Motorola, and IBM to participate in this market. The embedded processing market—those applications other than PCs, workstations, and servers—has opportunity for a number of other vendors and processors besides derivatives of the 8086. The different applications in telecommunications, video games, printers, automotive, and industrial control have both common basic needs as well as unique specific requirements. The vendor that offers an architecture that provides the basic needs as well as superior support for an application's unique requirements can tie down a corner of the market.

There are major players in the embedded market, with Motorola and its 68000-family architecture the long-time clear leader. But as with any market, the leader and all other vendors must continue to innovate, expand, and increase performance to stay ahead in an ever-changing market environment.

General Applications

Applications for embedded microprocessors can be separated into three categories. Traditional applications may have a favorite processor within an application or even a company. The 68000 is the biggest player, historically found in a wide variety of applications, but other processors can dominate individual applications. These "legacy" processors enjoy a bit of comfort because it can take significant effort for the OEM to move to a different architecture. However, complacency is dangerous in any fast-moving marketplace.

There is a group of high-volume applications that are fickle in their use of a processor. In spite of a significant base of existing program code, usually written for a specific architecture, these applications have been seen to switch to a completely different architecture, almost with each generation of the equipment. Laser printers and video games are key examples in the fickle group. The 68000 was king in laser printers, then was shoved aside for a while by the AMD 29000, which was later beaten out by Intel's 960, until the son-of-the-68000 ColdFire reclaimed the throne. Of course, by then there had been many battles, many self-declared victors and many fiefdoms. And this war is unlikely to be over. Video games are another application in this fickle group, where each OEM has a different processor for almost every generation of game.

The emerging markets seem to be most ripe for big wins for new architectures. For personal digital assistants (PDAs), digital cameras, or set-top boxes, selection of the processor architecture might be influenced by a similar, former application. But generally it is open to the processor vendor that has an appropriate architecture, demonstrates the best understanding of the application's fundamentals, buddies up with the founding OEMs, writes (and rewrites) code for the developing standards, and musters up the greatest third-party support. However, this is not for the faint of heart. The infant mortality rate of OEMs and their products in the emerging markets is very high, and great perseverance is necessary to see the process through to success. By the end of this process, the vendor will have a new appreciation of the term "investment." It is rare for a vendor to get really lucky and make a single foray into a new market that happens to be the one design that finally sets the pace and takes off. Where their performance is adequate, CISC processors have as good a chance of winning in the emerging markets as the newer architectures.

8-Bit Microprocessors

The 8-bit microprocessors are a fairly small part of the market. Little significant effort is put into developing the products in this category—mostly designs of 20 years ago that are in a maintenance mode. Its limited address range and small data width makes 8-bit architectures better suited to microcontroller products that combine the processor with peripherals and the necessary program and data memory on the same chip. Indeed, 8-bit chips are now, and are expected to continue to be, the dominant product in the microcontroller market.

16-Bit Microprocessors

The 16-bit microprocessors had also taken a back seat in the high-profile PC and workstation wars of the last 10 years, with 32-bit and RISC being the battle cry in the computing applications. However, in embedded applications, 16 bits of data is quite adequate for a variety of applications. The original 68000 built a tremendous following in the embedded market with its nice architecture, fast and secure interrupt handling, software support, small size, low cost, and growth path. Many applications had no need for the 32-bit data paths and higher performance of parts like the 68020, and so they stuck with the 16-bit 68000 and its very attractive price. Also, Motorola developed some integrated family products, splicing some attractive combinations of peripherals and even secondary processors alongside the 68000 processor. Some of these, such as the 68302, found a big following in their targeted markets.

Intel's integrated 186 found homes in additional applications where moderate performance was sufficient and the peripherals included made for a compact design. Although Intel, NEC, and others seemed to de-emphasize the 186 approach, AMD put some effort into further development of the part and its process, pushing the speed and varieties available. With some re-emphasis under way, there are signs that even more 186-family products will soon serve the 16-bit (and 32-bit) market.

Although the 16-bit microprocessor market may have not had a very glamorous or visible past few years, it has been a very active embedded market and is expected to have good growth in the near future. ARM, MIPS, and some of the other RISC architectures are expected to venture down into the 16-bit product path as customers pull them down into lower-cost, higher-volume applications.

32-Bit CISC

Let's be honest. CISC boils down to 8086 derivatives and 68000 derivatives. Any other CISCs have essentially faded into history. The term RISC took on such an aura that even these two architectures have attempted to shed their association with the term CISC. The really funny thing is that most RISC processors have taken on the positive characteristics of CISC, while later versions of the x86 and 68K architectures use RISC implementations, to the extent that there is little difference between the two categories.

Compute

The standout application, IC category, product, and vendor for semiconductors is Intel's 32-bit CISC microprocessor, the Pentium, used in the PC.

This product alone accounted for 33 million units sold and nearly $10 billion in revenue to exactly one company in 1995. That's one in seven microprocessors bringing in two-thirds of the revenue of all microprocessors (and 6.6 percent of all semiconductor revenue)! Any questions?

The high rollers in the microprocessor business have been in the computational arena of CISC. The 486, Pentium, and now the Pentium Pro and their equivalents from other vendors have had a high-stakes business of performance, performance, and first-to-market. Intel has won this game and shows no signs of weakening, although secondary players have still been able to keep Intel from attaining total dominance.

Embedded

The majority of 32-bit microprocessors being used in embedded applications are CISC MPUs. One key reason for this is availability. CISC processors have addressed the needs of the embedded market for longer than the newer RISCs. The RISC vendors have traditionally chased the much-higher ASPs of the workstation industry, where the greatest horsepower is the dominating factor. Another reason for CISC's popularity in embedded applications is its greater code density. Many embedded applications cannot afford great quantities of RAM or inclusion of a disk drive. If a RISC requires 50 percent more memory and much higher clock speeds to run the same algorithms, this can limit its appeal in most embedded applications.

68000

The 68000 architecture has now all but faded into memory in the computing applications since the Macintosh moved over to the PowerPC wholeheartedly in 1995. But in embedded applications, the 68000 architecture rules over all other MPUs, RISC or CISC, 8-, 16-, or 32-bit. Oddly enough, Motorola is essentially the only vendor that has developed this product line in the last 10 years, but it has done it so relentlessly that it has made it difficult for others to get a huge part of the embedded MPU market.

Workstations and Macintoshes (and Amigas) were pushing the performance of standalone processors up the curve, assuring customers of a full-performance range of products. Meanwhile, embedded applications were encouraging integration of peripheral functions onto the processors. A

32-bit "CPU32" core was later developed to streamline some processor functions for embedded applications. A modular peripheral and internal bus structure was established that made implementation of new combination parts easier while allowing customers more opportunity to reuse peripherals in new designs. Additional core versions of 68000 standalone processors were developed so even more integrated processors could be developed. Proper microcontrollers combining flash memory with the 68000 architecture are also available, although these are very few. The recent ColdFire core is currently the ultimate in streamlined 68000-type core processors for the embedded marketplace, although it is not 100 percent code-compatible with the original 68000. ColdFire promises to continue the legacy of the 68000 for a number of years more.

Years ago, Motorola focused substantial resources on moving its microprocessor products more securely into embedded applications in which they had already enjoyed success. Although there is no continuing development of the very top end of the 68000 product line for rocketing performance (the 68060 was the last primary engine developed), Motorola will continue to sow integrated processors in the middle section of the embedded market with emphasis on low price, variety, integration, and customization. This strategy means that Motorola and support vendors will continue to harvest returns from the 68000 architecture even though it was supplanted by the PowerPC in the Macintosh. Although Motorola has only used it in limited applications so far, the company could use the PowerPC card to trump a few higher-performance embedded markets.

x86

The x86 architecture, led initially by Intel's 186 product but later furthered by Advanced Micro Devices' marketing and product development of 186s, is the second most prominent processor in embedded microprocessors. As one of the first integrated processors available in the architectures of the late 1970s and early 1980s, the 186 won an early following in embedded applications desiring a variety of peripheral functions on a single chip with the processor.

In the embedded space, the x86 architecture has stood in the shadows with some success over the years, primarily in applications that borrow a lot from the PC in their implementation. More recently, there have been indications that the x86 architecture may gain additional non-PC applications because of the benefits of the overwhelming success of the architecture in the PC. In the last year, National, Intel, and AMD have brought out 32-bit 386- and 486-class products targeted to embedded applications and are focusing resources on developing that market. Texas Instruments may be working on a similar project. There is a supply and demand factor that will now have more supply feeding it, which should make it easier for more embedded applications to find the right x86-based microprocessor to do the job. This has the potential to become a come-from-behind medal winner in the race. Dataquest is watching this area carefully for a resurgence of the x86 family.

32-Bit RISC

The RISC microprocessors that were originally laid out to provide very high performance for workstations have been driven to expand into embedded applications. As the workstation business has matured, thinned out, and been encroached on by the promises of the likes of Pentium Pro and Windows NT, RISC vendors have sought new applications for their level of performance. Laser printers were early targets, with their high volumes and page-per-minute selling points. The high performance demands of central office switches and medical imaging have attracted the use of RISC processors. Most recently, the RISC vendors have brought key peripheral and support circuitry onto the chip to provide more of a system solution to embedded applications with integrated processors. This trend is expected to continue. There is no clear winner in the RISC category. Although Hitachi's SH-series leads this year in unit volume and in revenue, it is not certain to maintain that lead in the near term or long term. The Sony PlayStation and the Nintendo 64 have a MIPS architecture RISC in them. As sales of these video games overtake Sega Saturn sales, there is good potential for the MIPS architecture to surpass the SH. But as games go, this could be only a temporary lead for the MIPS camp; 1997 or 1998 could see yet another leader.

29000

AMD's 29000 microprocessors hit a milestone in 1995. AMD announced it was not furthering development of new core processors in the 29000 architecture. There are few processors that have had a life as significant as the 29000 and then faded into the history books. But that appears to be the fate of the 29000, an architecture to which AMD gave birth itself. It had many years of high-volume sales as one of the new RISC chips, quickly focused on embedded markets such as laser printers. However, AMD decided to focus its energy on a single architecture, the x86, which it originally licensed from Intel, rather than dividing its energy between the x86 and the 29000. AMD is still producing 29000 chips and is expected to continue as long as the demand exists. But it is unlikely that significant new designs will select a 29000 processors or that existing designs using a 29000 will continue with that architecture when a new generation of the design is needed. AMD will try to convert those designs to x86, but many other vendors will be knocking on the door as well.

SH Series RISC

Hitachi's SH series microprocessors have taken the lead in unit shipments in the RISC category. Although IBM's and Motorola's PowerPCs took in higher revenue for their architecture, the SH-1, SH-2, and SH-3 families from Hitachi have shipped more units than any other RISC architecture. This is primarily because of a single design-win with Sega, which uses two SH-2 processors in each Saturn video game (which, incidentally, is manufactured in part at Hitachi facilities), plus an SH-1 in the CD drive. The SH-2 is also in some digital cameras, which are growing in sales, as well as a number of other applications. Note that an overzealous press release recently indicated that the MIPS architecture was the unit-shipments leader in RISC, but this is accurate only with the inclusion of the term "computing" in the release, which would exclude games and cameras.

The SH architecture crosses both microcontroller and microprocessor boundaries. Hitachi's SH-1 products are actually microcontrollers with on-chip program ROM, while the SH-2 and SH-3 parts are microprocessors without on-chip program store. Therefore, the portion of Hitachi's SH revenue and units attributable to the SH-1 would qualify as microcontrollers, while revenue and units attributable to the SH-2 and SH-3 go into the RISC microprocessor category. For the complete SH architecture, both the 16-bit and up MCU SH series numbers as well as the 32-bit RISC MPU Hitachi numbers must be considered. Dataquest estimates that the entire SH architecture (SH-1, SH-2, and SH-3) accounted for 11.024 million units shipped and $132 million in revenue in 1995.

Chapter 4
Microprocessor Forecast and Assumptions

Emphasis on Embedded

Dataquest's Microcomponents Worldwide program changed its name to Embedded Microcomponents Worldwide in 1996. The intent of this change was to focus more on the processors, controllers, and digital signal processors that go into embedded systems. Detailed analysis of those x86 processors, RISC processors, and the remaining 68040 processors that operate as the central processor in personal computers, workstations, and servers (all considered "computational" applications) is provided in Dataquest's Semiconductor Directions in PCs and PC Multimedia Worldwide program. In this document, only top-line numbers for the compute part of the x86 family and CISC and RISC products are presented with minimal discussion. Greater detail on the computing microprocessor forecast is available in *Compute Microprocessor Market Trends and Forecast* (PSAM-WW-MT-9602, September 1996).

Care with Definitions

Everyone wants to be good at something. Gerrymandering the lines that define a subsegment of the market into which one sells is one common way of limiting one's competition. Dataquest uses definitions that serve the market best, assuring that products are grouped with the products they compete against in a design opportunity. Dataquest is careful to attribute those products' sales to the appropriate classification according to specific definitions. This may make it difficult for some vendors, since it may cause some profit and loss centers within the company to straddle classifications and appear to water down their strength. But the intent is to place competitive products from many vendors in the same categories. To assure that readers understand the categories that Dataquest uses, category definitions pertinent to embedded microprocessors are given in Appendix A.

Processor Word Width Changes

Beginning in 1996, Dataquest has modified its definition of the word width of a processor. The previous definition related to the ability of the device to perform an ADD instruction. The new definition ties the word width of the processor to its arithmetic and logic unit (ALU). This has the largest impact in the counting of 16-bit and 32-bit microprocessors, especially in the 68000 family. Products like the 68000 and the 68302 now fall into the 16-bit MPU category. Unlike many other manufacturers, Motorola still sells very high volumes of parts based on the original architecture, so the change in the 16-bit definition does have a noticeable effect on the market numbers.

The effect of the change is to move many of Motorola's products based on the original 68000 to the 16-bit category from the 32-bit category. The other noted architecture, the x86, had always cast the 8086, 186, and 286 as 16-bit products and so will be essentially unchanged. In this first year of the changeover, Dataquest will be diligent in providing sufficient data in tables to document the revenue and the units that move from the 32-bit category to the 16-bit category. The appendix lists key products subject to change and the effect of the change.

Microprocessor Categories

Microprocessors are categorized into 8-bit, 16-bit, and 32-bit and up processors, as well as by whether they are CISC and RISC and are sold into computational or embedded applications. Computational applications are personal computers, workstations, and servers. Embedded applications comprise most other applications. All 8-bit and 16-bit MPUs have CISC architectures and go into embedded applications only. Table 4-1 illustrates the various combinations of classifications.

Table 4-1
Microprocessor Categories

8-Bit MPU	16-Bit MPU	32-Bit and Up MPU			
CISC	CISC	CISC		RISC	
Embedded Applications	Embedded Applications	Embedded Applications	Computing Applications	Embedded Applications	Computing Applications

Source: Dataquest (August 1996)

Key Assumptions

The following are some of the assumptions about the embedded marketplace and the microprocessors and vendors serving it that influence the Dataquest forecast.

- The inventory corrections and general slowdown in the embedded marketplace seen in early 1996 turns around in the second half and returns to "normal" buying levels.
- The 68000 family continues to expand and serve its established base as well as new markets. The 68000 family will continue to be the dominant architecture in embedded systems.
- The x86 could emerge as a more significant architecture in embedded applications because of a carryover effect from its utter dominance of the PC industry. Some increased success by the x86 is factored into the forecast, though activities of the vendors could drastically increase or decrease this influence in future forecasts.
- The PowerPC architecture, driven by IBM and, more narrowly, by Motorola, experiences rapid growth in embedded applications.
- Many of the RISC architectures live a tenuous existence in fickle applications such as video games. These may become "one-hit wonders" and fade into memory in a few years, or they may be able to continue in another role depending on the vendors and the markets. The assumption is made that additional designs will fill in when the major customer or application jumps to another architecture, although with nominal growth.

- Some RISC architectures are counting on unproven or almost disproven applications, such as digital cameras, set-top boxes, and PDAs. The long-term success of the MPU may be highly dependent on the acceptance of products in the emerging market in general and of the OEM(s) that selected the processor in particular. Nonetheless, Dataquest is granting a fairly optimistic outlook for RISC architectures in the emerging markets for this forecast.
- Integrated processors are more attractive in embedded applications than standalone processors. They also provide vendors an opportunity to wrap up more of the total dollars spent on the design. ASPs rise as more peripheral functionality is put on the chip.
- RISC processor ASPs will decline drastically because of a movement to embedded applications and to the lower-performance integrated products and lower prices that embedded has to offer compared to workstation OEMs.
- Certain high-end digital applications such as high-definition TV (HDTV), network computers, satellite receivers, and DVD will experience a more modest growth in the time frame.

Table 4-2 and Figures 4-1 through 4-5 show the microprocessor forecast split by embedded and compute. Table 4-3 and Figures 4-6 through 4-10 show the microprocessor forecast split by CISC and RISC. Table 4-4 and Figures 4-11 through 4-14 show the microprocessor forecast by word width. Table 4-5 and Figures 4-15 and 4-16 show the microprocessor forecast by architecture.

Table 4-6 and Figures 4-17 through 4-21 show the embedded microprocessor forecast by word width. Table 4-7 and Figures 4-22 through 4-25 show the embedded microprocessor forecast by architecture.

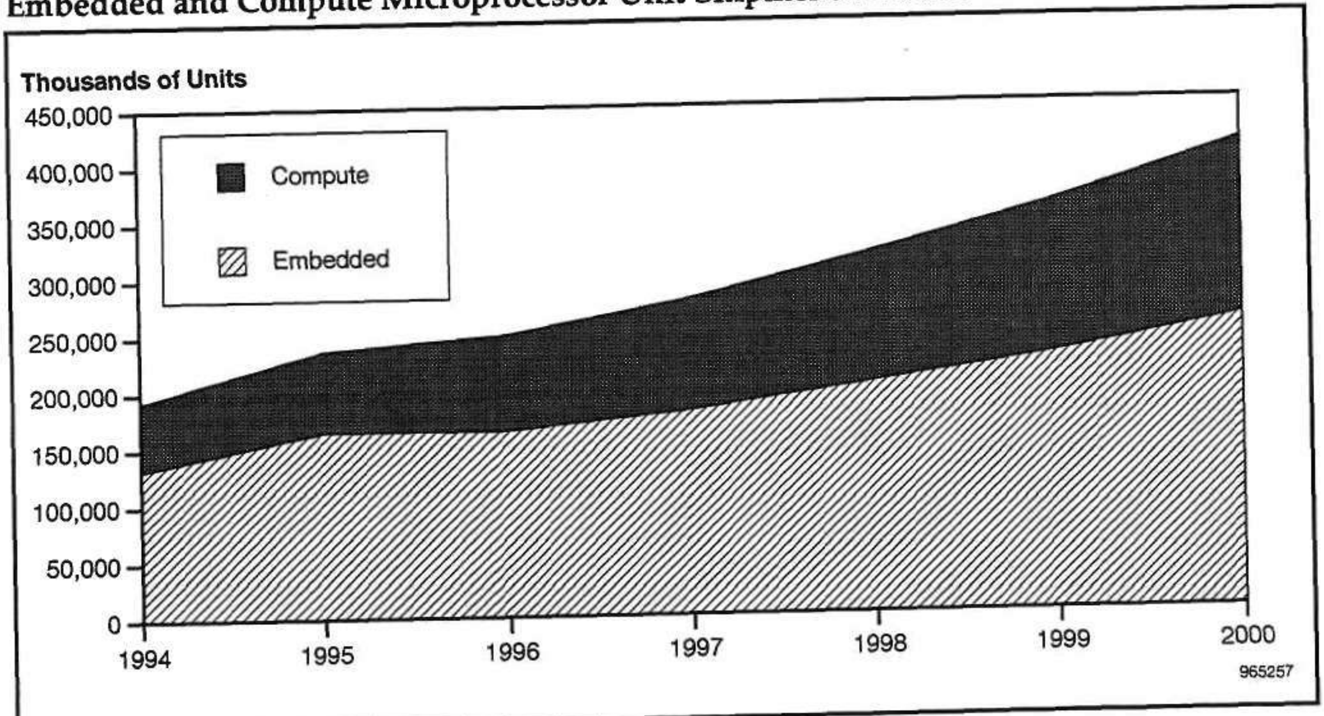
Table 4-8 and Figures 4-23 through 4-29 show the 32-bit microprocessor forecast by RISC and CISC, as well as by embedded and computational applications.

Table 4-2
Embedded and Compute Microprocessor Forecast

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
All Embedded Microprocessors								
Units (K)	131,960	164,491	164,000	180,000	203,000	227,000	258,000	9
ASP ($)	10	11	11	12	12	12	12	2
Revenue ($M)	1,349	1,818	1,870	2,090	2,380	2,720	3,130	11
All Compute Microprocessors								
Units (K)	59,754	71,590	85,300	98,700	115,000	134,000	155,000	17
ASP ($)	172	177	179	188	194	196	196	2
Revenue ($M)	10,263	12,650	15,300	18,500	22,200	26,300	30,500	19
All Microprocessors								
Units (K)	191,714	236,081	250,000	279,000	318,000	361,000	414,000	12
ASP ($)	61	61	69	74	77	80	81	6
Revenue ($M)	11,612	14,468	17,100	20,600	24,600	29,000	33,600	18
Embedded versus All Microprocessors								
Units (%)	69	70	66	65	64	63	62	
Revenue (%)	12	13	11	10	10	9	9	
Growth Rates								
All Embedded Microprocessors								
Units (%)		25	0	10	13	12	14	9
ASP (%)		8	3	2	1	2	1	2
Revenue (%)		35	3	12	14	14	15	11
All Compute Microprocessors								
Units (%)		20	19	16	17	17	16	17
ASP (%)		3	1	5	3	1	0	2
Revenue (%)		23	21	21	20	18	16	19
All Microprocessors								
Units (%)		23	6	12	14	14	15	12
ASP (%)		1	12	8	5	4	1	6
Revenue (%)		25	18	20	19	18	16	18

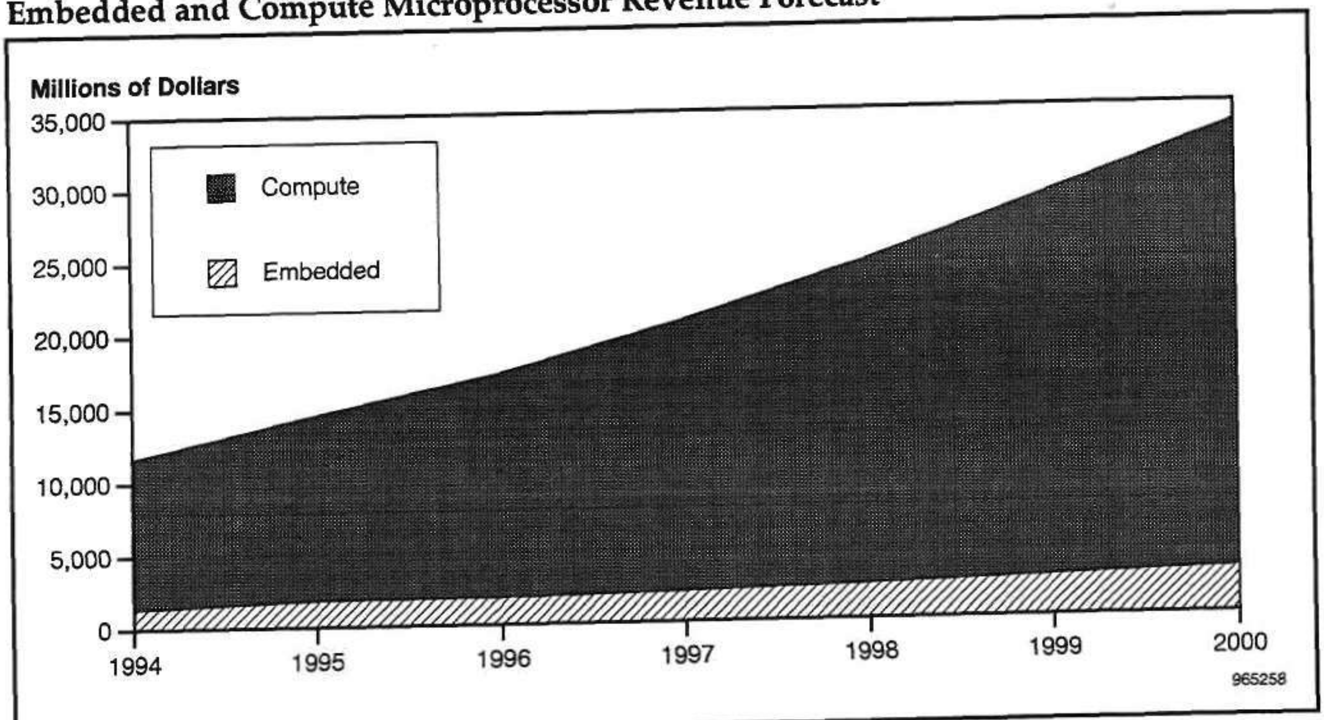
Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (August 1996)

Figure 4-1
Embedded and Compute Microprocessor Unit Shipment Forecast



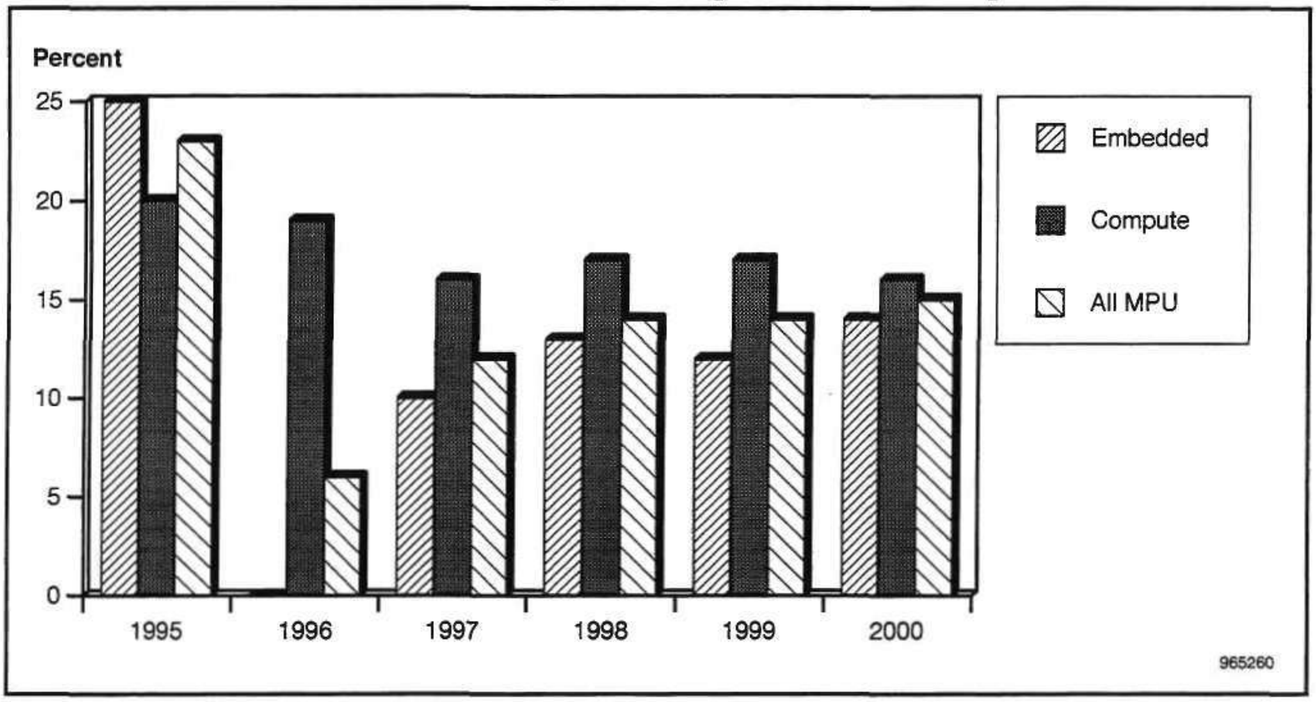
Source: Dataquest (August 1996)

Figure 4-2
Embedded and Compute Microprocessor Revenue Forecast



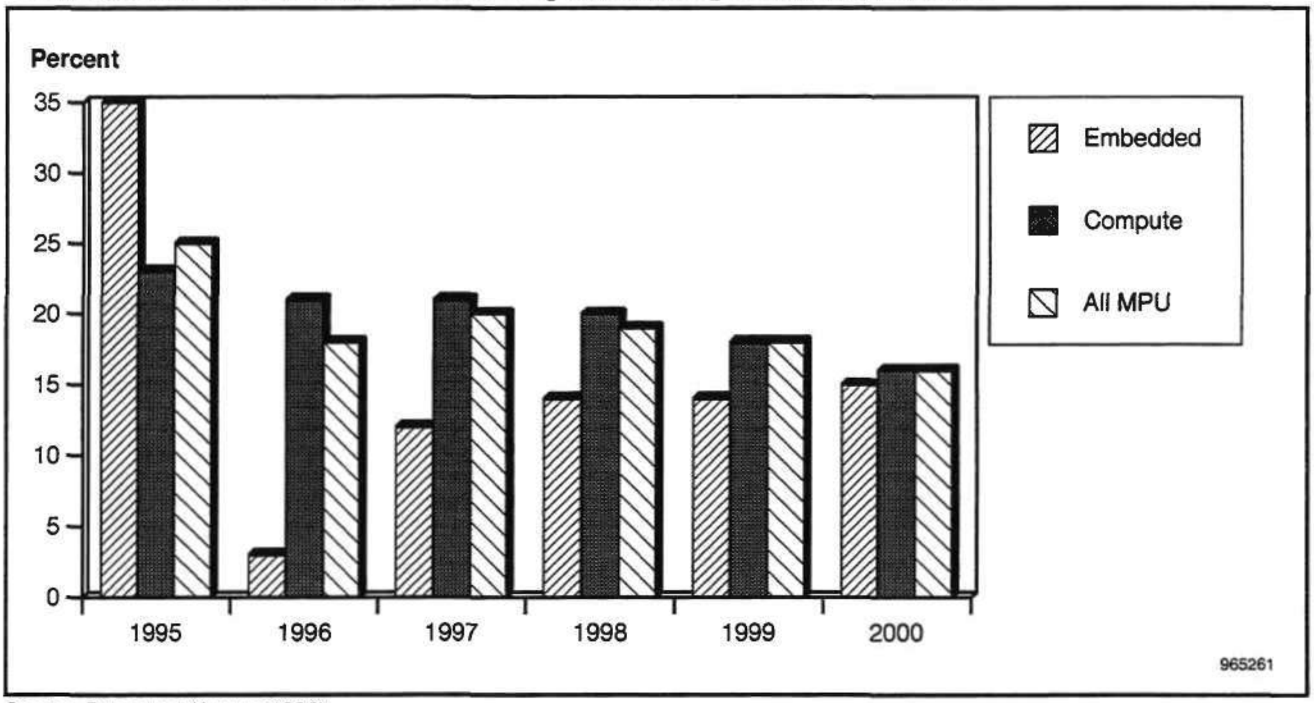
Source: Dataquest (August 1996)

Figure 4-3
Growth Rate of Embedded and Compute Microprocessor Unit Shipments



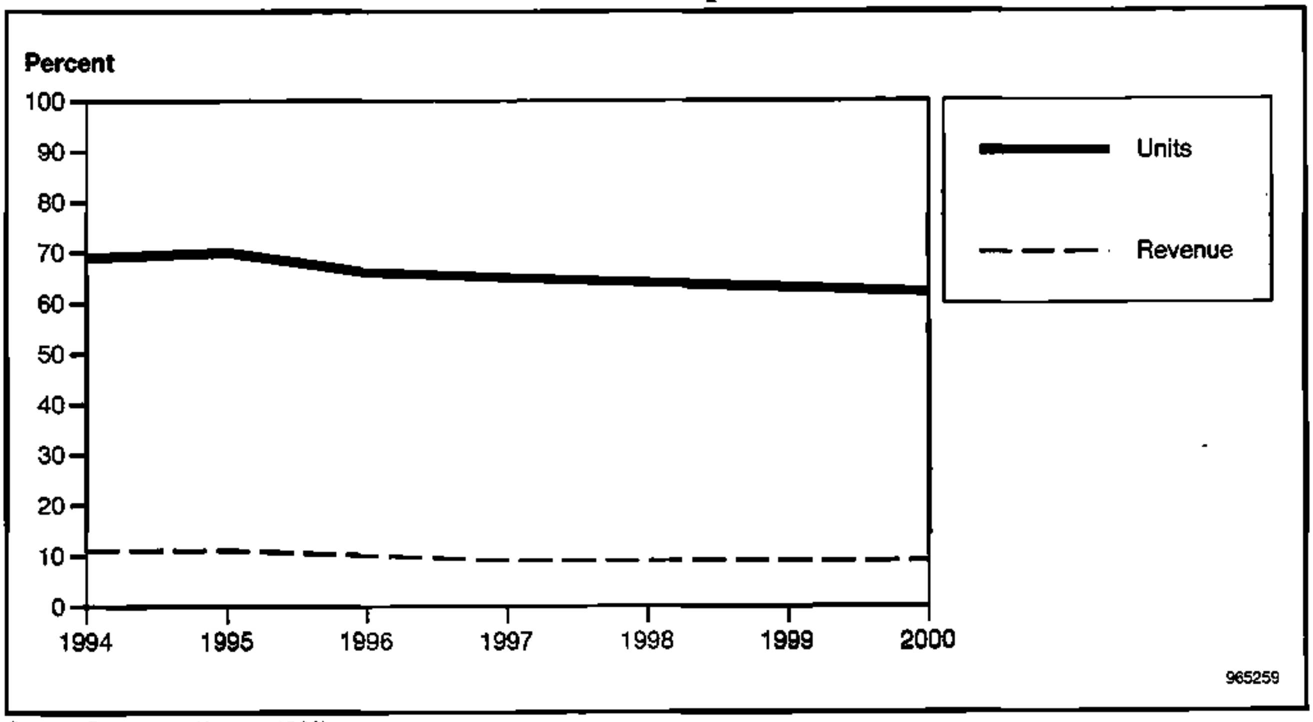
Source: Dataquest (August 1996)

Figure 4-4
Growth Rate of Embedded and Compute Microprocessor Revenue



Source: Dataquest (August 1996)

Figure 4-5
Forecast of Embedded as a Portion of All Microprocessors



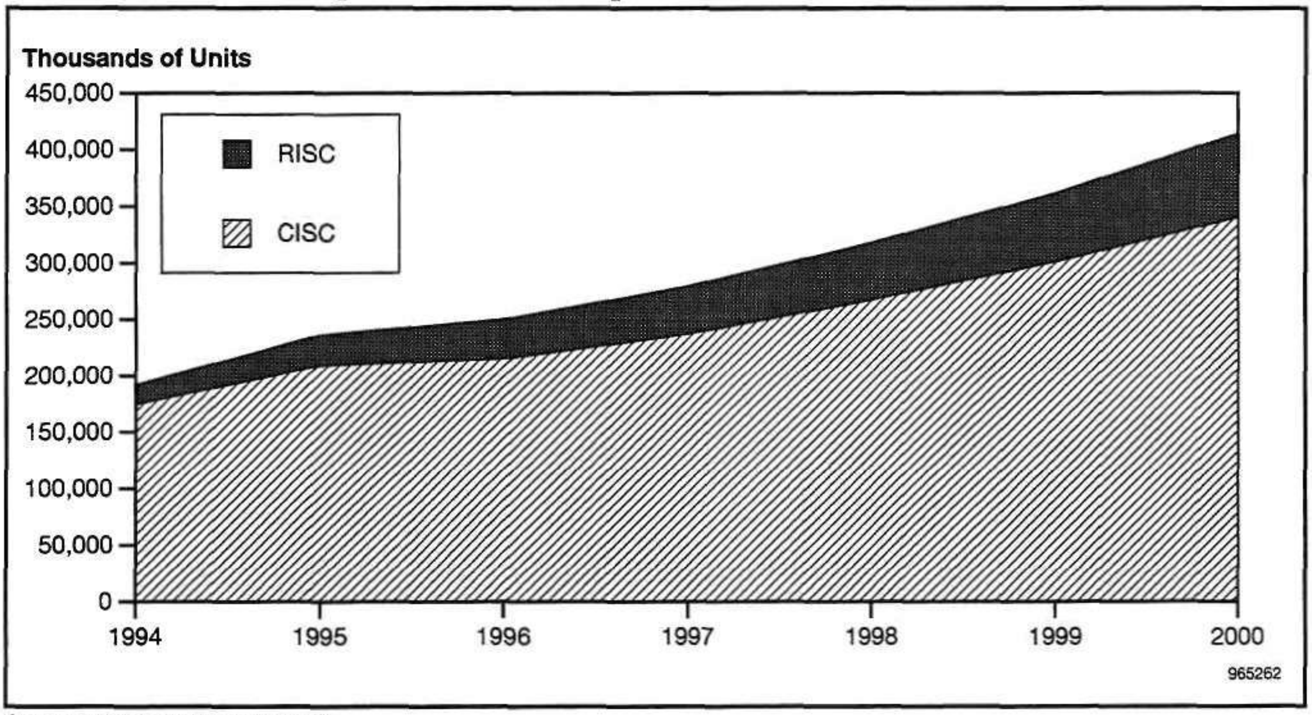
Source: Dataquest (August 1996)

Table 4-3
CISC and RISC Microprocessor Forecast

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
All CISC Microprocessors								
Units (K)	174,491	208,867	215,000	237,000	267,000	301,000	340,000	10
ASP ($)	60	61	70	78	83	88	91	8
Revenue ($M)	10,524	12,684	15,000	18,500	22,300	26,500	31,000	20
All RISC Microprocessors								
Units (K)	17,223	27,214	35,000	42,100	50,500	60,400	74,100	22
ASP ($)	63	66	60	52	46	41	36	-11
Revenue ($M)	1,089	1,785	2,100	2,180	2,310	2,450	2,650	8
All Microprocessors								
Units (K)	191,714	236,081	250,000	279,000	318,000	361,000	414,000	12
ASP ($)	61	61	69	74	77	80	81	6
Revenue ($M)	11,612	14,468	17,100	20,600	24,600	29,000	33,600	18
CISC versus All Microprocessors								
Units (%)	91	88	86	85	84	83	82	
Revenue (%)	91	88	88	90	91	91	92	
Growth Rates								
All CISC Microprocessors								
Units (%)		20	3	10	13	13	13	10
ASP (%)		1	15	12	7	6	3	8
Revenue (%)		21	18	23	21	19	17	20
All RISC Microprocessors								
Units (%)		58	29	20	20	20	23	22
ASP (%)		4	-9	-14	-12	-11	-12	-11
Revenue (%)		64	18	4	6	6	8	8
All Microprocessors								
Units (%)		23	6	12	14	14	15	12
ASP (%)		1	12	8	5	4	1	6
Revenue (%)		25	18	20	19	18	16	18

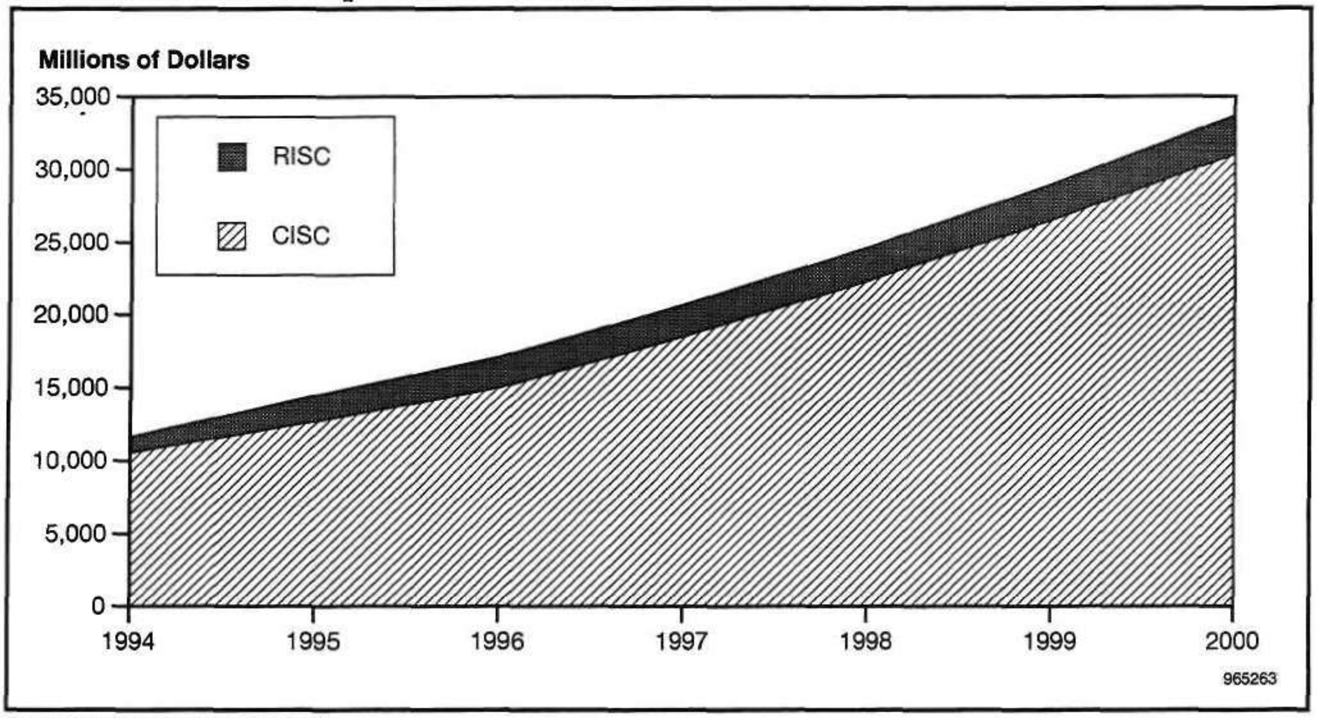
Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (August 1996)

Figure 4-6
CISC and RISC Microprocessor Unit Shipment Forecast



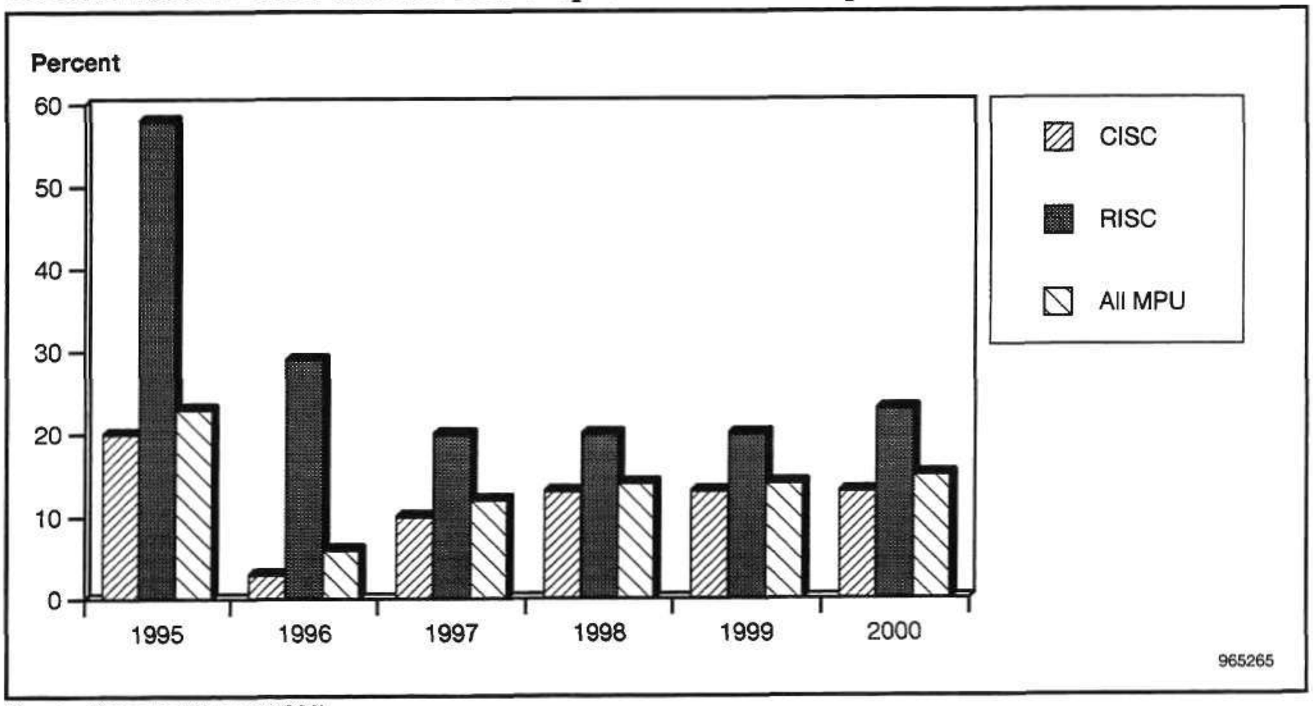
Source: Dataquest (August 1996)

Figure 4-7
CISC and RISC Microprocessor Revenue Forecast



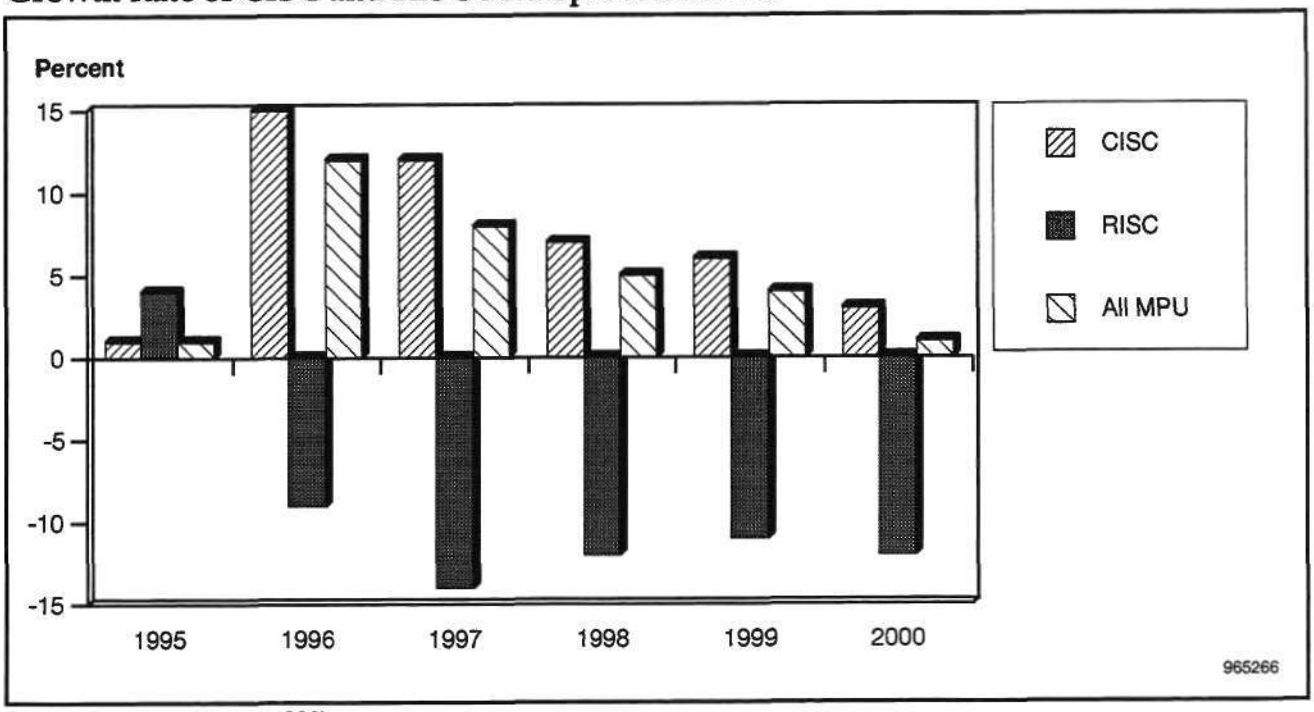
Source: Dataquest (August 1996)

Figure 4-8
Growth Rate of CISC and RISC Microprocessor Unit Shipments



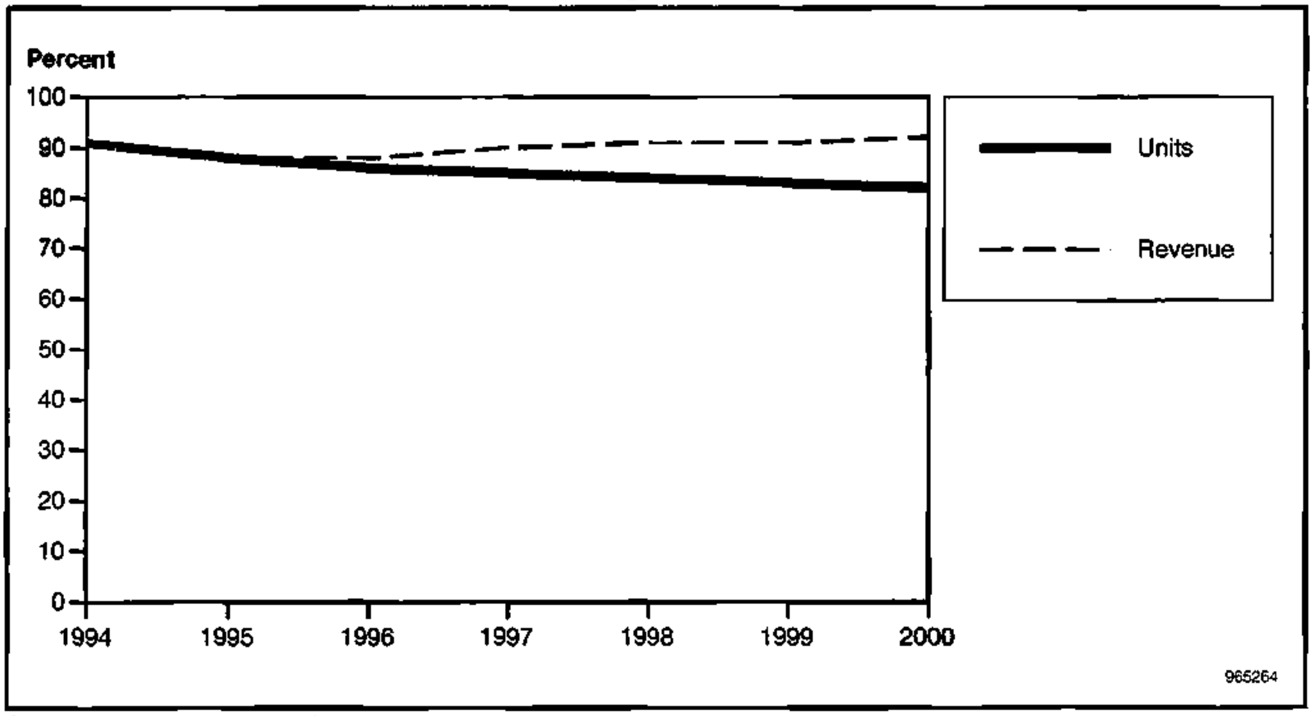
Source: Dataquest (August 1996)

Figure 4-9
Growth Rate of CISC and RISC Microprocessor ASP



Source: Dataquest (August 1996)

Figure 4-10
Forecast of CISC as a Portion of All Microprocessors



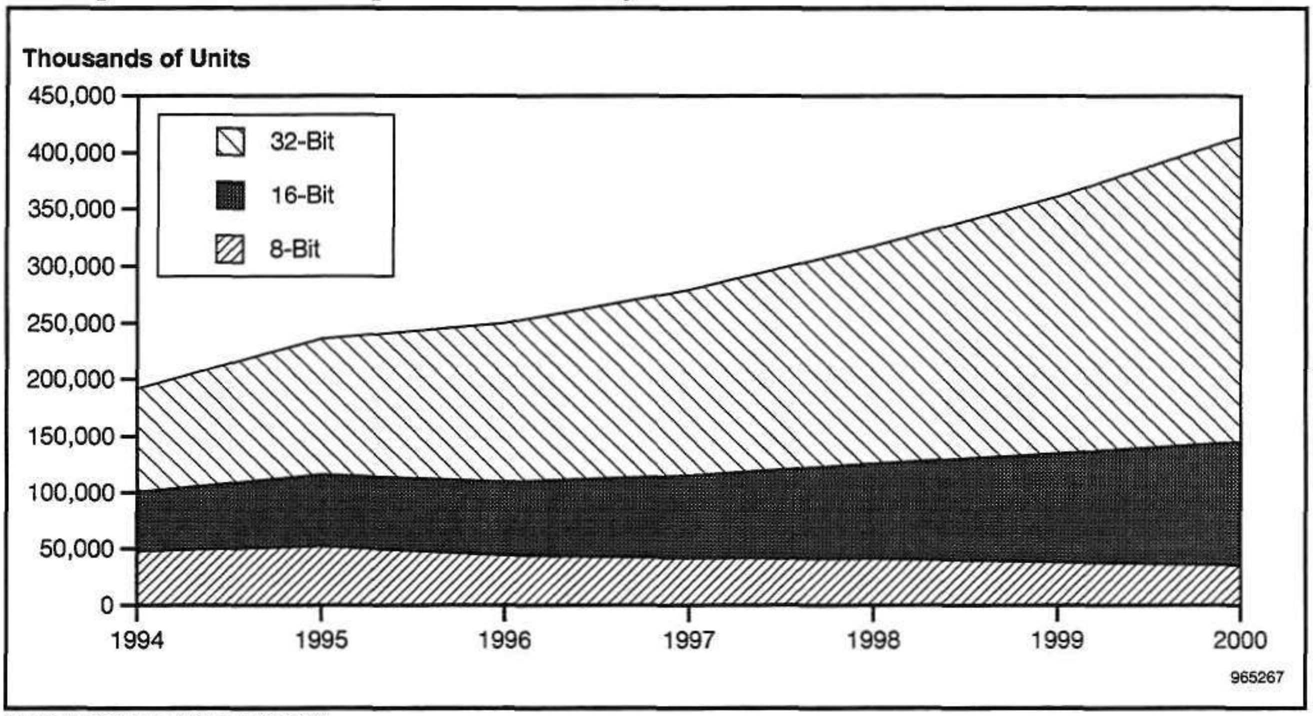
Source: Dataquest (August 1996)

Table 4-4
Microprocessor Forecast by Word Width

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
All 8-Bit Microprocessors								
Units (K)	47,990	52,125	44,300	41,300	41,200	38,100	35,400	-7
ASP ($)	7	6	7	7	7	6	6	2
Revenue ($M)	320	294	300	276	270	244	221	-6
All 16-Bit Microprocessors								
Units (K)	52,867	64,066	65,600	73,900	84,100	96,300	109,000	11
ASP ($)	8	7	7	7	8	8	9	5
Revenue ($M)	406	447	464	554	666	807	964	17
All 32-Bit Microprocessors								
Units (K)	90,857	119,890	140,000	164,000	192,000	227,000	270,000	18
ASP ($)	120	115	117	121	123	123	120	1
Revenue ($M)	10,887	13,727	16,400	19,800	23,700	27,900	32,400	19
All Microprocessors								
Units (K)	191,714	236,081	250,000	279,000	318,000	361,000	414,000	12
ASP ($)	61	61	69	74	77	80	81	6
Revenue ($M)	11,612	14,468	17,100	20,600	24,600	29,000	33,600	18
Word Width versus All Microprocessors (% Units)								
8-Bit	25	22	18	15	13	11	9	
16-Bit	28	27	26	26	26	27	26	
32-Bit	47	51	56	59	60	63	65	
Word Width versus All Microprocessors (% Revenue)								
8-Bit	3	2	2	1	1	1	1	
16-Bit	3	3	3	3	3	3	3	
32-Bit	94	95	96	96	96	96	96	

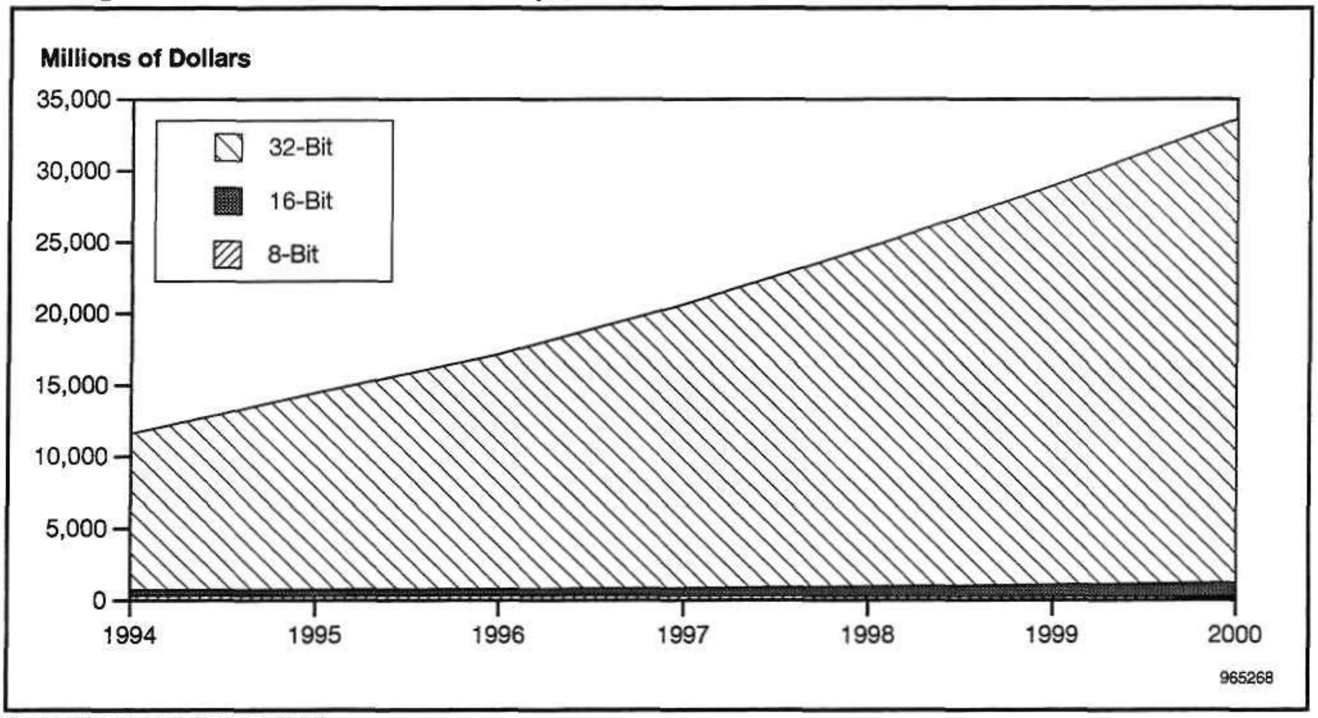
Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (August 1996)

Figure 4-11
Microprocessor Unit Shipment Forecast by Word Width



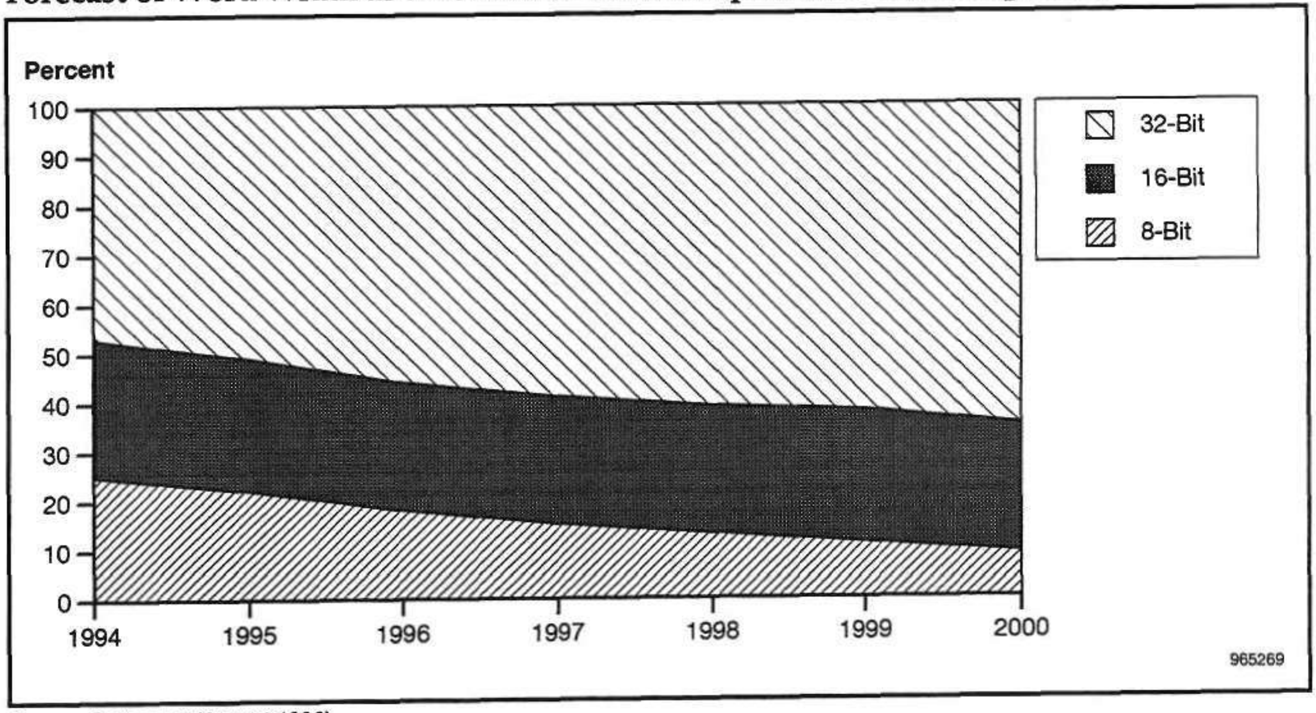
Source: Dataquest (August 1996)

Figure 4-12
Microprocessor Revenue Forecast by Word Width



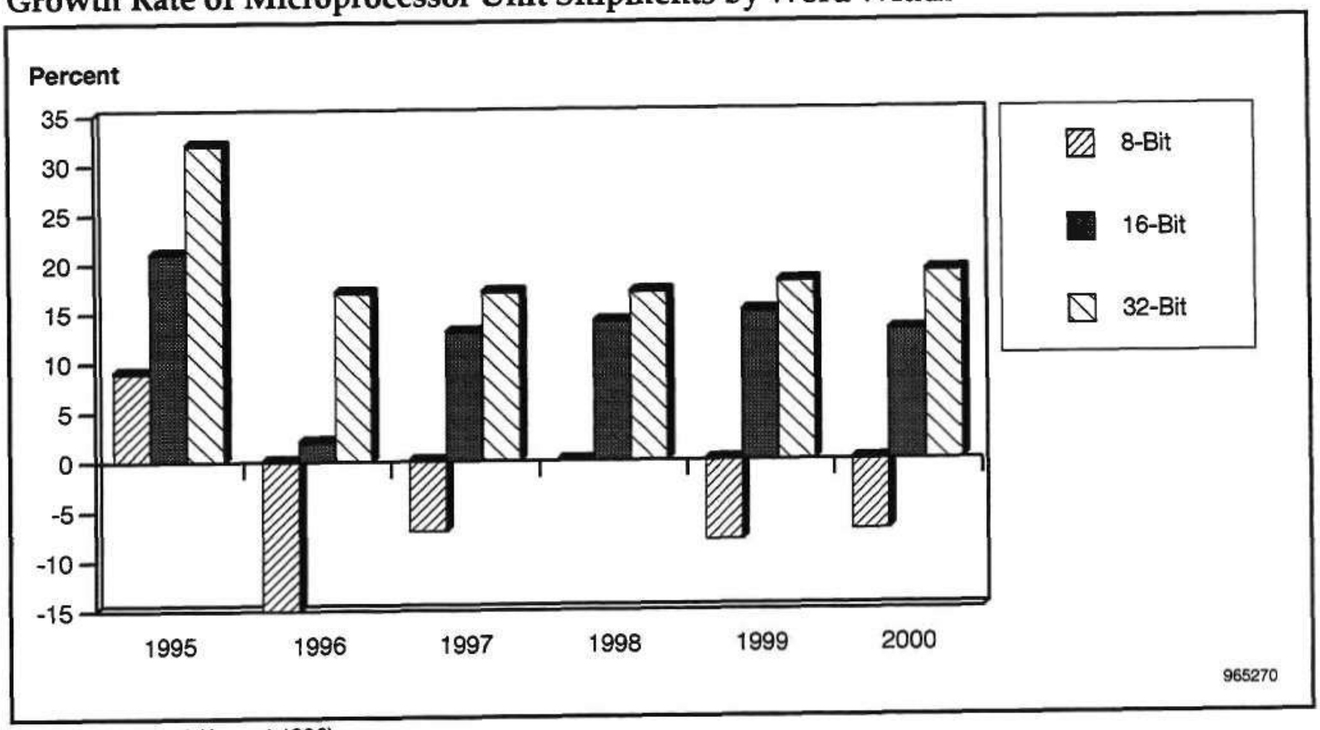
Source: Dataquest (August 1996)

Figure 4-13
Forecast of Word Width as a Portion of All Microprocessor Unit Shipments



Source: Dataquest (August 1996)

Figure 4-14
Growth Rate of Microprocessor Unit Shipments by Word Width



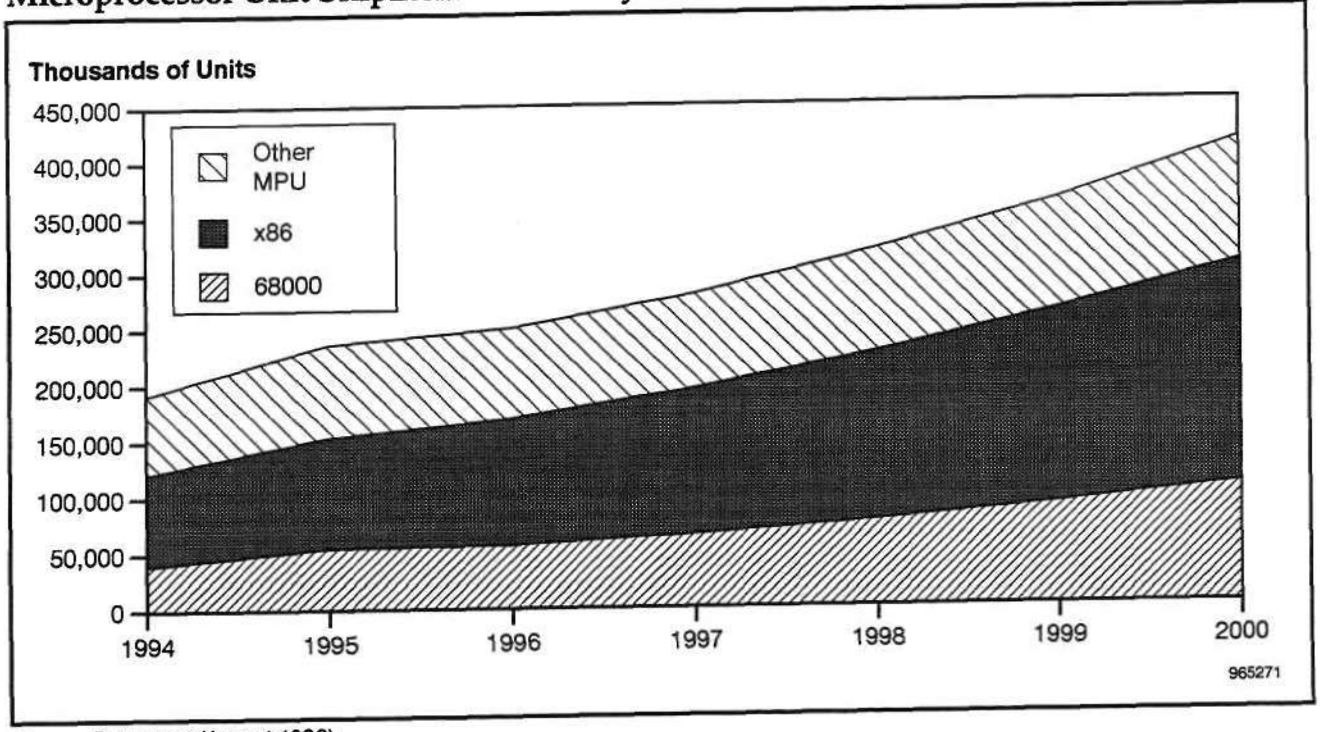
Source: Dataquest (August 1996)

Table 4-5
Microprocessor Forecast by Architecture

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
68000 Architecture								
Units (K)	39,622	54,446	56,100	64,500	75,500	89,500	106,000	14
ASP ($)	15	9	9	9	10	10	11	4
Revenue ($M)	576	496	501	598	736	933	1,170	19
x86 Architecture								
Units (K)	81,927	99,109	113,000	130,000	150,000	173,000	198,000	15
ASP ($)	116	119	126	135	142	147	149	5
Revenue ($M)	9,523	11,834	14,200	17,600	21,300	25,300	29,600	20
Other Architectures								
Units (K)	70,165	82,526	80,900	84,500	92,500	98,500	110,000	6
ASP ($)	22	26	30	28	28	28	26	0
Revenue ($M)	1,514	2,139	2,399	2,402	2,564	2,767	2,830	6
All Microprocessors								
Units (K)	191,714	236,081	250,000	279,000	318,000	361,000	414,000	12
ASP ($)	61	61	69	74	77	80	81	6
Revenue ($M)	11,612	14,468	17,100	20,600	24,600	29,000	33,600	18

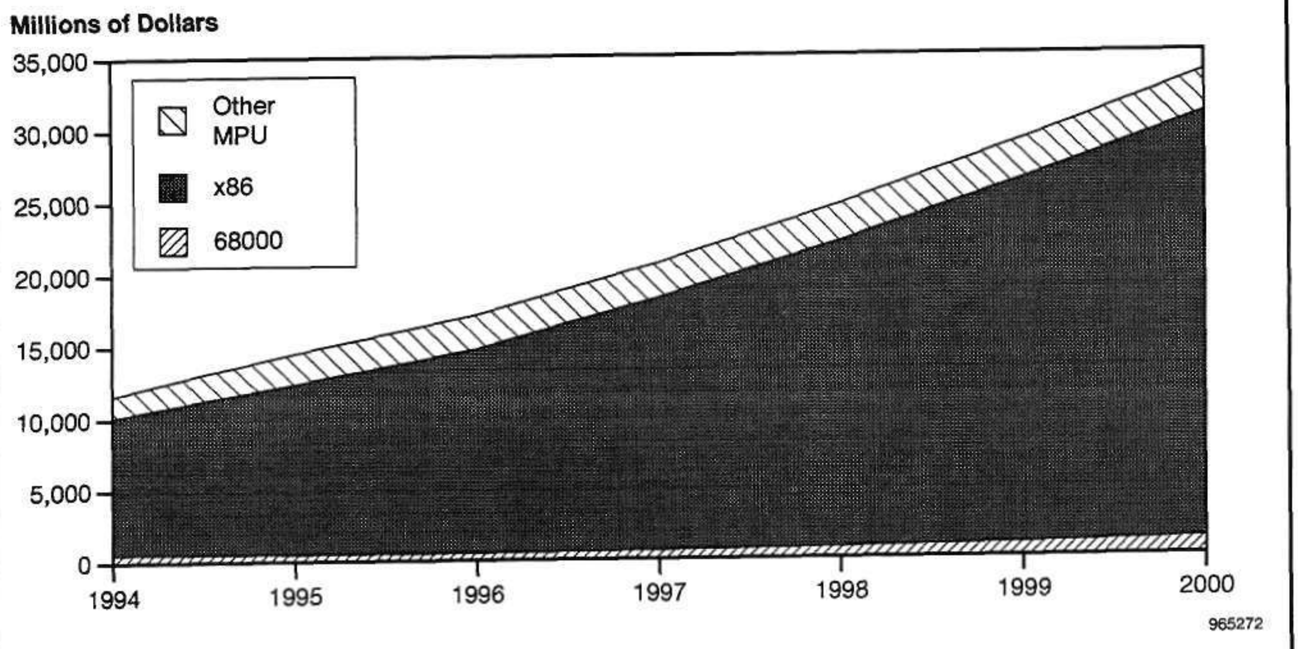
Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (August 1996)

Figure 4-15
Microprocessor Unit Shipment Forecast by Architecture



Source: Dataquest (August 1996)

Figure 4-16
Microprocessor Revenue Forecast by Architecture



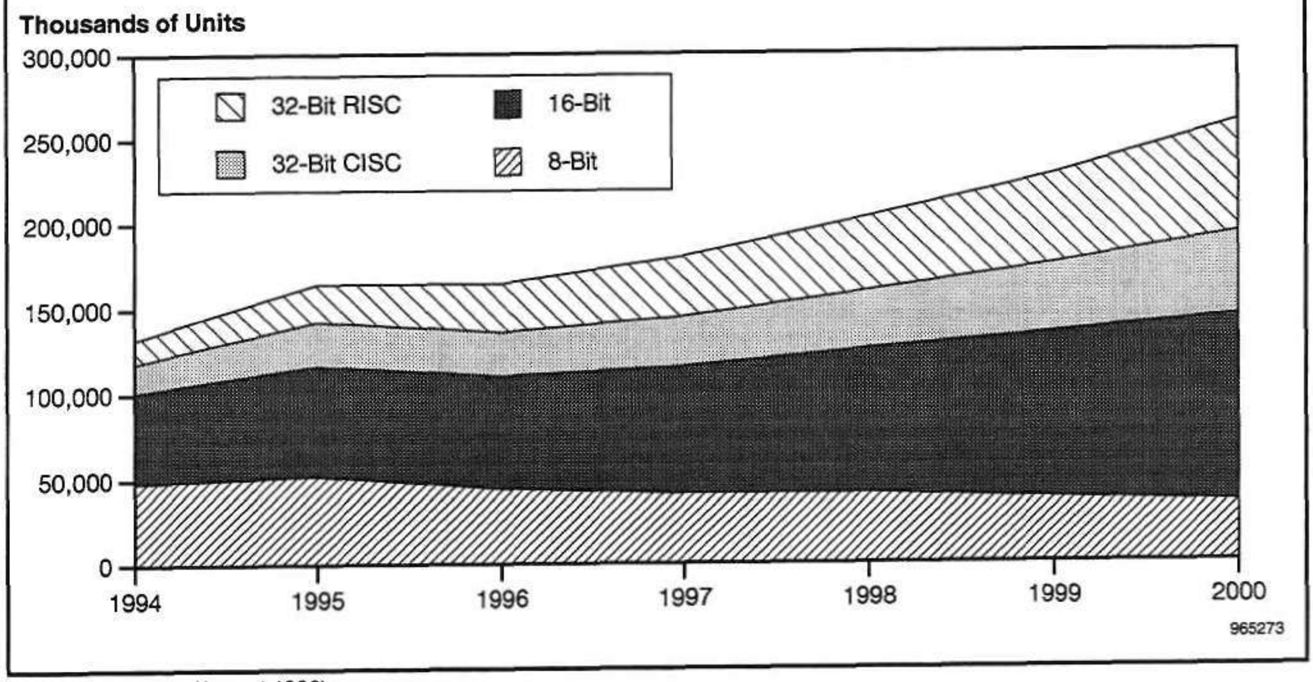
Source: Dataquest (August 1996)

Table 4-6
Embedded Microprocessor Forecast by Word Width

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
8-Bit Embedded Microprocessors								
Units (K)	47,990	52,125	44,300	41,300	41,200	38,100	35,400	-7
ASP ($)	7	6	7	7	7	6	6	2
Revenue ($M)	320	294	300	276	270	244	221	-6
16-Bit Embedded Microprocessors								
Units (K)	52,867	64,066	65,600	73,900	84,100	96,300	109,000	11
ASP ($)	8	7	7	7	8	8	9	5
Revenue ($M)	406	447	464	554	666	807	964	17
32-Bit Embedded CISC								
Units (K)	17,077	26,060	25,900	29,400	34,100	40,400	48,300	13
ASP ($)	19	16	14	15	15	16	16	0
Revenue ($M)	325	420	375	436	522	648	779	13
32-Bit Embedded RISC								
Units (K)	14,026	22,240	28,600	35,400	43,300	52,700	65,800	24
ASP ($)	21	30	26	23	21	19	18	-10
Revenue ($M)	299	657	730	825	920	1,020	1,170	12
All Embedded Microprocessors								
Units (K)	131,960	164,491	164,000	180,000	203,000	227,000	258,000	9
ASP ($)	10	11	11	12	12	12	12	2
Revenue ($M)	1,349	1,818	1,870	2,090	2,380	2,720	3,130	11

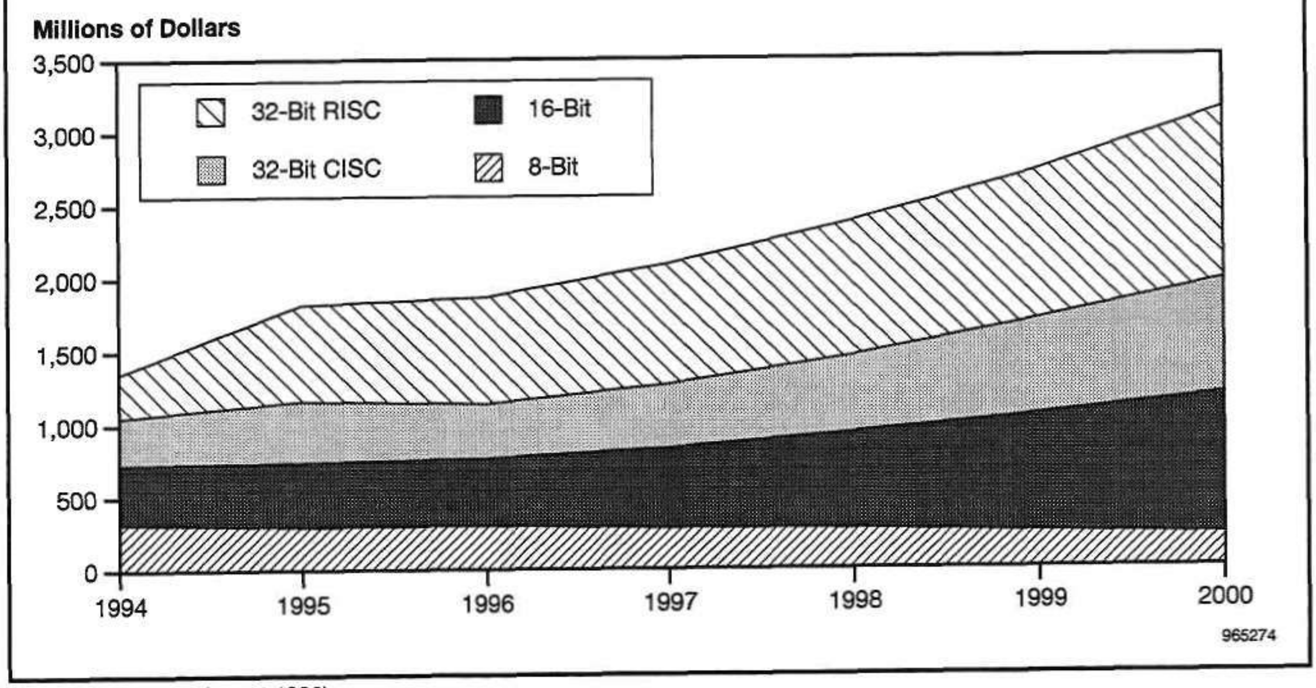
Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (August 1996)

Figure 4-17
Embedded Microprocessor Unit Shipment Forecast by Word Width



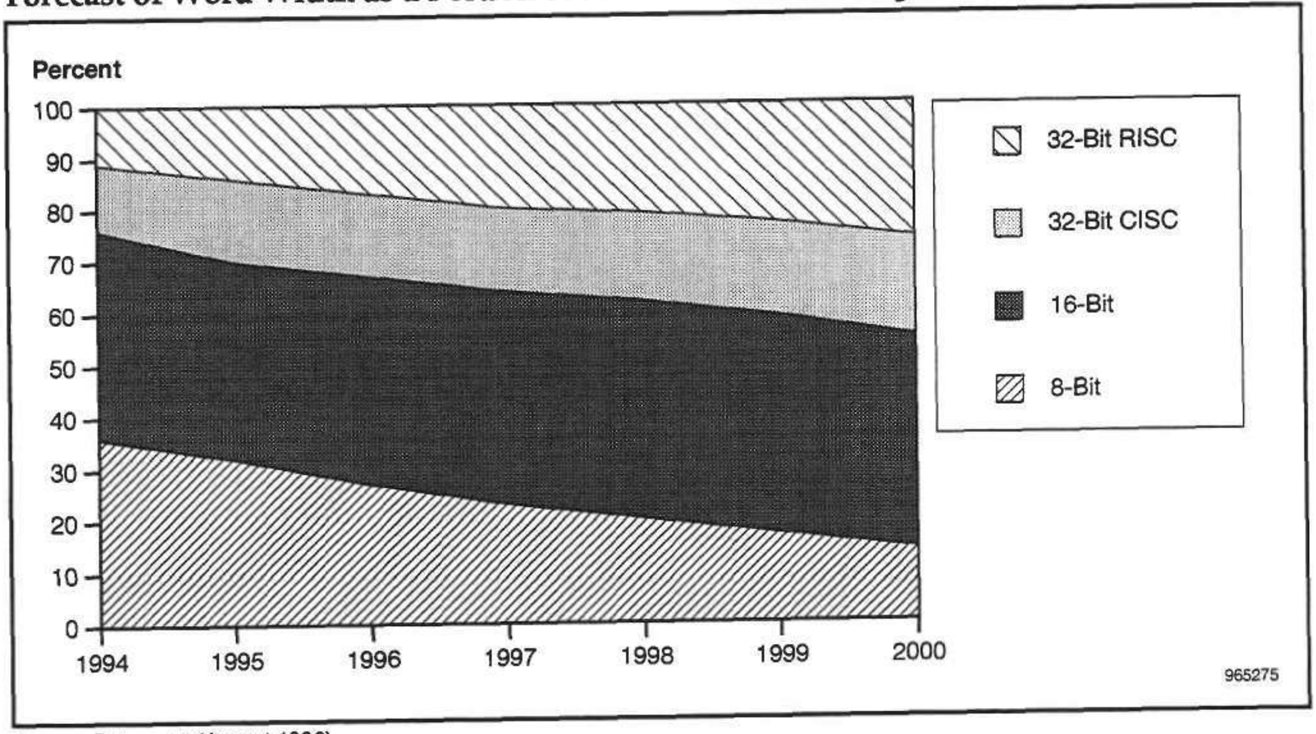
Source: Dataquest (August 1996)

Figure 4-18
Embedded Microprocessor Revenue Forecast by Word Width



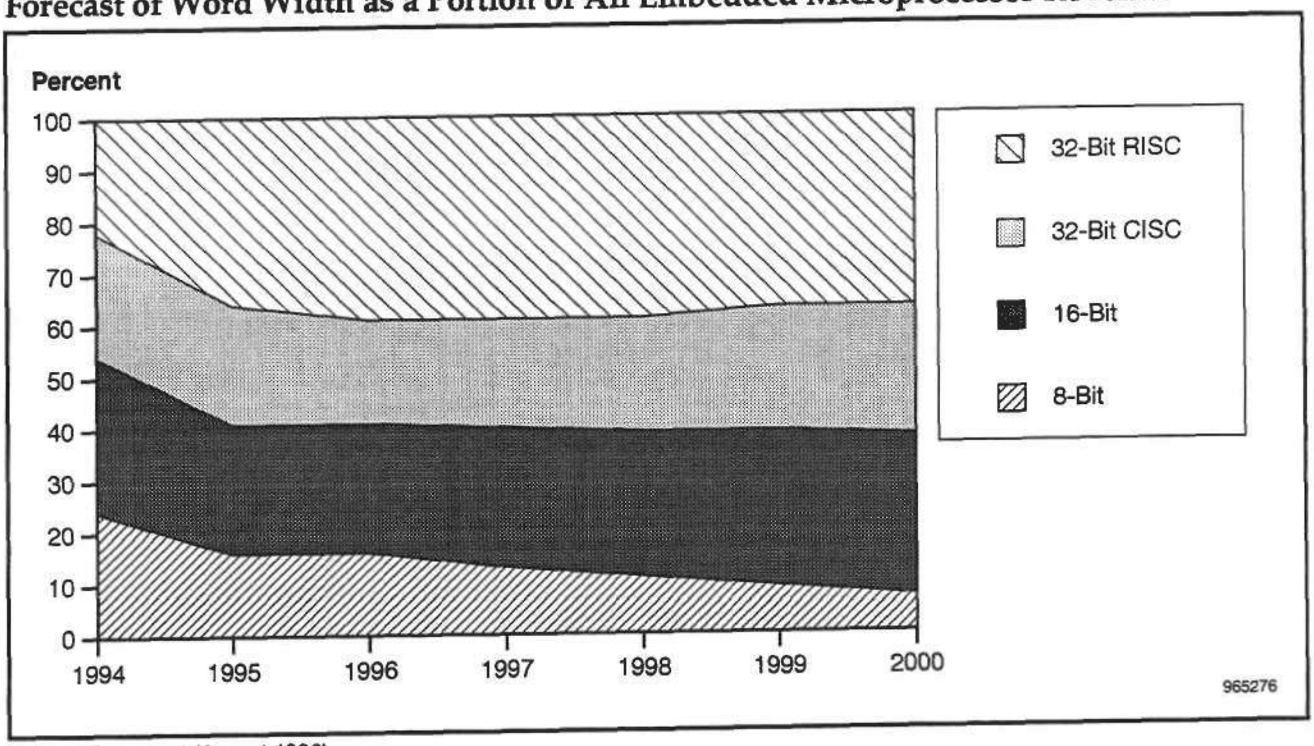
Source: Dataquest (August 1996)

Figure 4-19
Forecast of Word Width as a Portion of All Embedded Microprocessor Unit Shipments



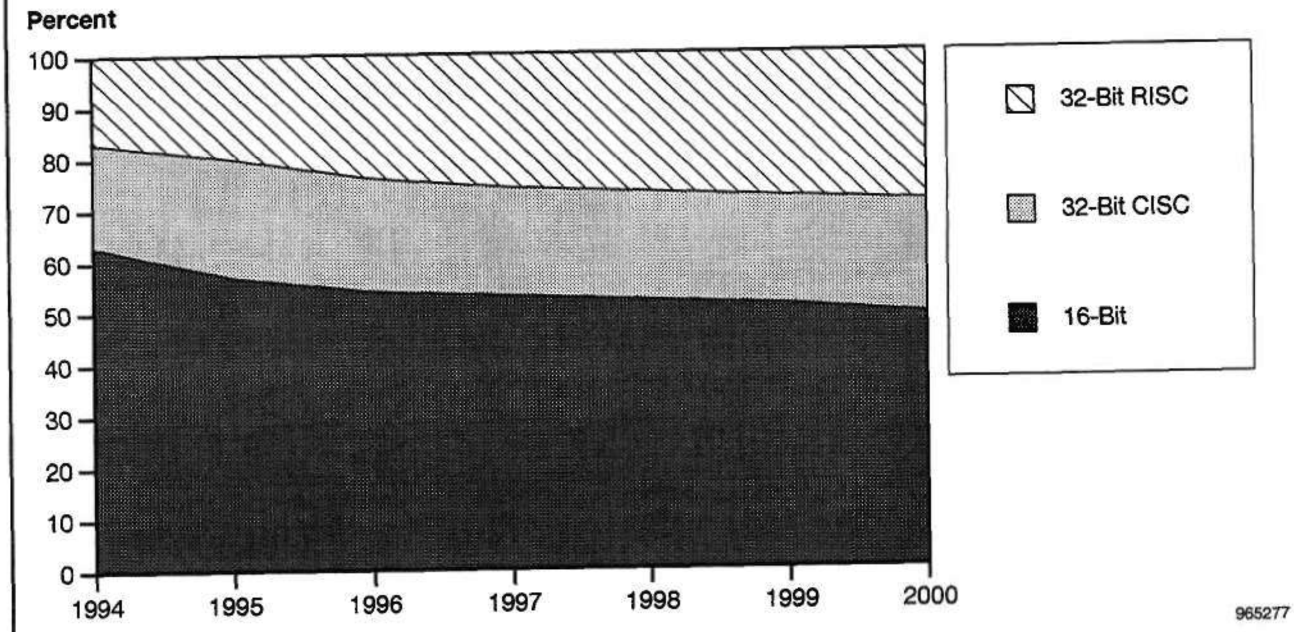
Source: Dataquest (August 1996)

Figure 4-20
Forecast of Word Width as a Portion of All Embedded Microprocessor Revenue



Source: Dataquest (August 1996)

Figure 4-21
Forecast of Word Width as a Portion of Embedded Microprocessor Unit Shipments Minus 8-Bit



Source: Dataquest (August 1996)

Table 4-7
Embedded Microprocessor Forecast by Architecture

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
32-Bit Embedded RISC								
Units (K)	14,026	22,240	28,600	35,400	43,300	52,700	65,800	24
ASP ($)	21	30	26	23	21	19	18	-10
Revenue ($M)	299	657	730	825	920	1,020	1,170	12
32-Bit Embedded 68000								
Units (K)	9,860	18,874	19,900	22,900	26,900	32,300	39,400	16
ASP ($)	16	12	12	13	14	15	15	5
Revenue ($M)	153	226	244	297	366	472	605	22
32-Bit Embedded x86								
Units (K)	3,325	4,672	4,940	5,770	6,780	7,860	8,820	14
ASP ($)	23	30	22	21	22	22	19	-8
Revenue ($M)	76	138	107	123	146	169	170	4
16-Bit Embedded 68000								
Units (K)	25,464	34,459	35,600	41,200	48,400	57,000	66,200	14
ASP ($)	7	7	7	7	7	8	8	5
Revenue ($M)	190	224	234	286	358	450	556	20
16-Bit Embedded x86								
Units (K)	26,343	28,934	29,700	32,500	35,600	39,200	42,500	8
ASP ($)	8	8	8	8	9	9	10	5
Revenue ($M)	207	218	228	266	308	356	408	13
8-Bit Embedded Microprocessors								
Units (K)	47,990	52,125	44,300	41,300	41,200	38,100	35,400	-7
ASP ($)	7	6	7	7	7	6	6	2
Revenue ($M)	320	294	300	276	270	244	221	-6

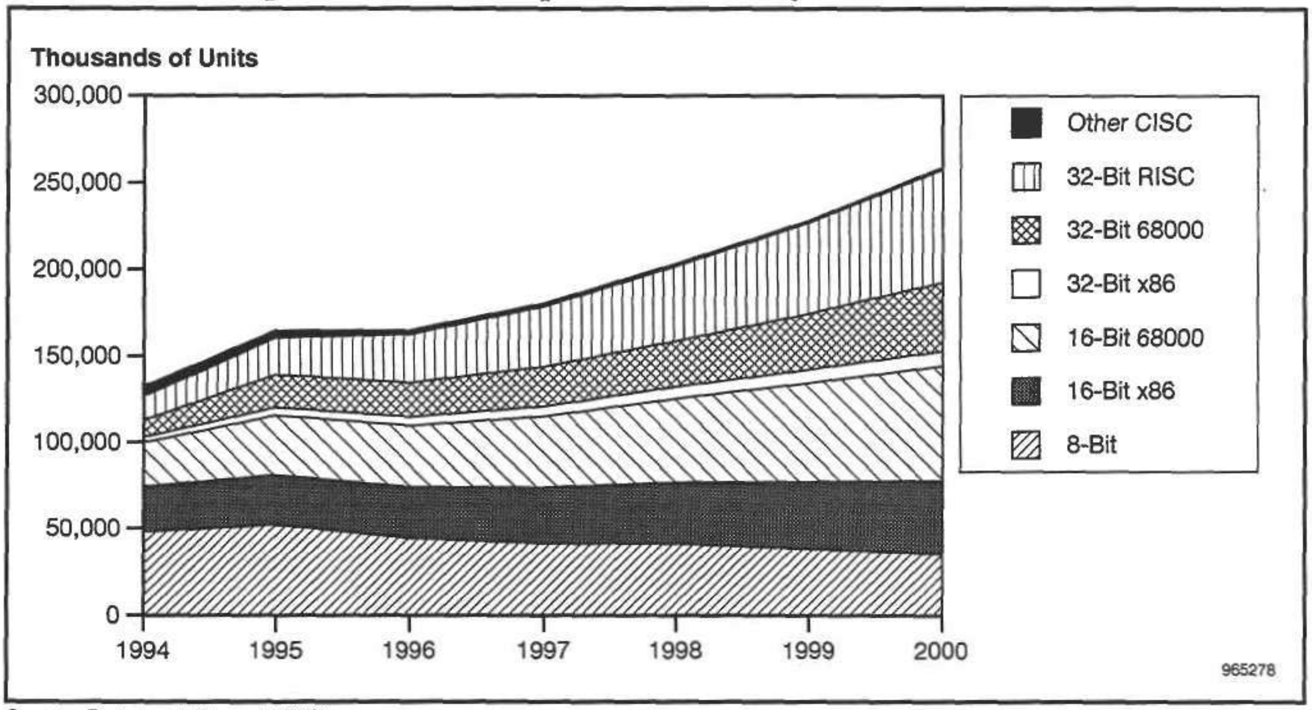
(Continued)

Table 4-7 (Continued)
Embedded Microprocessor Forecast by Architecture

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Other Embedded CISC								
Units (K)	4,952	3,187	1,433	861	516	320	200	-83
ASP ($)	21	19	19	20	21	22	22	3
Revenue ($M)	105	60	27	17	11	7	4	-78
All Embedded Microprocessors								
Units (K)	131,960	164,491	164,000	180,000	203,000	227,000	258,000	9
ASP ($)	10	11	11	12	12	12	12	2
Revenue ($M)	1,349	1,818	1,870	2,090	2,380	2,720	3,130	11

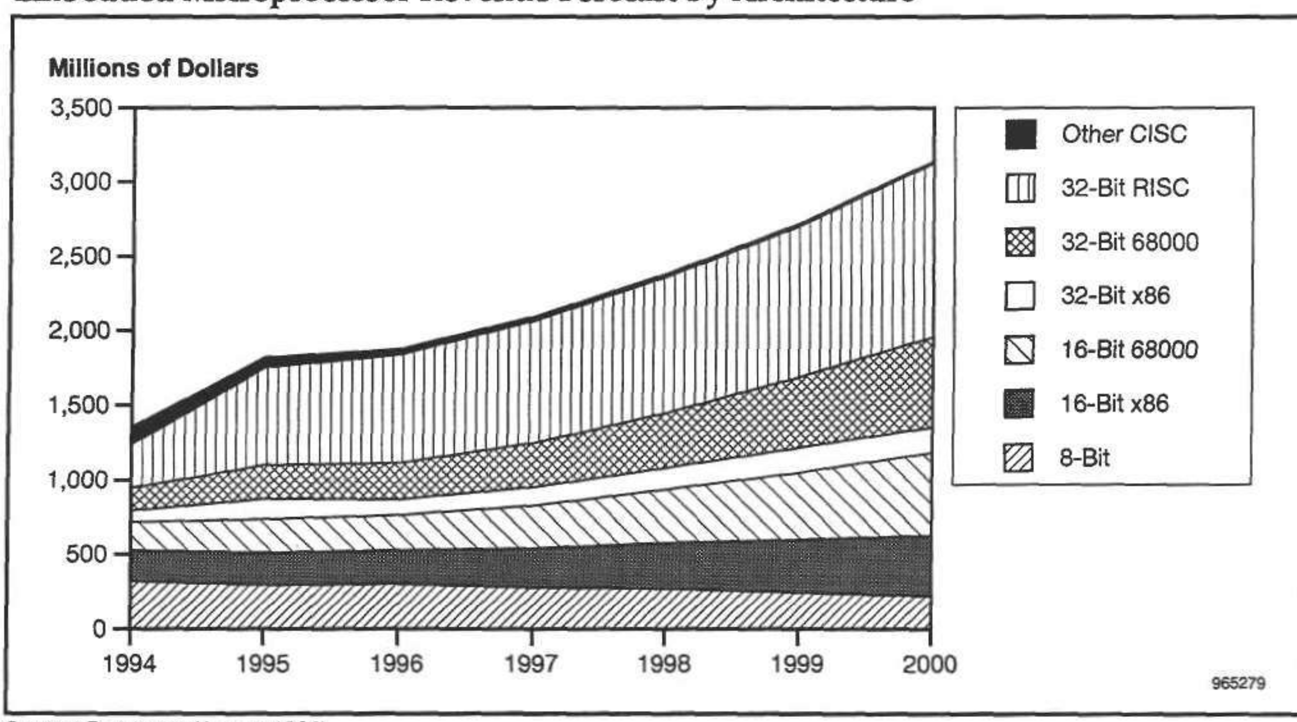
Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (August 1996)

Figure 4-22
Embedded Microprocessor Unit Shipment Forecast by Architecture



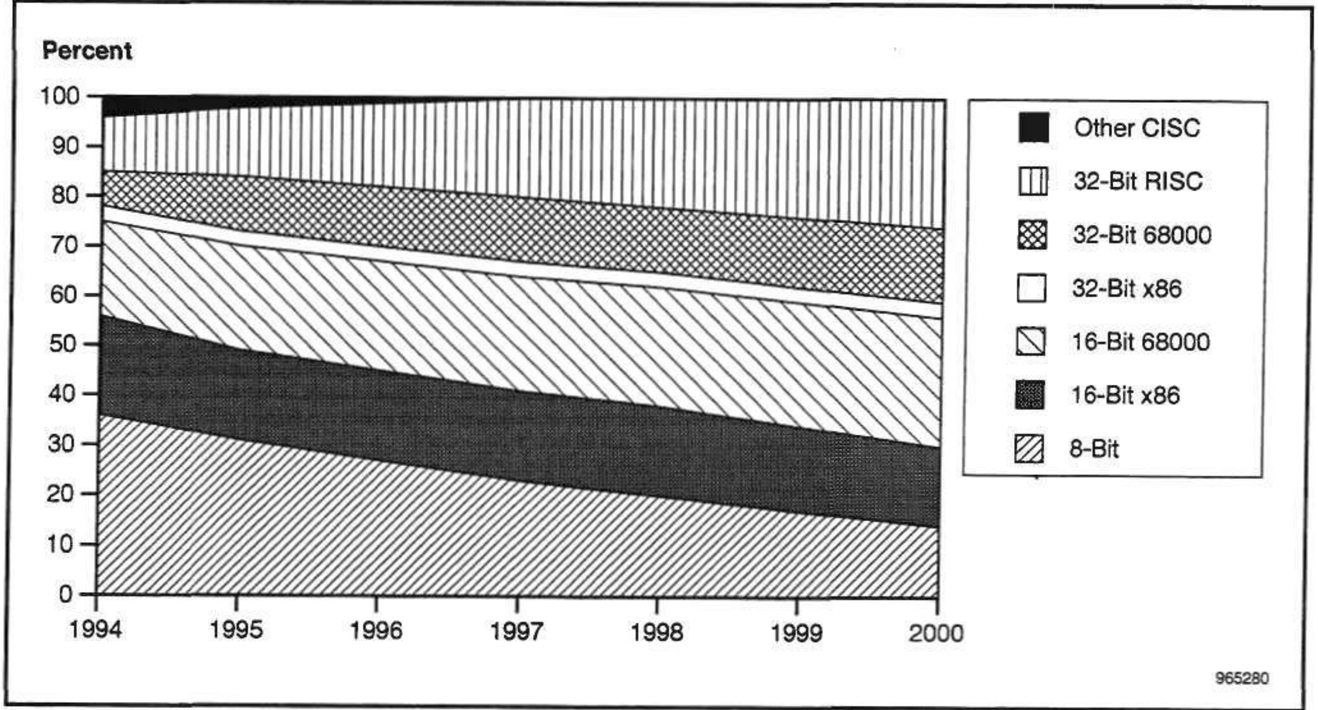
Source: Dataquest (August 1996)

Figure 4-23
Embedded Microprocessor Revenue Forecast by Architecture



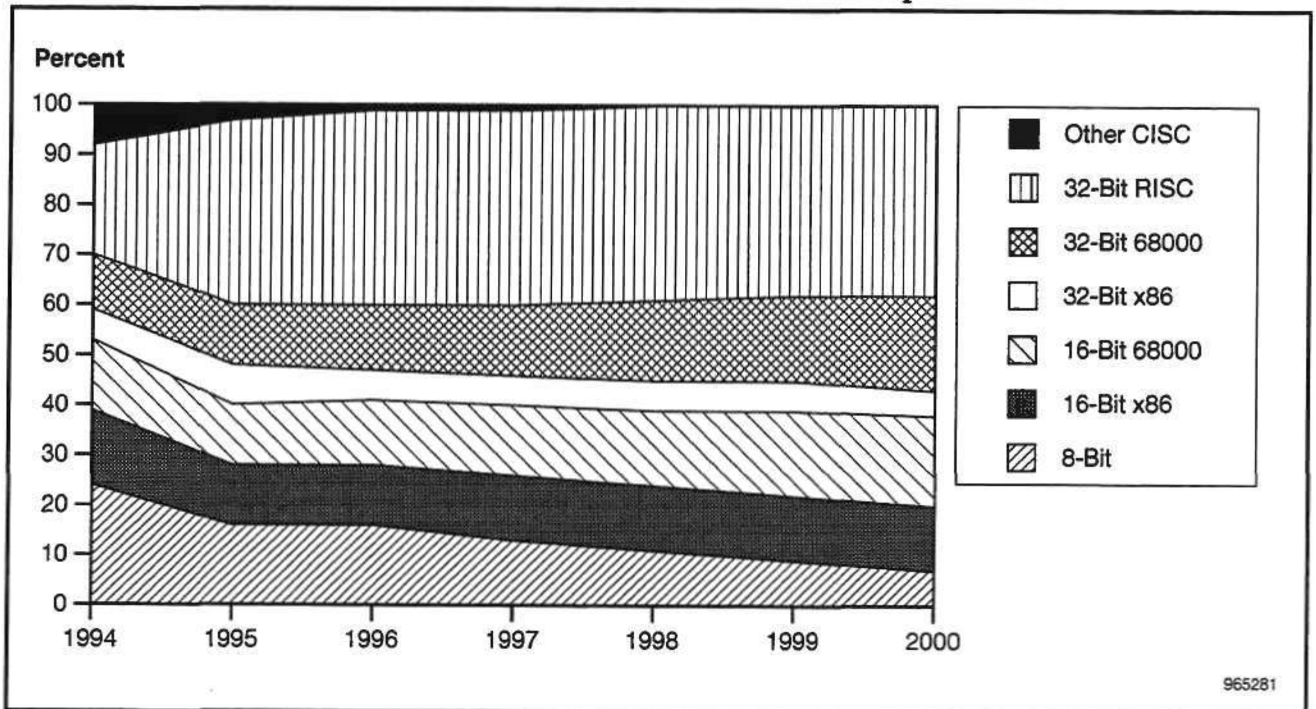
Source: Dataquest (August 1996)

Figure 4-24
Forecast of Architecture as a Portion of All Embedded Microprocessor Unit Shipments



Source: Dataquest (August 1996)

Figure 4-25
Forecast of Architecture as a Portion of All Embedded Microprocessor Revenue



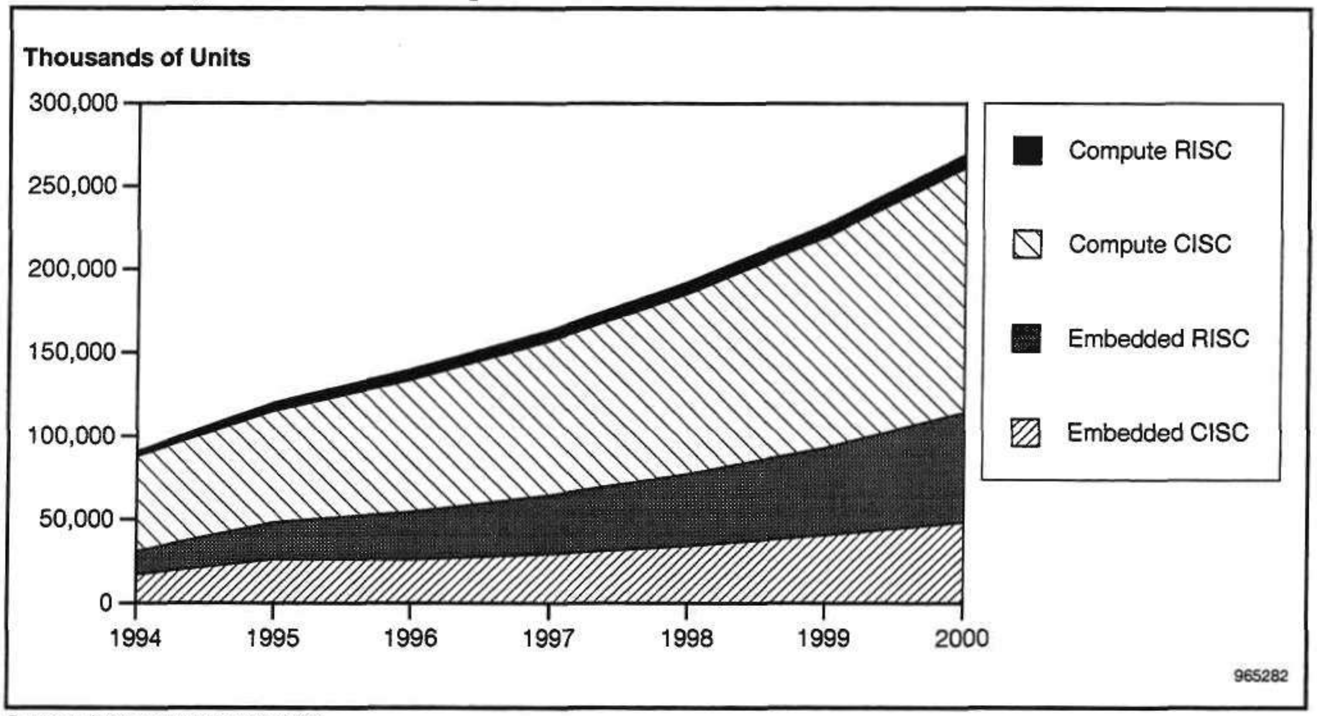
Source: Dataquest (August 1996)

Table 4-8
32-Bit Microprocessor Forecast

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Embedded CISC Microprocessors								
Units (K)	17,077	26,060	25,900	29,400	34,100	40,400	48,300	13
ASP ($)	19	16	14	15	15	16	16	0
Revenue ($M)	325	420	375	436	522	648	779	13
Embedded RISC Microprocessors								
Units (K)	14,026	22,240	28,600	35,400	43,300	52,700	65,800	24
ASP ($)	21	30	26	23	21	19	18	-10
Revenue ($M)	299	657	730	825	920	1,020	1,170	12
Compute CISC Microprocessors								
Units (K)	56,557	66,616	78,800	92,100	108,000	126,000	147,000	17
ASP ($)	168	173	176	187	194	197	197	3
Revenue ($M)	9,473	11,523	13,900	17,200	20,800	24,800	29,000	20
Compute RISC Microprocessors								
Units (K)	3,197	4,974	6,450	6,660	7,180	7,710	8,300	11
ASP ($)	247	227	212	203	193	185	179	-5
Revenue ($M)	790	1,127	1,370	1,350	1,390	1,430	1,480	-1
All 32-Bit Microprocessors								
Units (K)	90,857	119,890	140,000	164,000	192,000	227,000	270,000	18
ASP ($)	120	115	117	121	123	123	120	1
Revenue ($M)	10,887	13,727	16,400	19,800	23,700	27,900	32,400	19

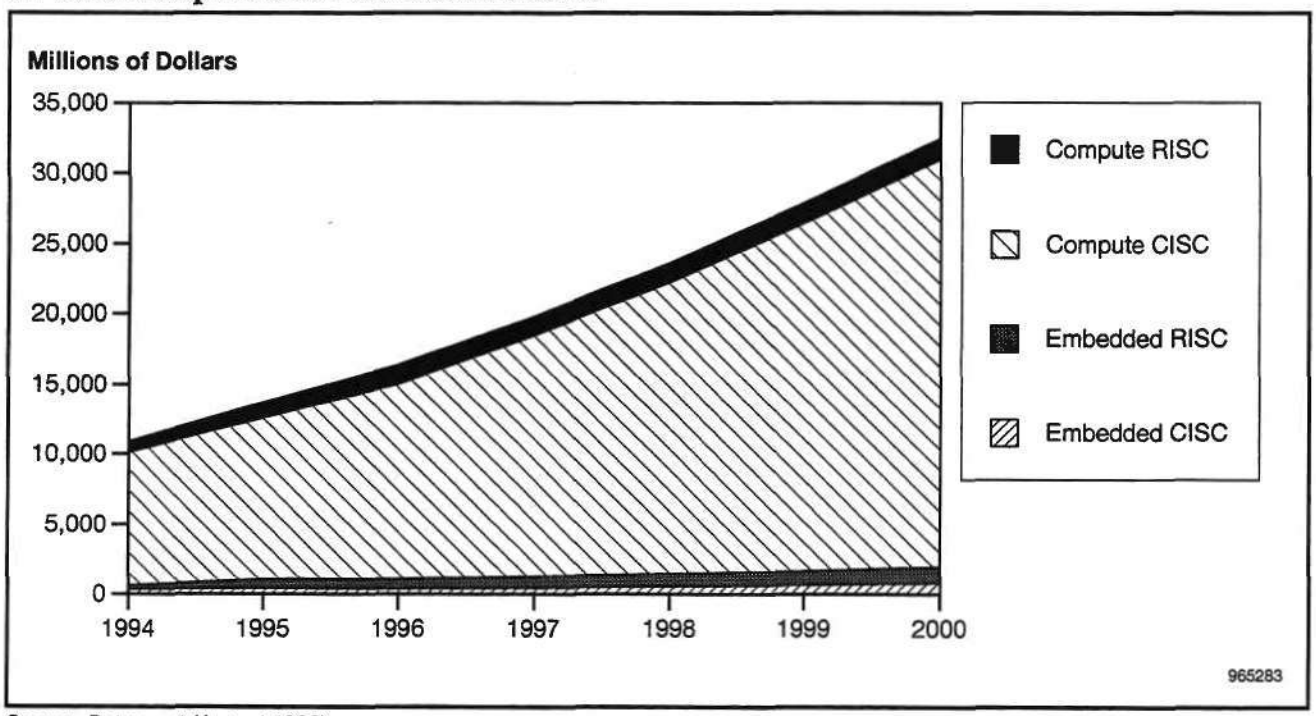
Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (August 1996)

Figure 4-26
32-Bit Microprocessor Unit Shipment Forecast



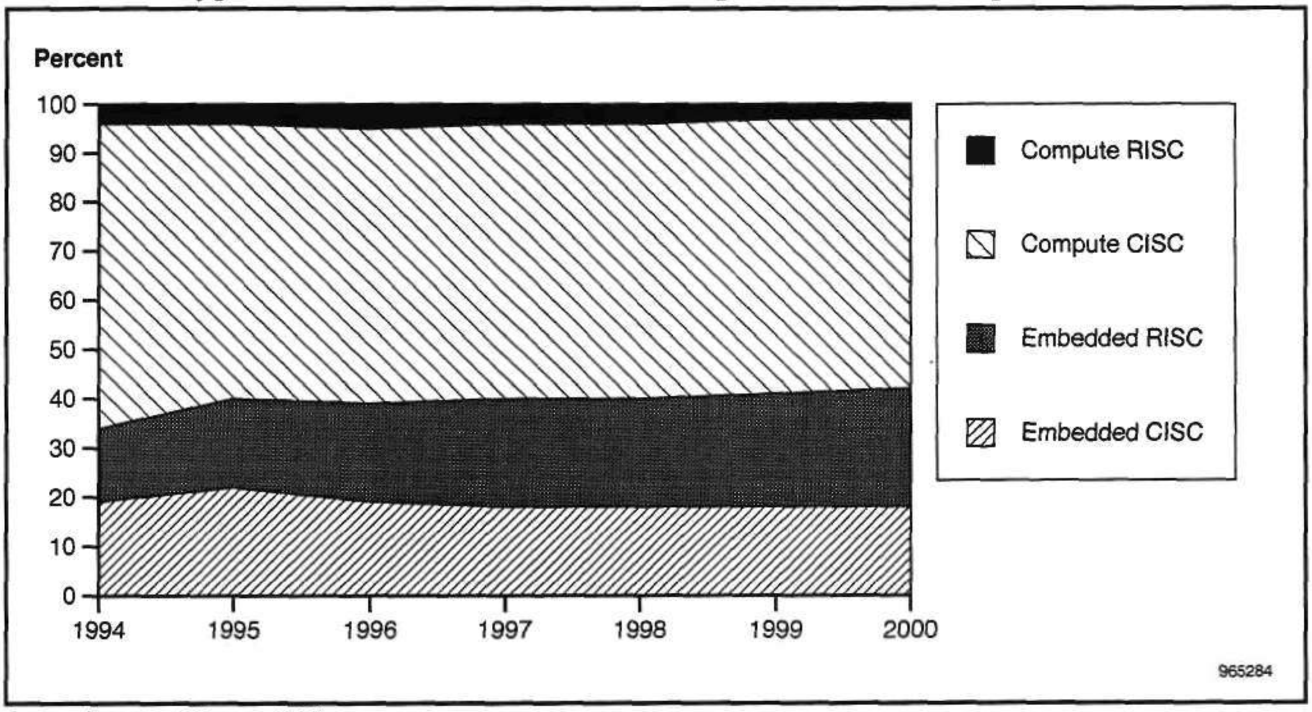
Source: Dataquest (August 1996)

Figure 4-27
32-Bit Microprocessor Revenue Forecast



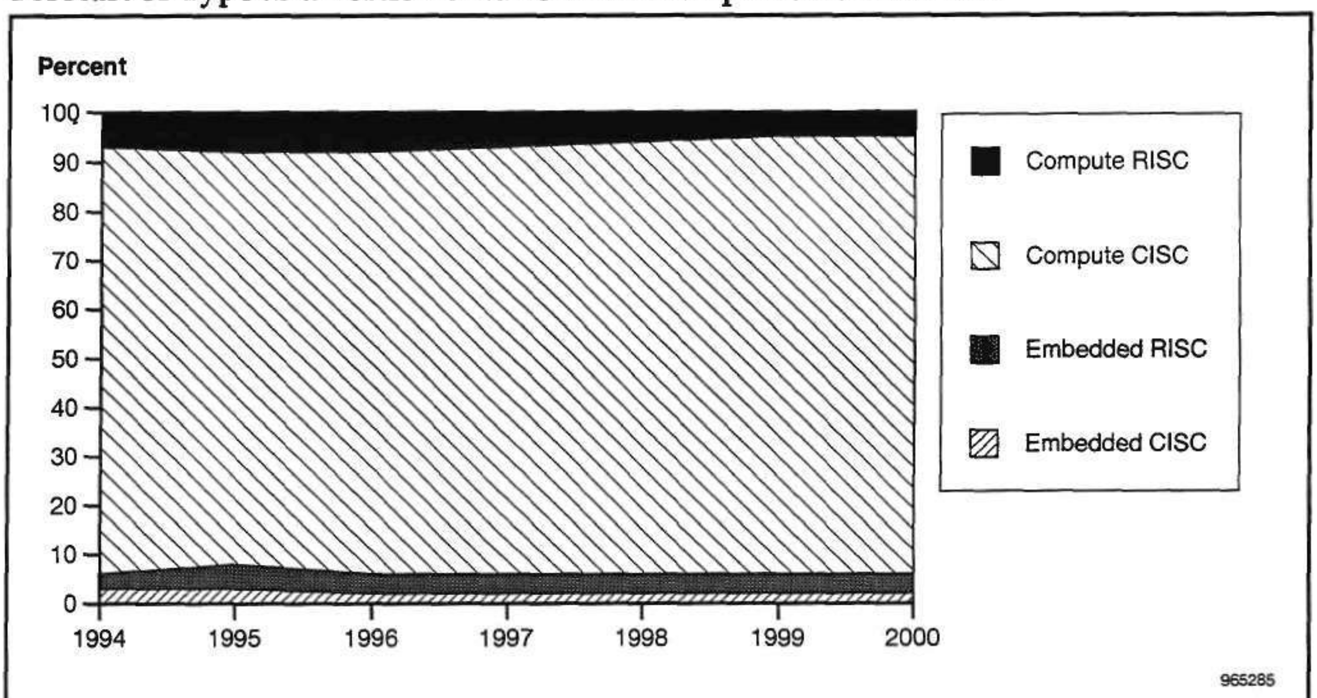
Source: Dataquest (August 1996)

Figure 4-28
Forecast of Type as a Portion of All 32-Bit Microprocessor Unit Shipments



Source: Dataquest (August 1996)

Figure 4-29
Forecast of Type as a Portion of All 32-Bit Microprocessor Revenue



Source: Dataquest (August 1996)

Appendix A
Definitions

Definitions

The following are some definitions that will be helpful in understanding this document better. Note that the definition of word width changed somewhat in 1996.

Unit shipments: This is the volume or number of finished units shipped by manufacturers to users, equipment manufacturers, or distributors. The units must include operating silicon and are generally assembled into packages, tested, and shipped in protective packaging. A manufacturer's own inventory is not included. Often reported in thousands (K) or millions (M) of units. Similar terms are units and volume.

Revenue: This is the total revenue value of the finished units shipped by manufacturers to users or distributors. In Dataquest's worldwide services, revenue is reported in equivalent U.S. dollars unless otherwise noted. Often reported in millions of dollars ($M) or billions of dollars ($B).

Average selling price (ASP): The ASP is the average price that a product sells for when considering all of the sales of the product in total, from very small quantities to large-volume orders. ASP is determined by dividing the total revenue derived from the sale of all of the category of product by the number of units that make up all of that category (ASP = revenue/units). It is quite possible that no sale of product ever takes place at a reported ASP. It is also possible that any one sale of product takes place at more than 50 percent variation from an ASP. ASPs are not intended to be manufacturers' suggested retail prices, one-piece prices, volume discount prices, or the best possible price. In Dataquest's worldwide services, ASPs are reported in equivalent U.S. dollars unless otherwise noted.

Compound annual growth rate (CAGR): This is a measure of the growth of an industry over time, usually a five-year span (N = 6). A positive number indicates a growing market. It is associated with revenue unless noted as units or ASP. CAGR is defined as follows and usually expressed as a percentage:

$$CAGR = \sqrt[N-1]{\frac{Value_{t=N}}{Value_{t=1}}} - 1$$

Microprocessor (MPU): An MPU is a MOS digital integrated circuit (IC) that includes an instruction decoder, arithmetic logic unit (ALU), registers, and additional logic. It may contain instruction, data, or unified caches, memory management systems, and auxiliary ALUs for floating point and other special data types. An MPU's functions are determined by fetching and executing instructions and manipulating data held in registers, internal cache, or external memory. MPUs operate out of external memory systems, typically ranging from 1MB to 64MB of RAM and often backed by secondary memory systems (like disks). More highly integrated versions of MPUs may contain on-chip peripheral, interface, and support circuits.

The MPU category includes MPUs incorporating or originating from an ASIC design. MPUs are divided into complex-instruction-set computing (CISC) or reduced-instruction-set computing (RISC) implementations having 8-bit, 16-bit, or 32-bit and greater word width. MPUs are designed into computational applications or into embedded applications. A similar term is processor.

Word width: The width, in bits, of the on-chip integer unit. This measurement is independent of the data bus width or any other bus associated with the device. Wider and narrower data types might be operated on by the processor, with multiple passes through the ALU or special hardware. Most microprocessors are 8 bits, 16 bits, or 32 bits wide. A similar term is bit size.

Computational applications: Computational applications of microprocessors are designed to be highly programmable by the end user while the manufacturer has only a vague idea of the final use of the system. The microprocessor is the central processor in the system, running an operating system performing task scheduling, system administration, and resource allocation according to the needs of the programs scheduled or initiated to execute. The programs are typically executed by the central processor, although they may be dispatched to subservient processors. The programs typically reside on mass storage media such as floppy disks or hard disks or may be downloaded over networks.

The programs executed from day to day may vary greatly according to the demands of the users of the product, so the system is designed to handle a wide variety of potential applications. The operating system might be DOS, Windows, UNIX, Mac OS, OS/2, Solaris, or any other OS, although it is rarely designed for real-time response. The application programs are normally computational in nature. Computational applications must be programmable by the end user in a higher-level language such as BASIC or FORTRAN. The most common computational applications are personal computers, workstations, and servers. Computational systems may have many embedded microcomponents in subsystems that support the central processor, such as the monitor, keyboard, mouse, disk drive, network interface, and modem, among others.

Embedded applications: Embedded applications of microprocessors are designed to perform a fixed set of functions once the system is shipped from the manufacturer. Those functions typically define the end product. The system may be reconfigurable by the end user but cannot be reprogrammed by a high-level language such as BASIC or FORTRAN. Usually the end user would not even know what type of processor was in the equipment.

The processor will typically run a real-time operating system (although real-time is not a requirement, nor is any OS) and a set of instructions that perform functions critical to the operation of the end product. Programs run by the processor may perform system monitoring, system control, data processing, peripheral interfacing, data movement, and motion control, among others. Programs often exist in ROM, although they may load from secondary storage, such as disks. Each processor or microcontroller in the system typically has a fairly narrow range of responsibilities.

Examples of embedded applications are many and varied but include feature phones, cellular phones, cellular infrastructure, telephone switches, bridges, routers, networking cards, modems, video games, arcade games, cameras, camcorders, VCRs, satellite receivers, remote controls, audio equipment (personal, home, and professional), keyboards, disk drives, CD drives, laser printers, other computer peripherals, medical instruments, motor control, industrial process control, robotics, engine control, airbags, antilock braking systems, and global positioning systems. Personal digital assistants (PDA) are also considered embedded, especially as they are used as exotic communications devices.

Appendix B

68000 Family Classification

Table B-1 lists key 68000 family products that are candidates for changing their category because of a refinement of Dataquest's definition of the word width of microprocessors, effective January 1, 1996. Table B-2 shows the result of the new division of 68000 products for shipments in 1994 and 1995. This breakdown of the 68000 family was not available previously.

Table B-1
Candidate Products for Changing Word Width Categories, All CISC, Previous and New Classification (Number of Bits)

Product	1995 MPU Category	1996 MPU Category
68000/EC000	32	16
68008/68010	32	16
68010	32	16
68020 and Later CPUs (030, 040, 060, and EC/LC Versions)	32	32
68000-Based Integrated Processors (68302, 6830x, 6832x, 68356, 68360)	32	16
CPU32-Based Integrated Processors (6833x, 6834x)	32	32
68F333		MCU 32[1]
Flexcore	32	16, 32[2]
ColdFire	32	32

[1]The 68F333 contains on-chip program memory and thus is an MCU.
[2]Flexcore products are classified according to their core processor and can be 16- or 32-bit MPUs.
Source: Dataquest (August 1996)

Table B-2
1994 and 1995 68000 Product Shipments, Apportioned into 16-Bit and 32-Bit Categories

	1994	1995
16-Bit 68000		
Units (K)	25,464	34,459
ASP ($)	7.45	6.50
Revenue ($M)	190	224
32-Bit 68000 Embedded		
Units (K)	9,860	18,874
ASP ($)	15.51	12.00
Revenue ($M)	153	226
32-Bit 68000 Compute		
Units (K)	4,298	1,113
ASP ($)	54.21	40.54
Revenue ($M)	233	45
Embedded 68000		
Units (K)	35,324	53,333
ASP ($)	9.70	8.45
Revenue ($M)	343	450
32-Bit 68000		
Units (K)	14,158	19,987
ASP ($)	27.26	13.59
Revenue ($M)	386	272
All 68000 Products		
Units (K)	39,622	54,446
ASP ($)	14.53	9.10
Revenue ($M)	576	496

Note: All 16-bit products go only into embedded applications. Numbers may not add to totals shown because of rounding.
Source: Dataquest (August 1996)

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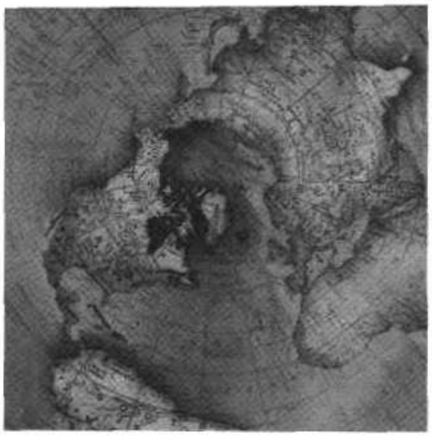

Dataquest

Semiconductor Five-Year Forecast Trends—Spring 1996

Market Trends

Program: Embedded Microcomponents Worldwide
Product Code: MCRO-WW-MT-9601
Publication Date: May 13, 1996
Filing: Market Trends

Semiconductor Five-Year Forecast Trends—Spring 1996

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Chapter 1
Introduction and Assumptions

Dataquest Semiconductor Group analysts provide a semiconductor device revenue forecast twice a year, in April and October. These revenue forecasts, which cover a five-year horizon, comprise forecasts for the major product families and the four main geographic semiconductor-consuming regions. This document, completed in April 1996, is the latest of these forecasts. Although revenue is subject to the vagaries of exchange rate variations, it is the most useful means to consolidate the forecasts of widely differing products and the most meaningful measure of markets and companies. Unit forecasts, which underlie the microcomponent and memory IC forecasts, are dollarized to arrive at the revenue forecast presented here. Average annual exchange rates are used for revenue history, and the most recent "average" exchange rate is extended into the five-year forecast horizon. Dataquest does not forecast exchange rates.

The forecast is presented in two local currencies in Appendixes A and B, in yen for the Japanese market forecast in Appendix A and in ECU for the European market forecast in Appendix B. The Americas market and the Asia/Pacific-ROW market are forecast only in U.S. dollars.

In 1996, the "North America" market has been expanded to include the total North and South America region and will be known as the "Americas" region from this point forward. This matches the divisions found in Dataquest's 1995 market share data.

Forecast Summary

The PC market, now the dominant market for semiconductors, grew nearly 26 percent in 1995. Semiconductors grew by 37 percent as demand continued to outstrip supply and DRAM average selling prices (ASPs) continued strong, at $25 per megabyte. DRAM revenue growth, which was 66 percent in 1993 and 60 percent in 1994, reached 81 percent in 1995. The brakes on this growth were applied early in 1996 as ASPs tumbled. The declining DRAM ASPs lead a number of factors that have aligned to take our 1996 forecast down to a surprising 7.6 percent growth. Beside DRAM, some other factors causing our 1996 forecast to drop under 8 percent are excess inventories, slowing markets, and a stronger yen. Inventory problems occurred as the fourth quarter PC market was well below expectations, leaving the first half of 1996 struggling with an inventory correction. Triggered by this correction, DRAM prices tumbled with prices per megabyte going from $25 in 1995 to under $15 early in 1996. Although we had anticipated DRAM price erosion in 1996, this price erosion occurred far sooner and faster than we had forecast last fall.

It is important to recognize that these corrections do not signal an evaporating market. Although the semiconductor end markets have slowed, they are still healthy. Dataquest's PC unit forecast for 1996 is still at 19 percent worldwide. If these problems were not severely impacting revenue, we would still be forecasting growth between 15 percent to 22 percent. Table 1-1 shows the impact of the major downside factors on our 1996 forecast.

Table 1-1
Changes in 1996 Forecast (Percent)

	October 1995 Forecast	This Forecast	Change to Dollar Growth (%)	Change to 1996 Worldwide Forecast (%)
DRAM Revenue Growth (%)	33	1*	-32	-8
Non-DRAM Product Growth (%)	18	14*	-4	-3
Yen/Dollar Exchange Rate	93.90	107.05	-12	-3
Total Growth in 1996 (%)	22.1	7.6	-14.5	-14.5

*Excludes change in yen/dollar exchange rate
Source: Dataquest (May 1996)

Both DRAM and Japan represent about one-fourth of the total semiconductor market, so their impact on the worldwide 1996 forecast shows up proportionately in the right column. If the 1996 yen-dollar exchange rate does not differ from 1995, the 3 percent change to the worldwide forecast would bring it back to double digits. If DRAM prices rebound more than expected, the growth could move the forecast up into the "normal" 15 percent range. This forecast is highly leveraged off of the fortunes of these two items.

Forecast Highlights

The following are the highlights of this forecast:

- Growth in 1996 drops under 8 percent after 37 percent growth in 1995.
- The PC market slows in 1996 to 19 percent unit growth versus 26 percent in 1995.
- The MPU market slows along with PC market. Price reductions bring 96 growth down to 17 percent.
- The DRAM price per bit will decline nearly 50 percent in 1996. Even with a high rate of bit growth, revenue growth will be nonexistent.
- Non-DRAM products will grow by 14 percent in 1996, growth consistent with historical rates.
- The Asia/Pacific regional market will exceed Japan in 1998 and will grow to 25 percent of the world market in 2000.
- The Americas forecast has decreased. Even with a 17 percent 1995 through 2000 compound annual growth rate (CAGR), the Americas will lose 1 percent of the world market (to 33.7 percent) by 1999 as Americas growth slows.
- Like the Americas, the European market's growth has been revised downward to a 17 percent CAGR from 1995 through 2000. Nonetheless, the European market share will remain at 18 percent over the forecast period.

We expect the semiconductor market to pass the $300 billion mark in 2000, as the adjustments seen in 1996 will not greatly impact the long-term growth of the market.

Exchange Rates

The following exchange rates are used for the 1994 through 1999 forecast:

- ¥107.05 per dollar
- ECU 0.774 per dollar

The following chapters will discuss the forecast by product and region in more detail.

Chapter 2
Worldwide Forecast by Product Family

The growth by product in 1995 as well as the past five-year CAGR and forecast 1995-through-2000 CAGR is shown in Table 2-1.

Memory ICs will show much slower growth as the five-year compounded growth rate of 16 percent brings memory IC growth back in line. Microcomponent growth, as well, will slow as the Americas market grows more slowly and prices stabilize. Logic ICs and analog ICs are settling into 14 percent growth rates, growth more consistent with the growth of electronic equipment markets. Discrete devices have gained greater growth potential with the lead of power and radio frequency (RF) transistors. Despite the growth potential of logic ICs, analog ICs, discrete devices, and optical semiconductors and the slowdown of memory IC growth, microcomponent and memory ICs will continue to increase their share of the semiconductor market at the expense of these other categories.

The tables on the following pages provide the complete five-year forecast by product type for the worldwide semiconductor market.

Worldwide Forecast Data

Tables 2-2 through 2-5 provide the five-year forecast by product type for the worldwide semiconductor market.

Table 2-1
Worldwide Semiconductor Growth by Product Type (Revenue in Millions of Dollars)

	1995 Revenue	1994-1995 Growth (%)	CAGR (%) 1990-1995 Actual	CAGR (%) 1995-2000 Forecast
Microcomponents	34,513	30.7	29.2	17.6
Memory Total	55,421	64.4	34.6	16.5
Logic/ASIC Total	22,961	22.0	13.5	13.8
Analog ICs	17,607	15.4	14.8	14.7
Monolithic IC Total	130,502	38.5	24.8	16.1
Hybrid ICs	1,935	16.2	8.5	1.4
Total ICs	132,437	38.2	24.4	15.9
Discrete Devices	14,023	30.3	12.8	11.6
Optical Semiconductors	4,811	23.7	14.8	12.1
Total Semiconductor	151,271	36.9	22.6	15.4

Source: Dataquest (May 1996)

Table 2-2
Worldwide Semiconductor Market, Six-Year Revenue History, 1990-1995 (Revenue in Millions of Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	9,584	11,774	14,359	19,947	26,408	34,513	29.2
Memory Total	12,559	13,197	15,626	23,550	33,704	55,421	34.6
Bipolar Memory	431	356	318	244	199	160	-18.0
MOS Memory	12,128	12,841	15,308	23,306	33,505	55,261	35.4
Logic/ASIC Total	12,182	12,972	12,918	15,956	18,821	22,961	13.5
Bipolar Logic	3,742	3,272	2,875	2,835	2,713	2,337	-9.0
MOS Logic	8,440	9,700	10,043	13,121	16,108	20,624	19.6
Analog ICs	8,845	9,517	10,180	12,513	15,263	17,607	14.8
Monolithic IC Total	43,170	47,460	53,083	71,966	94,196	130,502	24.8
Hybrid ICs	1,289	1,395	1,335	1,463	1,665	1,935	8.5
Total ICs	44,459	48,855	54,418	73,429	95,861	132,437	24.4
Discrete Devices	7,674	8,035	8,155	9,083	10,763	14,023	12.8
Optical Semiconductors	2,412	2,804	2,688	3,006	3,889	4,811	14.8
Total Semiconductor	54,545	59,694	65,261	85,518	110,513	151,271	22.6

Source: Dataquest (May 1996)

Table 2-3
Worldwide Semiconductor Market, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	34,513	39,945	46,524	54,885	65,532	77,645	17.6
Memory Total	55,421	55,749	64,213	75,098	93,666	118,680	16.5
Bipolar Memory	160	119	108	93	79	71	-15.0
MOS Memory	55,261	55,630	64,105	75,005	93,587	118,609	16.5
Logic/ASIC Total	22,961	24,910	27,692	31,906	37,212	43,748	13.8
Bipolar Logic	2,337	2,012	1,644	1,415	1,219	1,066	-14.5
MOS Logic	20,624	22,898	26,048	30,491	35,993	42,682	15.7
Analog ICs	17,607	19,562	21,698	25,147	29,531	34,911	14.7
Monolithic IC Total	130,502	140,166	160,127	187,036	225,941	274,984	16.1
Hybrid ICs	1,935	1,947	2,009	2,030	2,055	2,075	1.4
Total ICs	132,437	142,113	162,136	189,066	227,996	277,059	15.9
Discrete Devices	14,023	15,300	16,517	18,481	21,044	24,251	11.6
Optical Semiconductors	4,811	5,199	5,588	6,286	7,207	8,526	12.1
Total Semiconductor	151,271	162,612	184,241	213,833	256,247	309,836	15.4

Source: Dataquest (May 1996)

Table 2-4
Worldwide Semiconductor Market, Historic Revenue Growth, 1990-1995 (Percentage Revenue Growth over Preceding Year)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	22.7	22.9	22.0	38.9	32.4	30.7	29.2
Memory Total	-20.8	5.1	18.4	50.7	43.1	64.4	34.6
Bipolar Memory	-6.3	-17.4	-10.7	-23.3	-18.4	-19.6	-18.0
MOS Memory	-21.3	5.9	19.2	52.2	43.8	64.9	35.4
Logic/ASIC Total	3.4	6.5	-0.4	23.5	18.0	22.0	13.5
Bipolar Logic	-2.9	-12.6	-12.1	-1.4	-4.3	-13.9	-9.0
MOS Logic	6.5	14.9	3.5	30.6	22.8	28.0	19.6
Analog ICs	13.5	7.6	7.0	22.9	22.0	15.4	14.8
Monolithic IC Total	-0.2	9.9	11.8	35.6	30.9	38.5	24.8
Hybrid ICs	-5.8	8.2	-4.3	9.6	13.8	16.2	8.5
Total ICs	-0.3	9.9	11.4	34.9	30.5	38.2	24.4
Discrete Devices	4.8	4.7	1.5	11.4	18.5	30.3	12.8
Optical Semiconductors	0.2	16.3	-4.1	11.8	29.4	23.7	14.8
Total Semiconductor	0.4	9.4	9.3	31.0	29.2	36.9	22.6

Source: Dataquest (May 1996)

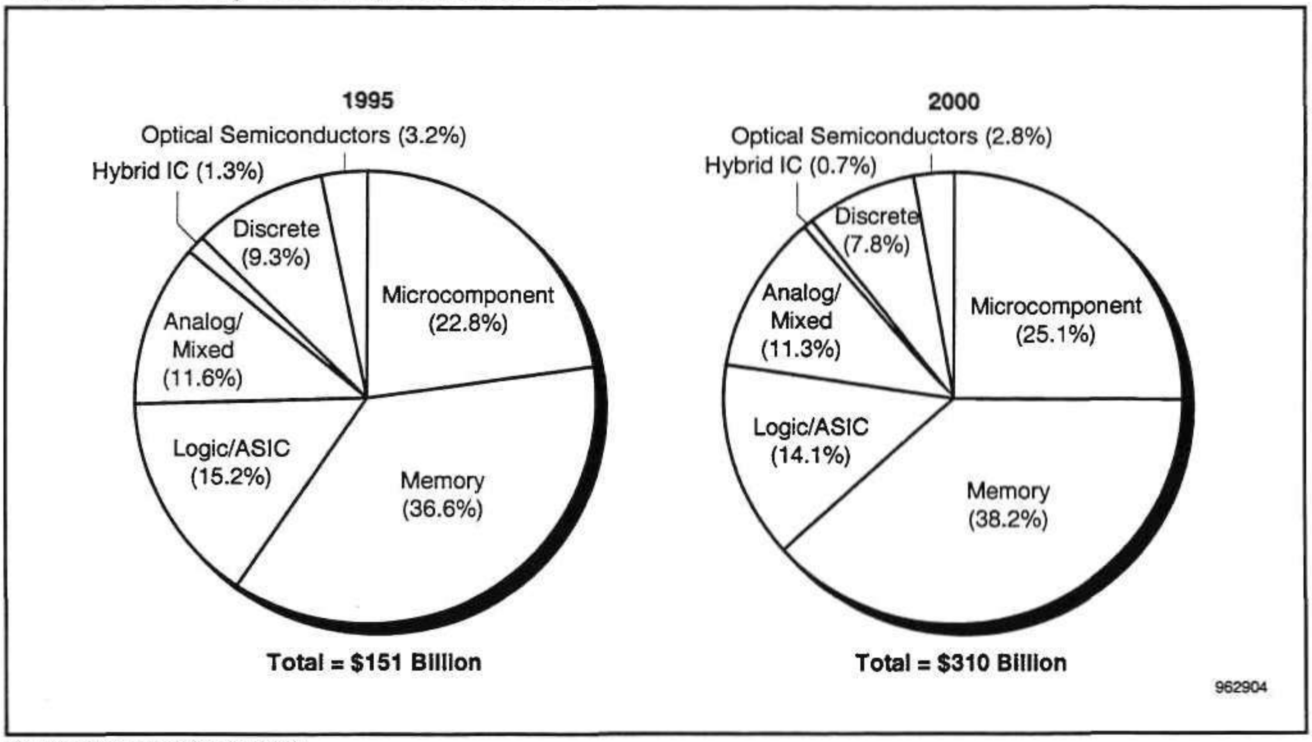
Table 2-5
Worldwide Semiconductor Market, Forecast Five-Year Revenue Growth (Percentage Revenue Growth over Preceding Year)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	30.7	16.1	16.5	18.0	19.4	18.5	17.6
Memory Total	64.4	0.6	15.2	17.0	24.7	26.7	16.5
Bipolar Memory	-19.6	-25.6	-9.2	-13.9	-15.1	-10.1	-15.0
MOS Memory	64.9	0.7	15.2	17.0	24.8	26.7	16.5
Logic/ASIC Total	22.0	8.5	11.2	15.2	16.6	17.6	13.8
Bipolar Logic	-13.9	-13.9	-18.3	-13.9	-13.9	-12.6	-14.5
MOS Logic	28.0	11.0	13.8	17.1	18.0	18.6	15.7
Analog ICs	15.4	11.1	10.9	15.9	17.4	18.2	14.7
Monolithic IC Total	38.5	7.5	14.2	16.8	20.8	21.7	16.1
Hybrid ICs	16.2	0.6	3.2	1.0	1.2	1.0	1.4
Total ICs	38.2	7.4	14.1	16.6	20.6	21.5	15.9
Discrete Devices	30.3	9.1	8.0	11.9	13.9	15.2	11.6
Optical Semiconductors	23.7	8.1	7.5	12.5	14.7	18.3	12.1
Total Semiconductor	36.9	7.6	13.3	16.1	19.8	20.9	15.4

Source: Dataquest (May 1996)

The impact of these varying rates of growth by product is shown in Figure 2-1. In 1995, the PC-driven combination of microcomponent and memory ICs gained market share rapidly, going from 54 percent of the worldwide market in 1994 to almost 60 percent of the market in 1995. In 1992, memory and microcomponent ICs combined to share only 46 percent of the semiconductor market. This gain in market share driven by PC growth will slow. As the figure shows, memories and microcomponents will only gain a 3 percent share in the coming five-year period, after gaining 12 percent in the past five years. All other semiconductor categories, logic ICs, analog ICs, discrete devices and optical semiconductors, will lose market share, but at a slower pace than in the past.

Figure 2-1
Market Share by Product, 1995 and 2000



Source: Dataquest (May 1996)

Chapter 3
Worldwide Semiconductor Forecast by Region

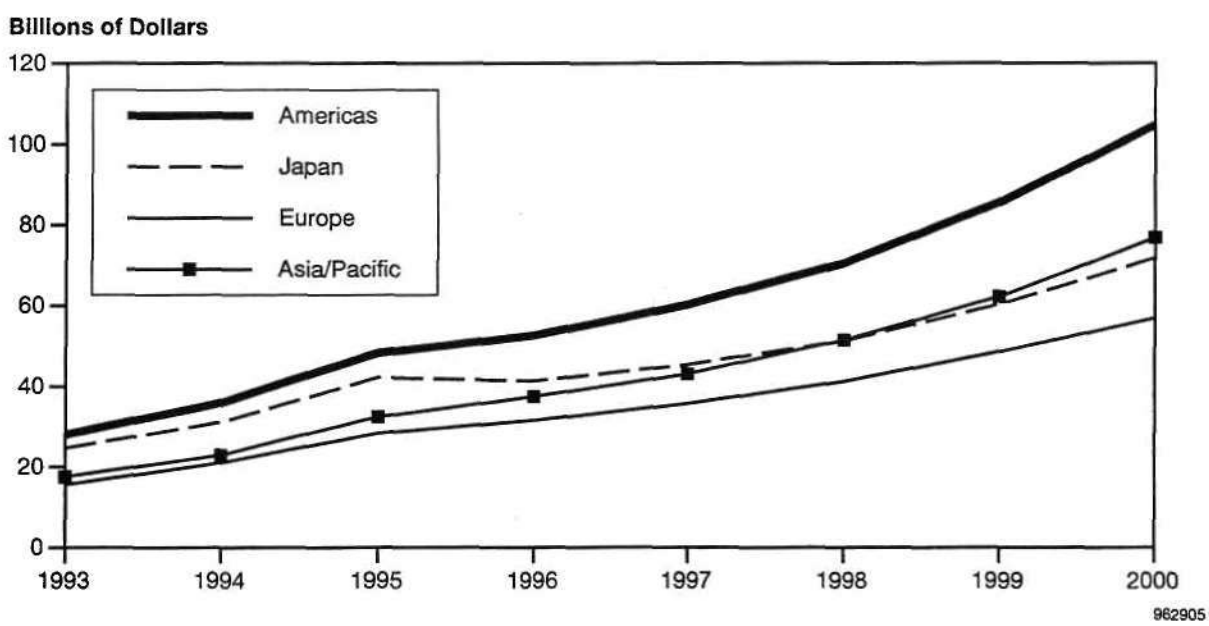
The worldwide revenue forecast is broken into the four constituent regional revenue shipment forecasts in Figure 3-1. A significant feature of this figure is the passing of Japan by Asia/Pacific in revenue by 1998.

The 1993-through-1995 period showed remarkable consistency in the growth of all regions; the three-year compounded growth rates for the Americas, Japan, Europe, and Asia/Pacific regions were 33 percent, 27 percent, 32 percent, and 39 percent, respectively. In the coming five years, these growth rates will drop by half, and regional differences will become more pronounced. Although we have forecast differing growth rates by region, the forecast still does not suggest a major downturn in the coming five years, only a period of adjustment. The negative growth shown for Japan in 1996 is because of an expected dollar devaluation; the growth would be nearly 12 percent in yen.

The regional revenue data for the five-year semiconductor forecast is listed in Table 3-1 and the annual growth by region in Table 3-2.

The effect of this forecast on the share of the total market by region is provided in Figure 3-2, where the lower anticipated growth for the Japanese market results in a continuing decline of the Japanese market share of the total market. The decline in the Japanese market is neatly mirrored by the rise in the Asia/Pacific market; these changes are tightly related with the shift of Japanese manufacturing to Asia/Pacific sites enhancing the growth of Asian markets.

Figure 3-1
Semiconductor History and Forecast by Region



Source: Dataquest (May 1996)

Table 3-1
Total Semiconductor Consumption by Region, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	48,349	52,478	60,217	70,352	85,481	104,579	16.7
Japan	42,164	41,244	45,286	51,144	60,212	71,693	11.2
Europe	28,341	31,479	35,734	41,079	48,433	56,828	14.9
Asia/Pacific	32,417	37,411	43,004	51,258	62,121	76,736	18.8
Semiconductor Total	151,271	162,612	184,241	213,833	256,247	309,836	15.4

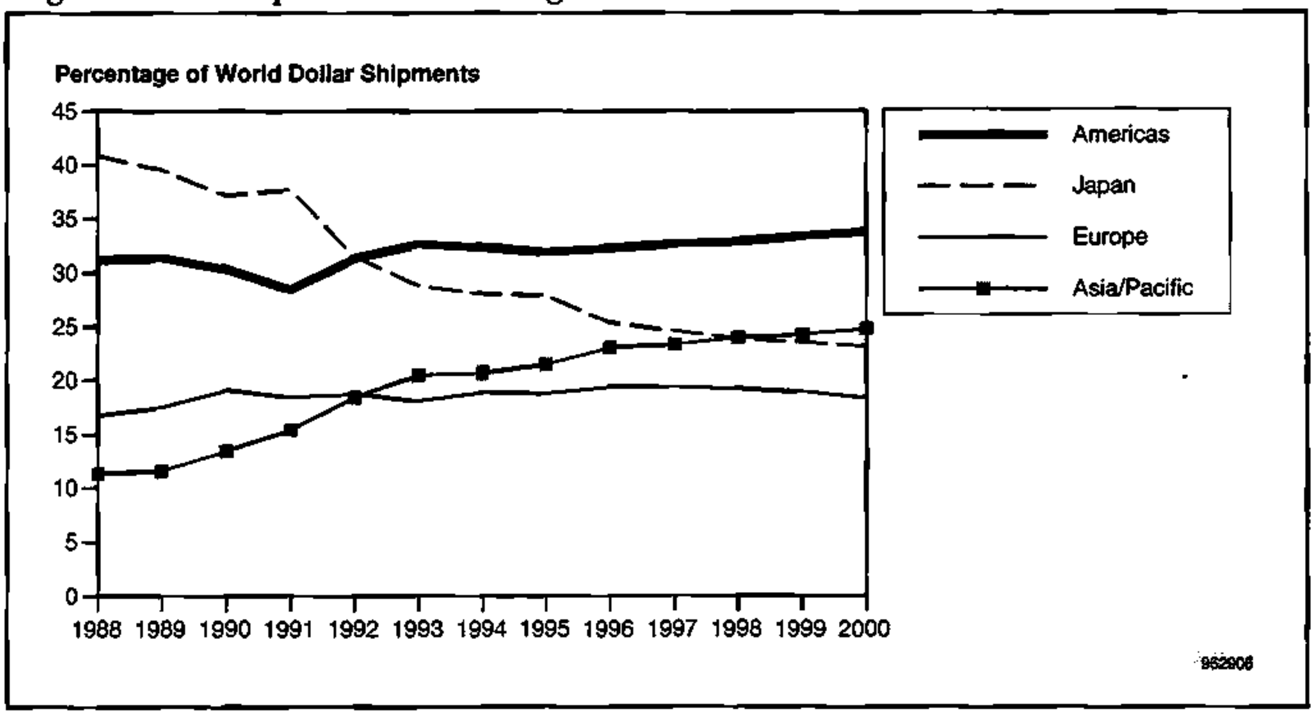
Source: Dataquest (May 1996)

Table 3-2
Total Semiconductor Growth Forecast by Region (Percentage Revenue Growth over Preceding Year)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	35.2	8.8	14.7	16.8	21.5	22.3	16.7
Japan	36.0	-2.2	9.8	12.9	17.7	19.1	11.2
Europe	35.6	11.1	13.5	15.0	17.9	17.3	14.9
Asia/Pacific	42.0	15.4	15.0	19.2	21.2	23.5	18.8
Semiconductor Total	36.9	7.6	13.3	16.1	19.8	20.9	15.4

Source: Dataquest (May 1996)

Figure 3-2
Regional Consumption as a Percentage of Total



Source: Dataquest (May 1996)

Chapter 4
Americas Forecast by Product Family

The five-year forecast for the Americas market (the more inclusive successor to the North America region) is based on the following assumptions:

- The Americas PC market is slowing. Windows 95 didn't materialize as *the* strong driver of growth. Many businesses are waiting for Windows NT before the next big hardware/software upgrade cycle. This slowing of PC demand in the business community coupled with a saturation of the home PC market has left the forecast unit growth in 1996 at 13 percent. The lowered growth expectation has impacted all PC-related business (more than 50 percent of the Americas semiconductor market).
- Pentium processors pushed up microprocessor (MPU) revenue strongly in 1995. With Intel's Pentium price reductions, a slowing Americas market, and no looming Pentium Pro changeover in 1996, MPU market growth is expected to drop to about half of 1995's 24 percent growth.
- High-ASP semiconductors, such as x86 processors and single in-line memory modules (SIMMs), will continue to be strongly consumed in the Americas and added to PCs or motherboards manufactured in the Asia/Pacific region.
- Price reductions in Pentium processors and free-falling DRAM prices will accelerate the consumption of higher-performance MPUs and larger DRAM configurations. The same money will buy twice the PC in 1996; a prospect that may develop new customers but that also runs the risk of alienating home PC consumers who may tire of the treadmill nature of PC buying and six-month obsolescence.
- Because of the strong computer market, microcomponent and memory ICs grew from 61 percent of semiconductor revenue in the Americas market in 1994 to 68 percent in 1995, a somewhat unnatural spurt of growth that will not be repeated in 1996. We expect this share to drop to 67 percent in 1996, because memory IC revenue growth will lag all other major device families. By the year 2000, microcomponent and memory ICs will account for 70 percent of semiconductor revenue in the Americas, a slow ramp from 1995's 68 percent.
- DRAM price-per-bit declines of 40 percent to 50 percent will be offset by increased bit demand, but this will barely keep DRAM revenue growth positive in 1996.
- Discrete device growth (22 percent in 1994 and 30 percent in 1995) increasingly comes from the use of power MOS field-effect transistors (MOSFETs) and insulated gate bipolar transistors (IGBTs) in switching power supplies and peripheral drivers and the increasing use of RF devices. MOSFETs and IGBTs showed 37 percent and 59 percent growth in 1995, respectively. These devices will continue to post double-digit growth in 1996.

Tables 4-1 through 4-4 provide details of the Americas semiconductor market.

Table 4-1
Americas Semiconductor Market, Six-Year Revenue History, 1990-1995 (Revenue in Millions of Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	3,381	3,916	5,282	7,620	9,839	12,421	29.7
Memory Total	4,485	4,641	5,837	8,868	12,535	20,530	35.6
Bipolar Memory	160	131	130	83	66	55	-19.2
MOS Memory	4,325	4,510	5,707	8,785	12,469	20,475	36.5
Logic/ASIC Total	4,101	4,070	4,287	5,549	6,323	7,528	12.9
Bipolar Logic	1,417	1,200	1,102	1,090	901	741	-12.2
MOS Logic	2,684	2,870	3,185	4,459	5,422	6,787	20.4
Analog ICs	2,404	2,397	2,689	3,304	3,820	3,995	10.7
Monolithic IC Total	14,371	15,024	18,095	25,341	32,517	44,474	25.3
Hybrid ICs	245	245	309	288	347	378	9.1
Total ICs	14,616	15,269	18,404	25,629	32,864	44,852	25.1
Discrete Devices	1,611	1,389	1,603	1,811	2,212	2,870	12.2
Optical Semiconductors	313	332	423	486	697	627	14.9
Total Semiconductor	16,540	16,990	20,430	27,926	35,773	48,349	23.9

Source: Dataquest (May 1996)

Table 4-2
Americas Semiconductor Market, Five-Year Revenue Forecast 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	12,421	14,073	16,182	18,779	21,950	25,575	15.5
Memory Total	20,530	21,145	24,297	28,647	36,710	47,307	18.2
Bipolar Memory	55	40	33	27	20	17	-20.9
MOS Memory	20,475	21,105	24,264	28,620	36,690	47,290	18.2
Logic/ASIC Total	7,528	8,400	9,581	11,074	12,887	15,320	15.3
Bipolar Logic	741	675	576	504	422	360	-13.4
MOS Logic	6,787	7,725	9,005	10,570	12,465	14,960	17.1
Analog ICs	3,995	4,575	5,315	6,232	7,329	8,652	16.7
Monolithic IC Total	44,474	48,193	55,375	64,732	78,876	96,854	16.8
Hybrid ICs	378	345	352	370	385	400	1.1
Total ICs	44,852	48,538	55,727	65,102	79,261	97,254	16.7
Discrete Devices	2,870	3,225	3,650	4,190	4,895	5,700	14.7
Optical Semiconductors	627	715	840	1,060	1,325	1,625	21.0
Total Semiconductor	48,349	52,478	60,217	70,352	85,481	104,579	16.7

Source: Dataquest (May 1996)

Table 4-3
Americas Semiconductor Market, Historic Revenue Growth, 1990-1995 (Percentage Revenue Growth over Preceding Year)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	20.9	15.8	34.9	44.3	29.1	26.2	29.7
Memory Total	-24.6	3.5	25.8	51.9	41.4	63.8	35.6
Bipolar Memory	-11.1	-18.1	-0.8	-36.2	-20.5	-16.7	-19.2
MOS Memory	-25.1	4.3	26.5	53.9	41.9	64.2	36.5
Logic/ASIC Total	5.8	-0.8	5.3	29.4	13.9	19.1	12.9
Bipolar Logic	-2.6	-15.3	-8.2	-1.1	-17.3	-17.8	-12.2
MOS Logic	10.9	6.9	11.0	40.0	21.6	25.2	20.4
Analog ICs	8.0	-0.3	12.2	22.9	15.6	4.6	10.7
Monolithic IC Total	-3.2	4.5	20.4	40.0	28.3	36.8	25.3
Hybrid ICs	-3.5	0	26.1	-6.8	20.5	8.9	9.1
Total ICs	-3.2	4.5	20.5	39.3	28.2	36.5	25.1
Discrete Devices	-1.7	-13.8	15.4	13.0	22.1	29.7	12.2
Optical Semiconductors	-4.9	6.1	27.4	14.9	43.4	-10.0	14.9
Total Semiconductor	-3.1	2.7	20.2	36.7	28.1	35.2	23.9

Source: Dataquest (May 1996)

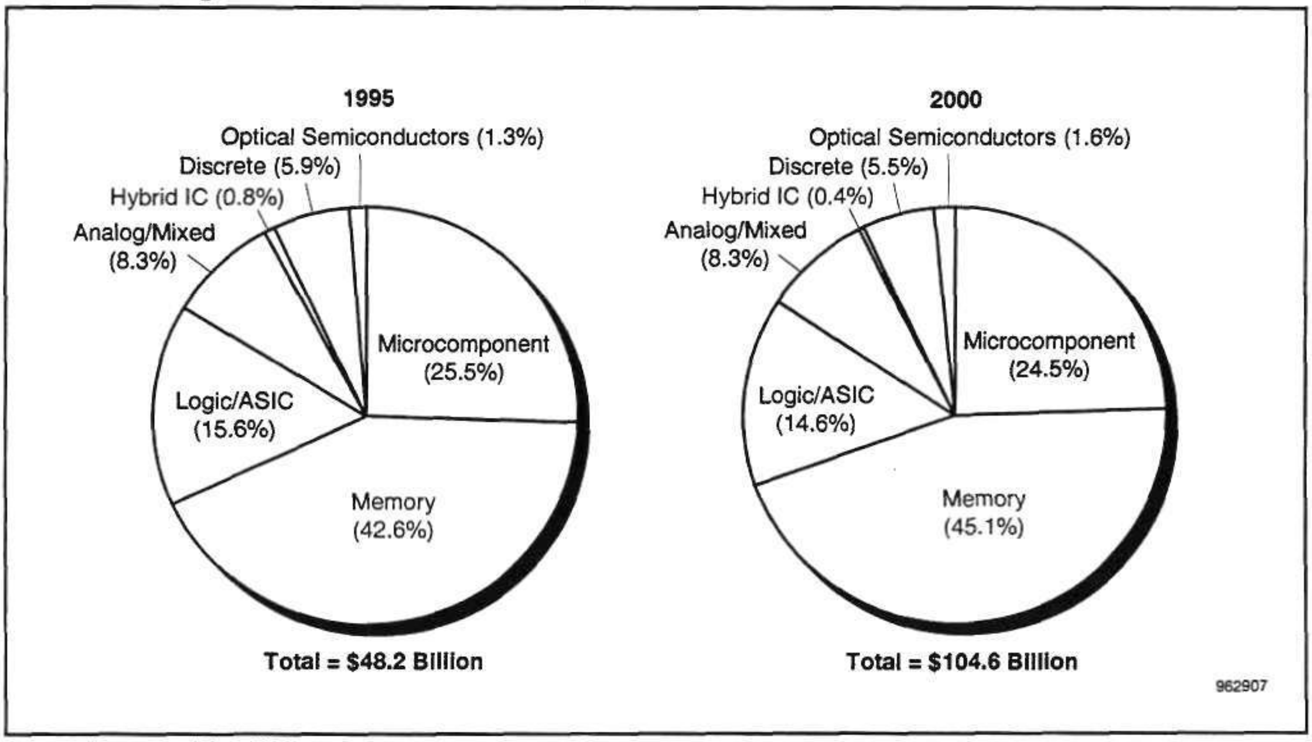
Table 4-4
Americas Semiconductor Market, Forecast Five-Year Revenue Growth (Percentage Revenue Growth over Preceding Year)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	26.2	14.2	15.0	16.0	16.9	16.5	15.5
Memory Total	63.8	3.0	14.9	17.9	28.1	28.9	18.2
Bipolar Memory	-16.7	-27.3	-17.5	-18.2	-25.9	-15.0	-20.9
MOS Memory	64.2	3.1	15.0	18.0	28.2	28.9	18.2
Logic/ASIC Total	19.1	11.6	14.1	15.6	16.4	18.9	15.3
Bipolar Logic	-17.8	-8.9	-14.7	-12.5	-16.3	-14.7	-13.4
MOS Logic	25.2	13.8	16.6	17.4	17.9	20.0	17.1
Analog ICs	4.6	14.5	16.2	17.3	17.6	18.1	16.7
Monolithic IC Total	36.8	8.6	14.9	16.9	21.9	22.8	16.8
Hybrid ICs	8.9	-8.7	2.0	5.1	4.1	3.9	1.1
Total ICs	36.5	8.5	14.8	16.8	21.7	22.7	16.7
Discrete Devices	29.7	12.4	13.2	14.8	16.8	16.4	14.7
Optical Semiconductors	-10.0	14.0	17.5	26.2	25.0	22.6	21.0
Total Semiconductor	35.2	8.8	14.7	16.8	21.5	22.3	16.7

Source: Dataquest (May 1996)

The effect of the Americas forecast on the relative consumption by product is shown in Figure 4-1. With 68 percent of the revenue in the Americas stemming from microcomponents and memories, the Americas market is highly dependent on the health of data processing. With lowered growth expectations in these two product types, we expect that market shares will hold more constant than in the past, with microcomponents actually losing 1 percent over the next five years. Logic ICs will lose a 1 percent share as bipolar logic declines.

Figure 4-1
Product Comparison, Americas Market, 1995 and 2000



Source: Dataquest (May 1996)

Chapter 5
Japan Forecast by Product Family

The five-year semiconductor forecast for the Japanese market is based on the following assumptions:

- Growth had been accelerating in Japan after the disastrous revenue decline in 1992, but this three-year growth period is slowing. A 36 percent dollar growth in 1995 will be followed by a 2 percent decline in 1996. Although the past three years have had dollar revenue enhancements because of the yen-to-dollar depreciation, the 1996 forecast includes a dollar appreciation of 14 percent, turning a 12 percent yen-based growth in 1996 to a 2 percent decline in dollars.
- The Japanese market is fundamentally sound. PC growth in Japan will drop from the 58 percent seen in 1995 to above 30 percent. The continued migration of electronic equipment manufacturing to Asia/Pacific sites is a factor that will reduce revenue growth over the forecast period, but this migration has been somewhat stunted by constraints in growing Asian infrastructures. The result of this migration is that the Japanese market will drop from 28 percent of worldwide shipments in 1994 to slightly over 23 percent in the year 2000, a lower loss of share than our past forecasts, because depreciation is expected to slow the rate of migration.
- Microcomponents will show Japan's strongest product growth in 1996 as the MPU category is dominated by the dollar-based x86 devices from Intel. The other product categories, more strongly supplied by domestic suppliers in yen-based revenue, are impacted by the devalued dollar exchange rate. The weak 1996/1995 growth of MCU, analog, optical semiconductor, and discrete is due to sluggish consumer equipment production.
- Microcomponents show the strongest five-year compounded growth in Japan. The 21 percent compounded growth forecast for PC shipments in Japan provides comparable growth for the MPU category.
- MCU, analog IC, and optical semiconductor growth in Japan will be reduced by the offshore production shift of consumer electronics, the biggest application for these devices in Japan.
- MOS memory revenue will decline by 16 percent in dollars (negative 4 percent in yen). Even with strong PC growth, the bit growth will be insufficient to bring revenue into positive growth as ASPs drop by half. DRAM consumption in Japan has been pumped up by robust growth in SIMM production, which will be impacted by any possible slowdown in worldwide PC shipments. Prices are weakening for other memory products like SRAM, flash, and MROMs.
- Optical semiconductors showed a 32 percent growth in 1995, a considerable increase over the 21 percent seen in 1994. An explosive increase in the consumption of optically oriented computer peripherals such as CD-ROM players, scanners, and laser/LED printers has helped to fuel this growth over the past two years. This growth will be blunted in 1996 and beyond as this multimedia frenzy slows. It is not expected that new growth opportunities in DVD will be seen in the optical semiconductor category until the end of the forecast period (the year 2000).

Tables 5-1 through 5-4 provide details on the Japanese semiconductor market.

Table 5-1
Japanese Semiconductor Market, Six-Year Revenue History, 1990-1995 (Revenue in Millions of Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	2,974	3,579	3,269	3,987	5,603	7,829	21.4
Memory Total	4,390	4,393	4,175	5,697	7,344	12,337	23.0
Bipolar Memory	194	165	138	127	98	82	-15.8
MOS Memory	4,196	4,228	4,037	5,570	7,246	12,255	23.9
Logic/ASIC Total	4,931	5,351	4,849	5,712	7,111	8,772	12.2
Bipolar Logic	1,441	1,277	1,016	1,001	1,118	988	-7.3
MOS Logic	3,490	4,074	3,833	4,711	5,993	7,784	17.4
Analog ICs	2,723	3,094	2,903	3,278	4,048	4,744	11.7
Monolithic IC Total	15,018	16,417	15,196	18,674	24,106	33,682	17.5
Hybrid ICs	776	860	750	820	889	1,034	5.9
Total ICs	15,794	17,277	15,946	19,494	24,995	34,716	17.1
Discrete Devices	2,969	3,432	3,077	3,423	3,916	4,681	9.5
Optical Semiconductors	1,494	1,787	1,556	1,728	2,097	2,767	13.1
Total Semiconductor	20,257	22,496	20,579	24,645	31,008	42,164	15.8

Source: Dataquest (May 1996)

Table 5-2
Japanese Semiconductor Market, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	7,829	8,558	10,130	12,001	14,286	16,934	16.7
Memory Total	12,337	10,409	11,853	13,481	17,163	22,162	12.4
Bipolar Memory	82	63	60	55	49	45	-11.3
MOS Memory	12,255	10,346	11,793	13,426	17,114	22,117	12.5
Logic/ASIC Total	8,772	8,934	9,663	10,919	12,501	14,180	10.1
Bipolar Logic	988	824	637	546	486	437	-15.1
MOS Logic	7,784	8,110	9,026	10,373	12,015	13,743	12.0
Analog ICs	4,744	4,801	4,846	5,331	5,922	6,612	6.9
Monolithic IC Total	33,682	32,702	36,492	41,732	49,872	59,888	12.2
Hybrid ICs	1,034	1,045	1,075	1,075	1,075	1,075	0.8
Total ICs	34,716	33,747	37,567	42,807	50,947	60,963	11.9
Discrete Devices	4,681	4,708	4,845	5,232	5,813	6,641	7.2
Optical Semiconductors	2,767	2,789	2,874	3,105	3,452	4,089	8.1
Total Semiconductor	42,164	41,244	45,286	51,144	60,212	71,693	11.2

Source: Dataquest (May 1996)

Table 5-3
Japanese Semiconductor Market, Historic Revenue Growth, 1990-1995 (Percentage Revenue Growth over Preceding Year)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	11.7	20.3	-8.7	22.0	40.5	39.7	21.4
Memory Total	-24.6	0.1	-5.0	36.5	28.9	68.0	23.0
Bipolar Memory	1.6	-14.9	-16.4	-8.0	-22.8	-16.3	-15.8
MOS Memory	-25.5	0.8	-4.5	38.0	30.1	69.1	23.9
Logic/ASIC Total	2.7	8.5	-9.4	17.8	24.5	23.4	12.2
Bipolar Logic	-1.1	-11.4	-20.4	-1.5	11.7	-11.6	-7.3
MOS Logic	4.3	16.7	-5.9	22.9	27.2	29.9	17.4
Analog ICs	-0.4	13.6	-6.2	12.9	23.5	17.2	11.7
Monolithic IC Total	-6.2	9.3	-7.4	22.9	29.1	39.7	17.5
Hybrid ICs	-7.7	10.8	-12.8	9.3	8.4	16.3	5.9
Total ICs	-6.3	9.4	-7.7	22.3	28.2	38.9	17.1
Discrete Devices	-3.6	15.6	-10.3	11.2	14.4	19.5	9.5
Optical Semiconductors	-3.7	19.6	-12.9	11.1	21.4	32.0	13.1
Total Semiconductor	-5.7	11.1	-8.5	19.8	25.8	36.0	15.8

Source: Dataquest (May 1996)

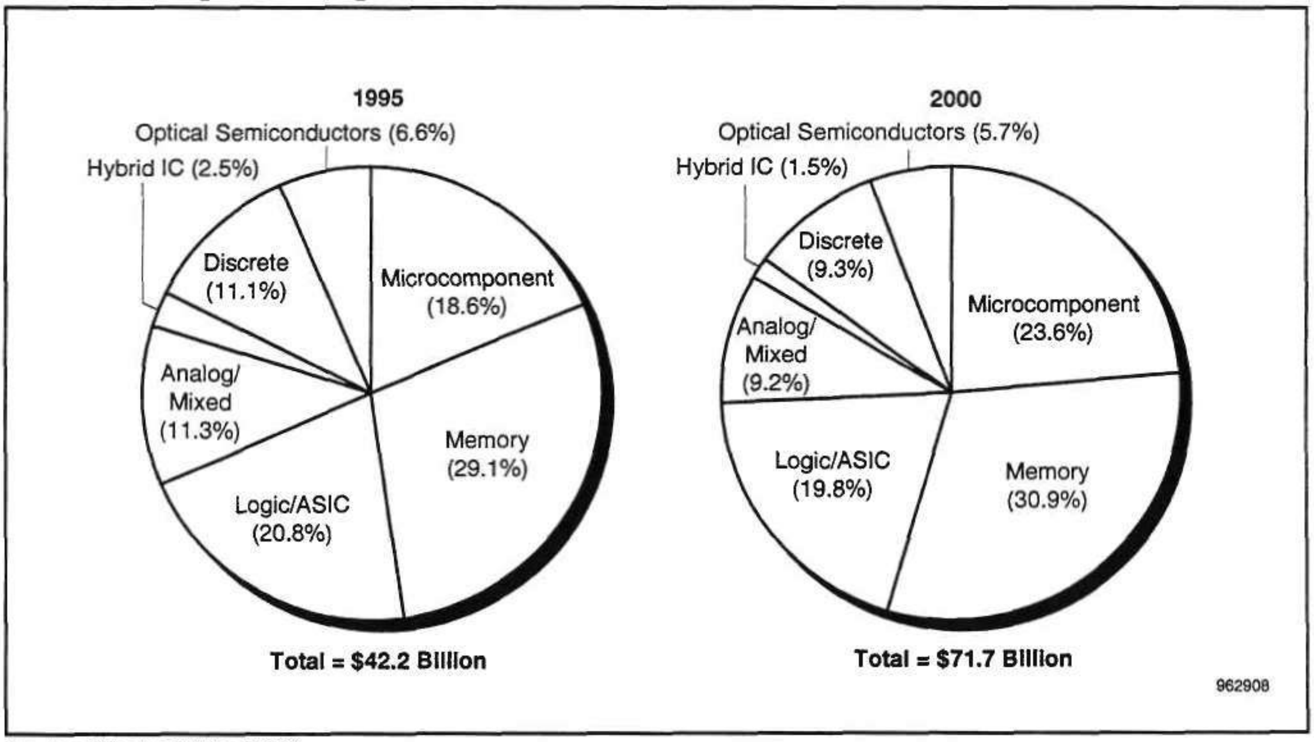
Table 5-4
Japanese Semiconductor Market, Forecast Five-Year Revenue Growth (Percentage Revenue Growth over Preceding Year)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	39.7	9.3	18.4	18.5	19.0	18.5	16.7
Memory Total	68.0	-15.6	13.9	13.7	27.3	29.1	12.4
Bipolar Memory	-16.3	-23.2	-4.8	-8.3	-10.9	-8.2	-11.3
MOS Memory	69.1	-15.6	14.0	13.8	27.5	29.2	12.5
Logic/ASIC Total	23.4	1.8	8.2	13.0	14.5	13.4	10.1
Bipolar Logic	-11.6	-16.6	-22.7	-14.3	-11.0	-10.1	-15.1
MOS Logic	29.9	4.2	11.3	14.9	15.8	14.4	12.0
Analog ICs	17.2	1.2	0.9	10.0	11.1	11.7	6.9
Monolithic IC Total	39.7	-2.9	11.6	14.4	19.5	20.1	12.2
Hybrid ICs	16.3	1.1	2.9	0	0	0	0.8
Total ICs	38.9	-2.8	11.3	13.9	19.0	19.7	11.9
Discrete Devices	19.5	0.6	2.9	8.0	11.1	14.2	7.2
Optical Semiconductors	32.0	0.8	3.0	8.0	11.2	18.5	8.1
Total Semiconductor	36.0	-2.2	9.8	12.9	17.7	19.1	11.2

Source: Dataquest (May 1996)

Figure 5-1 illustrates the effect of the Japanese market forecast on the relative consumption by product. The figure highlights three main trends. First, microcomponents are expected to track PC growth in Japan. Second, memory IC price erosion will hold memory growth down over the forecast period. Third, the non-DRAM, non-MPU devices will decline in market share as these devices increasingly move toward offshore equipment production. With a memory and microcomponent market share that is 20 percent less than that of the Americas, the Japanese market has had less dependence on the PC. Personal computers will make strong gains in the Japanese market in the coming years.

Figure 5-1
Product Comparison, Japanese Market, 1995 and 2000



Source: Dataquest (May 1996)

Chapter 6

Europe Forecast by Product Family

The five-year semiconductor forecast for the European market, shown on the following pages, is based on these assumptions:

- With two consecutive years of growth exceeding 35 percent, the European market has shown considerably more strength than we had expected. This growth, based on the PC and personal communications booms, is expected to moderate in 1996.
- The European PC market, which grew by 25 percent in 1995, is still expected to do more than 20 percent in 1996. Declining prices for DRAM will limit the semiconductor ride on this boom, however.
- DRAM revenue will be flat in 1996. Double-digit growth will return in 1997, although at a compounded rate below 20 percent. The more stable prices seen in 1997 will result in DRAM revenue growth consistent with PC unit growth (17 percent).
- MCU growth continued strongly into 1995, with revenue growth exceeding 40 percent. ASP erosion and a slowing of demand will limit revenue growth in 1996, and beyond, to less than 20 percent.
- Shortages in discrete products enhanced the market in 1994 and 1995 as ASPs were kept high. In 1995, a 45 percent annual growth more than doubled the 19 percent seen in 1994. Discrete growth will drop into lower growth in 1996 (10 percent) and beyond (11 percent CAGR, 1995 through 2000).

Tables 6-1 through 6-4 provide details on the European semiconductor market.

Figure 6-1 illustrates the consumption by product changes for the European market over the forecast period. Unlike past years of memory and microcomponent market incursion, the product mix remains fairly consistent over the forecast period. By the year 2000, microcomponents and memory ICs are expected to account for 62 percent of semiconductor shipment revenue, up slightly from the 60 percent of 1995. The growth in microcomponents derives from all segments of the microcomponent category, the MPUs and microperipherals (MPRs) in computers and the microcontroller (MCU) and digital signal processor (DSP) ICs used in communications and consumer products.

Table 6-1
European Semiconductor Market, Six-Year Revenue History, 1990-1995 (Revenue in Millions of Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	1,802	2,082	2,723	4,037	5,408	7,009	31.2
Memory Total	2,105	2,172	2,698	4,067	6,602	9,990	36.5
Bipolar Memory	55	43	38	27	28	19	-19.2
MOS Memory	2,050	2,129	2,660	4,040	6,574	9,971	37.2
Logic/ASIC Total	1,882	2,085	2,137	2,299	2,659	3,243	11.5
Bipolar Logic	510	443	388	363	329	291	-10.6
MOS Logic	1,372	1,642	1,749	1,936	2,330	2,952	16.6
Analog ICs	2,169	2,184	2,249	2,736	3,370	4,127	13.7
Monolithic IC Total	7,958	8,523	9,807	13,139	18,039	24,369	25.1
Hybrid ICs	157	178	151	179	178	239	8.8
Total ICs	8,115	8,701	9,958	13,318	18,217	24,608	24.8
Discrete Devices	1,895	1,828	1,826	1,769	2,108	3,053	10.0
Optical Semiconductors	405	485	434	374	575	680	10.9
Total Semiconductor	10,415	11,014	12,218	15,461	20,900	28,341	22.2

Source: Dataquest (May 1996)

Table 6-2
European Semiconductor Market, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	7,009	8,503	9,775	11,365	13,454	15,437	17.1
Memory Total	9,990	10,321	11,962	13,917	16,728	19,919	14.8
Bipolar Memory	19	13	13	10	9	8	-15.9
MOS Memory	9,971	10,308	11,949	13,907	16,719	19,911	14.8
Logic/ASIC Total	3,243	3,621	3,974	4,540	5,250	6,175	13.7
Bipolar Logic	291	251	203	174	151	134	-14.4
MOS Logic	2,952	3,370	3,771	4,366	5,099	6,041	15.4
Analog ICs	4,127	4,630	5,306	6,049	7,149	8,580	15.8
Monolithic IC Total	24,369	27,075	31,017	35,871	42,581	50,111	15.5
Hybrid ICs	239	249	245	248	258	263	1.9
Total ICs	24,608	27,324	31,262	36,119	42,839	50,374	15.4
Discrete Devices	3,053	3,367	3,603	3,985	4,491	5,178	11.1
Optical Semiconductors	680	788	869	975	1,103	1,276	13.4
Total Semiconductor	28,341	31,479	35,734	41,079	48,433	56,828	14.9

Source: Dataquest (May 1996)

Table 6-3
European Semiconductor Market, Historic Revenue Growth, 1990-1995 (Percentage Revenue Growth over Preceding Year)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	25.0	15.5	30.8	48.3	34.0	29.6	31.2
Memory Total	-15.4	3.2	24.2	50.7	62.3	51.3	36.5
Bipolar Memory	-22.5	-21.8	-11.6	-28.9	3.7	-32.1	-19.2
MOS Memory	-15.2	3.9	24.9	51.9	62.7	51.7	37.2
Logic/ASIC Total	-3.4	10.8	2.5	7.6	15.7	22.0	11.5
Bipolar Logic	-8.3	-13.1	-12.4	-6.4	-9.4	-11.6	-10.6
MOS Logic	-1.4	19.7	6.5	10.7	20.4	26.7	16.6
Analog ICs	39.4	0.7	3.0	21.7	23.2	22.5	13.7
Monolithic IC Total	7.0	7.1	15.1	34.0	37.3	35.1	25.1
Hybrid ICs	15.4	13.4	-15.2	18.5	-0.6	34.3	8.8
Total ICs	7.2	7.2	14.4	33.7	36.8	35.1	24.8
Discrete Devices	20.4	-3.5	-0.1	-3.1	19.2	44.8	10.0
Optical Semiconductors	14.4	19.8	-10.5	-13.8	53.7	18.3	10.9
Total Semiconductor	9.7	5.8	10.9	26.5	35.2	35.6	22.2

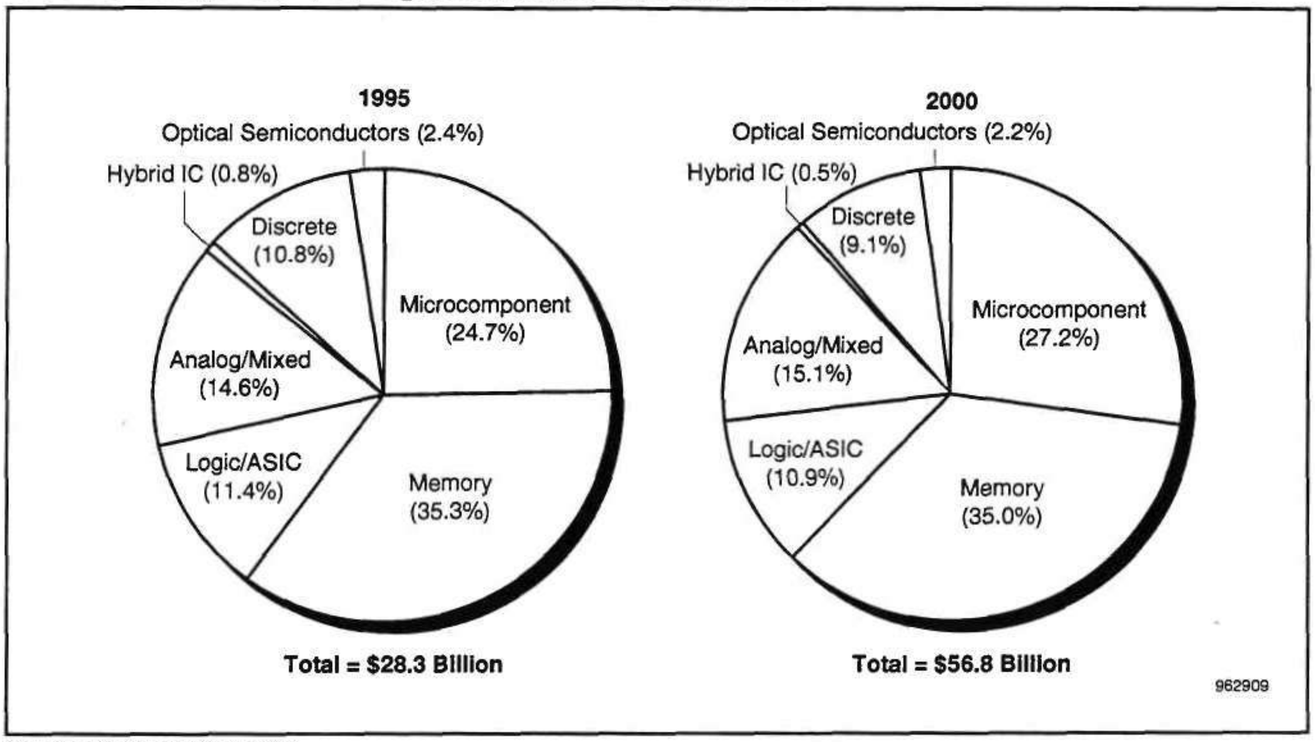
Source: Dataquest (May 1996)

Table 6-4
European Semiconductor Market, Forecast Five-Year Revenue Growth (Percentage Revenue Growth over Preceding Year)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	29.6	21.3	15.0	16.3	18.4	14.7	17.1
Memory Total	51.3	3.3	15.9	16.3	20.2	19.1	14.8
Bipolar Memory	-32.1	-31.6	0	-23.1	-10.0	-11.1	-15.9
MOS Memory	51.7	3.4	15.9	16.4	20.2	19.1	14.8
Logic/ASIC Total	22.0	11.7	9.7	14.2	15.6	17.6	13.7
Bipolar Logic	-11.6	-13.7	-19.1	-14.3	-13.2	-11.3	-14.4
MOS Logic	26.7	14.2	11.9	15.8	16.8	18.5	15.4
Analog ICs	22.5	12.2	14.6	14.0	18.2	20.0	15.8
Monolithic IC Total	35.1	11.1	14.6	15.6	18.7	17.7	15.5
Hybrid ICs	34.3	4.2	-1.6	1.2	4.0	1.9	1.9
Total ICs	35.1	11.0	14.4	15.5	18.6	17.6	15.4
Discrete Devices	44.8	10.3	7.0	10.6	12.7	15.3	11.1
Optical Semiconductors	18.3	15.9	10.3	12.2	13.1	15.7	13.4
Total Semiconductor	35.6	11.1	13.5	15.0	17.9	17.3	14.9

Source: Dataquest (May 1996)

Figure 6-1
Product Comparison, European Market, 1995 and 2000



Source: Dataquest (May 1996)

Chapter 7

Asia/Pacific Forecast by Product Family

The five-year forecast for the Asia/Pacific region shown on the following pages is based on the following assumptions:

- The PC business was slower than expected in 1995 and will slow again in 1996. DRAM, SRAM, and MPU growth have been reduced in 1996. The combined MOS memory growth will decline to 10 percent after 74 percent in 1995. Microcomponent growth will drop from 30 percent in 1995 to 21 percent in 1996.
- Decreasing ASPs, down 40 percent over those of 1995, will offset much of the bit growth in Asia/Pacific, reducing DRAM revenue growth below 10 percent in 1996.
- SRAM ASPs are declining, but not falling. SRAM revenue growth will drop to less than half of the 60 percent growth seen in 1995.
- Asia/Pacific's microprocessor market is almost totally dominated by x86 architectures. With ever-shortening PC life cycles, most PC products are shipped without the MPU on-board—92 percent of motherboards, 83 percent of desktop PCs, and 80 percent of notebook computers from Taiwan are shipped this way. This trend will continue over the forecast period.
- China and the southern Asia/Pacific regions have shown strong growth in telecom and consumer equipment. High-end telecommunications equipment is being built in China, and the shipment of pagers and cellular phones continues to expand.
- A strengthening yen continues to drive electronic equipment production out of Japan and into the Asia/Pacific region. This production shift enhances the Asia/Pacific growth that comes with the growth of its own consuming markets. As a semiconductor consuming region, Asia/Pacific will pass Japan in 1998.

Tables 7-1 through 7-4 provide details on the Asia/Pacific semiconductor market.

Figure 7-1 shows the impact of the five-year product forecast on the relative shares of the total Asia/Pacific market. The combined memory-microcomponent IC share increased from 56 percent of the market in 1994 to 61 percent in 1995. Like the three other geographical regions, Asia/Pacific will see little gain in the memory-microcomponent market (to 64 percent in 2000) as prices correct and the PC market slows. Analog and logic ICs, less affected by price erosion, will maintain market position.

Table 7-1
Asia/Pacific Semiconductor Market, Six-Year Revenue History, 1990-1995 (Revenue in Millions of Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	1,427	2,197	3,085	4,303	5,558	7,254	38.4
Memory Total	1,579	1,991	2,916	4,918	7,223	12,564	51.4
Bipolar Memory	22	17	12	7	7	4	-28.9
MOS Memory	1,557	1,974	2,904	4,911	7,216	12,560	51.8
Logic/ASIC Total	1,268	1,466	1,645	2,396	2,728	3,418	21.9
Bipolar Logic	374	352	369	381	365	317	-3.3
MOS Logic	894	1,114	1,276	2,015	2,363	3,101	28.2
Analog ICs	1,549	1,842	2,339	3,195	4,025	4,741	25.1
Monolithic IC Total	5,823	7,496	9,985	14,812	19,534	27,977	36.9
Hybrid ICs	111	112	125	176	251	284	20.7
Total ICs	5,934	7,608	10,110	14,988	19,785	28,261	36.6
Discrete Devices	1,199	1,386	1,649	2,080	2,527	3,419	23.3
Optical Semiconductors	200	200	275	418	520	737	29.8
Total Semiconductor	7,333	9,194	12,034	17,486	22,832	32,417	34.6

Source: Dataquest (May 1996)

Table 7-2
Asia/Pacific Semiconductor Market, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	7,254	8,811	10,437	12,740	15,842	19,699	22.1
Memory Total	12,564	13,874	16,101	19,053	23,065	29,292	18.4
Bipolar Memory	4	3	2	1	1	1	-24.2
MOS Memory	12,560	13,871	16,099	19,052	23,064	29,291	18.5
Logic/ASIC Total	3,418	3,955	4,474	5,373	6,574	8,073	18.8
Bipolar Logic	317	262	228	191	160	135	-15.7
MOS Logic	3,101	3,693	4,246	5,182	6,414	7,938	20.7
Analog ICs	4,741	5,556	6,231	7,535	9,131	11,067	18.5
Monolithic IC Total	27,977	32,196	37,243	44,701	54,612	68,131	19.5
Hybrid ICs	284	308	337	337	337	337	3.5
Total ICs	28,261	32,504	37,580	45,038	54,949	68,468	19.4
Discrete Devices	3,419	4,000	4,419	5,074	5,845	6,732	14.5
Optical Semiconductors	737	907	1,005	1,146	1,327	1,536	15.8
Total Semiconductor	32,417	37,411	43,004	51,258	62,121	76,736	18.8

Source: Dataquest (May 1996)

Table 7-3
Asia/Pacific Semiconductor Market, Historic Revenue Growth, 1990-1995 (Percentage Revenue Growth over Preceding Year)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	57.2	54.0	40.4	39.5	29.2	30.5	38.4
Memory Total	-1.6	26.1	46.5	68.7	46.9	73.9	51.4
Bipolar Memory	22.2	-22.7	-29.4	-41.7	0	-42.9	-28.9
MOS Memory	-1.9	26.8	47.1	69.1	46.9	74.1	51.8
Logic/ASIC Total	9.7	15.6	12.2	45.7	13.9	25.3	21.9
Bipolar Logic	-3.1	-5.9	4.8	3.3	-4.2	-13.2	-3.3
MOS Logic	16.1	24.6	14.5	57.9	17.3	31.2	28.2
Analog ICs	21.5	18.9	27.0	36.6	26.0	17.8	25.1
Monolithic IC Total	17.8	28.7	33.2	48.3	31.9	43.2	36.9
Hybrid ICs	-19.0	0.9	11.6	40.8	42.6	13.1	20.7
Total ICs	16.8	28.2	32.9	48.2	32.0	42.8	36.6
Discrete Devices	16.7	15.6	19.0	26.1	21.5	35.3	23.3
Optical Semiconductors	16.3	0	37.5	52.0	24.4	41.7	29.8
Total Semiconductor	16.8	25.4	30.9	45.3	30.6	42.0	34.6

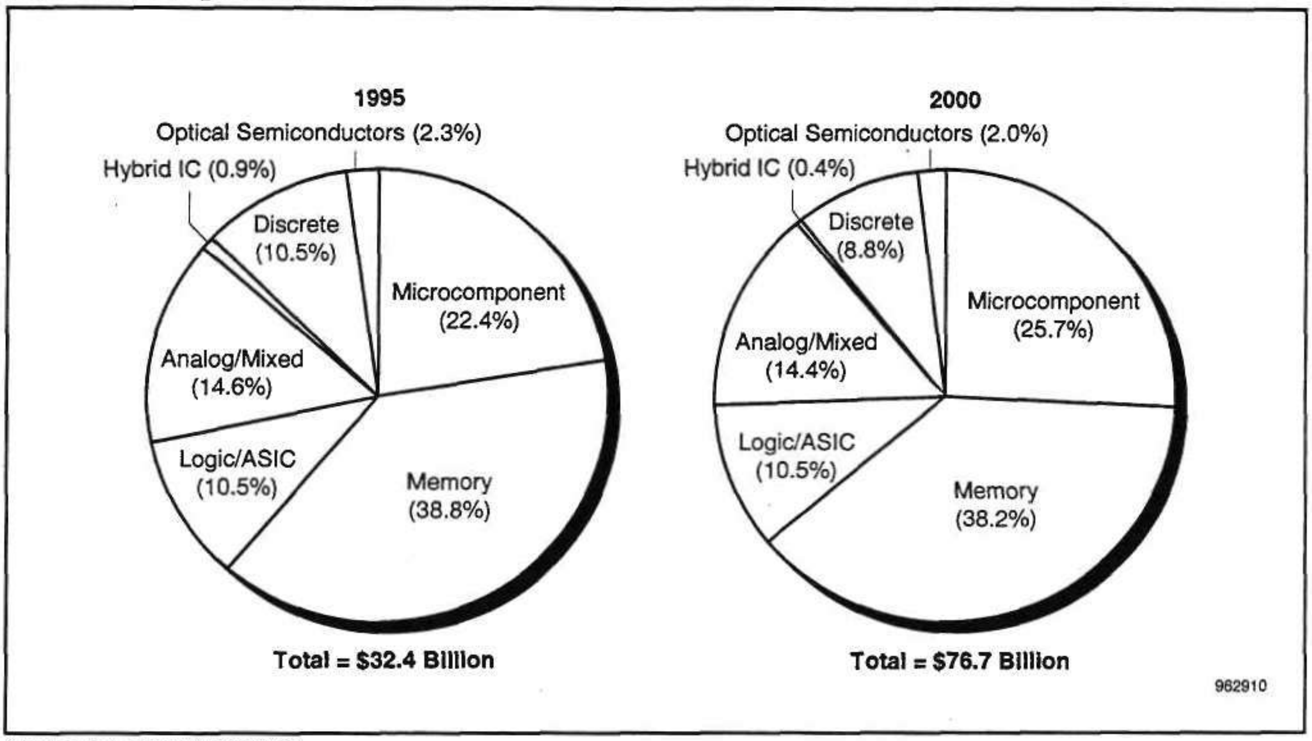
Source: Dataquest (May 1996)

Table 7-4
Asia/Pacific Semiconductor Market, Forecast Five-Year Revenue Growth (Percentage Revenue Growth over Preceding Year)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	30.5	21.5	18.5	22.1	24.3	24.3	22.1
Memory Total	73.9	10.4	16.1	18.3	21.1	27.0	18.4
Bipolar Memory	-42.9	-25.0	-33.3	-50.0	0	0	-24.2
MOS Memory	74.1	10.4	16.1	18.3	21.1	27.0	18.5
Logic/ASIC Total	25.3	15.7	13.1	20.1	22.4	22.8	18.8
Bipolar Logic	-13.2	-17.4	-13.0	-16.2	-16.2	-15.6	-15.7
MOS Logic	31.2	19.1	15.0	22.0	23.8	23.8	20.7
Analog ICs	17.8	17.2	12.1	20.9	21.2	21.2	18.5
Monolithic IC Total	43.2	15.1	15.7	20.0	22.2	24.8	19.5
Hybrid ICs	13.1	8.5	9.4	0	0	0	3.5
Total ICs	42.8	15.0	15.6	19.8	22.0	24.6	19.4
Discrete Devices	35.3	17.0	10.5	14.8	15.2	15.2	14.5
Optical Semiconductors	41.7	23.1	10.8	14.0	15.8	15.7	15.8
Total Semiconductor	42.0	15.4	15.0	19.2	21.2	23.5	18.8

Source: Dataquest (May 1996)

Figure 7-1
Product Comparison, Asia/Pacific Market, 1995 and 2000



Source: Dataquest (May 1996)

Chapter 8
Forecast by Product

Chapter 2 provided a brief discussion of the semiconductor product families. This chapter focuses on the individual products and summarizes the regional splits for each product category.

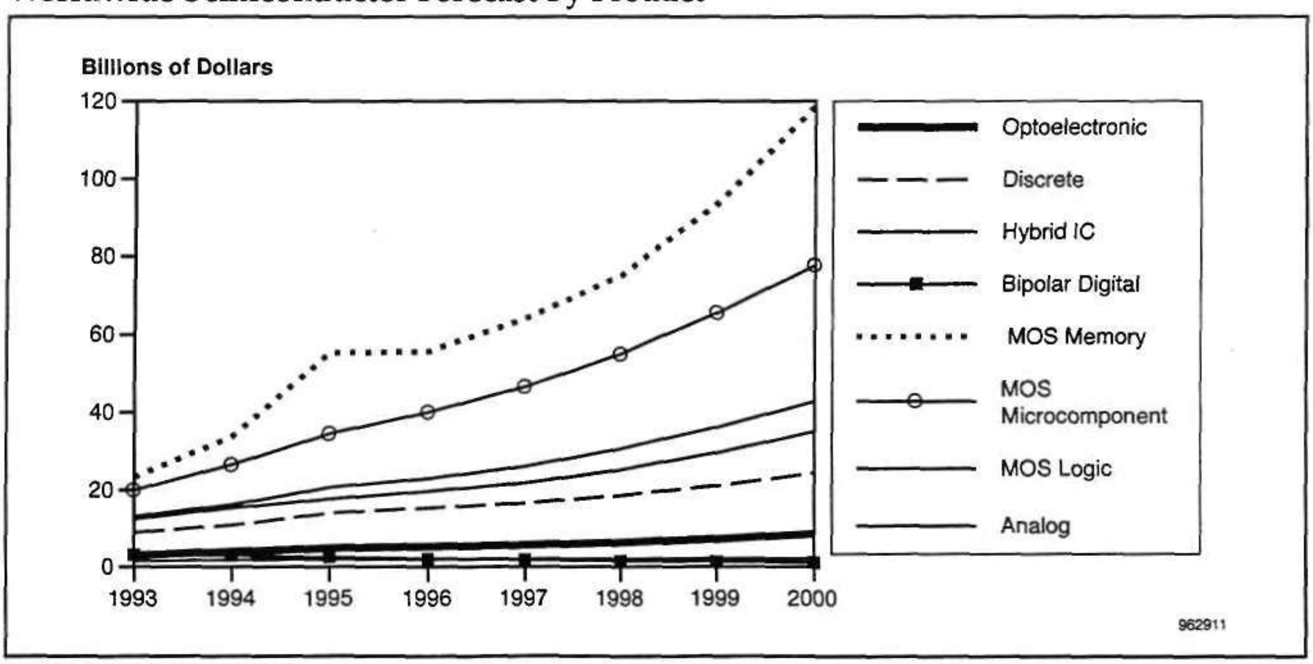
Figure 8-1 graphs the worldwide forecast by category for the forecast period. A major change to the forecast is the flat memory growth seen in 1996—a departure from last year's forecast, where we expected decelerating growth, but growth nevertheless. After this three-year correction period, memory revenue will again outpace microcomponent revenue growth, widening the gap toward the end of the forecast period.

Each of these major product categories is discussed in the following sections, and a regional forecast table is provided.

Microcomponent ICs

After six consecutive years of growth exceeding 20 percent, microcomponent growth is slowing. Growth will drop below 20 percent in 1996 and remain in the high teens for the duration of the forecast. The PC market is slowing somewhat and will post growth under 20 percent worldwide over the coming five years. Microprocessor ASPs will not rise as rapidly as in the recent past, and the slowing growth of PCs and multimedia peripherals will limit microperipheral growth. Communications and digital entertainment will keep DSP growth above 20 percent compounded. Microcontrollers continue to find new homes in every conceivable electronic product and will help hold the microcomponent CAGR near 18 percent. Table 8-1 shows the microcomponent growth by region for the coming five years, with some product detail presented below.

Figure 8-1
Worldwide Semiconductor Forecast by Product



Source: Dataquest (May 1996)

Table 8-1
Microcomponent IC Market, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	12,421	14,073	16,182	18,779	21,950	25,575	15.5
Japan	7,829	8,558	10,130	12,001	14,286	16,934	16.7
Europe	7,009	8,503	9,775	11,365	13,454	15,437	17.1
Asia/Pacific	7,254	8,811	10,437	12,740	15,842	19,699	22.1
Microcomponent IC Total	34,513	39,945	46,524	54,885	65,532	77,645	17.6

Source: Dataquest (May 1996)

Memory ICs

By accounting for 28 percent of total semiconductor revenue, DRAM has had an enormous effect on total semiconductor growth. With an 82 percent DRAM revenue growth in 1995, the semiconductor market grew by 37 percent; excluding DRAM revenue growth, all other semiconductor products showed a combined growth of 25 percent. In 1996, Dataquest anticipates no DRAM growth, a problem that will limit total semiconductor growth to 8 percent even as non-DRAM devices will grow by 14 percent on average.

Memory IC demand will continue unabated in 1996. The only difference is that we are in oversupply and prices have declined precipitously. The year 1996 marks the end of the DRAM shortage and the return to the "normal" declining price-per-bit scenario. Bit growth is expected to be substantial but not sufficient to counter the large price-per-bit declines that have dropped price-per-megabyte below $14. A compounded revenue growth rate of 17 percent for DRAM over the 1995-through-2000 period, although a drop from the past five years, will allow DRAM to grow faster than the semiconductor market and account for more than 30 percent of the semiconductor revenue in the year 2000. The five-year compounded growth for memory ICs has dropped to 16.5 percent. Despite a drop in revenue in Japan in 1996, all four regions will show double-digit CAGRs over the forecast period. Table 8-2 shows the memory IC forecast by region.

Table 8-2
Memory IC Market by Region, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	20,530	21,145	24,297	28,647	36,710	47,307	18.2
Japan	12,337	10,409	11,853	13,481	17,163	22,162	12.4
Europe	9,990	10,321	11,962	13,917	16,728	19,919	14.8
Asia/Pacific	12,564	13,874	16,101	19,053	23,065	29,292	18.4
Memory IC Total	55,421	55,749	64,213	75,098	93,666	118,680	16.5

Source: Dataquest (May 1996)

Logic ICs

Logic ICs include a broad and dissimilar set of products. These products can be cut by standard or ASIC, bipolar or MOS. A traditional cut used in this forecast is that of process technology—bipolar logic and MOS logic, which more or less track an "old versus new" division. After a two-year respite from rapidly declining revenue in 1993 and 1995, bipolar logic returned to a 14 percent decline in 1995, a "normal" rate that we expect to continue into 1996 and beyond.

MOS logic showed a 28 percent growth in revenue in 1995 after 27 percent in 1994. We expect growth to drop to eleven percent in 1996 and then settle into a long-term 16 percent growth rate driven by the still strong MOS programmable logic device (PLD), MOS gate array, and MOS cell-based products. MOS ASIC is the major driver of the MOS logic category. The total logic data combines both bipolar and MOS logic, giving an aggregate growth of 22 percent for 1995 and a five-year CAGR of 14 percent over the forecast period. Table 8-3 gives the combined logic forecast.

Analog ICs

Consumer entertainment products, being largely audio and video, are intrinsically analog in nature and have typically consumed about 40 percent of all analog ICs. The big declines seen in 1992 in the consumer market, especially in Japan and Europe, severely impacted the growth of analog ICs, resulting in a growth of only 6 percent. Since 1992, analog ICs have shown a consistent 23 percent annual growth. In 1995, we saw a drop from this trend, with a 15 percent growth.

Analog ICs show a very equal distribution among the four regions, with the Americas having the smallest share at 23 percent and Japan the largest at 27 percent. This distribution is changing as consumer equipment manufacturing increasingly migrates to Asia/Pacific sites. The increasing presence of analog ICs in computer and communications applications is stabilizing growth in the Americas and Europe. Table 8-4 shows the analog IC growth rate by region over the forecast period.

Total Monolithic ICs

The combination of microcomponent, memory, logic, and analog ICs gives the total monolithic IC market. The five-year forecast for this summary category is shown in Table 8-5.

Table 8-3
Logic IC Market by Region, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	7,528	8,400	9,581	11,074	12,887	15,320	15.3
Japan	8,772	8,934	9,663	10,919	12,501	14,180	10.1
Europe	3,243	3,621	3,974	4,540	5,250	6,175	13.7
Asia/Pacific	3,418	3,955	4,474	5,373	6,574	8,073	18.8
Logic IC Total	22,961	24,910	27,692	31,906	37,212	43,748	13.8

Source: Dataquest (May 1996)

Table 8-4
Analog IC Market by Region, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	3,995	4,575	5,315	6,232	7,329	8,652	16.7
Japan	4,744	4,801	4,846	5,331	5,922	6,612	6.9
Europe	4,127	4,630	5,306	6,049	7,149	8,580	15.8
Asia/Pacific	4,741	5,556	6,231	7,535	9,131	11,067	18.5
Analog IC Total	17,607	19,562	21,698	25,147	29,531	34,911	14.7

Source: Dataquest (May 1996)

Table 8-5
Total Monolithic IC Market by Region, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	44,474	48,193	55,375	64,732	78,876	96,854	16.8
Japan	33,682	32,702	36,492	41,732	49,872	59,888	12.2
Europe	24,369	27,075	31,017	35,871	42,581	50,111	15.5
Asia/Pacific	27,977	32,196	37,243	44,701	54,612	68,131	19.5
Monolithic IC Total	130,502	140,166	160,127	187,036	225,941	274,984	16.1

Source: Dataquest (May 1996)

Discrete Devices

Discrete devices showed a 30 percent revenue growth in 1995. Although the discrete device category has been losing market share because of the relentless integration of components, this category remains viable because power and RF devices are not readily integrated. Power transistors represent about one-third of discrete revenue and are expected to lead the discrete growth with a 14 percent CAGR. Table 8-6 gives the discrete forecast by region. The growing use of power discrete devices in power control and communications applications in the Americas has brought the compounded Americas growth rate back into double digits.

Table 8-6
Discrete Device Market by Region, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	2,870	3,225	3,650	4,190	4,895	5,700	14.7
Japan	4,681	4,708	4,845	5,232	5,813	6,641	7.2
Europe	3,053	3,367	3,603	3,985	4,491	5,178	11.1
Asia/Pacific	3,419	4,000	4,419	5,074	5,845	6,732	14.5
Discrete Devices Total	14,023	15,300	16,517	18,481	21,044	24,251	11.6

Source: Dataquest (May 1996)

Optical Semiconductors

Even more than analog ICs or discrete devices, optical semiconductors find their primary market in consumer entertainment products. With scanners and copiers using charge-coupled devices (CCDs), CD-ROMs using laser diodes, and optical-fiber data links using semiconductor receivers and transmitters, the data processing market is showing an increasing impact on the optical semiconductor market. This impact was seen as a 24 percent revenue growth in 1995. Growth in 1996 is anticipated to be 8 percent as the computer peripherals and consumer markets slow. Laser diodes have continued to lead the growth in this category; 1996 shows a 36 percent revenue growth for this product type. The optical semiconductor forecast by region is given in Table 8-7.

Table 8-7
Optical Semiconductor Market by Region, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	627	715	840	1,060	1,325	1,625	21.0
Japan	2,767	2,789	2,874	3,105	3,452	4,089	8.1
Europe	680	788	869	975	1,103	1,276	13.4
Asia/Pacific	737	907	1,005	1,146	1,327	1,536	15.8
Optical Semiconductors Total	4,811	5,199	5,588	6,286	7,207	8,526	12.1

Source: Dataquest (May 1996)

Chapter 9
Forecast by Technology

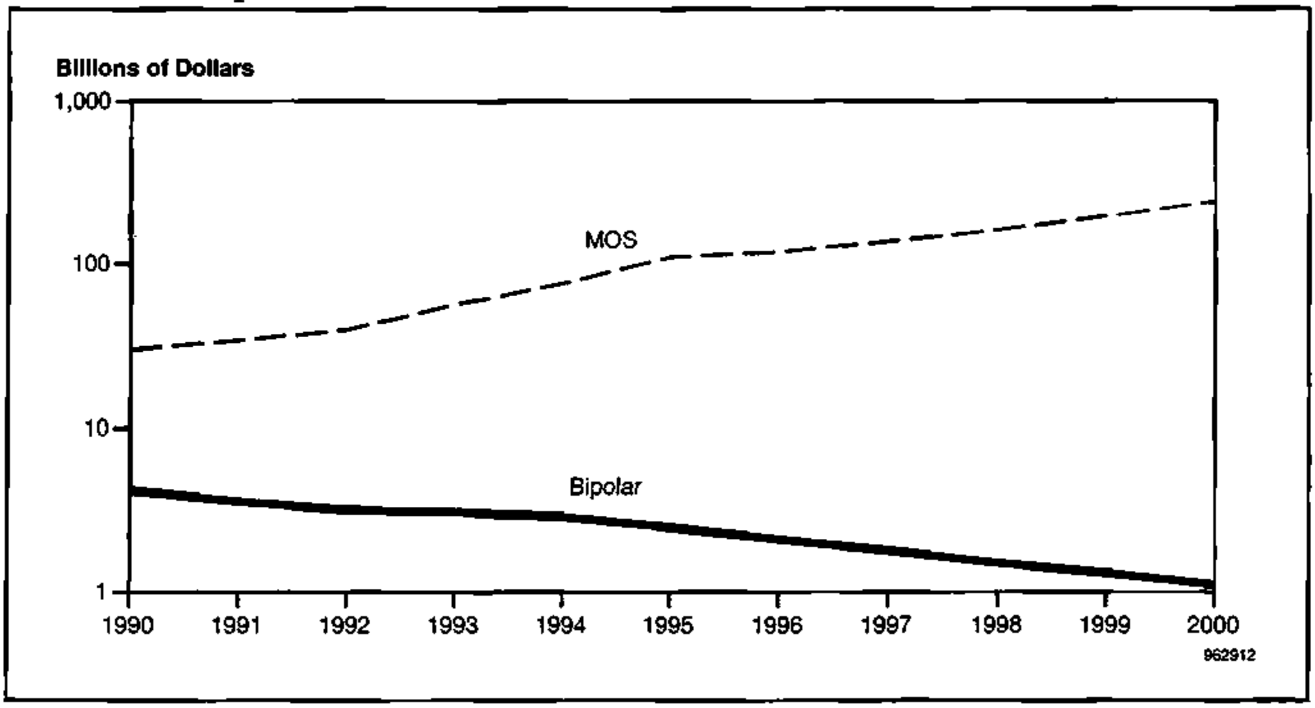
Digital MOS and Bipolar IC Forecast

The five-year IC forecast includes the process categories of MOS digital and bipolar digital ICs. This process split is still important for the logic IC category but is of decreasing importance for the memory IC category. For microcomponent ICs, the bipolar subsegment has become fairly irrelevant and is no longer reported or forecast separately.

The forecast data for digital ICs, by process, is plotted in Figure 9-1. The graph shows that the bipolar portion of the digital IC market is declining at a 12 percent CAGR over the forecast period. By the year 2000, bipolar digital ICs will have declined to less than 0.5 percent of the total digital IC market.

Tables 9-1 and 9-2 show the five-year history and forecast, respectively, for the bipolar and MOS portions of the three main digital IC categories. It can be seen that, as a memory IC process technology, bipolar has been in a rapid slide that is slowing as revenue becomes insignificant. Bipolar logic ICs accounted for 14 percent of logic IC revenue in 1994. By 2000, it is expected that bipolar logic will represent less than 3 percent of the logic IC revenue.

Figure 9-1
MOS versus Bipolar Forecast



Source: Dataquest (May 1996)

Table 9-1
Semiconductor Market by Process Technology, Six-Year Revenue History, 1990-1995
(Revenue in Millions of Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Bipolar Total	4,173	3,628	3,193	3,079	2,912	2,497	-9.8
Bipolar Memory	431	356	318	244	199	160	-18.0
Bipolar Logic	3,742	3,272	2,875	2,835	2,713	2,337	-9.0
MOS Total	30,152	34,315	39,710	56,374	76,021	110,298	29.6
MOS Micro	9,584	11,774	14,359	19,947	26,408	34,513	29.2
MOS Memory	12,128	12,841	15,308	23,306	33,505	55,261	35.4
MOS Logic	8,440	9,700	10,043	13,121	16,108	20,624	19.6
Total Digital IC	34,325	37,943	42,903	59,453	78,933	112,895	26.9

Source: Dataquest (May 1996)

Table 9-2
Semiconductor Market by Process Technology, Five-Year Revenue Forecast, 1995-2000
(Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Bipolar Total	2,497	2,131	1,752	1,508	1,298	1,137	-14.6
Bipolar Memory	160	119	108	93	79	71	-15.0
Bipolar Logic	2,337	2,012	1,644	1,415	1,219	1,066	-14.5
MOS Total	110,298	118,473	136,677	160,381	195,112	238,936	16.7
MOS Micro	34,513	39,945	46,524	54,885	65,532	77,645	17.6
MOS Memory	55,261	55,630	64,105	75,005	93,587	118,609	16.5
MOS Logic	20,624	22,898	26,048	30,491	35,993	42,682	15.7
Total Digital IC	112,895	120,604	138,429	161,889	196,410	240,073	16.3

Source: Dataquest (May 1996)

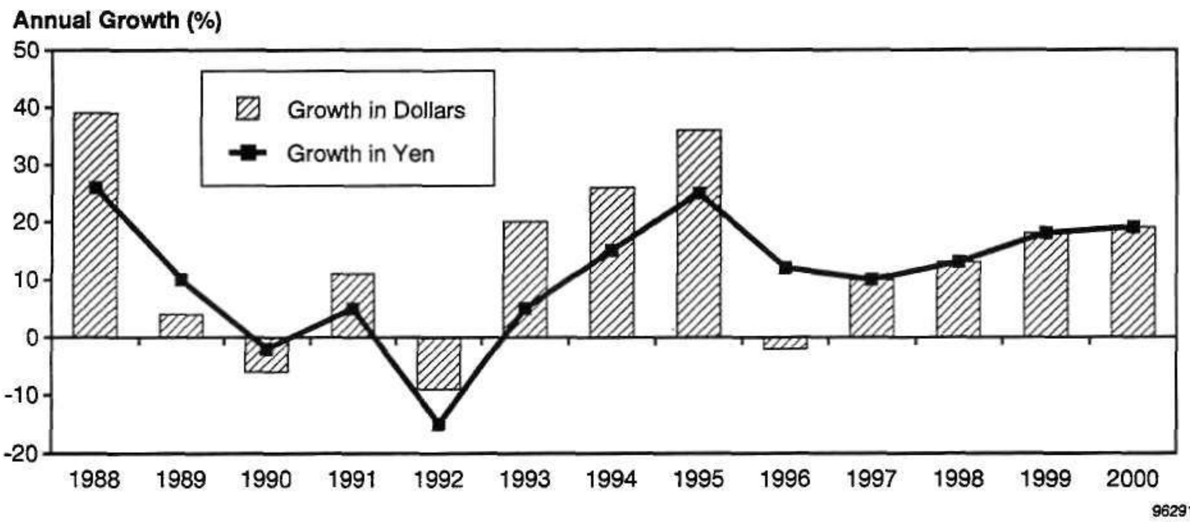
Appendix A

Japanese Revenue History and Forecast in Yen

Revenue growth in shipments to the Japan region differs according to whether the dollar or yen is used as the currency basis. As the dollar has typically weakened against the yen, Japanese growth has often been inflated by this exchange rate change. Figure A-1 shows the annual growth in each of these two currencies over both the historical 1988-through-1995 period and the forecast 1996-through-2000 period. Because Dataquest does not forecast exchange rates, the forecast growth rates are the same.

The following tables show the yen-based revenue shipment data for the Japan region. Tables A-1 and A-2 provide the Japanese revenue history and forecast, respectively, in yen. The historical exchange rates are shown at the bottom of these tables. Tables A-3 and A-4 show the annual growth associated with the year-to-year revenue growth. The rate of dollar appreciation against the yen for the period from 1990 through 1995 is shown at the bottom of Table A-3. Over the past five years, the dollar has declined in value, inflating the revenue growth of the Japanese market in dollars.

Figure A-1
Comparison of Revenue Shipment Growth in the Japan Region—Dollars versus Yen



Source: Dataquest (May 1996)

Table A-1
Japanese Semiconductor Market, Six-Year Yen Revenue History, 1990-1995 (Revenue in Billions of Yen)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	428	487	413	443	570	735	11.4
Memory Total	632	597	528	634	748	1,158	12.9
Bipolar Memory	28	22	17	14	10	8	-22.7
MOS Memory	604	575	510	619	738	1,151	13.8
Logic/ASIC Total	710	728	613	635	724	824	3.0
Bipolar Logic	208	174	128	111	114	93	-14.9
MOS Logic	503	554	485	524	610	731	7.8
Analog ICs	392	421	367	365	412	445	2.6
Monolithic IC Total	2,163	2,233	1,922	2,077	2,454	3,163	7.9
Hybrid ICs	112	117	95	91	91	97	-2.8
Total ICs	2,274	2,350	2,016	2,168	2,545	3,260	7.5
Discrete Devices	428	467	389	381	399	440	0.6
Optical Semiconductors	215	243	197	192	213	260	3.8
Total Semiconductor	2,917	3,059	2,602	2,741	3,157	3,959	6.3
Yen/U.S.$ Exchange Rate	144.00	136.00	126.45	111.20	101.81	93.90	

Source: Dataquest (May 1996)

Table A-2
Japanese Semiconductor Market, Five-Year Yen Revenue Forecast, 1995-2000 (Revenue in Billions of Yen)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	735	916	1,084	1,285	1,529	1,813	19.8
Memory Total	1,158	1,114	1,269	1,443	1,837	2,372	15.4
Bipolar Memory	8	7	6	6	5	5	-9.0
MOS Memory	1,151	1,108	1,262	1,437	1,832	2,368	15.5
Logic/ASIC Total	824	956	1,034	1,169	1,338	1,518	13.0
Bipolar Logic	93	88	68	58	52	47	-12.8
MOS Logic	731	868	966	1,110	1,286	1,471	15.0
Analog ICs	445	514	519	571	634	708	9.7
Monolithic IC Total	3,163	3,501	3,906	4,467	5,339	6,411	15.2
Hybrid ICs	97	112	115	115	115	115	3.5
Total ICs	3,260	3,613	4,022	4,582	5,454	6,526	14.9
Discrete Devices	440	504	519	560	622	711	10.1
Optical Semiconductors	260	299	308	332	370	438	11.0
Total Semiconductor	3,959	4,415	4,848	5,475	6,446	7,675	14.2
Yen/U.S.$ Exchange Rate	93.90	107.05	107.05	107.05	107.05	107.05	

Source: Dataquest (May 1996)

Table A-3
Japanese Semiconductor Market, Yen Revenue Growth, 1990-1995 (Percentage Revenue Growth in Yen)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	16.6	13.7	-15.1	7.3	28.7	28.9	11.4
Memory Total	-21.3	-5.5	-11.6	20.0	18.0	54.9	12.9
Bipolar Memory	6.0	-19.7	-22.2	-19.1	-29.4	-22.8	-22.7
MOS Memory	-22.2	-4.8	-11.2	21.3	19.1	56.0	13.8
Logic/ASIC Total	7.2	2.5	-15.7	3.6	14.0	13.8	3.0
Bipolar Logic	3.2	-16.3	-26.0	-13.4	2.3	-18.5	-14.9
MOS Logic	8.9	10.2	-12.5	8.1	16.5	19.8	7.8
Analog ICs	3.9	7.3	-12.8	-0.7	13.1	8.1	2.6
Monolithic IC Total	-2.2	3.2	-13.9	8.1	18.2	28.9	7.9
Hybrid ICs	-3.7	4.7	-18.9	-3.9	-0.7	7.3	-2.8
Total ICs	-2.2	3.3	-14.2	7.5	17.4	28.1	7.5
Discrete Devices	0.6	9.2	-16.6	-2.2	4.7	10.2	0.6
Optical Semiconductors	0.5	13.0	-19.0	-2.3	11.1	21.7	3.8
Total Semiconductor	-1.6	4.9	-14.9	5.3	15.2	25.4	6.3
U.S.$ Appreciation versus Yen	4.35	-5.56	-7.02	-12.06	-8.44	7.77	-8.20

Source: Dataquest (May 1996)

Table A-4
Japanese Semiconductor Market, Forecast Five-Year Yen Revenue Growth, 1995-2000 (Percentage Revenue Growth in Yen)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	28.9	24.6	18.4	18.5	19.0	18.5	19.8
Memory Total	54.9	-3.8	13.9	13.7	27.3	29.1	15.4
Bipolar Memory	-22.8	-12.4	-4.8	-8.3	-10.9	-8.2	-9.0
MOS Memory	56.0	-3.8	14.0	13.8	27.5	29.2	15.5
Logic/ASIC Total	13.8	16.1	8.2	13.0	14.5	13.4	13.0
Bipolar Logic	-18.5	-4.9	-22.7	-14.3	-11.0	-10.1	-12.8
MOS Logic	19.8	18.8	11.3	14.9	15.8	14.4	15.0
Analog ICs	8.1	15.4	0.9	10.0	11.1	11.7	9.7
Monolithic IC Total	28.9	10.7	11.6	14.4	19.5	20.1	15.2
Hybrid ICs	7.3	15.2	2.9	0	0	0	3.5
Total ICs	28.1	10.8	11.3	13.9	19.0	19.7	14.9
Discrete Devices	10.2	14.7	2.9	8.0	11.1	14.2	10.1
Optical Semiconductors	21.7	14.9	3.0	8.0	11.2	18.5	11.0
Total Semiconductor	25.4	11.5	9.8	12.9	17.7	19.1	14.2
U.S.$ Appreciation versus Yen	-7.77	14.00	0	0	0	0	2.66

Source: Dataquest (May 1996)

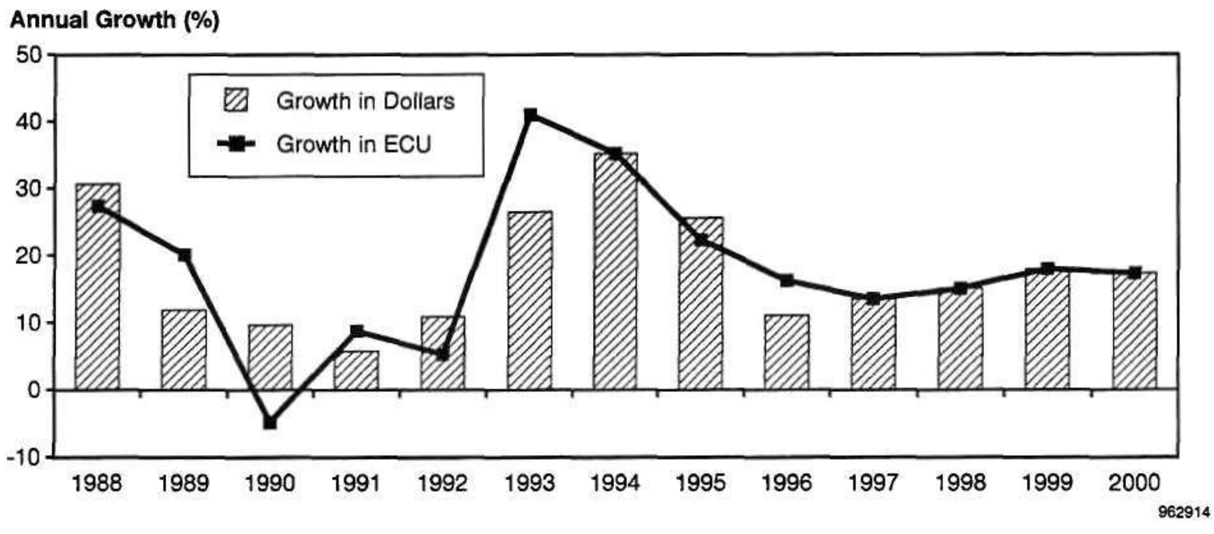
Appendix B

European Revenue History and Forecast in ECU

Revenue growth in shipments to the European region differs whether the dollar or ECU is used as the currency basis. The dollar has not had any consistent long-term change with the ECU; the exchange rate in 1995 was essentially the same as in 1990, although there were annual fluctuations. Figure B-1 shows the annual growth in each of these two currencies over both the historical 1988-through-1995 period and the forecast 1996-through-2000 period. Because Dataquest does not forecast exchange rates, the forecast growth rates are the same.

Tables B-1 and B-2 provide the European revenue history and forecast in ECU. The historical exchange rates are shown at the bottom of these tables. Tables B-3 and B-4 show the annual growth associated with the year-to-year revenue growth. The rate of dollar appreciation against the ECU for the period from 1990 through 1995 is shown at the bottom of Table B-3. Over the past seven years, the exchange rate has shown little fluctuation, on average.

Figure B-1
Comparison of Revenue Shipment Growth in European Region—Dollars versus ECU



Source: Dataquest (May 1996)

Table B-1
European Semiconductor Market, Six-Year ECU Revenue History, 1990-1995 (Revenue in Millions of ECU)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	1,420	1,689	2,097	3,464	4,543	5,425	30.7
Memory Total	1,659	1,761	2,077	3,489	5,546	7,732	36.1
Bipolar Memory	43	35	29	23	24	15	-19.4
MOS Memory	1,615	1,727	2,048	3,466	5,522	7,718	36.7
Logic/ASIC Total	1,483	1,691	1,645	1,973	2,234	2,510	11.1
Bipolar Logic	402	359	299	311	276	225	-10.9
MOS Logic	1,081	1,332	1,347	1,661	1,957	2,285	16.1
Analog ICs	1,709	1,771	1,732	2,347	2,831	3,194	13.3
Monolithic IC Total	6,271	6,912	7,551	11,273	15,153	18,862	24.6
Hybrid ICs	124	144	116	154	150	185	8.4
Total ICs	6,395	7,057	7,668	11,427	15,302	19,047	24.4
Discrete Devices	1,493	1,483	1,406	1,518	1,771	2,363	9.6
Optical Semiconductors	319	393	334	321	483	526	10.5
Total Semiconductor	8,207	8,932	9,408	13,266	17,556	21,936	21.7
ECU/U.S.$ Exchange Rate	0.788	0.811	0.77	0.858	0.84	0.774	

Source: Dataquest (May 1996)

Table B-2
European Semiconductor Market, Five-Year ECU Revenue Forecast, 1995-2000 (Revenue in Millions of ECU)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	5,425	6,887	7,918	9,206	10,898	12,504	18.2
Memory Total	7,732	8,360	9,689	11,273	13,550	16,134	15.8
Bipolar Memory	15	11	11	8	7	6	-15.1
MOS Memory	7,718	8,349	9,679	11,265	13,542	16,128	15.9
Logic/ASIC Total	2,510	2,933	3,219	3,677	4,253	5,002	14.8
Bipolar Logic	225	203	164	141	122	109	-13.6
MOS Logic	2,285	2,730	3,055	3,536	4,130	4,893	16.5
Analog ICs	3,194	3,750	4,298	4,900	5,791	6,950	16.8
Monolithic IC Total	18,862	21,931	25,124	29,056	34,491	40,590	16.6
Hybrid ICs	185	202	198	201	209	213	2.9
Total ICs	19,047	22,132	25,322	29,256	34,700	40,803	16.5
Discrete Devices	2,363	2,727	2,918	3,228	3,638	4,194	12.2
Optical Semiconductors	526	638	704	790	893	1,034	14.5
Total Semiconductor	21,936	25,498	28,945	33,274	39,231	46,031	16.0
ECU/U.S.$ Exchange Rate	0.774	0.81	0.81	0.81	0.81	0.81	

Source: Dataquest (May 1996)

Table B-3
European Semiconductor Market, Historic Revenue Growth, 1990-1995 (Revenue Growth in ECU)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	8.5	18.9	24.2	65.2	31.2	19.4	30.7
Memory Total	-26.6	6.2	17.9	68.0	58.9	39.4	36.1
Bipolar Memory	-32.8	-19.5	-16.1	-20.8	1.5	-37.5	-19.4
MOS Memory	-26.4	6.9	18.6	69.2	59.3	39.8	36.7
Logic/ASIC Total	-16.2	14.0	-2.7	19.9	13.2	12.4	11.1
Bipolar Logic	-20.4	-10.6	-16.8	4.2	-11.3	-18.5	-10.9
MOS Logic	-14.5	23.2	1.1	23.3	17.8	16.7	16.1
Analog ICs	21.0	3.6	-2.2	35.6	20.6	12.8	13.3
Monolithic IC Total	-7.1	10.2	9.2	49.3	34.4	24.5	24.6
Hybrid ICs	0.2	16.7	-19.5	32.1	-2.6	23.7	8.4
Total ICs	-7.0	10.4	8.7	49.0	33.9	24.5	24.4
Discrete Devices	4.5	-0.7	-5.2	8.0	16.7	33.4	9.6
Optical Semiconductors	-0.7	23.2	-15.0	-4.0	50.5	9.0	10.5
Total Semiconductor	-4.8	8.8	5.3	41.0	32.3	24.9	21.7
U.S.$ Appreciation versus ECU	-13.22	2.92	-5.06	11.43	-2.10	-7.86	-0.36

Source: Dataquest (May 1996)

Table B-4
European Semiconductor Market, Forecast Five-Year ECU Revenue Growth, 1995-2000 (Percentage Revenue Growth in ECU)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	19.4	27.0	15.0	16.3	18.4	14.7	18.2
Memory Total	39.4	8.1	15.9	16.3	20.2	19.1	15.8
Bipolar Memory	-37.5	-28.4	0	-23.1	-10.0	-11.1	-15.1
MOS Memory	39.8	8.2	15.9	16.4	20.2	19.1	15.9
Logic/ASIC Total	12.4	16.8	9.7	14.2	15.6	17.6	14.8
Bipolar Logic	-18.5	-9.7	-19.1	-14.3	-13.2	-11.3	-13.6
MOS Logic	16.7	19.5	11.9	15.8	16.8	18.5	16.5
Analog ICs	12.8	17.4	14.6	14.0	18.2	20.0	16.8
Monolithic IC Total	24.5	16.3	14.6	15.6	18.7	17.7	16.6
Hybrid ICs	23.7	9.0	-1.6	1.2	4.0	1.9	2.9
Total ICs	24.5	16.2	14.4	15.5	18.6	17.6	16.5
Discrete Devices	33.4	15.4	7.0	10.6	12.7	15.3	12.2
Optical Semiconductors	9.0	21.3	10.3	12.2	13.1	15.7	14.5
Total Semiconductor	24.9	16.2	13.5	15.0	17.9	17.3	16.0
U.S.$ Appreciation versus ECU	-7.86	4.65	0	0	0	0	0.91

Source: Dataquest (May 1996)

Appendix C
Definitions

Analog ICs

Analog ICs are a group of semiconductors that deal with electrical signals and electrical power. Analog components carry information as voltage, current, frequency, phase, duty cycle, or other electronic parameters. Because they are not based on number values, analog information is not limited to a finite range of values and has no inherent quantization noise or quantization error. The downside is that analog signal information exists in the time domain and can be corrupted as the information-carrying parameter is influenced by noise, drift, bandwidth, and component instability—all the vagaries of time.

Bipolar

These are semiconductor devices that use bipolar transistors rather than MOS transistors. Bipolar transistors are found in both ICs and discrete products. Bipolar transistors are so named because they carry electricity with two different types of "carriers"—holes and electrons.

Digital ICs

Digital ICs handle numbers in the binary format of ones and zeros. Digital ICs comprise logic, microcomponent, and memory ICs. The number-handling nature of digital electronics makes the data more immune to physical changes in the electronic components.

Discrete Devices

A discrete semiconductor is defined as a single semiconductor component such as a transistor, diode, or thyristor. Although multiple devices may be present in a package, they are still considered discretes if they have no internal functional interconnection and are applied in the same manner as other discrete devices. Some discrete devices may actually be similar to ICs in having integrated protection and sensing circuitry. Even if a device is an integrated circuit, it will be considered a discrete if it is used like one.

Hybrid IC

A hybrid is an IC that mixes semiconductor technology with other electronic technologies in a single package. It is this mixing of technologies within the IC package that gives these products the "hybrid" IC name. Other technologies include thin and thick film resistors and chip capacitors. A multiple-chip IC is not a true hybrid IC and is counted in the monolithic IC category. The mixing of technologies is most often done for analog hybrid ICs. Because of this, hybrid ICs are often added to monolithic analog IC revenue to provide the total analog IC market.

IC

An integrated circuit is a chip in which multiple transistors and diodes are interconnected to perform an electronic function. The function-specific nature of an IC differentiates it from the nonspecific array of discrete transistors.

Logic

This is an electronic function where bits (one and zeros) are processed. This bit processing is defined by hardwiring, mask programming, or field programming. Microcomponents and memory ICs are logic ICs, but they are logic ICs that are either dedicated to a function (such as microperipherals and memory ICs) or are software programmable (such as microprocessors and microcontrollers). Logic ICs also include customer-specific logic ICs.

Microcomponent

A microcomponent is a digital IC that can be programmable such as a microprocessor (MPU), microcontroller (MCU), digital signal processor (DSP), or an application-specific logic device that provides a supporting function to an MPU, MCU, or DSP.

Monolithic IC

A monolithic IC is an IC formed on a single chip of semiconducting material. This designation has been applied more broadly to mean any device, even a multiple-chip packaged device, that does not contain other, nonsemiconductor, components. This differentiates monolithic ICs from hybrid ICs that may also be multiple-chip, but represent a "hybrid" in the sense of mixing other technologies within the IC package, such as film resistors or chip capacitors.

MOS

MOS is an acronym for metal oxide semiconductor, a type of transistor used in ICs and discrete devices. Although the actual device may use different materials than metal or oxide, this acronym is used to define the whole family of similar processes that provide an insulated gate field-effect transistor (FET). MOSFETs, like all field-effect transistors, differ from bipolar devices in having an insulated gate and only a single carrier of electrical current (either electrons or holes). MOSFETs are found in both N and P channel varieties. A special IC process combines both the N and P channel device in a complementary configuration, an arrangement known as CMOS.

Memory IC

Memory ICs are ICs that can store and retrieve logic bits. Two major memory types are read-only memories (ROM), preloaded with data, or random-access memories (RAM), where data can be both stored and accessed. RAM subcategories include DRAM and SRAM. Memory ICs that do not lose their data when power is removed are called nonvolatile memories. DRAM and SRAM do not retain data when power is removed from the device. ROM, EPROM, EEPROM, and flash memory ICs are non-volatile memory devices.

Optical Semiconductors

These devices are the semiconductor subset of optoelectronic products. This family includes light-sensing products such as photosensors and CCDs as well as light-emitting devices such as LEDs and lasers. Optocouplers and interrupters use both functions.

Semiconductors

These electronic components are manufactured by introducing impurities into a semiconductor material to create special current conducting devices such as diodes, bipolar transistors, and MOS transistors. Semiconducting material is so named because its conducting capability falls between the range of insulators and metallic conductors.

Appendix D
Historical Exchange Rates

Table D-1 shows 10 years of exchange rates of the yen and ECU versus the U.S. dollar. The appreciation of the dollar against these local currencies is given in the last two columns.

Table D-1
Exchange Rates

Year	Yen per U.S.$	ECU per U.S.$	U.S.$ Growth versus Yen (%)	U.S.$ Growth versus ECU (%)
1980	227	-	3.6	-
1981	221	-	-2.7	-
1982	248	-	12.2	-
1983	235	-	-5.2	-
1984	237	-	0.9	-
1985	238	-	0.4	-
1986	167	-	-29.8	-
1987	144	-	-13.8	-
1988	130	0.846	-9.7	-2.5
1989	138	0.908	6.2	7.3
1990	144	0.788	4.3	-13.2
1991	136	0.811	-5.6	2.9
1992	126.5	0.770	-7.0	-5.0
1993	111.2	0.858	-12.1	11.4
1994	101.8	0.840	-8.4	-2.1
1995	93.90	0.774	-7.8	-7.9

Source: Dataquest (May 1996)

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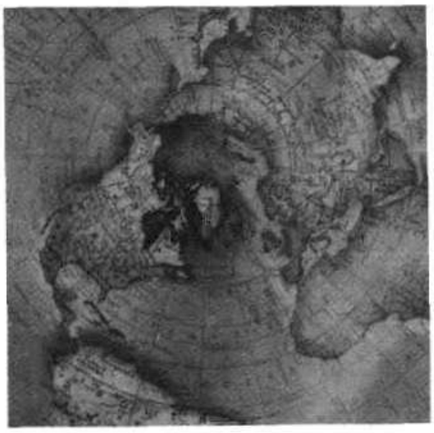

Dataquest

Microcomponent Market Definitions

Dataquest Guide

Program: Embedded Microcomponents Worldwide
Product Code: MCRO-WW-GU-9601
Publication Date: December 30, 1996
Filing: Guides

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Chapter 1
Market Share Survey Overview

Each year, Dataquest surveys microcomponent vendors to estimate their unit shipments and the revenue derived from the sale of those devices. The 1996 survey covers microcomponent vendors worldwide. This exercise helps Dataquest maintain its dynamic database of microcomponent supply by company. The information gained is supplemented by, and cross-checked with, Dataquest's various other information sources.

The microcomponent market share survey takes place after the end of the calendar year under review. The results are summarized and analyzed in several Dataquest reports.

The categories for which microcomponent unit shipments are reported are defined comprehensively for the purpose of clarity and guidance to survey participants. These definitions may occasionally be revised, altered, or expanded to reflect changes in the industry. To support these definitions, Dataquest will issue an annual survey guide to all participants in its microcomponent market share survey program. This document is the 1996 survey guide.

Note that the definition for word width for microprocessors, microcontrollers, and digital signal processors has changed for 1996 and beyond.

Chapter 2
Microcomponent Companies Surveyed Worldwide for 1996

In 1996, Dataquest surveyed microcomponent companies worldwide.

American Companies

The following North American companies are surveyed:

- Advanced Micro Devices
- Analog Devices
- Atmel
- California Micro Devices
- C-Cube
- Chips & Technologies
- Cirrus Logic
- Cypress Semiconductor
- Cyrix Semiconductor
- Dallas Semiconductor
- Digital Equipment Corporation
- DSP Group
- Harris Semiconductor
- Hewlett-Packard Company
- Hughes Microelectronics
- IBM Microelectronics
- Integrated Device Technology
- Integrated Information Technology
- Intel Corporation
- Intergraph Corporation
- LSI Logic
- Lucent Technologies
- Microchip Technology
- Motorola
- National Semiconductor
- Oak Technology
- Performance Semiconductor
- Rockwell International
- S3
- Symbios Logic

- Texas Instruments
- Trident Microsystems
- Tseng Labs
- VLSI Technology
- Weitek
- Zilog
- Zoran

European Companies

The following European companies are surveyed:

- GEC Plessey
- Matra MHS
- NV Philips BV
- SGS-Thomson Microelectronics
- Siemens AG
- TEMIC
- TMS

Japanese Companies

The following Japanese companies are surveyed:

- Fujitsu
- Hitachi
- Mitsubishi Electric
- NEC
- Oki Electric Industry
- Ricoh
- Rohm
- Sanyo Electric
- Seiko Epson
- Sharp
- Sony
- Toshiba
- Yamaha

Asia/Pacific Companies

The following Asia/Pacific companies are surveyed:

- Acer
- LG Semicon
- Samsung

Chapter 3
General Sales Definitions

Unit Shipments

This is the volume or number of finished units shipped by manufacturers to users, equipment manufacturers, or distributors. The units must include operating silicon and are generally assembled into packages, tested, and shipped in protective packaging. A manufacturer's own inventory is not included. Often reported in thousands (K) or millions (M) of units. Similar terms are units and volume.

Revenue

This is the total revenue value of the finished units shipped by manufacturers to users or distributors. In Dataquest's worldwide services, revenue is reported in equivalent U.S. dollars, unless otherwise noted. Often reported in millions of dollars ($M) or billions of dollars ($B).

Average Selling Price

The average selling price (ASP) is the average price for which a product sells when considering all the sales of the product in total, from very small quantities to large-volume orders. ASP is determined by dividing the total revenue derived from the sale of all of the category of products by the number of units that make up all of that category (ASP = revenue/units). It is quite possible that no sale of product ever takes place at a reported ASP. It is also possible that any one sale of product takes place at more than 50 percent variation from an ASP. ASPs are not intended to be the manufacturers' suggested retail prices, one-piece prices, volume-discount prices, or the best possible prices. In Dataquest's worldwide services, ASPs are reported in equivalent U.S. dollars unless otherwise noted.

Compound Annual Growth Rate

Compound annual growth rate (CAGR) is a measure of the growth of an industry over time, usually a five-year span (N = 5). A positive number indicates a growing market. The CAGR is associated with revenue unless noted as units or ASP. CAGR is defined as follows and is usually expressed as a percentage:

$$CAGR = \sqrt[N]{\frac{Value}{Value_{t=0}}} - 1$$

Market Share

Market share refers to the revenue of the desired product, vendor, or region divided by the revenue for all products, vendors, or regions in the same category, usually expressed as a percentage. Market share of units is also a valid measurement but is only used where explicitly stated. No implication should be made as to the "availability" of the market shared within the category.

Merchant versus Captive Consumption

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

Chapter 4

Exchange Rate Definitions

When converting a company's local currency sales into U.S. dollars, or vice versa, it is important to use the preliminary 1996 exchange rates provided in Table 4-1. This will prevent inconsistencies in the conversion of offshore sales between each company. The preliminary 1996 exchange rate estimate uses actual exchange rates through September 1996 and assumes that the September rate applies throughout the months of October through December.

The annual rate is estimated as the arithmetic mean of the 12 monthly rates. Table 4-1 outlines these rates. Exchange rates for historical years are available on request.

Table 4-1
Average 1995 and 1996 Exchange Rates per U.S. Dollar

Country	1995 Rate	1996 Rate	U.S. Dollar Appreciation (%) 1996
Australia (Dollar)	1.35	1.28	-5.21
Austria (Schilling)	10.06	10.55	4.82
Belgium (Franc)	29.42	30.84	4.84
Canada (Dollar)	NA	1.37	NM
China (Renminbi)	NA	8.34	NM
Denmark (Krone)	5.59	5.80	3.64
EU (ECU)	0.77	0.80	3.20
Finland (Markka)	4.37	4.58	4.86
France (Franc)	4.97	5.10	2.69
Germany (Mark)	1.43	1.50	4.77
Great Britain (Pound)	0.63	0.65	2.47
Greece (Drachma)	231.34	240.42	3.92
Hong Kong (Dollar)	7.74	7.73	-0.02
India (Rupee)	32.38	35.52	9.71
Ireland (Punt)	0.62	0.63	0.97
Italy (Lira)	1,628.21	1,542.35	-5.27
Japan (Yen)	93.90	108.06	15.08
Malaysia (Ringgit)	2.51	2.51	-0.09
Mexico (Peso)	6.41	7.53	17.49
Netherlands (Guilder)	1.60	1.68	4.79
New Zealand (Dollar)	1.52	1.46	-4.29
Norway (Krone)	6.33	6.46	2.18
Portugal (Escudo)	149.77	154.13	2.91
Singapore (Dollar)	1.43	1.41	-1.05
South Africa (Rand)	NA	4.28	NM

(Continued)

Table 4-1 (Continued)
Average 1995 and 1996 Exchange Rates per U.S. Dollar

Country	1995 Rate	1996 Rate	U.S. Dollar Appreciation (%) 1996
South Korea (Won)	770.57	802.37	4.13
Spain (Peseta)	124.40	126.24	1.48
Sri Lanka (Rupee)	NA	55.08	NM
Sweden (Krona)	7.14	6.70	-6.14
Switzerland (Franc)	1.18	1.22	3.66
Taiwan (Dollar)	26.48	27.46	3.73
Thailand (Baht)	24.91	25.33	1.68

NA = Not tracked until 1996
NM = Not meaningful
Source: Dataquest (November 1996)

Chapter 5

Microcomponent Product Category Hierarchy

The microcomponent product category hierarchy in Table 5-1 begins with total microcomponent and indents each subcategory in the left-hand column according to its position in the hierarchy. At each level in the hierarchy, all subcategories that contribute to this level are shown as a subcategory summation in the right-hand column. Any level in the hierarchy that does not depend on any subcategory is marked as a "Data Point."

Table 5-1
Microcomponent Product Category Hierarchy

Total MOS Digital Microcomponent Integrated Circuit (IC):	Microprocessor + Microcontroller + Digital Signal Processor + Microperipheral
Microprocessor (MPU):	8-Bit and 16-Bit CISC MPU + 32-Bit and Greater CISC MPU + 32-Bit and Greater RISC MPU
8-Bit and 16-Bit CISC MPU:	Data Point
32-Bit and Greater CISC MPU:	Data Point
32-Bit and Greater RISC MPU:	Data Point
Microcontroller (MCU):	4-Bit MCU + 8-Bit MCU + 16-Bit and Greater MCU
4-Bit MCU:	Data Point
8-Bit MCU:	Data Point
16-Bit and Greater MCU:	Data Point
Digital Signal Processor (DSP):	Data Point
Microperipheral (MPR):	System Core Logic Chipsets + Graphics and Imaging Controllers + Communications Controllers + Mass Storage Controllers + Audio/Other Controllers
System Core Logic Chipsets:	Data Point
Graphics and Imaging Controllers:	Data Point
Communications Controllers:	Data Point
Mass Storage Controllers:	Data Point
Audio/Other Controllers:	Data Point

Source: Dataquest (November 1996)

Chapter 6
Microcomponent Product Category Definitions

The microcomponent product category definitions in Table 6-1 begin with total microcomponent and continue through each subcategory in the same order as shown in the preceding microcomponent product category hierarchy. At each level in the hierarchy, all subcategories that contribute to this level are shown as a subcategory summation in the right-hand column. Comprehensive definitions are given at every level.

Table 6-1
Microcomponent Product Category Definitions

Total Microcomponent IC	(Microprocessor + Microcontroller + Digital Signal Processor + Microperipheral) Microcomponents are a category of metal oxide semiconductor (MOS) digital integrated circuits made up of the microprocessor (MPU), microcontroller (MCU), programmable digital signal processor (DSP), and microperipheral (MPR) product families.
Microprocessor	(8-Bit and 16-Bit CISC MPU + 32-Bit and Greater CISC MPU + 32-Bit and Greater RISC MPU) An MPU is a MOS digital integrated circuit that includes an instruction decoder, arithmetic logic unit (ALU), registers, and additional logic. It may contain instruction, data, or unified caches, memory management systems, and auxiliary ALUs for floating point and other special data types. An MPU's functions are determined by fetching and executing instructions and manipulating data held in registers, internal cache, or external memory. MPUs operate out of external memory systems typically ranging from 1MB to 64MB of RAM and often backed by secondary memory systems (like disks). More highly integrated versions of MPUs may contain on-chip peripherals, interface, and support circuits. The MPU category includes MPUs incorporating or originating from an ASIC design. MPUs are divided into complex-instruction-set computer (CISC) or reduced-instruction-set computer (RISC) implementations having 8-bit, 16-bit, or 32-bit and greater word width. MPUs are designed into computational applications or into embedded applications.

(Continued)

Table 6-1 (Continued)
Microcomponent Product Category Definitions

Microcontroller	(4-Bit MCU + 8-Bit MCU + 16-Bit and Greater MCU) An MCU is a MOS digital integrated circuit designed for standalone operation, that includes a programmable processing unit, program memory, read/write data memory, and some input/output capability. The processing unit contains an instruction decoder, arithmetic logic unit (ALU), registers, and additional logic. The MCU's functions are determined by fetching and executing instructions and manipulating data held in on-chip program and data memory (not including cache memories). MCU devices must be available with on-chip program or data store. As an option, some MCU devices can be purchased without on-chip memory for use during the debug and development phase of the system. Peripherals may be included on chip to assist in sophisticated input, output, and control functions. The MCU category includes MCUs incorporating or originating from an ASIC design. Standalone digital signal processors are not included with MCUs. MCUs are divided into 4-bit, 8-bit, or 16-bit and greater word width. All MCUs are designed into embedded applications.
Digital Signal Processor	A DSP is a programmable MOS digital integrated circuit designed for standalone operation, consisting of a high-speed arithmetic unit (typically a multiplier-accumulator unit) designed to perform complex mathematical operations such as Fourier transforms in real time to generate, manipulate, or interpret digital representations of analog signals. Modern DSPs typically access multiple pieces of data in different locations of on-chip memory over separate data paths using specialized addressing modes. Most DSP functions, such as the multiply-and-accumulate function, complete in a single instruction clock. DSPs usually include peripherals, which may include analog circuits like analog-to-digital converters. DSPs typically operate on 16 bits or 24 bits of fixed point data or 32 bits of floating point data, although Dataquest does not currently subdivide DSPs into these categories. DSPs that have no version that can be reprogrammed by the user in assembly language or a higher-level language are not included but are classified as application-specific standard products (ASSPs) or microperipherals. DSPs integrated on chip with an independent microprocessor or microcontroller are classified as either an MPU or MCU, respectively. All DSPs are designed into embedded applications. A similar term is pDSP.

(Continued)

Table 6-1 (Continued)
Microcomponent Product Category Definitions

Microperipheral	(System Core Logic Chipsets + Graphics and Imaging Controllers + Communications Controllers + Mass Storage Controllers + Audio/ Other Controllers) An MPR is a MOS digital integrated circuit that serves as a dedicated logical support function to a microprocessor or microcontroller in a system. Microperipherals are not programmable from assembly language, although they are often highly configurable by software or electrical signals. This definition includes MPRs comprising more than one device, such as PC or core logic chipsets. The MPR category includes MPRs incorporating, or originating from, an ASIC design. MPRs might be implemented using microprocessor, microcontroller, or digital signal processing elements, although this is generally not evident to the user.
System Core Logic Chipsets	Devices dedicated to a particular microprocessor interface that perform some of the basic interface functions such as memory management, DRAM control, cache control, bus interface control, DMA control, and interrupt control.
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).
Communications Controllers	Devices that control, format, and perform handshaking for the serial transmission and reception of information between systems or intelligent devices, including network controllers, integrated fax/modem chips, serial UARTs, and other communications interfaces.
Mass Storage Controllers	Devices that are used to control data storage into and retrieval from all forms of mass storage media (magnetic, optical, and others), which include controllers used within host computers (host-side) and within mass storage drives (device-side).
Audio/Other Controllers	Devices used to input or output information through other forms, including audio input/output controllers, keyboard controllers, pen input controllers, parallel port controllers, and various other devices.

Source: Dataquest (November 1996)

Word Width

This is the width, in bits, of the primary on-chip integer arithmetic and logic unit (ALU). This measurement is independent of the data bus width or any other bus associated with the device. The processor might operate on wider and narrower data types, with multiple passes through the ALU or with special hardware. The word width classification is not influenced by the existence of additional integer units or of floating point and other special data type processors. Table 6-2 shows the Dataquest word width category into which typical microcomponents are placed. A similar term is bit size.

Table 6-2
Microcomponent Word Widths

	4-Bit	8-Bit	16-Bit	24-Bit	32-Bit	64-Bit
MCU	4-bit	8-bit	16-bit and greater	-	16-bit and greater	-
MPU	-	8-bit and 16-bit	8-bit and 16-bit	-	32-bit and greater	32-bit and greater
DSP	-	-	DSP	DSP	DSP	-

Source: Dataquest (November 1996)

Chapter 7
Worldwide Geographic Region Definitions and Regional Roll-Ups

Americas

North America
Includes Canada, Mexico, and the United States (50 states).

South America

Central America

Japan

Japan is the only single-country region.

Europe, Africa, and Middle East

Europe

Western Europe
Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and Rest of Western Europe (Andorra, Cyprus, Gibraltar, Liechtenstein, Monaco, San Marino, Vatican City, Iceland, Malta, and Turkey).

Eastern Europe
Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (Belarus, Russian Federation, Ukraine, Georgia, Moldova, Armenia, Azerbaijan, Kazakhstan, Uzbekistan, Tajikistan, Kyrgyzstan, and Turkmenistan).

Africa

Middle East

Asia/Pacific

Includes Asia/Pacific's newly industrialized economies (NIEs) and the rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, South Korea, and Taiwan. The rest of Asia/Pacific region includes Australia, Bangladesh, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.

Chapter 8
Application Segment Definitions

Data Processing

Defined as computer systems, data storage, input/output (I/O) devices, dedicated systems, and other data processing equipment:

- Computer systems: The computer estimate does not include the value of the rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of graphics boards, motherboards, memory cards and single in-line memory modules (SIMMs), storage host adapters, and serial and parallel I/O boards. Worldwide computer systems production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group and to eliminate double-counting of system sales of storage devices, keyboards, and displays. Computer systems include supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and personal computers (including portable computers). Includes the value of central processing units (that is, boxes) only.
- Data storage includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.
- Input/output devices include alphanumeric terminals and graphics terminals (for example, X terminals), monitors, and funds transfer terminals; and printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, mice, keyboards, and digitizers.
- Dedicated systems include electronic copiers, electronic calculators and personal organizers, smart cards (IC cards), dictation/transcribing equipment, electronic typewriters and dedicated word processors, point-of-sale terminals and electronic cash registers, and mailing/letter-handling/addressing equipment.
- Other data processing includes sound/audio boards, digital video boards, accelerator boards, and embedded CPU boards.

Communications

Defined as premises telecom equipment, public telecom equipment, mobile communications equipment, broadcast and studio equipment, and other telecom equipment:

- Premises telecom equipment includes image and text communication, such as facsimile and facsimile cards, and video teleconferencing; data communications equipment such as modems and modem cards, statistical multiplexers, T1 multiplexers, front-end processors, DSU/CSU, protocol converters, local area network (LAN) interface cards, LAN hubs and internetworking equipment, and packet data switching systems; premises switching equipment, such as PBX telephone equipment, and key telephone systems; call processing equipment, such as voice messaging, interactive voice response systems, and automatic call distributors; and desktop terminal equipment, such as telephone sets/pay telephones and cordless telephones, and teleprinters.

- Public telecom equipment includes transmission equipment, such as multiplexers, carrier systems, microwave radio, laser and infrared transmission equipment, and satellite communications equipment; and central office switching equipment.
- Mobile communications equipment includes mobile radio systems such as cellular telephones, microcellular telephones, mobile radios, mobile radio base station equipment, and pagers; portable radio receivers and transmitters; and radio checkout equipment.
- Broadcast and studio equipment includes audio equipment, video equipment, transmitters and radio frequency (RF) power amplifiers, studio transmitter links, cable TV (head-end) equipment, closed-circuit TV equipment, and other equipment, such as studio and theater equipment.
- Other telecom equipment includes intercom equipment, electrical amplifiers, and communications equipment not elsewhere classified.

Industrial

Defined as security/energy management systems, manufacturing systems/instruments, medical equipment, and other industrial equipment:

- Security/energy management includes alarm systems, such as intrusion detection and fire detection systems, and energy management systems.
- Manufacturing systems/instruments include microcomponent production equipment, controls, process controls, and control and processing displays and robots, as well as test and measuring equipment such as microcomponent-dedicated automatic test equipment (ATE), other test and measurement equipment, and nuclear electronics.
- Medical equipment includes diagnostic equipment, therapeutic equipment, patient monitoring equipment, surgical support systems, and irradiation equipment.
- Other industrial equipment includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

Consumer

Defined as audio equipment, video equipment, personal electronics, appliances, and other consumer equipment:

- Audio equipment includes compact disc players, radios, stereo components, musical instruments, and tape recorders.

- Video equipment includes VCRs and VTRs, video cameras and camcorders, video disc players, color and monochrome TVs, and cable/satellite set-top decoders.
- Personal electronics includes electronic games and toys (systems and cartridges), cameras, watches, and clocks.
- Appliances includes air conditioners, microwave ovens, washers and dryers, refrigerators, dishwashers, and ranges and ovens.
- Other consumer equipment includes automatic garage door openers and consumer equipment not elsewhere classified.

Military and Civil Aerospace

Defined as military and civil aerospace electronic equipment.

- Military/civil aerospace: North American military/civil aerospace production has been re-estimated and revalued to reflect U.S. Department of Commerce estimates of U.S. defense and civil (aerospace) electronics. Military/civil aerospace includes radar/sonar/reconnaissance systems, missile/space-related electronics, navigation equipment, electronic warfare, aircraft flight systems, and command and control systems.

Transportation

Defined as in-car entertainment, body control electronics, power train systems, and safety and convenience systems.

- In-car entertainment includes systems such as AM/FM radios, cassette and compact disc players, and radio/cassette combination systems.
- Body control electronics includes four-wheel steering control, two-wheel drive/four-wheel drive control; multiplex systems such as driver's door console, door locks, windshield wipers, heated rear windows, memory seats, memory steering wheel, remote security systems, and suspension control and traction control systems; lighting controls including automatic headlight systems, timers, reminders, and sequential signal controls; and other body control electronics, including aerodynamic aid control and power roof/window controls; driver information systems, including electronic dashboard/instrument clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and location systems, signal and warning lights, and trip computers.
- Power train systems include engine management systems, power train sensors, ignition control, fuel injection systems, fuel flow, engine temperature, air temperature, coolant level, wheel speed sensors, and transmission control.
- Safety and convenience systems include climate control systems (air conditioning/heating), air purifier systems, air bag control systems, antilock braking systems, collision warning systems, and cruise control.

Applications

Computational Applications

Computational applications of microprocessors are designed to be highly programmable by the end user while the manufacturer has only a vague idea of the final use of the system. The microprocessor is the central processor in the system, running an operating system performing task scheduling, system administration, and resource allocation according to the needs of the programs scheduled or initiated to execute. The programs are typically executed by the central processor, although they may be dispatched to subservient processors. The programs typically reside on mass storage media such as floppy or hard disks or may be downloaded over networks.

The programs executed may vary greatly according to user demands on the product, so the system is designed to handle a wide variety of potential applications. The operating system might be DOS, Windows 95, Mac OS, UNIX, OS/2, Solaris, or any other, although it is rarely designed for real-time response. The application programs are normally computational in nature. Computational applications must be programmable by the end user of the equipment in a higher-level language such as BASIC or FORTRAN.

The most common computational applications are personal computers, workstations, and servers. Most computational MPUs can also be used in embedded applications. Computational systems may have many embedded microcomponents in subsystems that support the central processor, such as the monitor, keyboard, mouse, disk drive, network interface, and modem, among others.

Embedded Applications

Embedded applications of microcomponents are designed to perform a fixed set of functions once the system is shipped from the manufacturer. Those functions typically define the end product. The system may be reconfigurable by the end user but cannot be reprogrammed by a high-level language such as BASIC or FORTRAN. Usually the end user would not even know what type of processor was in the equipment.

The processor will typically run a real-time operating system (although real time is not a requirement, nor is any operating system) and a set of instructions that perform functions critical to the operation of the end product. Programs run by the processor may perform system monitoring, system control, data processing, peripherals interfacing, data movement, and motion control, among other functions. Programs often exist in ROM, although they may load from secondary storage, such as disks. Each processor or microcontroller in the system typically has a fairly narrow range of responsibilities.

Examples of embedded applications are many and varied but include feature phones, cellular phones, cellular infrastructure, telephone switches, bridges, routers, network cards, point of sale terminals, modems, arcade games, cameras, camcorders, VCRs, satellite receivers, set-top boxes, remote controls, audio equipment (personal, home, and professional), keyboards, disk drives, CD drives, laser printers, other computer peripherals, fax machines, copiers, medical instruments, motor control, industrial process control, robotics, engine control, airbags, antilock braking systems, and global positioning systems. Although personal digital assistants (PDA), video games, and organizers can be fed external programs, the purpose of the device is still primarily the same, and so they are considered embedded applications. All microcontrollers and all digital signal processors, as well as many microprocessors, are designed into embedded applications.

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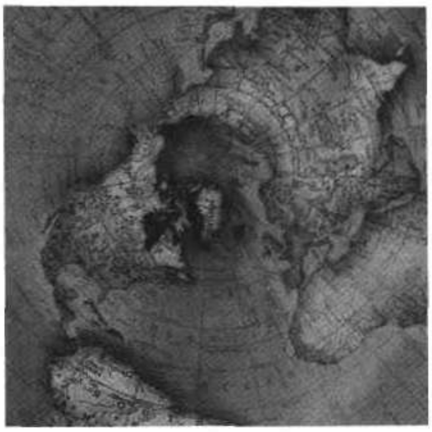

Dataquest

1995 Microcomponent Market Share

Market Statistics

Program: Microcomponents Worldwide
Product Code: MCRO-WW-MS-9601
Publication Date: May 27, 1996
Filing: Market Statistics

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Note: All tables show estimated data.

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Introduction

This document contains detailed information on Dataquest's view of the microcomponent market. Microcomponents include microprocessors, microcontrollers, digital signal processors, and peripheral circuits. Included in this document are the following:

- 1993-1995 revenue and market share estimates
- 1994-1995 revenue and market share rankings

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

Microcomponent market share estimates combine data from many countries, each of which has a different and fluctuating exchange rate. Estimates of non-U.S. market consumption or revenue are based on the average exchange rate for the given year. Refer to the section entitled "Exchange Rates" for more information regarding these average rates. As a rule, Dataquest's estimates are calculated in local currencies and then converted to U.S. dollars.

Further data on microprocessors and microcontrollers is detailed in other documents within Dataquest's Embedded Microcomponents Worldwide program and the Semiconductor Directions in PCs and PC Multimedia Worldwide program. More detail and qualitative analysis of microcomponent market data may also be available in other documents of these services or may be requested through Dataquest's client inquiry service.

Segmentation

This section outlines the market segments that are specific to this document. Dataquest's objective is to provide data along lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to clients.

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)
- Programmable Digital Signal Processor (DSP)

Definitions

MOS Digital Microprocessor (MPU) is defined as an IC that includes an instruction decoder, arithmetic logic unit (ALU), registers, and additional logic. It may contain instruction, data, or unified caches, memory management systems, and auxiliary ALUs for floating point. An MPU's functions are determined by fetching and executing instructions and manipulating data held in registers, internal cache, or external memory. MPUs typically operate out of external memory systems ranging from 1MB to 64MB and secondary memory systems (such as disks). More highly integrated versions of MPUs may contain on-chip peripheral circuits. The MPU category includes MPUs incorporating or originating from an ASIC design. MPUs are divided into complex instruction set computer (CISC) or reduced instruction set computer (RISC) and 8-bit, 16-bit, or 32-bit and greater word width. MPUs are designed into compute applications or into embedded applications.

MOS Digital Microcontroller (MCU) is defined as an IC designed for standalone operation that includes a programmable processing unit, program memory, read/write data memory, and some input/output capability. The processing unit contains an instruction decoder, arithmetic logic unit (ALU), registers, and additional logic. The MCU's functions are determined by fetching and executing instructions and manipulating data held in on-chip program and data memory (not including cache memories). MCU devices must be available with on-chip program or data store. As an option, some MCU devices can be purchased without on-chip memory. Peripherals may be included on-chip to assist in sophisticated input, output, and control functions. The MCU category includes MCUs incorporating or originating from an ASIC design. Standalone digital signal processors are not included with MCUs. MCUs are divided into 4-bit, 8-bit, or 16-bit and greater word width. All MCUs are designed into embedded applications.

MOS Digital Microperipheral (MPR) is defined as an IC that serves as a logical support function to an MPU in a system. This definition includes MPRs comprising more than one device, such as a PC or core logic chipsets. The MPR category includes MPRs incorporating or originating from an ASIC design.

Programmable Digital Signal Processor (DSP) is defined as a programmable IC composed of a high-speed arithmetic unit (typically a multiplier-accumulator unit) designed to perform complex mathematical operations such as Fourier transforms, manipulating digital representations of analog signals in real time. Modern DSPs typically access data in different locations over separate data paths using specialized addressing modes. Most DSP functions, such as the multiply-and-accumulate function, are completed in a single instruction clock. DSPs typically operate on 16 bits or 24 bits of fixed point data or 32 bits of floating-point data, although Dataquest does not subdivide DSPs into these categories. DSPs that have no version that can be reprogrammed by the user are not included but are categorized as application-specific special products

(ASSPs). DSPs integrated on-chip with an MPU or MCU are classified as either an MPU or MCU, respectively.

Regional Definitions

Americas

North America: Includes Canada, Mexico, and the United States (50 states)

South America

Central America

Japan

Japan is the only single-country region.

Europe, Africa, and the Middle East

Western Europe: Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and Rest of Western Europe (Andorra, Cyprus, Gibraltar, Liechtenstein, Monaco, San Marino, Vatican City, Iceland, Malta, and Turkey).

Eastern Europe: Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (Belarus, Russian Federation, Ukraine, Georgia, Moldavia, Armenia, Azerbaijan, Kazakhstan, Uzbekistan, Tadjikistan, Kyrgyzstan, and Turkmenistan).

Asia/Pacific

Includes Hong Kong, Singapore, South Korea, Taiwan, Australia, Bangladesh, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.

Line Item Definitions

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

Market Share Methodology

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

- Information published by major industry participants
- Estimates made by knowledgeable and reliable industry spokespersons

- Government data or trade association data (such as WSTS, MITI, and U.S. DOC)
- Published product literature and price lists
- Interviews with knowledgeable manufacturers, distributors, and users
- Relevant economic data
- Information and data from online and CD-ROM data banks
- Articles in both the general and trade press
- Reports from financial analysts
- End-user surveys

Dataquest believes that the estimates presented in this document are the most accurate and meaningful statistics available.

Despite the care taken in gathering, analyzing, and categorizing the data in a meaningful way, careful attention must be paid to the definitions and assumptions used herein when interpreting the estimates presented in this document. Various companies, government agencies, and trade associations may use slightly different definitions of product categories and regional groupings, or they may include different companies in their summaries. These differences should be kept in mind when making comparisons between data and numbers provided by Dataquest and those provided by other 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 product lines were acquired by Cirrus Logic in 1994.

2. Dialog, Eurosil, Matra, Telefunken, and Siliconix are now known as Temic.

3. LG Semicon was formerly known as Goldstar.

4. IMP was formerly known as International Microelectronic Products.

5. Inmos' revenue is included in SGS-Thomson's revenue.

6. Linfinity was formerly known as Silicon General.

7. NCR was acquired by Hyundai in 1994 and is operated as Symbios Logic Inc.

8. Philips' revenue includes Signetics revenue.

9. Thomson Semiconductors Specific (TCS) was formed through the merger of Thomson Composants Microndes (TCM) and Thomson Composants Militaires et Spatiaux (TMS).

10. The following companies were added to worldwide market share tables starting in 1994 and may result in higher 1994 market growth rates in certain product areas:

- Integrated Silicon Solution Inc.
- Ramtron
- Quick Logic
- International CMOS Technology

11. In 1994, three-quarters of Intel's PLD Divison's revenue is included in Intel's revenue and the last quarter's revenue is included in Altera's revenue to accurately reflect the sale of the PLD Division.

12. Tektronix's revenue is now included with Maxim's revenue.

13. Rockwell's 1994 revenue has been restated.

14. National Semiconductor's 1994 revenue has been restated.

15. Comlinear's revenue is included in National Semiconductor's revenue.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar amounts. Table 1 outlines these rates for 1993 through 1995.

Table 1
Exchange Rates

	1993	1994	1995
Japan (Yen/U.S.$)	111.20	101.81	93.90
France (Franc/U.S.$)	5.67	5.54	4.97
Germany (Deutsche Mark/U.S.$)	1.66	1.62	1.43
United Kingdom (U.S.$/Pound Sterling)	1.50	1.53	1.59

Source: Dataquest (April 1996)

Section 1: 1995 Microcomponent Market Share

Table 1-1
Factory Revenue from Shipments of MOS Microcomponents by Product and Regional Company Base Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
MOS Microcomponent						
North American Companies	14,395	18,843	24,210	72.2%	71.4%	70.1%
Japanese Companies	4,585	6,137	8,102	23.0%	23.2%	23.5%
European Companies	640	851	1,432	3.2%	3.2%	4.1%
Asia/Pacific Companies	327	577	774	1.6%	2.2%	2.2%
Total Market	19,947	26,408	34,518	100.0%	100.0%	100.0%
Microprocessor						
North American Companies	8,408	10,898	13,609	95.7%	95.3%	95.3%
Japanese Companies	311	461	562	3.5%	4.0%	3.9%
European Companies	61	67	85	0.7%	0.6%	0.6%
Asia/Pacific Companies	3	11	23	0.0%	0.1%	0.2%
Total Market	8,783	11,437	14,280	100.0%	100.0%	100.0%
Microcontroller						
North American Companies	1,984	2,514	3,115	33.6%	33.4%	30.4%
Japanese Companies	3,363	4,261	5,930	57.0%	56.7%	57.8%
European Companies	510	685	1,066	8.6%	9.1%	10.4%
Asia/Pacific Companies	47	57	144	0.8%	0.8%	1.4%
Total Market	5,904	7,517	10,255	100.0%	100.0%	100.0%
Microperipheral						
North American Companies	3,400	4,520	5,976	74.2%	70.4%	71.9%
Japanese Companies	835	1,301	1,456	18.2%	20.3%	17.5%
European Companies	69	94	274	1.5%	1.5%	3.3%
Asia/Pacific Companies	277	509	607	6.0%	7.9%	7.3%
Total Market	4,581	6,424	8,313	100.0%	100.0%	100.0%
Digital Signal Processor						
North American Companies	603	911	1,509	88.8%	88.4%	90.4%
Japanese Companies	76	114	154	11.2%	11.1%	9.2%
European Companies	0	5	7	0.0%	0.5%	0.4%
Asia/Pacific Companies	0	0	0	0.0%	0.0%	0.0%
Total Market	679	1,030	1,670	100.0%	100.0%	100.0%

NA = Not available
Source: Dataquest (May 1996)

Table 1-2
Each Company's Factory Revenue from Shipments of MOS Microcomponents Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	19,947	26,408	34,518	100.0	100.0	100.0
North American Companies	14,395	18,843	24,210	72.2	71.4	70.1
ACC Microelectronics	36	49	40	0.2	0.2	0.1
Adaptec	122	125	124	0.6	0.5	0.4
Advanced Micro Devices	563	1,021	922	2.8	3.9	2.7
Alliance Semiconductor	0	-	10	0	0	0
Analog Devices	69	85	117	0.3	0.3	0.3
AT&T	246	305	510	1.2	1.2	1.5
Atmel	5	5	28	0	0	0.1
California Micro Devices	6	5	6	0	0	0
Chips & Technologies	86	89	138	0.4	0.3	0.4
Cirrus Logic	371	681	886	1.9	2.6	2.6
Cypress Semiconductor	8	40	48	0	0.2	0.1
Cyrix	125	241	212	0.6	0.9	0.6
Dallas Semiconductor	56	22	20	0.3	0.1	0.1
ETEQ Microsystems	19	0	-	0.1	0	0
Harris	47	52	66	0.2	0.2	0.2
Hughes	3	3	3	0	0	0
IBM	337	399	703	1.7	1.5	2.0
Integrated Device Technology	48	51	63	0.2	0.2	0.2
Integrated Information Tech.	40	35	44	0.2	0.1	0.1
Intel	7,444	9,595	12,396	37.3	36.3	35.9
ITT	25	12	15	0.1	0	0
LSI Logic	77	78	107	0.4	0.3	0.3
Micro Linear	0	6	-	0	0	0
Microchip Technology	72	130	189	0.4	0.5	0.5
Motorola	2,065	2,363	2,996	10.4	8.9	8.7
National Semiconductor	477	452	541	2.4	1.7	1.6
Oak Technology	50	62	84	0.3	0.2	0.2
OPTi	86	130	167	0.4	0.5	0.5
Performance Semiconductor	18	15	21	0.1	0.1	0.1
Q Logic	21	45	60	0.1	0.2	0.2
Rockwell	17	509	738	0.1	1.9	2.1
S3	113	130	315	0.6	0.5	0.9
SEEQ Technology	4	17	21	0	0.1	0.1
Sierra Semiconductor	0	35	44	0	0.1	0.1
Standard Microsystems	43	100	150	0.2	0.4	0.4

(Continued)

Table 1-2 (Continued)
Each Company's Factory Revenue from Shipments of MOS Microcomponents Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Supertex	2	1	1	0	0	0
Symbios	63	81	85	0.3	0.3	0.2
Symphony Laboratories	66	12	15	0.3	0	0
Texas Instruments	781	1,006	1,254	3.9	3.8	3.6
Trident Microsystems	60	87	139	0.3	0.3	0.4
Tseng Labs	71	83	105	0.4	0.3	0.3
VLSI Technology	173	216	194	0.9	0.8	0.6
WaferScale Integration	5	3	18	0	0	0.1
Weitek	33	28	37	0.2	0.1	0.1
Western Digital	218	184	239	1.1	0.7	0.7
Zilog	203	222	265	1.0	0.8	0.8
Other North American Companies	15	25	69	0.1	0.1	0.2
Japanese Companies	4,585	6,137	8,102	23.0	23.2	23.5
Fuji Electric	1	2	3	0	0	0
Fujitsu	282	390	651	1.4	1.5	1.9
Hitachi	718	998	1,441	3.6	3.8	4.2
Matsushita	286	460	557	1.4	1.7	1.6
Mitsubishi	532	698	982	2.7	2.6	2.8
NEC	1,341	1,678	2,063	6.7	6.4	6.0
New JRC	0	2	4	0	0	0
Oki	180	217	235	0.9	0.8	0.7
Ricoh	89	83	75	0.4	0.3	0.2
Rohm	23	50	71	0.1	0.2	0.2
Sanyo	145	161	186	0.7	0.6	0.5
Seiko Epson	17	21	28	0.1	0.1	0.1
Sharp	170	192	221	0.9	0.7	0.6
Sony	112	194	235	0.6	0.7	0.7
Toshiba	540	718	1,095	2.7	2.7	3.2
Yamaha	149	273	245	0.7	1.0	0.7
Other Japanese Companies	0	0	10	0	0	0
European Companies	640	851	1,432	3.2	3.2	4.1
Elex	0	15	23	0	0.1	0.1
EM Microelectronics Marin	0	0	2	0	0	0
GEC Plessey	7	11	10	0	0	0
Philips	305	403	662	1.5	1.5	1.9
SGS-Thomson	162	227	437	0.8	0.9	1.3
Siemens	107	128	208	0.5	0.5	0.6

(Continued)

Table 1-2 (Continued)
Each Company's Factory Revenue from Shipments of MOS Microcomponents Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
TEMIC	44	51	68	0.2	0.2	0.2
TCS	15	16	22	0.1	0.1	0.1
Asia/Pacific Companies	327	577	774	1.6	2.2	2.2
Acer	50	68	77	0.3	0.3	0.2
Daewoo	7	17	23	0	0.1	0.1
Holtek	18	20	34	0.1	0.1	0.1
Hualon Microelectronics Corp.	10	0	-	0.1	0	0
Hyundai	0	2	1	0	0	0
LG Semicon	12	29	56	0.1	0.1	0.2
Macronix	15	21	35	0.1	0.1	0.1
Samsung	46	44	87	0.2	0.2	0.3
Silicon Integrated Systems	26	101	127	0.1	0.4	0.4
United Microelectronics	113	227	274	0.6	0.9	0.8
Winbond Electronics	30	48	60	0.2	0.2	0.2

NA = Not available
Source: Dataquest (May 1996)

Table 1-3
Each Company's Factory Revenue from Shipments of MOS Microcomponents to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	7,620	9,839	12,431	100.0	100.0	100.0
North American Companies	7,037	8,981	11,267	92.3	91.3	90.6
ACC Microelectronics	7	13	16	0.1	0.1	0.1
Adaptec	74	82	-	1.0	0.8	0
Advanced Micro Devices	207	387	325	2.7	3.9	2.6
Alliance Semiconductor	0	-	2	0	0	0
Analog Devices	28	37	37	0.4	0.4	0.3
AT&T	117	166	231	1.5	1.7	1.9
Atmel	4	2	10	0.1	0	0.1
California Micro Devices	3	3	4	0	0	0
Chips & Technologies	32	32	30	0.4	0.3	0.2
Cirrus Logic	139	293	369	1.8	3.0	3.0
Cypress Semiconductor	6	28	33	0.1	0.3	0.3
Cyrix	62	122	66	0.8	1.2	0.5
Dallas Semiconductor	34	9	7	0.4	0.1	0.1
ETEQ Microsystems	6	0	0	0.1	0	0
Harris	29	29	38	0.4	0.3	0.3
Hughes	3	3	3	0	0	0
IBM	218	240	395	2.9	2.4	3.2
Integrated Device Technology	35	33	44	0.5	0.3	0.4
Integrated Information Tech.	17	16	20	0.2	0.2	0.2
Intel	3,733	4,680	6,099	49.0	47.6	49.1
ITT	6	0	0	0.1	0	0
LSI Logic	47	26	43	0.6	0.3	0.3
Micro Linear	0	5	-	0	0.1	0
Microchip Technology	30	55	81	0.4	0.6	0.7
Motorola	957	1,132	1,417	12.6	11.5	11.4
National Semiconductor	242	235	283	3.2	2.4	2.3
Oak Technology	7	9	11	0.1	0.1	0.1
OPTi	36	56	82	0.5	0.6	0.7
Performance Semiconductor	17	15	21	0.2	0.2	0.2
Q Logic	9	19	24	0.1	0.2	0.2
Rockwell	11	165	263	0.1	1.7	2.1
S3	53	75	180	0.7	0.8	1.4
SEEQ Technology	3	15	19	0	0.2	0.2
Sierra Semiconductor	0	17	21	0	0.2	0.2
Standard Microsystems	18	50	60	0.2	0.5	0.5

(Continued)

Table 1-3 (Continued)
Each Company's Factory Revenue from Shipments of MOS Microcomponents to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Supertex	2	1	1	0	0	0
Symbios	57	64	66	0.7	0.7	0.5
Symphony Laboratories	7	1	1	0.1	0	0
Texas Instruments	422	517	520	5.5	5.3	4.2
Trident Microsystems	5	12	33	0.1	0.1	0.3
Tseng Labs	49	58	73	0.6	0.6	0.6
VLSI Technology	90	72	96	1.2	0.7	0.8
WaferScale Integration	2	1	6	0	0	0
Weitek	29	25	33	0.4	0.3	0.3
Western Digital	78	66	83	1.0	0.7	0.7
Zilog	93	100	106	1.2	1.0	0.9
Other North American Companies	8	8	14	0.1	0.1	0.1
Japanese Companies	402	580	682	5.3	5.9	5.5
Fujitsu	25	64	100	0.3	0.7	0.8
Hitachi	93	135	173	1.2	1.4	1.4
Matsushita	8	10	11	0.1	0.1	0.1
Mitsubishi	21	37	51	0.3	0.4	0.4
NEC	115	143	160	1.5	1.5	1.3
Oki	23	31	32	0.3	0.3	0.3
Ricoh	0	-	4	0	0	0
Rohm	2	3	9	0	0	0.1
Sanyo	4	15	16	0.1	0.2	0.1
Seiko Epson	1	1	2	0	0	0
Sharp	8	9	11	0.1	0.1	0.1
Sony	4	6	7	0.1	0.1	0.1
Toshiba	77	88	85	1.0	0.9	0.7
Yamaha	21	38	22	0.3	0.4	0.2
European Companies	173	267	437	2.3	2.7	3.5
GEC Plessey	1	3	6	0	0	0
Philips	104	149	233	1.4	1.5	1.9
SGS-Thomson	38	76	162	0.5	0.8	1.3
Siemens	11	12	13	0.1	0.1	0.1
TEMIC	13	21	15	0.2	0.2	0.1
TCS	6	6	8	0.1	0.1	0.1

(Continued)

Table 1-3 (Continued)
Each Company's Factory Revenue from Shipments of MOS Microcomponents to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Asia/Pacific Companies	8	11	45	0.1	0.1	0.4
Macronix	1	2	4	0	0	0
Samsung	5	6	9	0.1	0.1	0.1
Silicon Integrated Systems	1	0	29	0	0	0.2
Winbond Electronics	1	3	3	0	0	0

NA = Not available
Source: Dataquest (May 1996)

Table 1-4
Each Company's Factory Revenue from Shipments of MOS Microcomponents to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	3,987	5,603	7,828	100.0	100.0	100.0
North American Companies	1,151	1,792	2,676	28.9	32.0	34.2
ACC Microelectronics	1	1	1	0	0	0
Adaptec	5	5	18	0.1	0.1	0.2
Advanced Micro Devices	21	24	72	0.5	0.4	0.9
Analog Devices	5	5	13	0.1	0.1	0.2
AT&T	12	17	36	0.3	0.3	0.5
Chips & Technologies	7	6	53	0.2	0.1	0.7
Cirrus Logic	46	102	154	1.2	1.8	2.0
Cypress Semiconductor	0	4	6	0	0.1	0.1
Cyrix	11	17	29	0.3	0.3	0.4
Dallas Semiconductor	5	2	3	0.1	0	0
Harris	2	3	4	0.1	0.1	0.1
IBM	50	30	18	1.3	0.5	0.2
Integrated Device Technology	4	5	9	0.1	0.1	0.1
Intel	610	912	1,284	15.3	16.3	16.4
ITT	2	0	-	0.1	0	0
LSI Logic	0	36	30	0	0.6	0.4
Microchip Technology	2	2	3	0.1	0	0
Motorola	178	206	263	4.5	3.7	3.4
National Semiconductor	25	36	37	0.6	0.6	0.5
Oak Technology	2	23	35	0.1	0.4	0.4
OPTi	2	5	5	0.1	0.1	0.1
Performance Semiconductor	1	0	0	0	0	0
Q Logic	5	15	23	0.1	0.3	0.3
Rockwell	-	160	298	0	2.9	3.8
S3	4	13	5	0.1	0.2	0.1
Sierra Semiconductor	0	2	3	0	0	0
Standard Microsystems	1	1	5	0	0	0.1
Symbios	4	8	8	0.1	0.1	0.1
Symphony Laboratories	1	0	0	0	0	0
Texas Instruments	92	100	136	2.3	1.8	1.7
Trident Microsystems	0	-	23	0	0	0.3
VLSI Technology	3	7	17	0.1	0.1	0.2
WaferScale Integration	0	-	3	0	0	0
Weitek	2	2	3	0.1	0	0
Western Digital	36	31	47	0.9	0.6	0.6

(Continued)

Table 1-4 (Continued)
Each Company's Factory Revenue from Shipments of MOS Microcomponents to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Zilog	11	11	19	0.3	0.2	0.2
Other North American Companies	1	1	13	0	0	0.2
Japanese Companies	2,818	3,772	5,120	70.7	67.3	65.4
Fuji Electric	1	2	3	0	0	0
Fujitsu	190	232	458	4.8	4.1	5.9
Hitachi	422	588	818	10.6	10.5	10.5
Matsushita	242	403	488	6.1	7.2	6.2
Mitsubishi	316	443	676	7.9	7.9	8.6
NEC	867	1,083	1,353	21.7	19.3	17.3
New JRC	0	2	2	0	0	0
Oki	83	103	111	2.1	1.8	1.4
Ricoh	77	70	59	1.9	1.2	0.8
Rohm	17	39	47	0.4	0.7	0.6
Sanyo	54	67	69	1.4	1.2	0.9
Seiko Epson	12	15	19	0.3	0.3	0.2
Sharp	126	136	154	3.2	2.4	2.0
Sony	81	153	186	2.0	2.7	2.4
Toshiba	253	348	556	6.3	6.2	7.1
Yamaha	77	88	110	1.9	1.6	1.4
Other Japanese Companies	0	0	10	0	0	0.1
European Companies	17	18	30	0.4	0.3	0.4
GEC Plessey	3	4	1	0.1	0.1	0
Philips	7	6	17	0.2	0.1	0.2
SGS-Thomson	4	3	9	0.1	0.1	0.1
Siemens	2	2	3	0.1	0	0
TEMIC	1	3	-	0	0.1	0
Asia/Pacific Companies	1	21	3	0	0.4	0
Samsung	1	1	2	0	0	0
United Microelectronics	0	20	-	0	0.4	0
Winbond Electronics	0	-	1	0	0	0

NA = Not available
Source: Dataquest (May 1996)

Table 1-5
Each Company's Factory Revenue from Shipments of MOS Microcomponents to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	4,037	5,408	7,007	100.0	100.0	100.0
North American Companies	3,210	4,324	5,431	79.5	80.0	77.5
ACC Microelectronics	0	-	1	0	0	0
Adaptec	2	2	-	0	0	0
Advanced Micro Devices	129	301	254	3.2	5.6	3.6
Alliance Semiconductor	0	-	5	0	0	0.1
Analog Devices	29	35	57	0.7	0.6	0.8
AT&T	84	85	200	2.1	1.6	2.9
Atmel	0	1	3	0	0	0
Chips & Technologies	5	5	10	0.1	0.1	0.1
Cirrus Logic	10	54	66	0.2	1.0	0.9
Cypress Semiconductor	2	6	7	0	0.1	0.1
Cyrix	27	62	44	0.7	1.1	0.6
Dallas Semiconductor	9	4	4	0.2	0.1	0.1
ETEQ Microsystems	1	0	0	0	0	0
Harris	13	16	18	0.3	0.3	0.3
IBM	25	16	10	0.6	0.3	0.1
Integrated Device Technology	9	10	4	0.2	0.2	0.1
Integrated Information Tech.	13	11	13	0.3	0.2	0.2
Intel	1,928	2,491	3,045	47.8	46.1	43.5
ITT	12	12	15	0.3	0.2	0.2
LSI Logic	14	12	25	0.3	0.2	0.4
Micro Linear	0	1	-	0	0	0
Microchip Technology	20	44	54	0.5	0.8	0.8
Motorola	489	569	759	12.1	10.5	10.8
National Semiconductor	90	96	110	2.2	1.8	1.6
Oak Technology	3	4	5	0.1	0.1	0.1
OPTi	5	6	10	0.1	0.1	0.1
Q Logic	0	4	5	0	0.1	0.1
Rockwell	4	97	111	0.1	1.8	1.6
S3	12	18	50	0.3	0.3	0.7
SEEQ Technology	1	2	2	0	0	0
Sierra Semiconductor	0	8	10	0	0.1	0.1
Standard Microsystems	5	18	25	0.1	0.3	0.4
Symbios	2	4	6	0	0.1	0.1
Symphony Laboratories	5	0	0	0.1	0	0
Texas Instruments	149	221	370	3.7	4.1	5.3

(Continued)

Table 1-5 (Continued)
Each Company's Factory Revenue from Shipments of MOS Microcomponents to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Trident Microsystems	1	-	1	0	0	0
Tseng Labs	6	7	9	0.1	0.1	0.1
VLSI Technology	33	31	22	0.8	0.6	0.3
WaferScale Integration	1	1	6	0	0	0.1
Weitek	2	1	1	0	0	0
Western Digital	36	32	39	0.9	0.6	0.6
Zilog	33	36	41	0.8	0.7	0.6
Other North American Companies	0	-	12	0	0	0.2
Japanese Companies	474	641	848	11.7	11.9	12.1
Fujitsu	37	53	31	0.9	1.0	0.4
Hitachi	87	132	241	2.2	2.4	3.4
Matsushita	10	12	14	0.2	0.2	0.2
Mitsubishi	26	33	59	0.6	0.6	0.8
NEC	209	278	307	5.2	5.1	4.4
Oki	24	31	35	0.6	0.6	0.5
Rohm	1	1	1	0	0	0
Sanyo	2	3	4	0	0.1	0.1
Seiko Epson	1	1	1	0	0	0
Sharp	1	1	1	0	0	0
Toshiba	74	94	148	1.8	1.7	2.1
Yamaha	2	2	5	0	0	0.1
European Companies	350	427	705	8.7	7.9	10.1
Elex	0	15	23	0	0.3	0.3
EM Microelectronics Marin	0	0	2	0	0	0
GEC Plessey	1	2	2	0	0	0
Philips	130	150	260	3.2	2.8	3.7
SGS-Thomson	95	120	188	2.4	2.2	2.7
Siemens	90	108	182	2.2	2.0	2.6
TEMIC	25	22	34	0.6	0.4	0.5
TCS	9	10	14	0.2	0.2	0.2
Asia/Pacific Companies	3	16	22	0.1	0.3	0.3
Holtek	1	1	2	0	0	0
Samsung	0	4	5	0	0.1	0.1
Silicon Integrated Systems	0	0	1	0	0	0
United Microelectronics	2	11	14	0	0.2	0.2

NA = Not available
Source: Dataquest (May 1996)

Table 1-6
Each Company's Factory Revenue from Shipments of MOS Microcomponents to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	4,303	5,558	7,252	100.0	100.0	100.0
North American Companies	2,997	3,746	4,836	69.6	67.4	66.7
ACC Microelectronics	28	35	22	0.7	0.6	0.3
Adaptec	41	36	106	1.0	0.6	1.5
Advanced Micro Devices	206	309	271	4.8	5.6	3.7
Alliance Semiconductor	0	-	3	0	0	0
Analog Devices	7	8	9	0.2	0.1	0.1
AT&T	33	37	43	0.8	0.7	0.6
Atmel	1	2	15	0	0	0.2
California Micro Devices	3	2	3	0.1	0	0
Chips & Technologies	42	46	45	1.0	0.8	0.6
Cirrus Logic	176	232	297	4.1	4.2	4.1
Cypress Semiconductor	0	2	3	0	0	0
Cyrix	25	40	73	0.6	0.7	1.0
Dallas Semiconductor	8	7	6	0.2	0.1	0.1
ETEQ Microsystems	12	0	-	0.3	0	0
Harris	3	4	6	0.1	0.1	0.1
IBM	44	113	280	1.0	2.0	3.9
Integrated Device Technology	0	3	6	0	0.1	0.1
Integrated Information Tech.	10	8	10	0.2	0.1	0.1
Intel	1,173	1,512	1,970	27.3	27.2	27.2
ITT	5	0	-	0.1	0	0
LSI Logic	16	4	9	0.4	0.1	0.1
Microchip Technology	20	29	51	0.5	0.5	0.7
Motorola	441	456	556	10.2	8.2	7.7
National Semiconductor	120	85	111	2.8	1.5	1.5
Oak Technology	38	26	33	0.9	0.5	0.5
OPTi	43	63	70	1.0	1.1	1.0
Q Logic	7	7	9	0.2	0.1	0.1
Rockwell	2	87	66	0	1.6	0.9
S3	44	24	80	1.0	0.4	1.1
Sierra Semiconductor	0	8	10	0	0.1	0.1
Standard Microsystems	19	31	60	0.4	0.6	0.8
Symbios	0	5	5	0	0.1	0.1
Symphony Laboratories	53	11	14	1.2	0.2	0.2
Texas Instruments	118	168	228	2.7	3.0	3.1
Trident Microsystems	54	75	82	1.3	1.3	1.1
Tseng Labs	16	18	23	0.4	0.3	0.3
VLSI Technology	47	106	58	1.1	1.9	0.8

(Continued)

Table 1-6 (Continued)
Each Company's Factory Revenue from Shipments of MOS Microcomponents to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
WaferScale Integration	2	1	3	0	0	0
Western Digital	68	55	70	1.6	1.0	1.0
Zilog	66	75	99	1.5	1.3	1.4
Other North American Companies	6	16	30	0.1	0.3	0.4
Japanese Companies	891	1,144	1,452	20.7	20.6	20.0
Fujitsu	30	41	61	0.7	0.7	0.8
Hitachi	116	143	209	2.7	2.6	2.9
Matsushita	26	35	44	0.6	0.6	0.6
Mitsubishi	169	185	196	3.9	3.3	2.7
NEC	150	174	242	3.5	3.1	3.3
New JRC	0	0	2	0	0	0
Oki	50	52	57	1.2	0.9	0.8
Ricoh	12	13	12	0.3	0.2	0.2
Rohm	3	7	14	0.1	0.1	0.2
Sanyo	85	76	98	2.0	1.4	1.4
Seiko Epson	3	4	6	0.1	0.1	0.1
Sharp	35	46	55	0.8	0.8	0.8
Sony	27	35	41	0.6	0.6	0.6
Toshiba	136	188	306	3.2	3.4	4.2
Yamaha	49	145	108	1.1	2.6	1.5
European Companies	100	139	260	2.3	2.5	3.6
GEC Plessey	2	2	1	0	0	0
Philips	64	98	152	1.5	1.8	2.1
SGS-Thomson	25	28	78	0.6	0.5	1.1
Siemens	4	6	10	0.1	0.1	0.1
TEMIC	5	5	19	0.1	0.1	0.3
Asia/Pacific Companies	315	529	704	7.3	9.5	9.7
Acer	50	68	77	1.2	1.2	1.1
Daewoo	7	17	23	0.2	0.3	0.3
Holtek	17	19	32	0.4	0.3	0.4
Hualon Microelectronics Corp.	10	0	-	0.2	0	0
Hyundai	0	2	1	0	0	0
LG Semicon	12	29	56	0.3	0.5	0.8
Macronix	14	19	31	0.3	0.3	0.4
Samsung	40	33	71	0.9	0.6	1.0
Silicon Integrated Systems	25	101	97	0.6	1.8	1.3
United Microelectronics	111	196	260	2.6	3.5	3.6
Winbond Electronics	29	45	56	0.7	0.8	0.8

NA = Not available
Source: Dataquest (May 1996)

Table 1-7
Each Company's Factory Revenue from Shipments of Microprocessors Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	8,783	11,437	14,280	100.0	100.0	100.0
North American Companies	8,408	10,898	13,609	95.7	95.3	95.3
Advanced Micro Devices	511	985	885	5.8	8.6	6.2
AT&T	2	-	-	0	0	0
California Micro Devices	2	2	3	0	0	0
Chips & Technologies	6	7	5	0.1	0.1	0
Cypress Semiconductor	6	-	-	0.1	0	0
Cyrix	95	231	212	1.1	2.0	1.5
Harris	11	12	14	0.1	0.1	0.1
Hughes	3	3	3	0	0	0
IBM	88	246	600	1.0	2.2	4.2
Integrated Device Technology	43	51	63	0.5	0.4	0.4
Intel	6,569	8,370	10,755	74.8	73.2	75.3
LSI Logic	47	51	36	0.5	0.4	0.3
Motorola	705	597	666	8.0	5.2	4.7
National Semiconductor	38	50	45	0.4	0.4	0.3
Performance Semiconductor	16	15	21	0.2	0.1	0.1
Rockwell	5	5	7	0.1	0	0
Texas Instruments	200	214	230	2.3	1.9	1.6
VLSI Technology	3	2	4	0	0	0
Weitek	19	14	20	0.2	0.1	0.1
Zilog	39	43	42	0.4	0.4	0.3
Japanese Companies	311	461	562	3.5	4.0	3.9
Fujitsu	25	56	78	0.3	0.5	0.5
Hitachi	79	160	135	0.9	1.4	0.9
Matsushita	11	14	15	0.1	0.1	0.1
Mitsubishi	17	9	17	0.2	0.1	0.1
NEC	87	105	176	1.0	0.9	1.2
Oki	9	9	10	0.1	0.1	0.1
Ricoh	4	4	-	0	0	0
Sharp	11	12	16	0.1	0.1	0.1
Toshiba	68	92	115	0.8	0.8	0.8
European Companies	61	67	85	0.7	0.6	0.6
GEC Plessey	7	6	3	0.1	0.1	0
Philips	1	0	-	0	0	0
SGS-Thomson	39	51	68	0.4	0.4	0.5
Siemens	4	0	-	0	0	0
TCS	10	10	14	0.1	0.1	0.1

(Continued)

Table 1-7 (Continued)
Each Company's Factory Revenue from Shipments of Microprocessors Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Asia/Pacific Companies	3	11	23	0	0.1	0.2
LG Semicon	3	1	8	0	0	0.1
United Microelectronics	0	10	15	0	0.1	0.1

NA = Not available
Source: Dataquest (May 1996)

Table 1-8
Each Company's Factory Revenue from Shipments of Microprocessors to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	4,323	5,446	6,805	100.0	100.0	100.0
North American Companies	4,269	5,351	6,656	98.8	98.3	97.8
Advanced Micro Devices	187	371	311	4.3	6.8	4.6
AT&T	2	-	-	0	0	0
California Micro Devices	1	1	1	0	0	0
Chips & Technologies	4	5	1	0.1	0.1	0
Cypress Semiconductor	5	-	-	0.1	0	0
Cyrix	50	118	66	1.2	2.2	1.0
Harris	5	5	6	0.1	0.1	0.1
Hughes	3	3	3	0.1	0.1	0
IBM	44	133	325	1.0	2.4	4.8
Integrated Device Technology	30	33	44	0.7	0.6	0.6
Intel	3,343	4,135	5,319	77.3	75.9	78.2
LSI Logic	33	11	10	0.8	0.2	0.1
Motorola	337	305	328	7.8	5.6	4.8
National Semiconductor	13	12	7	0.3	0.2	0.1
Performance Semiconductor	15	15	21	0.3	0.3	0.3
Rockwell	3	4	6	0.1	0.1	0.1
Texas Instruments	159	167	169	3.7	3.1	2.5
VLSI Technology	0	-	1	0	0	0
Weitek	16	12	17	0.4	0.2	0.2
Zilog	19	21	21	0.4	0.4	0.3
Japanese Companies	39	71	102	0.9	1.3	1.5
Fujitsu	4	30	53	0.1	0.6	0.8
Hitachi	8	11	7	0.2	0.2	0.1
Mitsubishi	1	0	1	0	0	0
NEC	18	21	32	0.4	0.4	0.5
Oki	3	3	3	0.1	0.1	0
Toshiba	5	6	6	0.1	0.1	0.1
European Companies	15	24	46	0.3	0.4	0.7
GEC Plessey	1	1	1	0	0	0
SGS-Thomson	9	18	38	0.2	0.3	0.6
TCS	5	5	7	0.1	0.1	0.1

NA = Not available
Source: Dataquest (May 1996)

Table 1-9
Each Company's Factory Revenue from Shipments of Microprocessors to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	835	1,247	1,691	100.0	100.0	100.0
North American Companies	651	963	1,335	78.0	77.2	79.0
Advanced Micro Devices	19	23	68	2.3	1.8	4.0
Chips & Technologies	0	-	1	0	0	0.1
Cyrix	6	16	29	0.7	1.3	1.7
Harris	2	2	2	0.2	0.2	0.1
Integrated Device Technology	4	5	9	0.5	0.4	0.5
Intel	530	801	1,120	63.5	64.2	66.2
LSI Logic	0	33	20	0	2.6	1.2
Motorola	68	53	63	8.1	4.3	3.7
National Semiconductor	7	11	6	0.8	0.9	0.4
Performance Semiconductor	1	0	0	0.1	0	0
Texas Instruments	9	13	9	1.1	1.0	0.5
VLSI Technology	0	1	1	0	0.1	0.1
Weitek	1	1	1	0.1	0.1	0.1
Zilog	4	4	6	0.5	0.3	0.3
Japanese Companies	178	279	355	21.3	22.4	21.0
Fujitsu	8	9	16	1.0	0.7	1.0
Hitachi	54	129	123	6.5	10.3	7.3
Matsushita	10	13	14	1.2	1.0	0.8
Mitsubishi	11	8	14	1.3	0.6	0.8
NEC	56	70	128	6.7	5.6	7.6
Oki	2	2	3	0.2	0.2	0.2
Ricoh	4	4	-	0.5	0.3	0
Sharp	11	12	16	1.3	1.0	0.9
Toshiba	22	32	41	2.6	2.6	2.4
European Companies	6	5	1	0.7	0.4	0.1
GEC Plessey	3	2	-	0.4	0.2	0
SGS-Thomson	3	3	1	0.4	0.2	0.1

NA = Not available
Source: Dataquest (May 1996)

Table 1-10
Each Company's Factory Revenue from Shipments of Microprocessors to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	2,098	2,775	3,198	100.0	100.0	100.0
North American Companies	2,015	2,678	3,098	96.0	96.5	96.9
Advanced Micro Devices	109	288	241	5.2	10.4	7.6
Chips & Technologies	0	-	1	0	0	0
Cypress Semiconductor	1	-	-	0	0	0
Cyrix	26	62	44	1.2	2.2	1.4
Harris	3	4	5	0.1	0.1	0.2
Integrated Device Technology	9	10	4	0.4	0.4	0.1
Intel	1,673	2,131	2,596	79.7	76.8	81.2
LSI Logic	14	6	6	0.7	0.2	0.2
Motorola	139	123	134	6.6	4.4	4.2
National Semiconductor	10	18	13	0.5	0.6	0.4
Rockwell	2	1	1	0.1	0	0
Texas Instruments	17	25	42	0.8	0.9	1.3
VLSI Technology	3	1	1	0.1	0	0
Weitek	2	1	1	0.1	0	0
Zilog	7	8	7	0.3	0.3	0.2
Japanese Companies	47	61	62	2.2	2.2	1.9
Fujitsu	8	11	4	0.4	0.4	0.1
Hitachi	6	8	5	0.3	0.3	0.2
Matsushita	1	1	1	0	0	0
Mitsubishi	1	0	1	0	0	0
NEC	5	6	7	0.2	0.2	0.2
Oki	1	1	1	0	0	0
Toshiba	25	34	42	1.2	1.2	1.3
European Companies	36	34	34	1.7	1.2	1.1
GEC Plessey	1	1	1	0	0	0
Philips	1	0	-	0	0	0
SGS-Thomson	25	28	26	1.2	1.0	0.8
Siemens	4	0	-	0.2	0	0
TCS	5	5	7	0.2	0.2	0.2
Asia/Pacific Companies	0	2	4	0	0.1	0.1
United Microelectronics	0	2	4	0	0.1	0.1

NA = Not available
Source: Dataquest (May 1996)

Table 1-11
Each Company's Factory Revenue from Shipments of Microprocessors to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	1,527	1,969	2,587	100.0	100.0	100.0
North American Companies	1,473	1,906	2,520	96.5	96.8	97.4
Advanced Micro Devices	196	303	265	12.8	15.4	10.2
California Micro Devices	1	1	1	0.1	0.1	0
Chips & Technologies	2	2	2	0.1	0.1	0.1
Cyrix	13	35	73	0.9	1.8	2.8
Harris	1	1	1	0.1	0.1	0
IBM	44	113	275	2.9	5.7	10.6
Integrated Device Technology	0	3	6	0	0.2	0.2
Intel	1,023	1,303	1,719	67.0	66.2	66.5
LSI Logic	0	1	-	0	0.1	0
Motorola	161	116	141	10.5	5.9	5.4
National Semiconductor	8	9	19	0.5	0.5	0.7
Texas Instruments	15	9	10	1.0	0.5	0.4
Zilog	9	10	8	0.6	0.5	0.3
Japanese Companies	47	50	44	3.1	2.5	1.7
Fujitsu	5	6	4	0.3	0.3	0.2
Hitachi	11	12	-	0.7	0.6	0
Mitsubishi	4	1	1	0.3	0.1	0
NEC	8	8	9	0.5	0.4	0.4
Oki	3	3	3	0.2	0.2	0.1
Toshiba	16	20	26	1.0	1.0	1.0
European Companies	4	4	4	0.3	0.2	0.2
GEC Plessey	2	2	1	0.1	0.1	0
SGS-Thomson	2	2	3	0.1	0.1	0.1
Asia/Pacific Companies	3	9	19	0.2	0.5	0.7
LG Semicon	3	1	8	0.2	0.1	0.3
United Microelectronics	0	8	11	0	0.4	0.4

NA = Not available
Source: Dataquest (May 1996)

Table 1-12
Each Company's Factory Revenue from Shipments of Microcontrollers Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	5,904	7,517	10,255	100.0	100.0	100.0
North American Companies	1,984	2,514	3,115	33.6	33.4	30.4
Advanced Micro Devices	11	5	2	0.2	0.1	0
Atmel	2	5	28	0	0.1	0.3
Dallas Semiconductor	15	12	7	0.3	0.2	0.1
Harris	9	8	16	0.2	0.1	0.2
Intel	450	600	670	7.6	8.0	6.5
ITT	25	12	15	0.4	0.2	0.2
Microchip Technology	70	130	189	1.2	1.7	1.8
Motorola	1,107	1,424	1,838	18.8	18.9	17.9
National Semiconductor	105	100	101	1.8	1.3	1.0
Rockwell	8	7	8	0.1	0.1	0.1
Texas Instruments	120	143	169	2.0	1.9	1.7
Zilog	62	68	71	1.1	0.9	0.7
Japanese Companies	3,363	4,261	5,930	57.0	56.7	57.8
Fujitsu	129	180	388	2.2	2.4	3.8
Hitachi	458	577	1,038	7.8	7.7	10.1
Matsushita	251	405	488	4.3	5.4	4.8
Mitsubishi	465	637	918	7.9	8.5	9.0
NEC	1,100	1,275	1,554	18.6	17.0	15.2
Oki	149	178	185	2.5	2.4	1.8
Ricoh	82	76	61	1.4	1.0	0.6
Rohm	20	46	48	0.3	0.6	0.5
Sanyo	138	154	177	2.3	2.0	1.7
Seiko Epson	17	21	28	0.3	0.3	0.3
Sharp	149	169	191	2.5	2.2	1.9
Sony	104	140	213	1.8	1.9	2.1
Toshiba	301	403	641	5.1	5.4	6.3
European Companies	510	685	1,066	8.6	9.1	10.4
Elex	0	-	23	0	0	0.2
EM Microelectronics Marin	0	0	2	0	0	0
Philips	258	345	524	4.4	4.6	5.1
SGS-Thomson	113	161	241	1.9	2.1	2.3
Siemens	95	128	208	1.6	1.7	2.0
TEMIC	44	51	68	0.7	0.7	0.7

(Continued)

Table 1-12 (Continued)
Each Company's Factory Revenue from Shipments of Microcontrollers Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Asia/Pacific Companies	47	57	144	0.8	0.8	1.4
Daewoo	0	-	23	0	0	0.2
Holtek	15	20	34	0.3	0.3	0.3
LG Semicon	3	9	22	0.1	0.1	0.2
Samsung	29	28	65	0.5	0.4	0.6

NA = Not available
Source: Dataquest (May 1996)

Table 1-13
Each Company's Factory Revenue from Shipments of Microcontrollers to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	1,254	1,652	2,050	100.0	100.0	100.0
North American Companies	883	1,138	1,409	70.4	68.9	68.7
Advanced Micro Devices	5	3	-	0.4	0.2	0
Atmel	2	2	10	0.2	0.1	0.5
Dallas Semiconductor	10	5	2	0.8	0.3	0.1
Harris	6	5	11	0.5	0.3	0.5
Intel	225	302	336	17.9	18.3	16.4
ITT	6	0	0	0.5	0	0
Microchip Technology	28	55	81	2.2	3.3	4.0
Motorola	477	632	835	38.0	38.3	40.7
National Semiconductor	50	52	54	4.0	3.1	2.6
Rockwell	6	5	6	0.5	0.3	0.3
Texas Instruments	47	53	53	3.7	3.2	2.6
Zilog	21	24	21	1.7	1.5	1.0
Japanese Companies	244	321	382	19.5	19.4	18.6
Fujitsu	12	21	30	1.0	1.3	1.5
Hitachi	59	87	126	4.7	5.3	6.1
Matsushita	7	8	9	0.6	0.5	0.4
Mitsubishi	20	37	50	1.6	2.2	2.4
NEC	79	77	78	6.3	4.7	3.8
Oki	16	23	23	1.3	1.4	1.1
Rohm	2	3	3	0.2	0.2	0.2
Sanyo	4	15	16	0.3	0.9	0.8
Seiko Epson	1	1	2	0.1	0.1	0.1
Sharp	8	9	11	0.6	0.5	0.5
Sony	4	5	6	0.3	0.3	0.3
Toshiba	32	35	29	2.6	2.1	1.4
European Companies	127	191	256	10.1	11.6	12.5
Philips	78	108	175	6.2	6.5	8.5
SGS-Thomson	25	50	53	2.0	3.0	2.6
Siemens	11	12	13	0.9	0.7	0.6
TEMIC	13	21	15	1.0	1.3	0.7
Asia/Pacific Companies	0	2	4	0	0.1	0.2
Samsung	0	2	4	0	0.1	0.2

NA = Not available
Source: Dataquest (May 1996)

Table 1-14
Each Company's Factory Revenue from Shipments of Microcontrollers to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	2,284	2,964	4,140	100.0	100.0	100.0
North American Companies	166	214	263	7.3	7.2	6.4
Dallas Semiconductor	0	1	1	0	0	0
Harris	0	-	1	0	0	0
Intel	45	59	71	2.0	2.0	1.7
ITT	2	0	-	0.1	0	0
Microchip Technology	2	2	3	0.1	0.1	0.1
Motorola	98	136	173	4.3	4.6	4.2
National Semiconductor	2	1	-	0.1	0	0
Texas Instruments	16	14	13	0.7	0.5	0.3
Zilog	1	1	1	0	0	0
Japanese Companies	2,108	2,740	3,864	92.3	92.4	93.3
Fujitsu	85	109	296	3.7	3.7	7.1
Hitachi	289	345	582	12.7	11.6	14.1
Matsushita	214	361	434	9.4	12.2	10.5
Mitsubishi	287	413	644	12.6	13.9	15.6
NEC	707	838	1,034	31.0	28.3	25.0
Oki	75	90	92	3.3	3.0	2.2
Ricoh	70	63	49	3.1	2.1	1.2
Rohm	14	35	36	0.6	1.2	0.9
Sanyo	47	60	59	2.1	2.0	1.4
Seiko Epson	12	15	19	0.5	0.5	0.5
Sharp	105	113	124	4.6	3.8	3.0
Sony	73	114	174	3.2	3.8	4.2
Toshiba	130	184	321	5.7	6.2	7.8
European Companies	10	10	13	0.4	0.3	0.3
Philips	6	5	6	0.3	0.2	0.1
SGS-Thomson	1	-	4	0	0	0.1
Siemens	2	2	3	0.1	0.1	0.1
TEMIC	1	3	-	0	0.1	0

NA = Not available
Source: Dataquest (May 1996)

Table 1-15
Each Company's Factory Revenue from Shipments of Microcontrollers to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	1,106	1,431	2,036	100.0	100.0	100.0
North American Companies	472	615	787	42.7	43.0	38.7
Advanced Micro Devices	5	2	2	0.5	0.1	0.1
Atmel	0	1	3	0	0.1	0.1
Dallas Semiconductor	2	2	2	0.2	0.1	0.1
Harris	1	1	1	0.1	0.1	0.1
Intel	90	117	119	8.1	8.2	5.8
ITT	12	12	15	1.1	0.8	0.8
Microchip Technology	20	44	54	1.8	3.1	2.7
Motorola	267	344	469	24.1	24.0	23.0
National Semiconductor	29	29	31	2.6	2.0	1.5
Rockwell	1	1	1	0.1	0.1	0.1
Texas Instruments	30	46	72	2.7	3.2	3.5
Zilog	15	16	17	1.4	1.1	0.8
Japanese Companies	348	459	636	31.5	32.1	31.2
Fujitsu	19	31	25	1.7	2.2	1.2
Hitachi	51	84	186	4.6	5.9	9.1
Matsushita	9	11	13	0.8	0.8	0.6
Mitsubishi	23	32	54	2.1	2.2	2.7
NEC	183	220	244	16.5	15.4	12.0
Oki	19	26	29	1.7	1.8	1.4
Rohm	1	1	1	0.1	0.1	0.1
Sanyo	2	3	4	0.2	0.2	0.2
Seiko Epson	1	1	1	0.1	0.1	0.1
Sharp	1	1	1	0.1	0.1	0.1
Toshiba	39	49	77	3.5	3.4	3.8
European Companies	285	354	608	25.8	24.7	29.9
Elex	0	-	23	0	0	1.1
EM Microelectronics Marin	0	0	2	0	0	0.1
Philips	117	138	231	10.6	9.6	11.3
SGS-Thomson	65	86	136	5.9	6.0	6.7
Siemens	78	108	182	7.1	7.5	8.9
TEMIC	25	22	34	2.3	1.5	1.7
Asia/Pacific Companies	1	3	5	0.1	0.2	0.2
Holtek	1	1	2	0.1	0.1	0.1
Samsung	0	2	3	0	0.1	0.1

NA = Not available
Source: Dataquest (May 1996)

Table 1-16
Each Company's Factory Revenue from Shipments of Microcontrollers to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	1,260	1,470	2,029	100.0	100.0	100.0
North American Companies	463	547	657	36.7	37.2	32.4
Advanced Micro Devices	1	-	-	0.1	0	0
Atmel	0	2	15	0	0.1	0.7
Dallas Semiconductor	3	4	2	0.2	0.3	0.1
Harris	2	2	3	0.2	0.1	0.1
Intel	90	122	144	7.1	8.3	7.1
ITT	5	0	-	0.4	0	0
Microchip Technology	20	29	51	1.6	2.0	2.5
Motorola	265	312	361	21.0	21.2	17.8
National Semiconductor	24	18	16	1.9	1.2	0.8
Rockwell	1	1	1	0.1	0.1	0.1
Texas Instruments	27	30	31	2.1	2.0	1.5
Zilog	25	27	32	2.0	1.8	1.6
Japanese Companies	663	741	1,049	52.6	50.4	51.7
Fujitsu	13	19	37	1.0	1.3	1.8
Hitachi	59	61	144	4.7	4.1	7.1
Matsushita	21	25	32	1.7	1.7	1.6
Mitsubishi	135	155	170	10.7	10.5	8.4
NEC	131	140	198	10.4	9.5	9.8
Oki	39	39	42	3.1	2.7	2.1
Ricoh	12	13	12	1.0	0.9	0.6
Rohm	3	7	8	0.2	0.5	0.4
Sanyo	85	76	98	6.7	5.2	4.8
Seiko Epson	3	4	6	0.2	0.3	0.3
Sharp	35	46	55	2.8	3.1	2.7
Sony	27	21	33	2.1	1.4	1.6
Toshiba	100	135	214	7.9	9.2	10.5
European Companies	88	130	189	7.0	8.8	9.3
Philips	57	94	112	4.5	6.4	5.5
SGS-Thomson	22	25	48	1.7	1.7	2.4
Siemens	4	6	10	0.3	0.4	0.5
TEMIC	5	5	19	0.4	0.3	0.9
Asia/Pacific Companies	46	52	135	3.7	3.5	6.7
Daewoo	0	-	23	0	0	1.1
Holtek	14	19	32	1.1	1.3	1.6
LG Semicon	3	9	22	0.2	0.6	1.1
Samsung	29	24	58	2.3	1.6	2.9

NA = Not available
Source: Dataquest (May 1996)

Table 1-17
Each Company's Factory Revenue from Shipments of Microperipherals Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	4,581	6,424	8,313	100.0	100.0	100.0
North American Companies	3,400	4,520	5,976	74.2	70.4	71.9
ACC Microelectronics	36	49	40	0.8	0.8	0.5
Adaptec	122	125	124	2.7	1.9	1.5
Advanced Micro Devices	41	31	35	0.9	0.5	0.4
Alliance Semiconductor	0	-	10	0	0	0.1
AT&T	37	30	-	0.8	0.5	0
Atmel	3	-	-	0.1	0	0
California Micro Devices	4	3	4	0.1	0	0
Chips & Technologies	80	82	133	1.7	1.3	1.6
Cirrus Logic	371	681	886	8.1	10.6	10.7
Cypress Semiconductor	2	40	48	0	0.6	0.6
Cyrix	30	10	-	0.7	0.2	0
Dallas Semiconductor	41	10	13	0.9	0.2	0.2
ETEQ Microsystems	19	0	-	0.4	0	0
Harris	27	32	36	0.6	0.5	0.4
IBM	249	153	93	5.4	2.4	1.1
Integrated Device Technology	5	-	-	0.1	0	0
Integrated Information Tech.	40	35	44	0.9	0.5	0.5
Intel	425	625	972	9.3	9.7	11.7
LSI Logic	30	27	71	0.7	0.4	0.9
Micro Linear	0	6	-	0	0.1	0
Motorola	159	191	314	3.5	3.0	3.8
National Semiconductor	334	302	395	7.3	4.7	4.8
Oak Technology	50	62	84	1.1	1.0	1.0
OPTi	86	130	167	1.9	2.0	2.0
Performance Semiconductor	2	0	-	0	0	0
Q Logic	21	45	60	0.5	0.7	0.7
Rockwell	4	497	723	0.1	7.7	8.7
S3	113	130	315	2.5	2.0	3.8
SEEQ Technology	4	17	21	0.1	0.3	0.3
Sierra Semiconductor	0	35	44	0	0.5	0.5
Standard Microsystems	43	100	150	0.9	1.6	1.8
Supertex	2	1	1	0	0	0
Symbios	63	81	85	1.4	1.3	1.0

(Continued)

Table 1-17 (Continued)
Each Company's Factory Revenue from Shipments of Microperipherals Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Symphony Laboratories	66	12	15	1.4	0.2	0.2
Texas Instruments	230	249	220	5.0	3.9	2.6
Trident Microsystems	60	87	139	1.3	1.4	1.7
Tseng Labs	71	83	105	1.5	1.3	1.3
VLSI Technology	170	214	190	3.7	3.3	2.3
WaferScale Integration	5	3	18	0.1	0	0.2
Weitek	14	14	18	0.3	0.2	0.2
Western Digital	218	184	239	4.8	2.9	2.9
Zilog	102	111	93	2.2	1.7	1.1
Other North American Companies	15	25	69	0.3	0.4	0.8
Japanese Companies	835	1,301	1,456	18.2	20.3	17.5
Fuji Electric	1	2	3	0	0	0
Fujitsu	102	118	139	2.2	1.8	1.7
Hitachi	174	252	255	3.8	3.9	3.1
Matsushita	23	37	49	0.5	0.6	0.6
Mitsubishi	50	52	47	1.1	0.8	0.6
NEC	127	258	284	2.8	4.0	3.4
New JRC	0	2	4	0	0	0.1
Oki	22	28	37	0.5	0.4	0.4
Ricoh	3	3	14	0.1	0	0.2
Rohm	3	4	23	0.1	0.1	0.3
Sanyo	2	0	-	0	0	0
Sharp	10	11	14	0.2	0.2	0.2
Sony	8	54	22	0.2	0.8	0.3
Toshiba	161	207	310	3.5	3.2	3.7
Yamaha	149	273	245	3.3	4.2	2.9
Other Japanese Companies	0	0	10	0	0	0.1
European Companies	69	94	274	1.5	1.5	3.3
Elex	0	15	-	0	0.2	0
Philips	46	58	138	1.0	0.9	1.7
SGS-Thomson	10	15	128	0.2	0.2	1.5
Siemens	8	0	-	0.2	0	0
TCS	5	6	8	0.1	0.1	0.1

(Continued)

Table 1-17 (Continued)
Each Company's Factory Revenue from Shipments of Microperipherals Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Asia/Pacific Companies	277	509	607	6.0	7.9	7.3
Acer	50	68	77	1.1	1.1	0.9
Daewoo	7	17	-	0.2	0.3	0
Holtek	3	-	-	0.1	0	0
Hualon Microelectronics Corp.	10	0	-	0.2	0	0
Hyundai	0	2	1	0	0	0
LG Semicon	6	19	26	0.1	0.3	0.3
Macronix	15	21	35	0.3	0.3	0.4
Samsung	17	16	22	0.4	0.2	0.3
Silicon Integrated Systems	26	101	127	0.6	1.6	1.5
United Microelectronics	113	217	259	2.5	3.4	3.1
Winbond Electronics	30	48	60	0.7	0.7	0.7

NA = Not available
Source: Dataquest (May 1996)

Table 1-18
Each Company's Factory Revenue from Shipments of Microperipherals to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	1,764	2,320	2,981	100.0	100.0	100.0
North American Companies	1,617	2,088	2,631	91.7	90.0	88.3
ACC Microelectronics	7	13	16	0.4	0.6	0.5
Adaptec	74	82	-	4.2	3.5	0
Advanced Micro Devices	15	13	14	0.9	0.6	0.5
Alliance Semiconductor	0	-	2	0	0	0.1
AT&T	14	23	-	0.8	1.0	0
Atmel	2	-	-	0.1	0	0
California Micro Devices	2	2	3	0.1	0.1	0.1
Chips & Technologies	28	27	29	1.6	1.2	1.0
Cirrus Logic	139	293	369	7.9	12.6	12.4
Cypress Semiconductor	1	28	33	0.1	1.2	1.1
Cyrix	12	4	-	0.7	0.2	0
Dallas Semiconductor	24	4	5	1.4	0.2	0.2
ETEQ Microsystems	6	0	0	0.3	0	0
Harris	18	19	21	1.0	0.8	0.7
IBM	174	107	65	9.9	4.6	2.2
Integrated Device Technology	5	-	-	0.3	0	0
Integrated Information Tech.	17	16	20	1.0	0.7	0.7
Intel	165	243	443	9.4	10.5	14.9
LSI Logic	14	15	33	0.8	0.6	1.1
Micro Linear	0	5	-	0	0.2	0
Motorola	110	132	177	6.2	5.7	5.9
National Semiconductor	179	171	222	10.1	7.4	7.4
Oak Technology	7	9	11	0.4	0.4	0.4
OPTi	36	56	82	2.0	2.4	2.8
Performance Semiconductor	2	0	0	0.1	0	0
Q Logic	9	19	24	0.5	0.8	0.8
Rockwell	2	156	252	0.1	6.7	8.5
S3	53	75	180	3.0	3.2	6.0
SEEQ Technology	3	15	19	0.2	0.6	0.6
Sierra Semiconductor	0	17	21	0	0.7	0.7
Standard Microsystems	18	50	60	1.0	2.2	2.0
Supertex	2	1	1	0.1	0	0
Symbios	57	64	66	3.2	2.8	2.2
Symphony Laboratories	7	1	1	0.4	0	0
Texas Instruments	112	136	88	6.3	5.9	3.0

(Continued)

Table 1-18 (Continued)
Each Company's Factory Revenue from Shipments of Microperipherals to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Trident Microsystems	5	12	33	0.3	0.5	1.1
Tseng Labs	49	58	73	2.8	2.5	2.4
VLSI Technology	90	72	95	5.1	3.1	3.2
WaferScale Integration	2	1	6	0.1	0	0.2
Weitek	13	13	16	0.7	0.6	0.5
Western Digital	78	66	83	4.4	2.8	2.8
Zilog	53	55	54	3.0	2.4	1.8
Other North American Companies	8	8	14	0.5	0.3	0.5
Japanese Companies	108	173	178	6.1	7.5	6.0
Fujitsu	7	9	11	0.4	0.4	0.4
Hitachi	22	32	33	1.2	1.4	1.1
Matsushita	1	2	2	0.1	0.1	0.1
NEC	15	41	45	0.9	1.8	1.5
Oki	4	5	6	0.2	0.2	0.2
Ricoh	0	-	4	0	0	0.1
Rohm	0	0	6	0	0	0.2
Sony	0	1	1	0	0	0
Toshiba	38	45	47	2.2	1.9	1.6
Yamaha	21	38	22	1.2	1.6	0.7
European Companies	31	50	130	1.8	2.2	4.4
Philips	26	41	58	1.5	1.8	1.9
SGS-Thomson	4	8	71	0.2	0.3	2.4
TCS	1	1	1	0.1	0	0
Asia/Pacific Companies	8	9	41	0.5	0.4	1.4
Macronix	1	2	4	0.1	0.1	0.1
Samsung	5	4	5	0.3	0.2	0.2
Silicon Integrated Systems	1	0	29	0.1	0	1.0
Winbond Electronics	1	3	3	0.1	0.1	0.1

NA = Not available
Source: Dataquest (May 1996)

Table 1-19
Each Company's Factory Revenue from Shipments of Microperipherals to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	749	1,226	1,724	100.0	100.0	100.0
North American Companies	265	528	910	35.4	43.1	52.8
ACC Microelectronics	1	1	1	0.1	0.1	0.1
Adaptec	5	5	18	0.7	0.4	1.0
Advanced Micro Devices	2	1	4	0.3	0.1	0.3
AT&T	5	-	-	0.7	0	0
Chips & Technologies	7	6	52	0.9	0.5	3.0
Cirrus Logic	46	102	154	6.1	8.3	8.9
Cypress Semiconductor	0	4	6	0	0.3	0.4
Cyrix	5	1	-	0.7	0.1	0
Dallas Semiconductor	5	1	2	0.7	0.1	0.1
Harris	0	1	1	0	0.1	0.1
IBM	50	30	18	6.7	2.4	1.0
Intel	35	52	93	4.7	4.2	5.4
LSI Logic	0	3	10	0	0.2	0.6
Motorola	10	12	19	1.3	1.0	1.1
National Semiconductor	16	24	31	2.1	2.0	1.8
Oak Technology	2	23	35	0.3	1.9	2.0
OPTi	2	5	5	0.3	0.4	0.3
Q Logic	5	15	23	0.7	1.2	1.3
Rockwell	-	160	298	0	13.1	17.3
S3	4	13	5	0.5	1.1	0.3
Sierra Semiconductor	0	2	3	0	0.2	0.2
Standard Microsystems	1	1	5	0.1	0.1	0.3
Symbios	4	8	8	0.5	0.7	0.5
Symphony Laboratories	1	0	0	0.1	0	0
Texas Instruments	12	13	10	1.6	1.1	0.6
Trident Microsystems	0	-	23	0	0	1.3
VLSI Technology	3	6	16	0.4	0.5	0.9
WaferScale Integration	0	-	3	0	0	0.2
Weitek	1	1	2	0.1	0.1	0.1
Western Digital	36	31	47	4.8	2.5	2.7
Zilog	6	6	7	0.8	0.5	0.4
Other North American Companies	1	1	13	0.1	0.1	0.8

(Continued)

Table 1-19 (Continued)
Each Company's Factory Revenue from Shipments of Microperipherals to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Japanese Companies	482	676	795	64.4	55.1	46.1
Fuji Electric	1	2	3	0.1	0.2	0.2
Fujitsu	81	92	113	10.8	7.5	6.6
Hitachi	77	111	108	10.3	9.1	6.3
Matsushita	17	26	36	2.3	2.1	2.1
Mitsubishi	18	22	18	2.4	1.8	1.0
NEC	86	147	158	11.5	12.0	9.2
New JRC	0	2	2	0	0.2	0.1
Oki	6	9	13	0.8	0.7	0.8
Ricoh	3	3	10	0.4	0.2	0.6
Rohm	3	4	11	0.4	0.3	0.6
Sanyo	2	0	-	0.3	0	0
Sharp	10	11	14	1.3	0.9	0.8
Sony	8	39	12	1.1	3.2	0.7
Toshiba	93	120	176	12.4	9.8	10.2
Yamaha	77	88	110	10.3	7.2	6.4
Other Japanese Companies	0	0	10	0	0	0.6
European Companies	1	1	15	0.1	0.1	0.9
Philips	1	1	11	0.1	0.1	0.6
SGS-Thomson	0	-	4	0	0	0.2
Asia/Pacific Companies	1	21	3	0.1	1.7	0.2
Samsung	1	1	2	0.1	0.1	0.1
United Microelectronics	0	20	-	0	1.6	0
Winbond Electronics	0	-	1	0	0	0.1

NA = Not available
Source: Dataquest (May 1996)

Table 1-20
Each Company's Factory Revenue from Shipments of Microperipherals to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	615	897	1,225	100.0	100.0	100.0
North American Companies	513	737	1,008	83.4	82.2	82.3
ACC Microelectronics	0	-	1	0	0	0.1
Adaptec	2	2	-	0.3	0.2	0
Advanced Micro Devices	15	11	10	2.4	1.2	0.8
Alliance Semiconductor	0	-	5	0	0	0.4
AT&T	8	2	-	1.3	0.2	0
Chips & Technologies	5	5	9	0.8	0.6	0.7
Cirrus Logic	10	54	66	1.6	6.0	5.4
Cypress Semiconductor	1	6	7	0.2	0.7	0.6
Cyrix	1	-	-	0.2	0	0
Dallas Semiconductor	7	2	2	1.1	0.2	0.2
ETEQ Microsystems	1	0	0	0.2	0	0
Harris	9	11	12	1.5	1.2	1.0
IBM	25	16	10	4.1	1.8	0.8
Integrated Information Tech.	13	11	13	2.1	1.2	1.1
Intel	165	243	330	26.8	27.1	26.9
LSI Logic	0	6	19	0	0.7	1.6
Micro Linear	0	1	-	0	0.1	0
Motorola	28	32	66	4.6	3.6	5.4
National Semiconductor	51	49	66	8.3	5.5	5.4
Oak Technology	3	4	5	0.5	0.4	0.4
OPTi	5	6	10	0.8	0.7	0.8
Q Logic	0	4	5	0	0.4	0.4
Rockwell	1	95	108	0.2	10.6	8.8
S3	12	18	50	2.0	2.0	4.1
SEEQ Technology	1	2	2	0.2	0.2	0.2
Sierra Semiconductor	0	8	10	0	0.9	0.8
Standard Microsystems	5	18	25	0.8	2.0	2.0
Symbios	2	4	6	0.3	0.4	0.5
Symphony Laboratories	5	0	0	0.8	0	0
Texas Instruments	52	44	75	8.5	4.9	6.1
Trident Microsystems	1	-	1	0.2	0	0.1
Tseng Labs	6	7	9	1.0	0.8	0.7
VLSI Technology	30	30	21	4.9	3.3	1.7
WaferScale Integration	1	1	6	0.2	0.1	0.5
Western Digital	36	32	39	5.9	3.6	3.2

(Continued)

Table 1-20 (Continued)
Each Company's Factory Revenue from Shipments of Microperipherals to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Zilog	11	12	7	1.8	1.3	0.6
Other North American Companies	0	-	12	0	0	1.0
Japanese Companies	71	111	142	11.5	12.4	11.6
Fujitsu	5	5	1	0.8	0.6	0.1
Hitachi	30	40	50	4.9	4.5	4.1
Mitsubishi	2	1	4	0.3	0.1	0.3
NEC	18	48	52	2.9	5.4	4.2
Oki	4	4	5	0.7	0.4	0.4
Toshiba	10	11	26	1.6	1.2	2.1
Yamaha	2	2	5	0.3	0.2	0.4
European Companies	29	38	62	4.7	4.2	5.1
Elex	0	15	-	0	1.7	0
Philips	12	12	29	2.0	1.3	2.4
SGS-Thomson	5	6	26	0.8	0.7	2.1
Siemens	8	0	-	1.3	0	0
TCS	4	5	7	0.7	0.6	0.6
Asia/Pacific Companies	2	11	13	0.3	1.2	1.0
Samsung	0	2	2	0	0.2	0.2
Silicon Integrated Systems	0	0	1	0	0	0.1
United Microelectronics	2	9	10	0.3	1.0	0.8

NA = Not available
Source: Dataquest (May 1996)

Table 1-21
Each Company's Factory Revenue from Shipments of Microperipherals to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	1,453	1,981	2,383	100.0	100.0	100.0
North American Companies	1,005	1,167	1,426	69.2	58.9	59.8
ACC Microelectronics	28	35	22	1.9	1.8	0.9
Adaptec	41	36	106	2.8	1.8	4.4
Advanced Micro Devices	9	6	6	0.6	0.3	0.3
Alliance Semiconductor	0	-	3	0	0	0.1
AT&T	10	5	-	0.7	0.3	0
Atmel	1	-	-	0.1	0	0
California Micro Devices	2	1	1	0.1	0.1	0.1
Chips & Technologies	40	44	43	2.8	2.2	1.8
Cirrus Logic	176	232	297	12.1	11.7	12.5
Cypress Semiconductor	0	2	3	0	0.1	0.1
Cyrix	12	5	-	0.8	0.3	0
Dallas Semiconductor	5	3	4	0.3	0.2	0.2
ETEQ Microsystems	12	0	-	0.8	0	0
Harris	0	1	2	0	0.1	0.1
Integrated Information Tech.	10	8	10	0.7	0.4	0.4
Intel	60	87	106	4.1	4.4	4.5
LSI Logic	16	3	9	1.1	0.2	0.4
Motorola	11	15	52	0.8	0.8	2.2
National Semiconductor	88	58	76	6.1	2.9	3.2
Oak Technology	38	26	33	2.6	1.3	1.4
OPTi	43	63	70	3.0	3.2	2.9
Q Logic	7	7	9	0.5	0.4	0.4
Rockwell	1	86	65	0.1	4.3	2.7
S3	44	24	80	3.0	1.2	3.4
Sierra Semiconductor	0	8	10	0	0.4	0.4
Standard Microsystems	19	31	60	1.3	1.6	2.5
Symbios	0	5	5	0	0.3	0.2
Symphony Laboratories	53	11	14	3.6	0.6	0.6
Texas Instruments	54	56	47	3.7	2.8	2.0
Trident Microsystems	54	75	82	3.7	3.8	3.4
Tseng Labs	16	18	23	1.1	0.9	1.0
VLSI Technology	47	106	58	3.2	5.4	2.5
WaferScale Integration	2	1	3	0.1	0.1	0.1
Western Digital	68	55	70	4.7	2.8	3.0
Zilog	32	38	25	2.2	1.9	1.0
Other North American Companies	6	16	30	0.4	0.8	1.3

(Continued)

Table 1-21 (Continued)
Each Company's Factory Revenue from Shipments of Microperipherals to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Japanese Companies	174	341	340	12.0	17.2	14.3
Fujitsu	9	12	14	0.6	0.6	0.6
Hitachi	45	69	64	3.1	3.5	2.7
Matsushita	5	9	11	0.3	0.5	0.4
Mitsubishi	30	29	25	2.1	1.5	1.0
NEC	8	22	29	0.6	1.1	1.2
New JRC	0	0	2	0	0	0.1
Oki	8	10	12	0.6	0.5	0.5
Rohm	0	0	6	0	0	0.3
Sony	0	14	8	0	0.7	0.4
Toshiba	20	31	61	1.4	1.6	2.6
Yamaha	49	145	108	3.4	7.3	4.5
European Companies	8	5	67	0.6	0.3	2.8
Philips	7	4	40	0.5	0.2	1.7
SGS-Thomson	1	1	27	0.1	0.1	1.1
Asia/Pacific Companies	266	468	550	18.3	23.6	23.1
Acer	50	68	77	3.4	3.4	3.2
Daewoo	7	17	-	0.5	0.9	0
Holtek	3	-	-	0.2	0	0
Hualon Microelectronics Corp.	10	0	-	0.7	0	0
Hyundai	0	2	1	0	0.1	0
LG Semicon	6	19	26	0.4	1.0	1.1
Macronix	14	19	31	1.0	1.0	1.3
Samsung	11	9	13	0.8	0.5	0.5
Silicon Integrated Systems	25	101	97	1.7	5.1	4.1
United Microelectronics	111	188	249	7.6	9.5	10.4
Winbond Electronics	29	45	56	2.0	2.3	2.3

NA = Not available
Source: Dataquest (May 1996)

Table 1-22
Each Company's Factory Revenue from Shipments of Digital Signal Processors Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	679	1,030	1,670	100.0	100.0	100.0
North American Companies	603	911	1,509	88.8	88.4	90.4
Analog Devices	69	85	117	10.2	8.3	7.0
AT&T	207	275	510	30.5	26.7	30.6
IBM	-	-	10	0	0	0.6
Microchip Technology	2	-	-	0.3	0	0
Motorola	94	151	178	13.8	14.7	10.7
Texas Instruments	231	400	635	34.0	38.8	38.0
Zilog	0	-	59	0	0	3.5
Japanese Companies	76	114	154	11.2	11.1	9.2
Fujitsu	26	36	46	3.8	3.5	2.8
Hitachi	7	9	13	1.0	0.9	0.8
Matsushita	1	4	5	0.1	0.4	0.3
NEC	27	40	49	4.0	3.9	2.9
Oki	0	2	3	0	0.2	0.2
Sanyo	5	7	10	0.7	0.7	0.6
Toshiba	10	16	28	1.5	1.6	1.7
European Companies	0	5	7	0	0.5	0.4
GEC Plessey	0	5	7	0	0.5	0.4

NA = Not available
Source: Dataquest (May 1996)

Table 1-23
Each Company's Factory Revenue from Shipments of Digital Signal Processors to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	279	421	595	100.0	100.0	100.0
North American Companies	268	404	570	96.1	96.0	95.8
Analog Devices	28	37	37	10.0	8.8	6.3
AT&T	101	143	231	36.2	34.0	38.8
IBM	0	0	5	0	0	0.8
Microchip Technology	2	0	0	0.7	0	0
Motorola	33	63	77	11.8	15.0	12.9
Texas Instruments	104	161	210	37.3	38.2	35.3
Zilog	0	0	10	0	0	1.7
Japanese Companies	11	15	20	3.9	3.6	3.4
Fujitsu	2	4	6	0.7	1.0	1.0
Hitachi	4	5	7	1.4	1.2	1.2
NEC	3	4	5	1.1	1.0	0.8
Toshiba	2	2	2	0.7	0.5	0.3
European Companies	0	2	5	0	0.5	0.8
GEC Plessey	0	2	5	0	0.5	0.8

NA = Not available
Source: Dataquest (May 1996)

Table 1-24
Each Company's Factory Revenue from Shipments of Digital Signal Processors to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	119	166	273	100.0	100.0	100.0
North American Companies	69	87	167	58.0	52.4	61.0
Analog Devices	5	5	13	4.2	3.0	4.7
AT&T	7	17	36	5.9	10.2	13.2
Motorola	2	5	9	1.7	3.0	3.3
Texas Instruments	55	60	104	46.2	36.1	38.0
Zilog	0	0	5	0	0	1.8
Japanese Companies	50	77	106	42.0	46.4	38.6
Fujitsu	16	22	33	13.4	13.3	12.1
Hitachi	2	3	5	1.7	1.8	1.8
Matsushita	1	3	4	0.8	1.8	1.5
NEC	18	28	33	15.1	16.9	12.1
Oki	0	2	3	0	1.2	1.1
Sanyo	5	7	10	4.2	4.2	3.5
Toshiba	8	12	18	6.7	7.2	6.6
European Companies	0	2	1	0	1.2	0.4
GEC Plessey	0	2	1	0	1.2	0.4

NA = Not available
Source: Dataquest (May 1996)

Table 1-25
Each Company's Factory Revenue from Shipments of Digital Signal Processors to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	218	305	548	100.0	100.0	100.0
North American Companies	210	294	538	96.3	96.4	98.2
Analog Devices	29	35	57	13.3	11.5	10.5
AT&T	76	83	200	34.9	27.2	36.5
Motorola	55	70	90	25.2	23.0	16.4
Texas Instruments	50	106	181	22.9	34.8	33.0
Zilog	0	0	10	0	0	1.8
Japanese Companies	8	10	9	3.7	3.3	1.6
Fujitsu	5	6	1	2.3	2.0	0.2
NEC	3	4	5	1.4	1.3	0.8
Toshiba	0	0	3	0	0	0.5
European Companies	0	1	1	0	0.3	0.2
GEC Plessey	0	1	1	0	0.3	0.2

NA = Not available
Source: Dataquest (May 1996)

Table 1-26
Each Company's Factory Revenue from Shipments of Digital Signal Processors to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	63	138	253	100.0	100.0	100.0
North American Companies	56	126	234	88.9	91.3	92.3
Analog Devices	7	8	9	11.1	5.8	3.7
AT&T	23	32	43	36.5	23.2	17.1
IBM	0	0	5	0	0	2.0
Motorola	4	13	2	6.3	9.4	0.8
Texas Instruments	22	73	140	34.9	52.9	55.3
Zilog	0	0	34	0	0	13.4
Japanese Companies	7	12	19	11.1	8.7	7.7
Fujitsu	3	4	6	4.8	2.9	2.4
Hitachi	1	1	1	1.6	0.7	0.5
Matsushita	0	1	1	0	0.7	0.5
NEC	3	4	6	4.8	2.9	2.4
Toshiba	0	2	5	0	1.4	2.0

NA = Not available
Source: Dataquest (May 1996)

Section 2: 1995 Microcomponent Market Share Ranking

Table 2-1
Top 50 Companies' Factory Revenue from Shipments of MOS Microcomponents Worldwide (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Percent Change	1995 Market Share
1	1	Intel	9,595	12,396	29	35.9
2	2	Motorola	2,363	2,996	27	8.7
3	3	NEC	1,678	2,063	23	6.0
4	6	Hitachi	998	1,441	44	4.2
5	5	Texas Instruments	1,006	1,254	25	3.6
6	7	Toshiba	718	1,095	52	3.2
7	8	Mitsubishi	698	982	41	2.8
8	4	Advanced Micro Devices	1,021	922	-10	2.7
9	9	Cirrus Logic	681	886	30	2.6
10	10	Rockwell	509	738	45	2.1
11	14	IBM	399	703	76	2.0
12	13	Philips	403	662	64	1.9
13	15	Fujitsu	390	651	67	1.9
14	11	Matsushita	460	557	21	1.6
15	12	National Semiconductor	452	541	20	1.6
16	16	AT&T	305	510	67	1.5
17	19	SGS-Thomson	227	437	92	1.3
18	28	S3	130	315	142	0.9
19	20	United Microelectronics	227	274	21	0.8
20	21	Zilog	222	265	19	0.8
21	17	Yamaha	273	245	-10	0.7
22	26	Western Digital	184	239	30	0.7
23	22	Oki	217	235	8	0.7
24	24	Sony	194	235	21	0.7
25	25	Sharp	192	221	15	0.6
26	18	Cyrix	241	212	-12	0.6
27	31	Siemens	128	208	63	0.6
28	23	VLSI Technology	216	194	-10	0.6
29	29	Microchip Technology	130	189	45	0.5
30	27	Sanyo	161	186	16	0.5
31	30	OPTi	130	167	28	0.5
32	34	Standard Microsystems	100	150	50	0.4
33	36	Trident Microsystems	87	139	60	0.4
34	35	Chips & Technologies	89	138	55	0.4
35	33	Silicon Integrated Systems	101	127	26	0.4

(Continued)

Table 2-1 (Continued)
Top 50 Companies' Factory Revenue from Shipments of MOS Microcomponents Worldwide (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Percent Change	1995 Market Share
36	32	Adaptec	125	124	-1	0.4
37	37	Analog Devices	85	117	37	0.3
38	41	LSI Logic	78	107	37	0.3
39	38	Tseng Labs	83	105	26	0.3
40	51	Samsung	44	87	98	0.3
41	40	Symbios	81	85	5	0.2
42	43	Oak Technology	62	84	36	0.2
43	42	Acer	68	77	14	0.2
44	39	Ricoh	83	75	-10	0.2
45	47	Rohm	50	71	43	0.2
46	46	TEMIC	51	68	33	0.2
47	44	Harris	52	66	27	0.2
48	45	Integrated Device Technology	51	63	24	0.2
49	50	Q Logic	45	60	34	0.2
50	49	Winbond Electronics	48	60	25	0.2
		All Others	477	696	46	2.0
		North American Companies	18,843	24,210	28	70.1
		Japanese Companies	6,137	8,102	32	23.5
		European Companies	851	1,432	68	4.1
		Asia/Pacific Companies	577	774	34	2.2
		Total Market	26,408	34,518	31	100.0

NA = Not available
NM = Not meaningful
Source: Dataquest (May 1996)

Table 2-2
Top 20 Companies' Factory Revenue from Shipments of Microprocessors Worldwide (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Percent Change	1995 Market Share
1	1	Intel	8,370	10,755	28	75.3
2	2	Advanced Micro Devices	985	885	-10	6.2
3	3	Motorola	597	666	12	4.7
4	4	IBM	246	600	144	4.2
5	6	Texas Instruments	214	230	7	1.6
6	5	Cyrix	231	212	-8	1.5
7	8	NEC	105	176	68	1.2
8	7	Hitachi	160	135	-16	0.9
9	9	Toshiba	92	115	25	0.8
10	10	Fujitsu	56	78	38	0.5
11	11	SGS-Thomson	51	68	34	0.5
12	13	Integrated Device Technology	51	63	24	0.4
13	14	National Semiconductor	50	45	-9	0.3
14	15	Zilog	43	42	-3	0.3
15	12	LSI Logic	51	36	-29	0.3
16	16	Performance Semiconductor	15	21	40	0.1
17	18	Weitek	14	20	40	0.1
18	23	Mitsubishi	9	17	90	0.1
19	19	Sharp	12	16	33	0.1
20	21	United Microelectronics	10	15	50	0.1
		All Others	75	85	13	0.6
		North American Companies	10,898	13,609	25	95.3
		Japanese Companies	461	562	22	3.9
		European Companies	67	85	27	0.6
		Asia/Pacific Companies	11	23	109	0.2
		Total Market	11,437	14,280	25	100.0

NA = Not available
NM = Not meaningful
Source: Dataquest (May 1996)

Table 2-3
Top 20 Companies' Factory Revenue from Shipments of Microcontrollers Worldwide (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Percent Change	1995 Market Share
1	1	Motorola	1,424	1,838	29	17.9
2	2	NEC	1,275	1,554	22	15.2
3	5	Hitachi	577	1,038	80	10.1
4	3	Mitsubishi	637	918	44	9.0
5	4	Intel	600	670	12	6.5
6	7	Toshiba	403	641	59	6.3
7	8	Philips	345	524	52	5.1
8	6	Matsushita	405	488	20	4.8
9	9	Fujitsu	180	388	116	3.8
10	12	SGS-Thomson	161	241	49	2.3
11	15	Sony	140	213	52	2.1
12	17	Siemens	128	208	63	2.0
13	11	Sharp	169	191	13	1.9
14	16	Microchip Technology	130	189	45	1.8
15	10	Oki	178	185	4	1.8
16	13	Sanyo	154	177	15	1.7
17	14	Texas Instruments	143	169	18	1.7
18	18	National Semiconductor	100	101	1	1.0
19	20	Zilog	68	71	5	0.7
20	21	TEMIC	51	68	33	0.7
		All Others	249	383	54	3.7
		North American Companies	2,514	3,115	24	30.4
		Japanese Companies	4,261	5,930	39	57.8
		European Companies	685	1,066	56	10.4
		Asia/Pacific Companies	57	144	153	1.4
		Total Market	7,517	10,255	36	100.0

NA = Not available
NM = Not meaningful
Source: Dataquest (May 1996)

Table 2-4
Top 40 Companies' Factory Revenue from Shipments of Microperipherals Worldwide (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Percent Change	1995 Market Share
1	2	Intel	625	972	56	11.7
2	1	Cirrus Logic	681	886	30	10.7
3	3	Rockwell	497	723	45	8.7
4	4	National Semiconductor	302	395	31	4.8
5	15	S3	130	315	142	3.8
6	12	Motorola	191	314	64	3.8
7	11	Toshiba	207	310	50	3.7
8	6	NEC	258	284	10	3.4
9	9	United Microelectronics	217	259	19	3.1
10	7	Hitachi	252	255	1	3.1
11	5	Yamaha	273	245	-10	2.9
12	13	Western Digital	184	239	30	2.9
13	8	Texas Instruments	249	220	-12	2.6
14	10	VLSI Technology	214	190	-11	2.3
15	16	OPTi	130	167	28	2.0
16	21	Standard Microsystems	100	150	50	1.8
17	18	Fujitsu	118	139	18	1.7
18	22	Trident Microsystems	87	139	60	1.7
19	28	Philips	58	138	138	1.7
20	24	Chips & Technologies	82	133	63	1.6
21	49	SGS-Thomson	15	128	753	1.5
22	20	Silicon Integrated Systems	101	127	26	1.5
23	17	Adaptec	125	124	-1	1.5
24	23	Tseng Labs	83	105	26	1.3
25	14	IBM	153	93	-39	1.1
26	19	Zilog	111	93	-16	1.1
27	25	Symbios	81	85	5	1.0
28	27	Oak Technology	62	84	36	1.0
29	26	Acer	68	77	14	0.9
30	42	LSI Logic	27	71	163	0.9
31	33	Q Logic	45	60	34	0.7
32	32	Winbond Electronics	48	60	25	0.7
33	45	DSP Group	18	60	233	0.7
34	35	Matsushita	37	49	34	0.6
35	34	Cypress Semiconductor	40	48	21	0.6
36	30	Mitsubishi	52	47	-10	0.6
37	36	Sierra Semiconductor	35	44	27	0.5

(Continued)

Table 2-4 (Continued)
Top 40 Companies' Factory Revenue from Shipments of Microperipherals Worldwide (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Percent Change	1995 Market Share
38	37	Integrated Information Tech.	35	44	25	0.5
39	31	ACC Microelectronics	49	40	-18	0.5
40	41	Oki	28	37	31	0.4
		All Others	356	363	2	4.4
		North American Companies	4,520	5,976	32	71.9
		Japanese Companies	1,301	1,456	12	17.5
		European Companies	94	274	191	3.3
		Asia/Pacific Companies	509	607	19	7.3
		Total Market	6,424	8,313	29	100.0

NA = Not available
NM = Not meaningful
Source: Dataquest (May 1996)

Table 2-5
Top 10 Companies' Factory Revenue from Shipments of Digital Signal Processors Worldwide (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Percent Change	1995 Market Share
1	1	Texas Instruments	400	635	59	38.0
2	2	AT&T	275	510	86	30.6
3	3	Motorola	151	178	18	10.7
4	4	Analog Devices	85	117	37	7.0
5	52	Zilog	0	59	NA	3.5
6	5	NEC	40	49	22	2.9
7	6	Fujitsu	36	46	28	2.8
8	7	Toshiba	16	28	75	1.7
9	8	Hitachi	9	13	47	0.8
10	16	IBM	0	10	NA	0.6
		All Others	18	25	38	1.5
		North American Companies	911	1,509	66	90.4
		Japanese Companies	114	154	35	9.2
		European Companies	5	7	40	0.4
		Asia/Pacific Companies	0	0	NA	0
		Total Market	1,030	1,670	62	100.0

NA = Not available
NM = Not meaningful
Source: Dataquest (May 1996)

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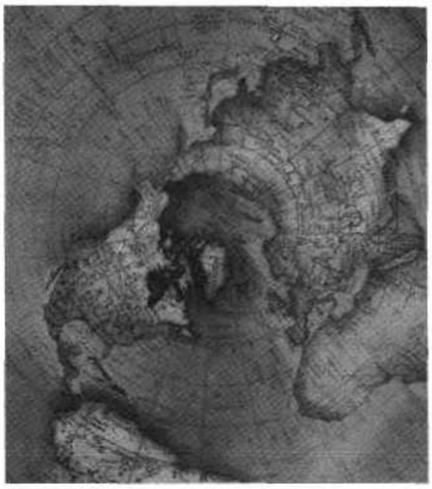

Dataquest

1995 Microcontroller Market Share and Shipments

Market Statistics

Program: Microcomponents Worldwide
Product Code: MCRO-WW-MS-9602
Publication Date: May 27, 1996
Filing: Market Statistics

1995 Microcontroller Market Share and Shipments

Market Statistics

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Note: All tables show estimated data.

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Note: All tables show estimated data.

1995 Microcontroller Market Share and Shipments

Introduction

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

- 1994-1995 unit shipment and market share estimates
- 1993-1995 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.

Microcontroller market share estimates combine data from many countries, each of which has a different and fluctuating exchange rate. Estimates of non-U.S. market consumption or revenue are based on the average exchange rate for the given year. Refer to the section entitled "Exchange Rates" for more information regarding these average rates. As a rule, Dataquest's estimates are calculated in local currencies and then converted to U.S. dollars.

Qualitative analysis of microcontroller market data may be available in other documents of Dataquest's Embedded Microcomponents Worldwide service or may be requested through Dataquest's client inquiry service.

Segmentation

This section outlines the market segments that are specific to this document. Dataquest's objective is to provide data along lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to clients.

For market share purposes, Dataquest defines the microcomponent market according to the following functional segmentation scheme, with microcontrollers a subsegment of microcomponents:

- Digital Microcomponent IC
    - Digital Microprocessor (MPU)
    - Digital Microcontroller (MCU)
    - Digital Microperipheral (MPR)
    - Programmable 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 Definitions Guide.*

MOS Digital Microcontroller. An IC designed for standalone operation that includes a programmable processing unit, program memory, read/write data memory, and some input/output capability. The processing unit contains an instruction decoder, arithmetic logic unit (ALU), registers, and additional logic. The MCU's functions are determined by fetching and executing instructions and manipulating data held in on-chip program and data memory (not including cache memories). MCU devices must be available with on-chip program or data store. As an option, some MCU devices can be purchased without on-chip memory. Peripherals may be included on-chip to assist in sophisticated input, output, and control functions. The MCU category includes MCUs incorporating or originating from an ASIC design. Standalone digital signal processors are not included with MCUs. MCUs are divided into 4-bit, 8-bit, or 16-bit and greater word width. All MCUs are considered as designed into embedded applications.

Word Width. The width, in bits, of the on-chip integer unit. This measurement is independent of the data bus width or any other bus associated with the device being discussed.

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

Regional Definitions

Americas

North America: Includes Canada, Mexico, and the United States (50 states)

South America

Central America

Japan

Japan is the only single-country region.

Europe, Africa, and the Middle East

Western Europe: Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cyprus, Gibraltar, Liechtenstein, Monaco, San Marino, Vatican City, Iceland, Malta, and Turkey).

Eastern Europe: Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (Belarus, Russian Federation, Ukraine, Georgia, Moldova, Armenia, Azerbaijan, Kazakhstan, Uzbekistan, Tadjikistan, Kyrgyzstan, and Turkmenistan).

Asia/Pacific

Includes Hong Kong, Singapore, South Korea, Taiwan, Australia, Bangladesh, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.

Line Item Definitions

Factory revenue is defined as the money value received by a semiconductor manufacturer for its products. Revenue from the sale of semiconductors sold either as finished goods, 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 chipsets.

Market Share Methodology

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

- Information published by major industry participants
- Estimates made by knowledgeable and reliable industry spokespersons
- Government data or trade association data (such as WSTS, MITI, and U.S. DOC)
- Published product literature and price lists
- Interviews with knowledgeable manufacturers, distributors, and users
- Relevant economic data
- Information and data from online and CD-ROM data banks
- Articles in both the general and trade press
- Reports from financial analysts
- End-user surveys

Dataquest believes that the estimates presented in this document are the most accurate and meaningful statistics available.

Despite the care taken in gathering, analyzing, and categorizing the data in a meaningful way, careful attention must be paid to the definitions and assumptions used herein when interpreting the estimates presented in this document. Various companies, government agencies, and trade associations may use slightly different definitions of product categories and regional groupings, or they may include different companies in their summaries. These differences should be kept in mind when making comparisons between data and numbers provided by Dataquest and those provided by other 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. Inmos' unit shipments are included in SGS-Thomson.

2. Starting in 1994, Dataquest published microcontroller unit shipments by family rather than by product.

3. Revenue in 1994 was re-evaluated and restated for several companies in 1995.

4. Unit shipments in 1994 were re-evaluated and restated for some companies in 1995.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar amounts. Table 1 outlines these rates for 1993 through 1995.

Table 1
Exchange Rates

	1993	1994	1995
Japan (Yen/U.S.$)	111.20	101.81	93.90
France (Franc/U.S.$)	5.67	5.54	4.97
Germany (Deutsche Mark/U.S.$)	1.66	1.62	1.43
United Kingdom (U.S.$/Pound Sterling)	1.50	1.53	1.59

Source: Dataquest (April 1996)

Section 1: 1995 Microcontroller Revenue Estimates and Rankings

Table 1-1
Each Company's Factory Revenue from Shipments of Microcontrollers Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	5,904	7,517	10,255	100.0	100.0	100.0
North American Companies	1,984	2,514	3,115	33.6	33.4	30.4
Advanced Micro Devices	11	5	2	0.2	0.1	0
Atmel	2	5	28	0	0.1	0.3
Dallas Semiconductor	15	12	7	0.3	0.2	0.1
Harris	9	8	16	0.2	0.1	0.2
Intel	450	600	670	7.6	8.0	6.5
ITT	25	12	15	0.4	0.2	0.2
Microchip Technology	70	130	189	1.2	1.7	1.8
Motorola	1,107	1,424	1,838	18.8	18.9	17.9
National Semiconductor	105	100	101	1.8	1.3	1.0
Rockwell	8	7	8	0.1	0.1	0.1
Texas Instruments	120	143	169	2.0	1.9	1.7
Zilog	62	68	71	1.1	0.9	0.7
Japanese Companies	3,363	4,261	5,930	57.0	56.7	57.8
Fujitsu	129	180	388	2.2	2.4	3.8
Hitachi	458	577	1,038	7.8	7.7	10.1
Matsushita	251	405	488	4.3	5.4	4.8
Mitsubishi	465	637	918	7.9	8.5	9.0
NEC	1,100	1,275	1,554	18.6	17.0	15.2
Oki	149	178	185	2.5	2.4	1.8
Ricoh	82	76	61	1.4	1.0	0.6
Rohm	20	46	48	0.3	0.6	0.5
Sanyo	138	154	177	2.3	2.0	1.7
Seiko Epson	17	21	28	0.3	0.3	0.3
Sharp	149	169	191	2.5	2.2	1.9
Sony	104	140	213	1.8	1.9	2.1
Toshiba	301	403	641	5.1	5.4	6.3
European Companies	510	685	1,066	8.6	9.1	10.4
Elex	0	-	23	0	0	0.2
EM Microelectronics Marin	0	0	2	0	0	0
Philips	258	345	524	4.4	4.6	5.1
SGS-Thomson	113	161	241	1.9	2.1	2.3
Siemens	95	128	208	1.6	1.7	2.0
TEMIC	44	51	68	0.7	0.7	0.7

(Continued)

Table 1-1 (Continued)
Each Company's Factory Revenue from Shipments of Microcontrollers Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Asia/Pacific Companies	47	57	144	0.8	0.8	1.4
Daewoo	0	-	23	0	0	0.2
Holtek	15	20	34	0.3	0.3	0.3
LG Semicon	3	9	22	0.1	0.1	0.2
Samsung	29	28	65	0.5	0.4	0.6

Source: Dataquest (May 1996)

Table 1-2
Each Company's Factory Revenue from Shipments of 4-Bit MCUs Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	1,691	1,472	1,679	100.0	100.0	100.0
North American Companies	25	18	21	1.5	1.2	1.3
Harris	0	-	9	0	0	0.5
National Semiconductor	20	13	9	1.2	0.9	0.5
Rockwell	1	-	-	0.1	0	0
Texas Instruments	4	5	3	0.2	0.3	0.2
Japanese Companies	1,619	1,397	1,527	95.7	94.9	91.0
Fujitsu	71	58	75	4.2	3.9	4.5
Hitachi	161	139	126	9.5	9.4	7.5
Matsushita	132	105	111	7.8	7.1	6.6
Mitsubishi	170	192	157	10.1	13.0	9.4
NEC	650	422	506	38.4	28.7	30.2
Oki	77	72	72	4.6	4.9	4.3
Rohm	0	15	16	0	1.0	1.0
Sanyo	88	96	98	5.2	6.5	5.8
Seiko Epson	14	18	20	0.8	1.2	1.2
Sharp	83	88	94	4.9	6.0	5.6
Sony	59	63	43	3.5	4.3	2.6
Toshiba	114	129	208	6.7	8.8	12.4
European Companies	0	-	9	0	0	0.5
Elex	0	-	7	0	0	0.4
EM Microelectronics Marin	0	0	2	0	0	0.1
Asia/Pacific Companies	47	57	121	2.8	3.9	7.2
Daewoo	0	-	6	0	0	0.4
Holtek	15	20	34	0.9	1.4	2.0
LG Semicon	3	9	16	0.2	0.6	1.0
Samsung	29	28	65	1.7	1.9	3.9

Source: Dataquest (May 1996)

Table 1-3
Each Company's Factory Revenue from Shipments of 8-Bit MCUs Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	3,590	4,965	6,415	100.0	100.0	100.0
North American Companies	1,675	2,069	2,461	46.7	41.7	38.4
Advanced Micro Devices	11	5	2	0.3	0.1	0
Atmel	2	5	28	0.1	0.1	0.4
Dallas Semiconductor	15	12	7	0.4	0.2	0.1
Harris	9	8	7	0.3	0.2	0.1
Intel	200	250	279	5.6	5.0	4.3
ITT	25	12	15	0.7	0.2	0.2
Microchip Technology	70	130	189	1.9	2.6	2.9
Motorola	1,097	1,369	1,620	30.6	27.6	25.3
National Semiconductor	61	65	69	1.7	1.3	1.1
Rockwell	7	7	8	0.2	0.1	0.1
Texas Instruments	116	138	165	3.2	2.8	2.6
Zilog	62	68	71	1.7	1.4	1.1
Japanese Companies	1,454	2,289	3,003	40.5	46.1	46.8
Fujitsu	53	85	198	1.5	1.7	3.1
Hitachi	257	352	421	7.2	7.1	6.6
Matsushita	118	285	355	3.3	5.7	5.5
Mitsubishi	250	371	464	7.0	7.5	7.2
NEC	274	554	675	7.6	11.2	10.5
Oki	62	83	87	1.7	1.7	1.4
Ricoh	82	76	61	2.3	1.5	1.0
Rohm	20	31	32	0.6	0.6	0.5
Sanyo	50	58	79	1.4	1.2	1.2
Seiko Epson	3	3	8	0.1	0.1	0.1
Sharp	66	81	97	1.8	1.6	1.5
Sony	44	71	161	1.2	1.4	2.5
Toshiba	175	239	364	4.9	4.8	5.7
European Companies	461	607	928	12.8	12.2	14.5
Elex	0	-	16	0	0	0.2
Philips	258	340	519	7.2	6.8	8.1
SGS-Thomson	75	111	167	2.1	2.2	2.6
Siemens	84	105	159	2.3	2.1	2.5
TEMIC	44	51	68	1.2	1.0	1.1
Asia/Pacific Companies	0	-	23	0	0	0.4
Daewoo	0	-	17	0	0	0.3
LG Semicon	0	-	6	0	0	0.1

Source: Dataquest (May 1996)

Table 1-4
Each Company's Factory Revenue from Shipments of 16-Bit MCUs Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	623	1,080	2,161	100.0	100.0	100.0
North American Companies	284	427	633	45.6	39.5	29.3
Intel	250	350	391	40.1	32.4	18.1
Motorola	10	55	218	1.6	5.1	10.1
National Semiconductor	24	22	23	3.9	2.0	1.1
Texas Instruments	-	-	1	0	0	0
Japanese Companies	290	575	1,400	46.5	53.2	64.8
Fujitsu	5	37	115	0.8	3.4	5.3
Hitachi	40	86	491	6.4	8.0	22.7
Matsushita	1	15	21	0.2	1.4	1.0
Mitsubishi	45	74	297	7.2	6.9	13.7
NEC	176	299	372	28.3	27.7	17.2
Oki	10	23	26	1.6	2.1	1.2
Sony	1	6	8	0.2	0.6	0.4
Toshiba	12	35	69	1.9	3.2	3.2
European Companies	49	78	129	7.9	7.2	5.9
Philips	0	5	5	0	0.5	0.2
SGS-Thomson	38	50	74	6.1	4.6	3.4
Siemens	11	23	50	1.8	2.1	2.3

Source: Dataquest (May 1996)

Table 1-5
Each Company's Factory Revenue from Shipments of Microcontrollers to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	1,254	1,652	2,050	100.0	100.0	100.0
North American Companies	883	1,138	1,409	70.4	68.9	68.7
Advanced Micro Devices	5	3	-	0.4	0.2	0
Atmel	2	2	10	0.2	0.1	0.5
Dallas Semiconductor	10	5	2	0.8	0.3	0.1
Harris	6	5	11	0.5	0.3	0.5
Intel	225	302	336	17.9	18.3	16.4
ITT	6	0	0	0.5	0	0
Microchip Technology	28	55	81	2.2	3.3	4.0
Motorola	477	632	835	38.0	38.3	40.7
National Semiconductor	50	52	54	4.0	3.1	2.6
Rockwell	6	5	6	0.5	0.3	0.3
Texas Instruments	47	53	53	3.7	3.2	2.6
Zilog	21	24	21	1.7	1.5	1.0
Japanese Companies	244	321	382	19.5	19.4	18.6
Fujitsu	12	21	30	1.0	1.3	1.5
Hitachi	59	87	126	4.7	5.3	6.1
Matsushita	7	8	9	0.6	0.5	0.4
Mitsubishi	20	37	50	1.6	2.2	2.4
NEC	79	77	78	6.3	4.7	3.8
Oki	16	23	23	1.3	1.4	1.1
Rohm	2	3	3	0.2	0.2	0.2
Sanyo	4	15	16	0.3	0.9	0.8
Seiko Epson	1	1	2	0.1	0.1	0.1
Sharp	8	9	11	0.6	0.5	0.5
Sony	4	5	6	0.3	0.3	0.3
Toshiba	32	35	29	2.6	2.1	1.4
European Companies	127	191	256	10.1	11.6	12.5
Philips	78	108	175	6.2	6.5	8.5
SGS-Thomson	25	50	53	2.0	3.0	2.6
Siemens	11	12	13	0.9	0.7	0.6
TEMIC	13	21	15	1.0	1.3	0.7
Asia/Pacific Companies	0	2	4	0	0.1	0.2
Samsung	0	2	4	0	0.1	0.2

Source: Dataquest (May 1996)

Table 1-6
Each Company's Factory Revenue from Shipments of Microcontrollers to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	2,284	2,964	4,140	100.0	100.0	100.0
North American Companies	166	214	263	7.3	7.2	6.4
Dallas Semiconductor	0	1	1	0	0	0
Harris	0	-	1	0	0	0
Intel	45	59	71	2.0	2.0	1.7
ITT	2	0	-	0.1	0	0
Microchip Technology	2	2	3	0.1	0.1	0.1
Motorola	98	136	173	4.3	4.6	4.2
National Semiconductor	2	1	-	0.1	0	0
Texas Instruments	16	14	13	0.7	0.5	0.3
Zilog	1	1	1	0	0	0
Japanese Companies	2,108	2,740	3,864	92.3	92.4	93.3
Fujitsu	85	109	296	3.7	3.7	7.1
Hitachi	289	345	582	12.7	11.6	14.1
Matsushita	214	361	434	9.4	12.2	10.5
Mitsubishi	287	413	644	12.6	13.9	15.6
NEC	707	838	1,034	31.0	28.3	25.0
Oki	75	90	92	3.3	3.0	2.2
Ricoh	70	63	49	3.1	2.1	1.2
Rohm	14	35	36	0.6	1.2	0.9
Sanyo	47	60	59	2.1	2.0	1.4
Seiko Epson	12	15	19	0.5	0.5	0.5
Sharp	105	113	124	4.6	3.8	3.0
Sony	73	114	174	3.2	3.8	4.2
Toshiba	130	184	321	5.7	6.2	7.8
European Companies	10	10	13	0.4	0.3	0.3
Philips	6	5	6	0.3	0.2	0.1
SGS-Thomson	1	-	4	0	0	0.1
Siemens	2	2	3	0.1	0.1	0.1
TEMIC	1	3	-	0	0.1	0

Source: Dataquest (May 1996)

Table 1-7
Each Company's Factory Revenue from Shipments of Microcontrollers to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	1,106	1,431	2,036	100.0	100.0	100.0
North American Companies	472	615	787	42.7	43.0	38.7
Advanced Micro Devices	5	2	2	0.5	0.1	0.1
Atmel	0	1	3	0	0.1	0.1
Dallas Semiconductor	2	2	2	0.2	0.1	0.1
Harris	1	1	1	0.1	0.1	0.1
Intel	90	117	119	8.1	8.2	5.8
ITT	12	12	15	1.1	0.8	0.8
Microchip Technology	20	44	54	1.8	3.1	2.7
Motorola	267	344	469	24.1	24.0	23.0
National Semiconductor	29	29	31	2.6	2.0	1.5
Rockwell	1	1	1	0.1	0.1	0.1
Texas Instruments	30	46	72	2.7	3.2	3.5
Zilog	15	16	17	1.4	1.1	0.8
Japanese Companies	348	459	636	31.5	32.1	31.2
Fujitsu	19	31	25	1.7	2.2	1.2
Hitachi	51	84	186	4.6	5.9	9.1
Matsushita	9	11	13	0.8	0.8	0.6
Mitsubishi	23	32	54	2.1	2.2	2.7
NEC	183	220	244	16.5	15.4	12.0
Oki	19	26	29	1.7	1.8	1.4
Rohm	1	1	1	0.1	0.1	0.1
Sanyo	2	3	4	0.2	0.2	0.2
Seiko Epson	1	1	1	0.1	0.1	0.1
Sharp	1	1	1	0.1	0.1	0.1
Toshiba	39	49	77	3.5	3.4	3.8
European Companies	285	354	608	25.8	24.7	29.9
Elex	0	-	23	0	0	1.1
EM Microelectronics Marin	0	0	2	0	0	0.1
Philips	117	138	231	10.6	9.6	11.3
SGS-Thomson	65	86	136	5.9	6.0	6.7
Siemens	78	108	182	7.1	7.5	8.9
TEMIC	25	22	34	2.3	1.5	1.7
Asia/Pacific Companies	1	3	5	0.1	0.2	0.2
Holtek	1	1	2	0.1	0.1	0.1
Samsung	0	2	3	0	0.1	0.1

Source: Dataquest (May 1996)

Table 1-8
Each Company's Factory Revenue from Shipments of Microcontrollers to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	1,260	1,470	2,029	100.0	100.0	100.0
North American Companies	463	547	657	36.7	37.2	32.4
Advanced Micro Devices	1	-	-	0.1	0	0
Atmel	0	2	15	0	0.1	0.7
Dallas Semiconductor	3	4	2	0.2	0.3	0.1
Harris	2	2	3	0.2	0.1	0.1
Intel	90	122	144	7.1	8.3	7.1
ITT	5	0	-	0.4	0	0
Microchip Technology	20	29	51	1.6	2.0	2.5
Motorola	265	312	361	21.0	21.2	17.8
National Semiconductor	24	18	16	1.9	1.2	0.8
Rockwell	1	1	1	0.1	0.1	0.1
Texas Instruments	27	30	31	2.1	2.0	1.5
Zilog	25	27	32	2.0	1.8	1.6
Japanese Companies	663	741	1,049	52.6	50.4	51.7
Fujitsu	13	19	37	1.0	1.3	1.8
Hitachi	59	61	144	4.7	4.1	7.1
Matsushita	21	25	32	1.7	1.7	1.6
Mitsubishi	135	155	170	10.7	10.5	8.4
NEC	131	140	198	10.4	9.5	9.8
Oki	39	39	42	3.1	2.7	2.1
Ricoh	12	13	12	1.0	0.9	0.6
Rohm	3	7	8	0.2	0.5	0.4
Sanyo	85	76	98	6.7	5.2	4.8
Seiko Epson	3	4	6	0.2	0.3	0.3
Sharp	35	46	55	2.8	3.1	2.7
Sony	27	21	33	2.1	1.4	1.6
Toshiba	100	135	214	7.9	9.2	10.5
European Companies	88	130	189	7.0	8.8	9.3
Philips	57	94	112	4.5	6.4	5.5
SGS-Thomson	22	25	48	1.7	1.7	2.4
Siemens	4	6	10	0.3	0.4	0.5
TEMIC	5	5	19	0.4	0.3	0.9
Asia/Pacific Companies	46	52	135	3.7	3.5	6.7
Daewoo	0	-	23	0	0	1.1
Holtek	14	19	32	1.1	1.3	1.6
LG Semicon	3	9	22	0.2	0.6	1.1
Samsung	29	24	58	2.3	1.6	2.9

Source: Dataquest (May 1996)

Table 1-9
Top 30 Companies' Factory Revenue from Shipments of Microcontrollers Worldwide (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	1995 Market Share (%)
1	1	Motorola	1,424	1,838	29	17.9
2	2	NEC	1,275	1,554	22	15.2
3	5	Hitachi	577	1,038	80	10.1
4	3	Mitsubishi	637	918	44	9.0
5	4	Intel	600	670	12	6.5
6	7	Toshiba	403	641	59	6.3
7	8	Philips	345	524	52	5.1
8	6	Matsushita	405	488	20	4.8
9	9	Fujitsu	180	388	116	3.8
10	12	SGS-Thomson	161	241	49	2.3
11	15	Sony	140	213	52	2.1
12	17	Siemens	128	208	63	2.0
13	11	Sharp	169	191	13	1.9
14	16	Microchip Technology	130	189	45	1.8
15	10	Oki	178	185	4	1.8
16	13	Sanyo	154	177	15	1.7
17	14	Texas Instruments	143	169	18	1.7
18	18	National Semiconductor	100	101	1	1.0
19	20	Zilog	68	71	5	0.7
20	21	TEMIC	51	68	33	0.7
21	23	Samsung	28	65	132	0.6
22	19	Ricoh	76	61	-20	0.6
23	22	Rohm	46	48	5	0.5
24	25	Holtek	20	34	70	0.3
25	24	Seiko Epson	21	28	34	0.3
26	32	Atmel	5	28	455	0.3
27	155	Elex	0	23	NA	0.2
28	166	Daewoo	0	23	NA	0.2
29	28	LG Semicon	9	22	144	0.2
30	29	Harris	8	16	104	0.2
		All Others	36	35	-3	0.3
		North American Companies	2,514	3,115	24	30.4
		Japanese Companies	4,261	5,930	39	57.8
		European Companies	685	1,066	56	10.4
		Asia/Pacific Companies	57	144	153	1.4
		Total Market	7,517	10,255	36	100.0

NA = Not available

Source: Dataquest (May 1996)

Table 1-10
Top 15 Companies' Factory Revenue from Shipments of Microcontrollers to North America (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	1995 Market Share (%)
1	1	Motorola	632	835	32	40.7
2	2	Intel	302	336	11	16.4
3	3	Philips	108	175	62	8.5
4	4	Hitachi	87	126	45	6.1
5	6	Microchip Technology	55	81	47	4.0
6	5	NEC	77	78	1	3.8
7	8	National Semiconductor	52	54	3	2.6
8	7	Texas Instruments	53	53	0	2.6
9	9	SGS-Thomson	50	53	6	2.6
10	10	Mitsubishi	37	50	35	2.4
11	14	Fujitsu	21	30	43	1.5
12	11	Toshiba	35	29	-16	1.4
13	13	Oki	23	23	-2	1.1
14	12	Zilog	24	21	-13	1.0
15	16	Sanyo	15	16	4	0.8
		All Others	81	91	12	4.4
		North American Companies	1,138	1,409	24	68.7
		Japanese Companies	321	382	19	18.6
		European Companies	191	256	34	12.5
		Asia/Pacific Companies	2	4	100	0.2
		Total Market	1,652	2,050	24	100.0

Source: Dataquest (May 1996)

Table 1-11
Top 15 Companies' Factory Revenue from Shipments of Microcontrollers to Japan (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	1995 Market Share (%)
1	1	NEC	838	1,034	23	25.0
2	2	Mitsubishi	413	644	56	15.6
3	4	Hitachi	345	582	69	14.1
4	3	Matsushita	361	434	20	10.5
5	5	Toshiba	184	321	74	7.8
6	9	Fujitsu	109	296	172	7.1
7	7	Sony	114	174	53	4.2
8	6	Motorola	136	173	27	4.2
9	8	Sharp	113	124	10	3.0
10	10	Oki	90	92	2	2.2
11	13	Intel	59	71	20	1.7
12	12	Sanyo	60	59	-2	1.4
13	11	Ricoh	63	49	-22	1.2
14	14	Rohm	35	36	3	0.9
15	15	Seiko Epson	15	19	27	0.5
		All Others	29	32	11	0.8
		North American Companies	214	263	23	6.4
		Japanese Companies	2,740	3,864	41	93.3
		European Companies	10	13	26	0.3
		Asia/Pacific Companies	0	0	NA	0
		Total Market	2,964	4,140	40	100.0

NA = Not available
Source: Dataquest (May 1996)

Table 1-12
Top 15 Companies' Factory Revenue from Shipments of Microcontrollers to Europe (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	1995 Market Share (%)
1	1	Motorola	344	469	36	23.0
2	2	NEC	220	244	11	12.0
3	3	Philips	138	231	67	11.3
4	7	Hitachi	84	186	121	9.1
5	5	Siemens	108	182	69	8.9
6	6	SGS-Thomson	86	136	58	6.7
7	4	Intel	117	119	2	5.8
8	8	Toshiba	49	77	57	3.8
9	9	Texas Instruments	46	72	57	3.5
10	10	Microchip Technology	44	54	23	2.7
11	11	Mitsubishi	32	54	69	2.7
12	15	TEMIC	22	34	55	1.7
13	13	National Semiconductor	29	31	7	1.5
14	14	Oki	26	29	12	1.4
15	12	Fujitsu	31	25	-19	1.2
		All Others	55	93	69	4.6
		North American Companies	615	787	28	38.7
		Japanese Companies	459	636	39	31.2
		European Companies	354	608	72	29.9
		Asia/Pacific Companies	3	5	67	0.2
		Total Market	1,431	2,036	42	100.0

Source: Dataquest (May 1996)

Table 1-13
Top 15 Companies' Factory Revenue from Shipments of Microcontrollers to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	1995 Market Share (%)
1	1	Motorola	312	361	16	17.8
2	4	Toshiba	135	214	59	10.5
3	3	NEC	140	198	41	9.8
4	2	Mitsubishi	155	170	10	8.4
5	5	Intel	122	144	18	7.1
6	8	Hitachi	61	144	136	7.1
7	6	Philips	94	112	19	5.5
8	7	Sanyo	76	98	29	4.8
9	16	Samsung	24	58	142	2.9
10	9	Sharp	46	55	20	2.7
11	12	Microchip Technology	29	51	76	2.5
12	14	SGS-Thomson	25	48	92	2.4
13	10	Oki	39	42	7	2.1
14	18	Fujitsu	19	37	95	1.8
15	17	Sony	21	33	57	1.6
		All Others	172	264	54	13.0
		North American Companies	547	657	20	32.4
		Japanese Companies	741	1,049	42	51.7
		European Companies	130	189	45	9.3
		Asia/Pacific Companies	52	135	160	6.7
		Total Market	1,470	2,029	38	100.0

Source: Dataquest (May 1996)

Table 1-14
Ranking of Each Company's Factory Revenue from Shipments of 4-Bit MCUs Worldwide (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	1995 Market Share (%)
1	1	NEC	422	506	20	30.2
2	4	Toshiba	129	208	61	12.4
3	2	Mitsubishi	192	157	-18	9.4
4	3	Hitachi	139	126	-9	7.5
5	5	Matsushita	105	111	6	6.6
6	6	Sanyo	96	98	2	5.8
7	7	Sharp	88	94	7	5.6
8	10	Fujitsu	58	75	29	4.5
9	8	Oki	72	72	0	4.3
10	11	Samsung	28	65	132	3.9
11	9	Sony	63	43	-31	2.6
12	12	Holtek	20	34	70	2.0
13	13	Seiko Epson	18	20	12	1.2
14	14	Rohm	15	16	8	1.0
15	16	LG Semicon	9	16	78	1.0
16	15	National Semiconductor	13	9	-30	0.5
17	29	Harris	0	9	NA	0.5
18	32	Elex	0	7	NA	0.4
19	24	Daewoo	0	6	NA	0.4
20	17	Texas Instruments	5	3	-34	0.2
21	35	EM Microelectronics Marin	0	2	NA	0.1
		All Others	0	0	NA	0
		North American Companies	18	21	19	1.3
		Japanese Companies	1,397	1,527	9	91.0
		European Companies	0	9	NA	0.5
		Asia/Pacific Companies	57	121	112	7.2
		Total Market	1,472	1,679	14	100.0

NA = Not available
Source: Dataquest (May 1996)

Table 1-15
Ranking of Each Company's Factory Revenue from Shipments of 8-Bit MCUs Worldwide (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	1995 Market Share (%)
1	1	Motorola	1,369	1,620	18	25.3
2	2	NEC	554	675	22	10.5
3	5	Philips	340	519	53	8.1
4	3	Mitsubishi	371	464	25	7.2
5	4	Hitachi	352	421	20	6.6
6	8	Toshiba	239	364	52	5.7
7	6	Matsushita	285	355	25	5.5
8	7	Intel	250	279	12	4.3
9	13	Fujitsu	85	198	133	3.1
10	10	Microchip Technology	130	189	45	2.9
11	11	SGS-Thomson	111	167	50	2.6
12	9	Texas Instruments	138	165	20	2.6
13	17	Sony	71	161	127	2.5
14	12	Siemens	105	159	51	2.5
15	15	Sharp	81	97	20	1.5
16	14	Oki	83	87	5	1.4
17	20	Sanyo	58	79	36	1.2
18	18	Zilog	68	71	5	1.1
19	19	National Semiconductor	65	69	6	1.1
20	21	TEMIC	51	68	33	1.1
21	16	Ricoh	76	61	-20	1.0
22	22	Rohm	31	32	4	0.5
23	27	Atmel	5	28	455	0.4
24	34	Daewoo	0	17	NA	0.3
25	33	Elex	0	16	NA	0.2
26	24	ITT	12	15	29	0.2
27	26	Rockwell	7	8	19	0.1
28	29	Seiko Epson	3	8	167	0.1
29	25	Harris	8	7	-9	0.1
30	23	Dallas Semiconductor	12	7	-42	0.1
31	32	LG Semicon	0	6	NA	0.1
32	28	Advanced Micro Devices	5	2	-60	0
		All Others	0	0	NA	0
		North American Companies	2,069	2,461	19	38.4
		Japanese Companies	2,289	3,003	31	46.8
		European Companies	607	928	53	14.5
		Asia/Pacific Companies	0	23	NA	0.4
		Total Market	4,965	6,415	29	100.0

NA = Not available
Source: Dataquest (May 1996)

Table 1-16
Ranking of Each Company's Factory Revenue from Shipments of 16-Bit MCUs Worldwide (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	1995 Market Share (%)
1	3	Hitachi	86	491	471	22.7
2	1	Intel	350	391	12	18.1
3	2	NEC	299	372	25	17.2
4	4	Mitsubishi	74	297	301	13.7
5	5	Motorola	55	218	296	10.1
6	7	Fujitsu	37	115	211	5.3
7	6	SGS-Thomson	50	74	48	3.4
8	8	Toshiba	35	69	97	3.2
9	9	Siemens	23	50	115	2.3
10	10	Oki	23	26	14	1.2
11	11	National Semiconductor	22	23	4	1.1
12	12	Matsushita	15	21	40	1.0
13	13	Sony	6	8	40	0.4
14	14	Philips	5	5	0	0.2
15	16	Texas Instruments	0	1	NA	0
		All Others	0	0	NA	0
		North American Companies	427	633	48	29.3
		Japanese Companies	575	1,400	144	64.8
		European Companies	78	129	65	5.9
		Asia/Pacific Companies	0	0	NA	0
		Total Market	1,080	2,161	100	100.0

NA = Not available
Source: Dataquest (May 1996)

Section 2: Microcontroller Unit Shipments Overview

Table 2-1
Ranking of Each Company's Shipments of Microcontrollers to the World (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Change (%)	1995 Market Share (%)
1	1	Motorola	430,737	490,529	13.9	16.5
2	2	NEC	428,680	475,300	10.9	16.0
3	3	Mitsubishi	196,612	274,402	39.6	9.2
4	4	Toshiba	159,850	193,320	20.9	6.5
5	6	Hitachi	145,615	183,163	25.8	6.2
6	5	Sharp	149,275	148,600	-0.5	5.0
7	7	Intel	122,000	126,220	3.5	4.2
8	11	Fujitsu	81,870	112,300	37.2	3.8
9	9	Sanyo	86,540	112,220	29.7	3.8
10	10	Philips	83,000	103,051	24.2	3.5
11	13	Microchip Technology	68,023	101,900	49.8	3.4
12	14	SGS-Thomson	62,950	99,080	57.4	3.3
13	8	Matsushita	110,360	91,240	-17.3	3.1
14	12	Oki	68,620	71,200	3.8	2.4
15	16	Sony	51,390	67,834	32.0	2.3
16	15	National Semiconductor	51,975	47,603	-8.4	1.6
17	21	Samsung	19,964	44,210	121.4	1.5
18	17	Texas Instruments	38,420	43,300	12.7	1.5
19	18	Ricoh	32,500	42,900	32.0	1.4
20	20	Siemens	24,500	38,350	56.5	1.3
21	19	Zilog	24,886	27,271	9.6	0.9
22	22	TEMIC	17,386	22,949	32.0	0.8
23	23	Rohm	14,950	19,734	32.0	0.7
24	24	Holtek	13,333	12,788	-4.1	0.4
25	25	Seiko Epson	6,005	6,327	5.4	0.2
26	26	LG Semicon	4,500	5,940	32.0	0.2
		T	3,840	4,191	9.1	0.1
			625	3,630	480.8	0.1
		cro Devices	2,470	1,550	-37.2	0.1
		onductor	2,500	1,329	-46.8	0
			331	284	-14.2	0
		iconductor	267	240	-10.1	0
		s	0	0	0	0
		rket	2,503,974	2,972,955	18.7	

ls shown because of rounding.

Table 2-2
Shipments of Microcontrollers to the World, by Word Length (Thousands of Units)

	1994 Units	1995 Units	Change (%)	1995 Market Share (%)
4 Bit				
Total North American Companies	14,970	8,632	-42.3	0.3
Total Japanese Companies	940,470	974,904	3.7	32.8
Total European Companies	6,200	9,200	48.4	0.3
Total Asian Companies	37,797	62,938	66.5	2.1
Total 4-Bit Market	999,437	1,055,674	5.6	35.5
8 Bit				
Total North American Companies	676,795	781,248	15.4	26.3
Total Japanese Companies	493,167	656,531	33.1	22.1
Total European Companies	180,086	249,580	38.6	8.4
Total Asian Companies	0	0	0	0
Total 8-Bit Market	1,350,048	1,687,359	25.0	56.8
16-Bit-and-Up				
Total North American Companies	54,309	58,167	7.1	2.0
Total Japanese Companies	98,630	167,105	69.4	5.6
Total European Companies	1,550	4,650	200.0	0.2
Total Asian Companies	0	0	0	0
Total 16-Bit-and-Up Market	154,489	229,922	48.8	7.7
Total	2,503,974	2,972,955	18.7	

Source: Dataquest (May 1996)

Table 2-3
Top 10 Family Shipments of Bitsize Microcontrollers to the World (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Change (%)	1995 Market Share (%)
1	1	uPD-F	426,400	473,500	11.0	15.9
2	2	6805-F	328,482	378,890	15.3	12.7
3	3	8051-F	183,011	219,490	19.9	7.4
4	4	TLCS-F	153,900	183,400	19.2	6.2
5	5	SM-F	149,000	148,300	-0.5	5.0
6	7	H8-F	86,100	116,500	35.3	3.9
7	6	68HC11-F	103,886	113,403	9.2	3.8
8	9	PIC16/17-F	68,023	101,900	49.8	3.4
9	8	M50XX-F	85,560	89,740	4.9	3.0
10	17	M37XX-F	47,100	66,300	40.8	2.2
		All Others	872,512	1,081,532	24.0	36.4
		Families	2,503,974	2,972,955	18.7	100.0

Source: Dataquest (May 1996)

Section 3: Microcontroller Unit Shipments—4-Bit Architectures

Table 3-1
Ranking of Each Company's Shipments of 4-Bit Microcontrollers to the World (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Change (%)	1995 Market Share (%)
1	1	NEC	308,000	331,000	7.5	31.4
2	2	Sharp	128,000	127,300	-0.5	12.1
3	3	Toshiba	114,700	109,100	-4.9	10.3
4	4	Mitsubishi	79,860	95,500	19.6	9.0
5	5	Sanyo	70,240	88,220	25.6	8.4
6	6	Hitachi	57,300	53,800	-6.1	5.1
7	7	Matsushita	54,000	46,600	-13.7	4.4
8	11	Samsung	19,964	44,210	121.4	4.2
9	9	Oki	44,900	42,000	-6.5	4.0
10	10	Sony	30,600	40,392	32.0	3.8
11	8	Fujitsu	47,170	35,030	-25.7	3.3
12	12	Holtek	13,333	12,788	-4.1	1.2
13	14	SGS-Thomson	6,200	9,200	48.4	0.9
14	13	National Semiconductor	10,150	6,332	-37.6	0.6
15	15	Seiko Epson	5,700	5,962	4.6	0.6
16	17	LG Semicon	4,500	5,940	32.0	0.6
17	16	Texas Instruments	4,820	2,300	-52.3	0.2
		All Others	0	0	0	0
		Total Market	999,437	1,055,674	5.6	

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (May 1996)

Table 3-2
Top 10 Family Shipments of 4-Bit Microcontrollers to the World (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Change (%)	1995 Market Share (%)
1	1	uPD-F	308,000	331,000	7.5	31.4
2	2	SM-F	128,000	127,300	-0.5	12.1
3	3	TLCS-F	114,700	109,100	-4.9	10.3
4	4	M50XX-F	72,960	80,840	10.8	7.7
5	5	HMCS-F	57,300	53,800	-6.1	5.1
6	9	LC57-F	39,000	51,000	30.8	4.8
7	6	MN1X00	54,000	46,600	-13.7	4.4
8	12	56C82-F	19,964	44,210	121.4	4.2
9	8	OLMS-F	44,900	42,000	-6.5	4.0
10	10	SPC500-F	30,600	40,392	32.0	3.8
		All Others	130,013	129,432	0	12.3
		Families	999,437	1,055,674	5.6	100.0

Source: Dataquest (May 1996)

Section 4: Microcontroller Unit Shipments—8-Bit Architectures

Table 4-1
Ranking of Each Company's Shipments of 8-Bit Microcontrollers to the World (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Change (%)	1995 Market Share (%)
1	1	Motorola	420,286	481,595	14.6	28.5
2	2	Mitsubishi	91,552	130,452	42.5	7.7
3	3	NEC	89,800	107,500	19.7	6.4
4	4	Philips	83,000	103,051	24.2	6.1
5	6	Microchip Technology	68,023	101,900	49.8	6.0
6	7	SGS-Thomson	56,700	89,780	58.3	5.3
7	5	Intel	81,000	79,720	-1.6	4.7
8	9	Hitachi	51,715	76,850	48.6	4.6
9	10	Toshiba	45,150	75,920	68.2	4.5
10	14	Fujitsu	32,000	62,500	95.3	3.7
11	13	Ricoh	32,500	42,900	32.0	2.5
12	8	Matsushita	56,000	42,000	-25.0	2.5
13	12	Texas Instruments	33,600	41,000	22.0	2.4
14	11	National Semiconductor	38,967	38,538	-1.1	2.3
15	16	Siemens	23,000	33,800	47.0	2.0
16	15	Zilog	24,886	27,271	9.6	1.6
17	19	Sony	20,500	27,060	32.0	1.6
18	18	Oki	21,120	25,950	22.9	1.5
19	21	Sanyo	16,300	24,000	47.2	1.4
20	20	TEMIC	17,386	22,949	32.0	1.4
21	17	Sharp	21,275	21,300	0.1	1.3
22	22	Rohm	14,950	19,734	32.0	1.2
23	23	ITT	3,840	4,191	9.1	0.2
24	26	Atmel	625	3,630	480.8	0.2
25	25	Advanced Micro Devices	2,470	1,550	-37.2	0.1
26	24	Dallas Semiconductor	2,500	1,329	-46.8	0.1
27	28	Seiko Epson	305	365	19.7	0
28	27	Rockwell	331	284	-14.2	0
29	29	Harris Semiconductor	267	240	-10.1	0
		All Others	0	0	0	0
		Total Market	1,350,048	1,687,359	25.0	

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (May 1996)

Table 4-2
Top 10 Family Shipments of 8-Bit Microcontrollers to the World (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Change (%)	1995 Market Share (%)
1	1	6805-F	328,482	378,890	15.3	22.5
2	2	8051-F	183,011	219,490	19.9	13.0
3	3	68HC11-F	103,886	113,403	9.2	6.7
4	4	uPD-F	89,800	107,500	19.7	6.4
5	5	PIC16/17-F	68,023	101,900	49.8	6.0
6	8	H8-F	49,500	68,500	38.4	4.1
7	10	M37XX-F	47,100	66,300	40.8	3.9
8	11	TLCS-F	39,200	66,000	68.4	3.9
9	13	MB8XXX	32,000	62,500	95.3	3.7
10	9	8048-F	49,447	58,442	18.2	3.5
		All Others	359,599	444,434	23.6	26.3
		Families	1,350,048	1,687,359	25.0	100.0

Source: Dataquest (May 1996)

Section 5: Microcontroller Unit Shipments—16-Bit and Up Architectures

Table 5-1
Ranking of Each Company's Shipments of 16-Bit and Greater Microcontrollers to the World (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Change (%)	1995 Market Share (%)
1	2	Hitachi	36,600	52,513	43.5	22.8
2	4	Mitsubishi	25,200	48,450	92.3	21.1
3	1	Intel	41,000	46,500	13.4	20.2
4	3	NEC	30,880	36,800	19.2	16.0
5	7	Fujitsu	2,700	14,770	447.0	6.4
6	5	Motorola	10,451	8,934	-14.5	3.9
7	28	Toshiba	0	8,300	0	3.6
8	9	Siemens	1,500	4,550	203.3	2.0
9	8	Oki	2,600	3,250	25.0	1.4
10	6	National Semiconductor	2,858	2,733	-4.4	1.2
11	10	Matsushita	360	2,640	633.3	1.1
12	11	Sony	290	382	31.7	0.2
13	12	SGS-Thomson	50	100	100.0	0
		All Others	0	0	0	0
		Total Market	154,489	229,922	48.8	

Note: Columns may not add to totals shown because of rounding
Source: Dataquest (May 1996)

Table 5-2
Top 10 Family Shipments of 16-Bit and Up Microcontrollers to the World (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Change (%)	1995 Market Share (%)
1	4	M377XX-F	25,200	48,450	92.3	21.1
2	2	H8-F	36,600	48,000	31.1	20.9
3	1	8096-F	41,000	46,500	13.4	20.2
4	3	uPD-F	28,600	35,000	22.4	15.2
5	8	MB907X-F	2,700	12,600	366.7	5.5
6	6	68HC16-F	4,809	8,934	85.8	3.9
7	33	TLCS-F	0	8,300	0	3.6
8	10	C16X-F	1,500	4,550	203.3	2.0
9	24	SHX	0	4,513	0	2.0
10	9	OLMS-F	2,600	3,250	25.0	1.4
		All Others	11,480	9,825	-0.1	4.3
		Families	154,489	229,922	48.8	100.0

Source: Dataquest (May 1996)

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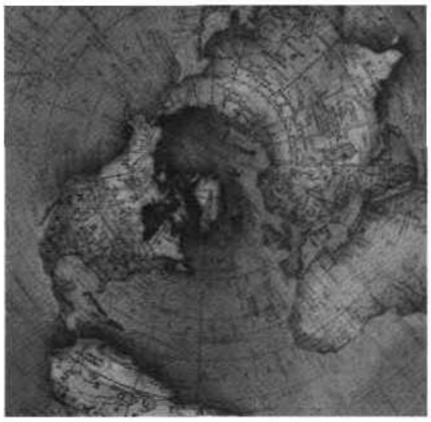

Dataquest

1995 Microprocessor Market Share and Shipments

Market Statistics

Program: Embedded Microcomponents Worldwide
Product Code: MCRO-WW-MS-9603
Publication Date: July 29, 1996
Filing: Market Statistics

1995 Microprocessor Market Share and Shipments

Market Statistics

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Note: All tables show estimated data.

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Note: All tables show estimated data.

1995 Microprocessor Market Share and Shipments

Introduction

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

- 1994-1995 unit shipment and market share estimates
- 1993-1995 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.

Microprocessor market share estimates combine data from many countries, each of which has a different and fluctuating exchange rate. Estimates of non-U.S. market consumption or revenue are based on the average exchange rate for the given year. Refer to the section titled "Exchange Rates" for more information regarding these average rates. As a rule, Dataquest's estimates are calculated in local currencies and then converted to U.S. dollars.

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

Segmentation

This section outlines the market segments that are specific to this document. Dataquest's objective is to provide data along lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to clients.

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

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

Definitions

This document details revenue and shipments of microprocessors. MCRO-WW-MS-9602 details microcontrollers and MCRO-WW-MS-9604 covers total microcomponents. 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 Definitions Guide.*

MOS Digital Microprocessor (MPU): Defined as an IC that includes an instruction decoder, arithmetic logic unit (ALU), registers, and additional logic. It may contain instruction, data, or unified caches, memory management systems, and auxiliary ALUs for floating point. An MPU's functions are determined by fetching and executing instructions and manipulating data held in registers, internal cache, or external memory. MPUs typically operate out of external memory systems. More highly integrated versions of MPUs may contain on-chip peripheral circuits. The MPU category includes MPUs incorporating or originating from an ASIC design. MPUs are divided into complex instruction set computer (CISC) or reduced instruction set computer (RISC) and 8-bit, 16-bit, or 32-bit and greater word width. MPUs are designed into compute applications or into embedded applications.

Word Width: The word width of a microprocessor architecture is determined by the maximum word width of the software that can be run by the architecture. This is defined by the computed accuracy of a single ADD instruction. If an architecture can perform a 32-bit ADD in a single instruction, then it is a 32-bit architecture. This is independent of the I/O bus width or the width of the integer unit. Examples of 32-bit MPUs include: 80386, 80486, and 68000.

Some of the broader microprocessor product families are explained in this section. For all families, only products that meet the definition of a microprocessor are included (microcontroller versions with their on-chip program store are excluded).

- x86 family: All upward-compatible versions of the 8086 microprocessor, regardless of word width, instruction extensions, or level of integration. The x86 is a CISC architecture. These include:
  - 16-bit x86: 8088, 8086, 16-bit V-series families (V20/V30/V40/V50), 80188, 80186-families, and 80286
  - 32-bit x86: 386-series, 486-series, Pentium, 5K86, 5x86, 6x86, and Pentium Pro

    Note that the Cyrix 5x86 uses a 486-style bus and is included in the 486 classification in Table 5-2.

    Note that the Cyrix 6x86 and the AMD 5K86 use a Pentium-style bus and are included in the Pentium classification in Table 5-2.
- 68K family: All upward-compatible versions of the 68000 microprocessor, regardless of word width, instruction extensions, or level of integration. These include: 680x0, 68EC0x0, 68HC000, 68008, 683xx families, Flexcore, and ColdFire. All are classified as 32-bit CISC. Note that some of these will be reclassified as 16-bit CISC for 1996 and beyond.
- SPARC family: All upward-compatible versions of the SPARC RISC microprocessor, regardless of word width, instruction extensions, or level of integration. These include: SPARC, MicroSPARC, SuperSPARC, and UltraSPARC.

- MIPS family: All upward-compatible versions of the MIPS RISC microprocessor, regardless of word width, instruction extensions, or level of integration. These include: R2000, R3000, R4000, and R4xxx.
- PowerPC family: All upward-compatible versions of the PowerPC RISC microprocessor, regardless of word width, instruction extensions, or level of integration. These include: PPC40x, 60x, and 8xx.
- ARM family: All upward-compatible versions of the ARM RISC microprocessor, regardless of word width, instruction extensions, or level of integration. These include: 6x0, 7x00, and Thumb.
- SH family: All upward-compatible versions of the SH RISC microprocessor, regardless of word width, instruction extensions, or level of integration. These include the SH-2 and SH-3.
- 960 family: All upward-compatible versions of the 960 RISC microprocessor, regardless of word width, instruction extensions, or level of integration.

Note that listings of total microprocessor shipments include these families as well as all others in the stated classification.

Merchant versus Captive Consumption

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

The unit tables in this book include the following microprocessors not counted in the revenue tables:

- Digital Equipment Corporation Alpha RISC chip
- Hewlett-Packard PA-RISC chip

HP PA-RISC processors are typically not sold alone in the merchant market but are integrated into RISC computer systems assembled and sold by Hewlett-Packard. As such, chip-only revenue estimates do not exist, and imputed estimates are difficult to interpret. However, microprocessor suppliers do face competition from these chips, even though they are sold integrated into a computer system. Although Digital does offer its Alpha MPU for sale on a standalone basis, the majority of these devices have been consumed by systems assembled and sold by Digital.

Regional Definitions

Americas

North America: Includes Canada, Mexico, and the United States (50 states)

South America

Central America

Japan

Japan is the only single-country region.

Europe, Africa, and the Middle East

Western Europe: Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and Rest of Western Europe (Andorra, Cyprus, Gibraltar, Liechtenstein, Monaco, San Marino, Vatican City, Iceland, Malta, and Turkey).

Eastern Europe: Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (Belarus, Russian Federation, Ukraine, Georgia, Moldavia, Armenia, Azerbaijan, Kazakhstan, Uzbekistan, Tadjikistan, Kyrgyzstan, and Turkmenistan).

Asia/Pacific

Includes Hong Kong, Singapore, South Korea, Taiwan, Australia, Bangladesh, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.

Line Item Definitions

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

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

Market Share Methodology

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

- Information published by major industry participants
- Estimates made by knowledgeable and reliable industry spokespersons
- Government data or trade association data (such as WSTS, MITI, and U.S. DOC)
- Published product literature and price lists
- Interviews with knowledgeable manufacturers, distributors, and users
- Relevant economic data

- Information and data from online and CD-ROM data banks
- Articles in both the general and trade press
- Reports from financial analysts
- End-user surveys

Dataquest believes that the estimates presented in this document are the most accurate and meaningful statistics available.

Despite the care taken in gathering, analyzing, and categorizing the data in a meaningful way, careful attention must be paid to the definitions and assumptions used herein when interpreting the estimates presented in this document. Various companies, government agencies, and trade associations may use slightly different definitions of product categories and regional groupings, or they may include different companies in their summaries. These differences should be kept in mind when making comparisons between data and numbers provided by Dataquest and those provided by other suppliers.

Notes to Market Share

1. Hewlett-Packard's PA-RISC microprocessors have been reclassified to compute for 1995. These devices were included inadvertently in the embedded category in prior years.

2. Some totals and rankings may differ from Dataquest's *1994 Market Statistics* because of changes in classifications and restatements.

3. As many as 5 million microprocessors based on the 68000 architecture are believed to have been produced by licensed OEM customers for their own internal consumption and therefore are not included in Dataquest totals.

4. LG Semicon was formerly known as Goldstar.

5. Hitachi's SH-1 products were reclassified as microcontrollers for 1995, making Hitachi's growth in microprocessors appear significantly lower than the growth of the entire SH family. For the complete SH series, consider both the 16-bit and up MCU SH series numbers as well as the 32-bit MPU Hitachi numbers.

6. All 8-bit and 16-bit microprocessors are classified as CISC and go into embedded applications only.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar amounts. The following outlines these rates for 1993 through 1995.

Table 1
Exchange Rates

	1993	1994	1995
Japan (Yen/U.S.$)	111.20	101.81	93.04
France (Franc/U.S.$)	5.67	5.54	4.99
Germany (Deutsche Mark/U.S.$)	1.66	1.62	1.44
United Kingdom (U.S.$/Pound Sterling)	1.50	1.53	1.58

Source: Dataquest (May 1995)

Section 1: 1995 Microprocessor Revenue Estimates and Rankings

Table 1-1
Each Company's Shipments of Total Microprocessors Worldwide— Embedded and Compute (Thousands of Units)

	1995 Total Microprocessors	Embedded	Compute	Percentage Embedded	Percentage Compute
Total Market	236,080	164,492	71,590	69.7	30.3
Total Americas Companies	184,404	113,469	70,937	61.5	38.5
Advanced Micro Devices	22,525	13,043	9,482	57.9	42.1
California Micro Devices	500	500	0	100.0	0
Cyrix	3,642	238	3,404	6.5	93.5
Digital Equipment Corporation	180	15	165	8.3	91.7
Harris Semiconductor	343	343	0	100.0	0
Hewlett-Packard	225	0	225	0	100.0
Hughes	116	116	0	100.0	0
IBM	4,254	448	3,806	10.5	89.5
Integrated Device Technology	1,000	875	125	87.5	12.5
Intel	65,247	14,441	50,806	22.1	77.9
LSI Logic	3,100	3,100	0	100.0	0
Motorola	52,671	50,308	2,363	95.5	4.5
National Semiconductor	2,472	2,472	0	100.0	0
Rockwell	484	484	0	100.0	0
Texas Instruments	1,842	1,282	561	69.6	30.5
VLSI Technology	138	138	0	100.0	0
Weitek	62	62	0	100.0	0
Zilog	25,604	25,604	0	100.0	0
Total Japanese Companies	45,499	44,856	643	98.6	1.4
Fujitsu	578	308	270	53.3	46.7
Hitachi	13,231	13,231	0	100.0	0
Matsushita	60	60	0	100.0	0
Mitsubishi	312	312	0	100.0	0
NEC	15,298	15,030	268	98.2	1.8
Oki	1,190	1,190	0	100.0	0
Ricoh	750	750	0	100.0	0
Sharp	2,770	2,770	0	100.0	0
Toshiba	11,310	11,205	105	99.1	0.9

(Continued)

Table 1-1 (Continued)
Each Company's Shipments of Total Microprocessors Worldwide—Embedded and Compute (Thousands of Units)

	1995 Total Microprocessors	Embedded	Compute	Percentage Embedded	Percentage Compute
Total European Companies	5,217	5,217	0	100.0	0
GEC Plessey	686	686	0	100.0	0
SGS-Thomson	4,500	4,500	0	100.0	0
TCS	31	31	0	100.0	0
Total Asia/Pacific Companies	960	950	10	99.0	1.0
LG Semicon	950	950	0	100.0	0
United Microelectronics	10	0	10	0	100.0

Source: Dataquest (June 1996)

Table 1-2
Each Company's Shipments of Total Microprocessors Worldwide—CISC and RISC (Thousands of Units)

	1995 Total Microprocessors	CISC	RISC	Percentage CISC	Percentage RISC
Total Market	236,080	208,868	27,212	88.5	11.5
Total Americas Companies	184,404	168,162	16,242	91.2	8.8
Advanced Micro Devices	22,525	20,595	1,930	91.4	8.6
California Micro Devices	500	500	0	100.0	0
Cyrix	3,642	3,642	0	100.0	0
Digital Equipment Corporation	180	0	180	0	100.0
Harris Semiconductor	343	343	0	100.0	0
Hewlett-Packard	225	0	225	0	100.0
Hughes	116	116	0	100.0	0
IBM	4,254	2,133	2,121	50.1	49.9
Integrated Device Technology	1,000	0	1,000	0	100.0
Intel	65,247	59,530	5,717	91.2	8.8
LSI Logic	3,100	0	3,100	0	100.0
Motorola	52,671	51,365	1,306	97.5	2.5
National Semiconductor	2,472	2,452	20	99.2	0.8
Rockwell	484	484	0	100.0	0
Texas Instruments	1,842	1,398	444	75.9	24.1
VLSI Technology	138	0	138	0	100.0
Weitek	62	0	62	0	100.0
Zilog	25,604	25,604	0	100.0	0
Total Japanese Companies	45,499	35,565	9,934	78.2	21.8
Fujitsu	578	8	570	1.4	98.6
Hitachi	13,231	6,720	6,511	50.8	49.2
Matsushita	60	60	0	100.0	0
Mitsubishi	312	287	25	92.0	8.0
NEC	15,298	12,600	2,698	82.4	17.6
Oki	1,190	1,190	0	100.0	0
Ricoh	750	750	0	100.0	0
Sharp	2,770	2,770	0	100.0	0
Toshiba	11,310	11,180	130	98.9	1.1
Total European Companies	5,217	4,181	1,036	80.1	19.9
GEC Plessey	686	0	686	0	100.0
SGS-Thomson	4,500	4,150	350	92.2	7.8
TCS	31	31	0	100.0	0
Total Asia/Pacific Companies	960	960	0	100.0	0
LG Semicon	950	950	0	100.0	0
United Microelectronics	10	10	0	100.0	0

Source: Dataquest (June 1996)

Table 1-3
Each Company's Factory Revenue from Shipments of Microprocessors Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	8,783	11,437	14,280	100.0	100.0	100.0
Americas Companies	8,408	10,898	13,609	95.7	95.3	95.3
Advanced Micro Devices	511	985	885	5.8	8.6	6.2
AT&T	2	0	0	0	0	0
California Micro Devices	2	2	3	0	0	0
Chips & Technologies	6	7	5	0.1	0.1	0
Cypress Semiconductor	6	0	0	0.1	0	0
Cyrix	95	231	212	1.1	2.0	1.5
Harris	11	12	14	0.1	0.1	0.1
Hughes	3	3	3	0	0	0
IBM	88	246	600	1.0	2.2	4.2
Integrated Device Technology	43	51	63	0.5	0.4	0.4
Intel	6,569	8,370	10,755	74.8	73.2	75.3
LSI Logic	47	51	36	0.5	0.4	0.3
Motorola	705	597	666	8.0	5.2	4.7
National Semiconductor	38	50	45	0.4	0.4	0.3
Performance Semiconductor	16	15	21	0.2	0.1	0.1
Rockwell	5	5	7	0.1	0	0
Texas Instruments	200	214	230	2.3	1.9	1.6
VLSI Technology	3	2	4	0	0	0
Weitek	19	14	20	0.2	0.1	0.1
Zilog	39	43	42	0.4	0.4	0.3
Japanese Companies	311	461	562	3.5	4.0	3.9
Fujitsu	25	56	78	0.3	0.5	0.5
Hitachi	79	160	135	0.9	1.4	0.9
Matsushita	11	14	15	0.1	0.1	0.1
Mitsubishi	17	9	17	0.2	0.1	0.1
NEC	87	105	176	1.0	0.9	1.2
Oki	9	9	10	0.1	0.1	0.1
Ricoh	4	4	0	0	0	0
Sharp	11	12	16	0.1	0.1	0.1
Toshiba	68	92	115	0.8	0.8	0.8
European Companies	61	67	85	0.7	0.6	0.6
GEC Plessey	7	6	3	0.1	0.1	0
Philips	1	0	0	0	0	0
SGS-Thomson	39	51	68	0.4	0.4	0.5
Siemens	4	0	0	0	0	0
TCS	10	10	14	0.1	0.1	0.1
Asia/Pacific Companies	3	11	23	0	0.1	0.2
LG Semicon	3	1	8	0	0	0.1
United Microelectronics	0	10	15	0	0.1	0.1

Source: Dataquest (June 1996)

Table 1-4
Each Company's Factory Revenue from Shipments of Microprocessors to the Americas (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	4,323	5,446	6,805	100.0	100.0	100.0
Americas Companies	4,269	5,351	6,656	98.8	98.3	97.8
Advanced Micro Devices	187	371	311	4.3	6.8	4.6
AT&T	2	0	0	0	0	0
California Micro Devices	1	1	1	0	0	0
Chips & Technologies	4	5	1	0.1	0.1	0
Cypress Semiconductor	5	0	0	0.1	0	0
Cyrix	50	118	66	1.2	2.2	1.0
Harris	5	5	6	0.1	0.1	0.1
Hughes	3	3	3	0.1	0.1	0
IBM	44	133	325	1.0	2.4	4.8
Integrated Device Technology	30	33	44	0.7	0.6	0.6
Intel	3,343	4,135	5,319	77.3	75.9	78.2
LSI Logic	33	11	10	0.8	0.2	0.1
Motorola	337	305	328	7.8	5.6	4.8
National Semiconductor	13	12	7	0.3	0.2	0.1
Performance Semiconductor	15	15	21	0.3	0.3	0.3
Rockwell	3	4	6	0.1	0.1	0.1
Texas Instruments	159	167	169	3.7	3.1	2.5
VLSI Technology	0	0	1	0	0	0
Weitek	16	12	17	0.4	0.2	0.2
Zilog	19	21	21	0.4	0.4	0.3
Japanese Companies	39	71	102	0.9	1.3	1.5
Fujitsu	4	30	53	0.1	0.6	0.8
Hitachi	8	11	7	0.2	0.2	0.1
Mitsubishi	1	0	1	0	0	0
NEC	18	21	32	0.4	0.4	0.5
Oki	3	3	3	0.1	0.1	0
Toshiba	5	6	6	0.1	0.1	0.1
European Companies	15	24	46	0.3	0.4	0.7
GEC Plessey	1	1	1	0	0	0
SGS-Thomson	9	18	38	0.2	0.3	0.6
TCS	5	5	7	0.1	0.1	0.1

Source: Dataquest (June 1996)

Table 1-5
Each Company's Factory Revenue from Shipments of Microprocessors to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	835	1,247	1,691	100.0	100.0	100.0
Americas Companies	651	963	1,335	78.0	77.2	79.0
Advanced Micro Devices	19	23	68	2.3	1.8	4.0
Chips & Technologies	0	0	1	0	0	0.1
Cyrix	6	16	29	0.7	1.3	1.7
Harris	2	2	2	0.2	0.2	0.1
Integrated Device Technology	4	5	9	0.5	0.4	0.5
Intel	530	801	1,120	63.5	64.2	66.2
LSI Logic	0	33	20	0	2.6	1.2
Motorola	68	53	63	8.1	4.3	3.7
National Semiconductor	7	11	6	0.8	0.9	0.4
Performance Semiconductor	1	0	0	0.1	0	0
Texas Instruments	9	13	9	1.1	1.0	0.5
VLSI Technology	0	1	1	0	0.1	0.1
Weitek	1	1	1	0.1	0.1	0.1
Zilog	4	4	6	0.5	0.3	0.3
Japanese Companies	178	279	355	21.3	22.4	21.0
Fujitsu	8	9	16	1.0	0.7	1.0
Hitachi	54	129	123	6.5	10.3	7.3
Matsushita	10	13	14	1.2	1.0	0.8
Mitsubishi	11	8	14	1.3	0.6	0.8
NEC	56	70	128	6.7	5.6	7.6
Oki	2	2	3	0.2	0.2	0.2
Ricoh	4	4	0	0.5	0.3	0
Sharp	11	12	16	1.3	1.0	0.9
Toshiba	22	32	41	2.6	2.6	2.4
European Companies	6	5	1	0.7	0.4	0.1
GEC Plessey	3	2	0	0.4	0.2	0
SGS-Thomson	3	3	1	0.4	0.2	0.1

Source: Dataquest (June 1996)

Table 1-6
Each Company's Factory Revenue from Shipments of Microprocessors to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	2,098	2,775	3,198	100.0	100.0	100.0
Americas Companies	2,015	2,678	3,098	96.0	96.5	96.9
Advanced Micro Devices	109	288	241	5.2	10.4	7.6
Chips & Technologies	0	0	1	0	0	0
Cypress Semiconductor	1	0	0	0	0	0
Cyrix	26	62	44	1.2	2.2	1.4
Harris	3	4	5	0.1	0.1	0.2
Integrated Device Technology	9	10	4	0.4	0.4	0.1
Intel	1,673	2,131	2,596	79.7	76.8	81.2
LSI Logic	14	6	6	0.7	0.2	0.2
Motorola	139	123	134	6.6	4.4	4.2
National Semiconductor	10	18	13	0.5	0.6	0.4
Rockwell	2	1	1	0.1	0	0
Texas Instruments	17	25	42	0.8	0.9	1.3
VLSI Technology	3	1	1	0.1	0	0
Weitek	2	1	1	0.1	0	0
Zilog	7	8	7	0.3	0.3	0.2
Japanese Companies	47	61	62	2.2	2.2	1.9
Fujitsu	8	11	4	0.4	0.4	0.1
Hitachi	6	8	5	0.3	0.3	0.2
Matsushita	1	1	1	0	0	0
Mitsubishi	1	0	1	0	0	0
NEC	5	6	7	0.2	0.2	0.2
Oki	1	1	1	0	0	0
Toshiba	25	34	42	1.2	1.2	1.3
European Companies	36	34	34	1.7	1.2	1.1
GEC Plessey	1	1	1	0	0	0
Philips	1	0	0	0	0	0
SGS-Thomson	25	28	26	1.2	1.0	0.8
Siemens	4	0	0	0.2	0	0
TCS	5	5	7	0.2	0.2	0.2
Asia/Pacific Companies	0	2	4	0	0.1	0.1
United Microelectronics	0	2	4	0	0.1	0.1

Source: Dataquest (June 1996)

Table 1-7
Each Company's Factory Revenue from Shipments of Microprocessors to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	1,527	1,969	2,587	100.0	100.0	100.0
Americas Companies	1,473	1,906	2,520	96.5	96.8	97.4
Advanced Micro Devices	196	303	265	12.8	15.4	10.2
California Micro Devices	1	1	1	0.1	0.1	0
Chips & Technologies	2	2	2	0.1	0.1	0.1
Cyrix	13	35	73	0.9	1.8	2.8
Harris	1	1	1	0.1	0.1	0
IBM	44	113	275	2.9	5.7	10.6
Integrated Device Technology	0	3	6	0	0.2	0.2
Intel	1,023	1,303	1,719	67.0	66.2	66.5
LSI Logic	0	1	0	0	0.1	0
Motorola	161	116	141	10.5	5.9	5.4
National Semiconductor	8	9	19	0.5	0.5	0.7
Texas Instruments	15	9	10	1.0	0.5	0.4
Zilog	9	10	8	0.6	0.5	0.3
Japanese Companies	47	50	44	3.1	2.5	1.7
Fujitsu	5	6	4	0.3	0.3	0.2
Hitachi	11	12	0	0.7	0.6	0
Mitsubishi	4	1	1	0.3	0.1	0
NEC	8	8	9	0.5	0.4	0.4
Oki	3	3	3	0.2	0.2	0.1
Toshiba	16	20	26	1.0	1.0	1.0
European Companies	4	4	4	0.3	0.2	0.2
GEC Plessey	2	2	1	0.1	0.1	0
SGS-Thomson	2	2	3	0.1	0.1	0.1
Asia/Pacific Companies	3	9	19	0.2	0.5	0.7
LG Semicon	3	1	8	0.2	0.1	0.3
United Microelectronics	0	8	11	0	0.4	0.4

Source: Dataquest (June 1996)

Table 1-8
Top 20 Companies' Factory Revenue from Shipments of Microprocessors Worldwide (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Percentage Change	1995 Market Share (%)
1	1	Intel	8,370	10,755	28	75.3
2	2	Advanced Micro Devices	985	885	-10	6.2
3	3	Motorola	597	666	12	4.7
4	4	IBM	246	600	144	4.2
5	6	Texas Instruments	214	230	7	1.6
6	5	Cyrix	231	212	-8	1.5
7	8	NEC	105	176	68	1.2
8	7	Hitachi	160	135	-16	0.9
9	9	Toshiba	92	115	25	0.8
10	10	Fujitsu	56	78	38	0.5
11	11	SGS-Thomson	51	68	34	0.5
12	13	Integrated Device Technology	51	63	24	0.4
13	14	National Semiconductor	50	45	-9	0.3
14	15	Zilog	43	42	-3	0.3
15	12	LSI Logic	51	36	-29	0.3
16	16	Performance Semiconductor	15	21	40	0.1
17	18	Weitek	14	20	40	0.1
18	23	Mitsubishi	9	17	90	0.1
19	20	Sharp	12	16	33	0.1
20	22	United Microelectronics	10	15	50	0.1
		All Others	75	85	13	0.6
		Americas Companies	10,898	13,609	25	95.3
		Japanese Companies	461	562	22	3.9
		European Companies	67	85	27	0.6
		Asia/Pacific Companies	11	23	109	0.2
		Total Market	11,437	14,280	25	100.0

Source: Dataquest (June 1996)

Table 1-9
Top 10 Companies' Factory Revenue from Shipments of Microprocessors to the Americas (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Percentage Change	1995 Market Share (%)
1	1	Intel	4,135	5,319	29	78.2
2	3	Motorola	305	328	8	4.8
3	5	IBM	133	325	144	4.8
4	2	Advanced Micro Devices	371	311	-16	4.6
5	4	Texas Instruments	167	169	1	2.5
6	6	Cyrix	118	66	-44	1.0
7	8	Fujitsu	30	53	77	0.8
8	7	Integrated Device Technology	33	44	33	0.6
9	11	SGS-Thomson	18	38	111	0.6
10	9	NEC	21	32	52	0.5
		All Others	115	119	4	1.8
		Americas Companies	5,351	6,656	24	97.8
		Japanese Companies	71	102	44	1.5
		European Companies	24	46	92	0.7
		Asia/Pacific Companies	0	0	0	0
		Total Market	5,446	6,805	25	100.0

Source: Dataquest (June 1996)

Table 1-10
Top 10 Companies' Factory Revenue from Shipments of Microprocessors to Japan (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Percentage Change	1995 Market Share (%)
1	1	Intel	801	1,120	40	66.2
2	3	NEC	70	128	83	7.6
3	2	Hitachi	129	123	-5	7.3
4	7	Advanced Micro Devices	23	68	196	4.0
5	4	Motorola	53	63	18	3.7
6	6	Toshiba	32	41	28	2.4
7	8	Cyrix	16	29	81	1.7
8	5	LSI Logic	33	20	-39	1.2
9	13	Fujitsu	9	16	81	1.0
10	11	Sharp	12	16	33	0.9
		All Others	69	67	-3	4.0
		Americas Companies	963	1,335	39	79.0
		Japanese Companies	279	355	27	21.0
		European Companies	5	1	-80	0.1
		Asia/Pacific Companies	0	0	0	0
		Total Market	1,247	1,691	36	100.0

Source: Dataquest (June 1996)

Table 1-11
Top 10 Companies' Factory Revenue from Shipments of Microprocessors to Europe (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Percentage Change	1995 Market Share (%)
1	1	Intel	2,131	2,596	22	81.2
2	2	Advanced Micro Devices	288	241	-16	7.6
3	3	Motorola	123	134	9	4.2
4	4	Cyrix	62	44	-29	1.4
5	5	Toshiba	34	42	24	1.3
6	7	Texas Instruments	25	42	68	1.3
7	6	SGS-Thomson	28	26	-7	0.8
8	8	National Semiconductor	18	13	-26	0.4
9	13	NEC	6	7	19	0.2
10	12	Zilog	8	7	-13	0.2
		All Others	52	44	-15	1.4
		Americas Companies	2,678	3,098	16	96.9
		Japanese Companies	61	62	1	1.9
		European Companies	34	34	0	1.1
		Asia/Pacific Companies	2	4	100	0.1
		Total Market	2,775	3,198	15	100.0

Source: Dataquest (June 1996)

Table 1-12
Top 10 Companies' Factory Revenue from Shipments of Microprocessors to Asia/Pacific (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Percentage Change	1995 Market Share (%)
1	1	Intel	1,303	1,719	32	66.5
2	4	IBM	113	275	143	10.6
3	2	Advanced Micro Devices	303	265	-13	10.2
4	3	Motorola	116	141	22	5.4
5	5	Cyrix	35	73	109	2.8
6	6	Toshiba	20	26	30	1.0
7	10	National Semiconductor	9	19	111	0.7
8	12	United Microelectronics	8	11	38	0.4
9	9	Texas Instruments	9	10	9	0.4
10	11	NEC	8	9	15	0.4
		All Others	45	39	-14	1.5
		Americas Companies	1,906	2,520	32	97.4
		Japanese Companies	50	44	-13	1.7
		European Companies	4	4	8	0.2
		Asia/Pacific Companies	9	19	111	0.7
		Total Market	1,969	2,587	31	100.0

Source: Dataquest (June 1996)

Section 2: Microprocessor Unit Shipments—Overview

Table 2-1
Ranking of Each Company's Shipments of Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Intel	55,645	65,247	17.3	27.6
2	2	Motorola	38,080	52,671	38.3	22.3
3	3	Zilog	21,935	25,604	16.7	10.8
4	4	Advanced Micro Devices	15,316	22,525	47.1	9.5
5	6	NEC	11,440	15,298	33.7	6.5
6	5	Hitachi	13,018	13,231	1.6	5.6
7	7	Toshiba	7,528	11,310	50.2	4.8
8	8	SGS-Thomson	5,660	4,500	-20.5	1.9
9	10	IBM	3,515	4,254	21.0	1.8
10	11	Cyrix	2,382	3,642	52.9	1.5
11	17	LSI Logic	900	3,100	244.4	1.3
12	13	Sharp	2,236	2,770	23.9	1.2
13	9	National Semiconductor	3,919	2,472	-36.9	1.0
14	12	Texas Instruments	2,370	1,842	-22.3	0.8
15	14	Oki	1,400	1,190	-15.0	0.5
16	18	Integrated Device Technology	603	1,000	65.8	0.4
17	16	LG Semicon	1,000	950	-5.0	0.4
18	15	Ricoh	1,000	750	-25.0	0.3
19	20	GEC Plessey	550	686	24.7	0.3
20	21	Fujitsu	463	578	24.8	0.2
21	22	California Micro Devices	400	500	25.0	0.2
22	19	Rockwell	567	484	-14.6	0.2
23	25	Harris Semiconductor	275	343	24.7	0.1
24	24	Mitsubishi	276	312	13.0	0.1
25	26	Hewlett-Packard	175	225	28.6	0.1
26	30	Digital Equipment Corporation	65	180	176.9	0.1
27	28	VLSI Technology	109	138	27.1	0.1
28	29	Hughes	93	116	24.7	0
29	31	Weitek	60	62	3.3	0
30	23	Matsushita	340	60	-82.4	0

(Continued)

Table 2-1 (Continued)
Ranking of Each Company's Shipments of Microprocessors Worldwide
(Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
31	33	TCS	25	31	24.0	0
32	34	United Microelectronics	25	10	-60.0	0
33	27	Chips & Technologies	147	0	-100.0	0
34	32	Performance Semiconductor	30	0	-100.0	0
		All Others	0	0	0	0
		Total Market	191,547	236,080	23.0	100.0

Source: Dataquest (June 1996)

Table 2-2
Ranking of Each Company's Shipments of Embedded Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Motorola	33,750	50,308	49.1	30.6
2	2	Zilog	21,935	25,604	16.7	15.6
3	5	NEC	11,320	15,030	32.8	9.1
4	3	Intel	17,120	14,441	-15.6	8.8
5	4	Hitachi	13,018	13,231	1.6	8.0
6	7	Advanced Micro Devices	7,106	13,043	83.5	7.9
7	6	Toshiba	7,454	11,205	50.3	6.8
8	8	SGS-Thomson	5,660	4,500	-20.5	2.7
9	14	LSI Logic	900	3,100	244.4	1.9
10	10	Sharp	2,236	2,770	23.9	1.7
11	9	National Semiconductor	3,919	2,472	-36.9	1.5
12	18	Texas Instruments	430	1,282	198.1	0.8
13	11	Oki	1,400	1,190	-15.0	0.7
14	13	LG Semicon	1,000	950	-5.0	0.6
15	17	Integrated Device Technology	539	875	62.3	0.5
16	12	Ricoh	1,000	750	-25.0	0.5
17	16	GEC Plessey	550	686	24.7	0.4
18	19	California Micro Devices	400	500	25.0	0.3
19	15	Rockwell	567	484	-14.6	0.3
20	32	IBM	0	448	NM	0.3
21	23	Harris Semiconductor	275	343	24.7	0.2
22	22	Mitsubishi	276	312	13.0	0.2
23	21	Fujitsu	283	308	8.8	0.2
24	30	Cyrix	0	238	NM	0.1
25	25	VLSI Technology	109	138	27.1	0.1
26	26	Hughes	93	116	24.7	0.1
27	27	Weitek	50	62	24.0	0
28	20	Matsushita	340	60	-82.4	0
29	29	TCS	25	31	24.0	0
30	31	Digital Equipment Corporation	0	15	NM	0
31	24	Hewlett-Packard	175	0	-100.0	0
32	28	Performance Semiconductor	30	0	-100.0	0
		All Others	0	0	0	0
		Total Market	131,960	164,492	25.0	100.0

NM = Not meaningful
Source: Dataquest (June 1996)

Table 2-3
Ranking of Each Company's Shipments of Compute Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Intel	38,525	50,806	31.9	71.0
2	2	Advanced Micro Devices	8,210	9,482	15.5	13.2
3	4	IBM	3,515	3,806	8.3	5.3
4	5	Cyrix	2,382	3,404	42.9	4.8
5	3	Motorola	4,330	2,363	-45.4	3.3
6	6	Texas Instruments	1,940	561	-71.1	0.8
7	7	Fujitsu	180	270	50.0	0.4
8	9	NEC	120	268	123.3	0.4
9	15	Hewlett-Packard	0	225	NM	0.3
10	11	Digital Equipment Corporation	65	165	153.8	0.2
11	12	Integrated Device Technology	64	125	95.3	0.2
12	10	Toshiba	74	105	41.9	0.1
13	13	United Microelectronics	25	10	-60.0	0
14	8	Chips & Technologies	147	0	-100.0	0
15	14	Weitek	10	0	-100.0	0
		All Others	0	0	0	0
		Total Market	59,587	71,590	20.0	100.0

NM = Not meaningful
Source: Dataquest (June 1996)

Section 3: Microprocessor Unit Shipments by Word Width

Table 3-1
Ranking of Each Company's Shipments of 8-Bit Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Zilog	21,780	25,411	16.7	48.7
2	2	Toshiba	6,200	9,580	54.5	18.4
3	3	Hitachi	5,060	4,420	-12.6	8.5
4	4	SGS-Thomson	4,510	3,350	-25.7	6.4
5	5	Sharp	2,180	2,630	20.6	5.0
6	6	Motorola	1,891	1,049	-44.5	2.0
7	7	Oki	1,200	1,030	-14.2	2.0
8	9	LG Semicon	1,000	950	-5.0	1.8
9	10	Intel	700	875	25.0	1.7
10	8	Ricoh	1,000	750	-25.0	1.4
11	13	California Micro Devices	400	500	25.0	1.0
12	11	Rockwell	567	484	-14.6	0.9
13	12	NEC	540	440	-18.5	0.8
14	16	National Semiconductor	219	262	19.6	0.5
15	15	Mitsubishi	255	210	-17.6	0.4
16	17	Hughes	93	116	24.7	0.2
17	19	Harris Semiconductor	50	62	24.0	0.1
18	14	Texas Instruments	260	6	-97.7	0
19	18	Fujitsu	85	0	-100.0	0
		All Others	0	0	0	0
		Total Market	47,990	52,125	9.0	100.0

Source: Dataquest (June 1996)

Table 3-2
Ranking of Each Company's Shipments of 16-Bit Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	NEC	10,580	12,050	13.9	40.7
2	3	Advanced Micro Devices	4,582	9,718	112.1	32.8
3	2	Intel	10,500	6,405	-39.0	21.6
4	4	Hitachi	400	400	0	1.4
5	7	Harris Semiconductor	225	281	24.9	0.9
6	5	SGS-Thomson	350	200	-42.9	0.7
7	9	Zilog	155	193	24.5	0.7
8	8	Oki	200	160	-20.0	0.5
9	10	Sharp	56	140	150.0	0.5
10	6	Matsushita	340	60	-82.4	0.2
11	11	Performance Semiconductor	15	0	-100.0	0
		All Others	0	0	0	0
		Total Market	27,403	29,607	8.0	100.0

Source: Dataquest (June 1996)

Table 3-3
Ranking of Each Company's Shipments of 32-Bit-and-Up Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Intel	44,445	57,967	30.4	37.6
2	2	Motorola	36,189	51,621	42.6	33.4
3	3	Advanced Micro Devices	10,734	12,807	19.3	8.3
4	4	Hitachi	7,558	8,411	11.3	5.4
5	6	IBM	3,515	4,254	21.0	2.8
6	7	Cyrix	2,382	3,642	52.9	2.4
7	10	LSI Logic	900	3,100	244.4	2.0
8	15	NEC	320	2,808	777.5	1.8
9	5	National Semiconductor	3,700	2,210	-40.3	1.4
10	8	Texas Instruments	2,110	1,836	-13.0	1.2
11	9	Toshiba	1,328	1,730	30.3	1.1
12	12	Integrated Device Technology	603	1,000	65.8	0.6
13	11	SGS-Thomson	800	950	18.8	0.6
14	13	GEC Plessey	550	686	24.7	0.4
15	14	Fujitsu	378	578	52.9	0.4
16	16	Hewlett-Packard	175	225	28.6	0.1
17	19	Digital Equipment Corporation	65	180	176.9	0.1
18	18	VLSI Technology	109	138	27.1	0.1
19	23	Mitsubishi	21	102	385.7	0.1
20	20	Weitek	60	62	3.3	0
21	21	TCS	25	31	24.0	0
22	22	United Microelectronics	25	10	-60.0	0
23	17	Chips & Technologies	147	0	-100.0	0
24	24	Performance Semiconductor	15	0	-100.0	0
		All Others	0	0	0	0
		Total Market	116,154	154,347	33.0	100.0

Source: Dataquest (June 1996)

Table 3-4
Ranking of Each Company's Shipments of 32-Bit-and-Up Embedded Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Motorola	31,859	49,258	54.6	59.5
2	2	Hitachi	7,558	8,411	11.3	10.2
3	3	Intel	5,920	7,161	21.0	8.7
4	5	Advanced Micro Devices	2,524	3,325	31.7	4.0
5	7	LSI Logic	900	3,100	244.4	3.7
6	11	NEC	200	2,540	1,170.0	3.1
7	4	National Semiconductor	3,700	2,210	-40.3	2.7
8	6	Toshiba	1,254	1,625	29.6	2.0
9	14	Texas Instruments	170	1,276	650.6	1.5
10	8	SGS-Thomson	800	950	18.8	1.1
11	10	Integrated Device Technology	539	875	62.3	1.1
12	9	GEC Plessey	550	686	24.7	0.8
13	22	IBM	0	448	NM	0.5
14	12	Fujitsu	198	308	55.6	0.4
15	20	Cyrix	0	238	NM	0.3
16	15	VLSI Technology	109	138	27.1	0.2
17	18	Mitsubishi	21	102	385.7	0.1
18	16	Weitek	50	62	24.0	0.1
19	17	TCS	25	31	24.0	0
20	21	Digital Equipment Corporation	0	15	NM	0
21	13	Hewlett-Packard	175	0	-100.0	0
22	19	Performance Semiconductor	15	0	-100.0	0
		All Others	0	0	0	0
		Total Market	56,567	82,759	46.0	100.0

NM = Not meaningful
Source: Dataquest (June 1996)

Table 3-5
Ranking of Each Company's Shipments of 32-Bit-and-Up Compute Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Intel	38,525	50,806	31.9	71.0
2	2	Advanced Micro Devices	8,210	9,482	15.5	13.2
3	4	IBM	3,515	3,806	8.3	5.3
4	5	Cyrix	2,382	3,404	42.9	4.8
5	3	Motorola	4,330	2,363	-45.4	3.3
6	6	Texas Instruments	1,940	561	-71.1	0.8
7	7	Fujitsu	180	270	50.0	0.4
8	9	NEC	120	268	123.3	0.4
9	15	Hewlett-Packard	0	225	NM	0.3
10	11	Digital Equipment Corporation	65	165	153.8	0.2
11	12	Integrated Device Technology	64	125	95.3	0.2
12	10	Toshiba	74	105	41.9	0.1
13	13	United Microelectronics	25	10	-60.0	0
14	8	Chips & Technologies	147	0	-100.0	0
15	14	Weitek	10	0	-100.0	0
		All Others	0	0	0	0
		Total Market	59,587	71,590	20.0	100.0

NM = Not meaningful
Source: Dataquest (June 1996)

Table 3-6
Shipments of Compute Microprocessors Worldwide, by Word Length and Company Base (Thousands of Units)

	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
32-Bit				
Total Americas Companies	59,059	70,634	19.6	98.7
Total Japanese Companies	180	270	50.0	0.4
Total European Companies	0	0	0	0
Total Asia/Pacific Companies	25	10	-60.0	0
Total 32-Bit Market	59,264	70,914	19.7	99.1
64-Bit				
Total Americas Companies	129	303	134.9	0.4
Total Japanese Companies	194	373	92.3	0.5
Total European Companies	0	0	0	0
Total Asia/Pacific Companies	0	0	0	0
Total 64-Bit Market	323	676	109.3	0.9
Total	59,587	71,590	20.1	100.0

Source: Dataquest (June 1996)

Table 3-7
Each Company's Factory Revenue from Shipments of 8-Bit and 16-Bit CISC Microprocessors Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	440	536	517	100.0	100.0	100.0
Americas Companies	221	301	319	50.2	56.2	61.8
Advanced Micro Devices	38	81	61	8.6	15.1	11.8
California Micro Devices	2	2	3	0.5	0.4	0.5
Chips & Technologies	0	0	5	0	0	1.0
Harris	11	12	14	2.5	2.2	2.6
Hughes	3	3	3	0.7	0.6	0.6
Intel	90	115	137	20.5	21.5	26.6
Motorola	0	5	10	0	0.9	1.9
National Semiconductor	4	4	3	0.9	0.7	0.5
Performance Semiconductor	7	11	15	1.6	2.1	3.0
Rockwell	5	5	7	1.1	0.9	1.3
Texas Instruments	22	20	20	5.0	3.7	3.8
Zilog	39	43	42	8.9	8.0	8.1
Japanese Companies	215	234	190	48.9	43.7	36.7
Fujitsu	8	8	8	1.8	1.5	1.6
Hitachi	73	80	2	16.6	14.9	0.4
Matsushita	10	12	12	2.3	2.2	2.4
Mitsubishi	15	9	11	3.4	1.7	2.2
NEC	43	46	67	9.8	8.6	13.0
Oki	9	9	10	2.0	1.7	1.9
Ricoh	4	4	0	0.9	0.7	0
Sharp	11	12	16	2.5	2.2	3.1
Toshiba	42	54	63	9.5	10.1	12.2
European Companies	1	0	0	0.2	0	0
Philips	1	0	0	0.2	0	0
Asia/Pacific Companies	3	1	8	0.7	0.2	1.5
LG Semicon	3	1	8	0.7	0.2	1.5

Source: Dataquest (June 1996)

Table 3-8
Top 20 Companies' Factory Revenue from Shipments of 8-Bit and 16-Bit CISC Microprocessors Worldwide (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Percentage Change	1995 Market Share (%)
1	1	Intel	115	137	19.0	26.6
2	5	NEC	46	67	46.0	13.0
3	4	Toshiba	54	63	17.0	12.2
4	2	Advanced Micro Devices	81	61	-25.0	11.8
5	6	Zilog	43	42	-3.0	8.1
6	7	Texas Instruments	20	20	-1.0	3.8
7	10	Sharp	12	16	33.0	3.1
8	11	Performance Semiconductor	11	15	40.0	3.0
9	8	Harris	12	14	13.0	2.6
10	9	Matsushita	12	12	2.0	2.4
11	12	Mitsubishi	9	11	24.0	2.2
12	13	Oki	9	10	12.0	1.9
13	15	Motorola	5	10	100.0	1.9
14	14	Fujitsu	8	8	3.0	1.6
15	21	LG Semicon	1	8	700.0	1.5
16	16	Rockwell	5	7	38.0	1.3
17	95	Chips & Technologies	0	5	NM	1.0
18	19	Hughes	3	3	0	0.6
19	17	National Semiconductor	4	3	-30.0	0.5
20	20	California Micro Devices	2	3	34.0	0.5
		All Others	84	2	-98.0	0.4
		Americas Companies	301	319	6.0	61.8
		Japanese Companies	234	190	-19.0	36.7
		European Companies	0	0	0	0
		Asia/Pacific Companies	1	8	700.0	1.5
		Total Market	536	517	-4.0	100.0

NM = Not meaningful
Source: Dataquest (June 1996)

Table 3-9
Each Company's Factory Revenue from Shipments of 32-Bit CISC Microprocessors Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	7,701	9,812	12,043	100.0	100.0	100.0
Americas Companies	7,666	9,763	11,980	99.5	99.5	99.5
Advanced Micro Devices	440	823	750	5.7	8.4	6.2
Chips & Technologies	6	7	0	0.1	0.1	0
Cyrix	95	231	212	1.2	2.4	1.8
IBM	46	0	75	0.6	0	0.6
Intel	6,319	8,050	10,386	82.1	82.0	86.2
Motorola	685	561	479	8.9	5.7	4.0
National Semiconductor	34	46	43	0.4	0.5	0.4
Performance Semiconductor	9	4	6	0.1	0	0
Texas Instruments	32	41	30	0.4	0.4	0.2
Japanese Companies	25	29	34	0.3	0.3	0.3
Fujitsu	1	1	1	0	0	0
Hitachi	2	3	1	0	0	0
Mitsubishi	0	0	6	0	0	0
NEC	22	25	25	0.3	0.3	0.2
European Companies	10	10	14	0.1	0.1	0.1
TCS	10	10	14	0.1	0.1	0.1
Asia/Pacific Companies	0	10	15	0	0.1	0.1
United Microelectronics	0	10	15	0	0.1	0.1

Source: Dataquest (June 1996)

Table 3-10
Top 15 Companies' Factory Revenue from Shipments of 32-Bit CISC Microprocessors Worldwide (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Percentage Change	1995 Market Share (%)
1	1	Intel	8,050	10,386	29.0	86.2
2	2	Advanced Micro Devices	823	750	-9.0	6.2
3	3	Motorola	561	479	-15.0	4.0
4	4	Cyrix	231	212	-8.0	1.8
5	28	IBM	0	75	NM	0.6
6	5	National Semiconductor	46	43	-8.0	0.4
7	6	Texas Instruments	41	30	-27.0	0.2
8	7	NEC	25	25	2.0	0.2
9	9	United Microelectronics	10	15	50.0	0.1
10	8	TCS	10	14	40.0	0.1
11	19	Mitsubishi	0	6	NM	0
12	11	Performance Semiconductor	4	6	40.0	0
13	13	Fujitsu	1	1	27.0	0
14	12	Hitachi	3	1	-67.0	0
15	10	Chips & Technologies	7	0	-100.0	0
		All Others	0	0	0	0
		Americas Companies	9,763	11,980	23.0	99.5
		Japanese Companies	29	34	16.0	0.3
		European Companies	10	14	40.0	0.1
		Asia/Pacific Companies	10	15	50.0	0.1
		Total Market	9,812	12,043	23.0	100.0

NM = Not meaningful
Source: Dataquest (June 1996)

Table 3-11
Ranking of Each Company's Shipments of 32-Bit CISC Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Intel	40,290	52,250	29.7	41.1
2	2	Motorola	36,157	50,315	39.2	39.6
3	3	Advanced Micro Devices	9,595	10,877	13.4	8.6
4	5	Cyrix	2,382	3,642	52.9	2.9
5	4	National Semiconductor	3,700	2,190	-40.8	1.7
6	8	IBM	1,515	2,133	40.8	1.7
7	7	Hitachi	1,550	1,900	22.6	1.5
8	9	Toshiba	1,250	1,600	28.0	1.3
9	6	Texas Instruments	1,710	1,392	-18.6	1.1
10	10	SGS-Thomson	650	600	-7.7	0.5
11	12	NEC	90	110	22.2	0.1
12	16	Mitsubishi	4	77	1,825.0	0.1
13	13	TCS	25	31	24.0	0
14	14	United Microelectronics	25	10	-60.0	0
15	15	Fujitsu	8	8	NM	0
16	11	Chips & Technologies	147	0	-100.0	0
		All Others	0	0	0	0
		Total Market	99,098	127,135	28.0	100.0

NM = Not meaningful
Source: Dataquest (June 1996)

Table 3-12
Ranking of Each Company's Shipments of 32-Bit CISC Embedded Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Motorola	31,859	49,202	54.4	81.3
2	2	National Semiconductor	3,700	2,190	-40.8	3.6
3	4	Hitachi	1,550	1,900	22.6	3.1
4	6	Toshiba	1,250	1,600	28.0	2.6
5	3	Intel	1,850	1,444	-21.9	2.4
6	5	Advanced Micro Devices	1,385	1,395	0.7	2.3
7	8	Texas Instruments	170	1,276	650.6	2.1
8	7	SGS-Thomson	650	600	-7.7	1.0
9	14	IBM	0	448	NM	0.7
10	13	Cyrix	0	238	NM	0.4
11	9	NEC	90	110	22.2	0.2
12	12	Mitsubishi	4	77	1,825.0	0.1
13	10	TCS	25	31	24.0	0.1
14	11	Fujitsu	8	8	NM	0
		All Others	0	0	0	0
		Total Market	42,541	60,519	42.0	100.0

NM = Not meaningful
Source: Dataquest (June 1996)

Table 3-13
Ranking of Each Company's Shipments of 32-Bit CISC Compute Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Intel	38,440	50,806	32.2	76.3
2	2	Advanced Micro Devices	8,210	9,482	15.5	14.2
3	4	Cyrix	2,382	3,404	42.9	5.1
4	6	IBM	1,515	1,685	11.2	2.5
5	3	Motorola	4,298	1,113	-74.1	1.7
6	5	Texas Instruments	1,540	116	-92.5	0.2
7	8	United Microelectronics	25	10	-60.0	0
8	7	Chips & Technologies	147	0	-100.0	0
		All Others	0	0	0	0
		Total Market	56,557	66,616	18.0	100.0

Source: Dataquest (June 1996)

Table 3-14
Each Company's Factory Revenue from Shipments of 32-Bit-and-Up RISC Microprocessors Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1993	1994	1995	1993	1994	1995
Total Market	642	1,089	1,720	100.0	100.0	100.0
Americas Companies	521	834	1,310	81.2	76.6	76.2
Advanced Micro Devices	33	81	74	5.1	7.4	4.3
AT&T	2	0	0	0.3	0	0
Cypress Semiconductor	6	0	0	0.9	0	0
IBM	42	246	525	6.5	22.6	30.5
Integrated Device Technology	43	51	63	6.7	4.7	3.7
Intel	160	205	231	24.9	18.8	13.4
LSI Logic	47	51	36	7.3	4.7	2.1
Motorola	20	31	177	3.1	2.8	10.3
Texas Instruments	146	153	180	22.7	14.0	10.5
VLSI Technology	3	2	4	0.5	0.2	0.2
Weitek	19	14	20	3.0	1.3	1.1
Japanese Companies	71	198	339	11.1	18.2	19.7
Fujitsu	16	47	68	2.5	4.3	4.0
Hitachi	4	77	132	0.6	7.1	7.7
Matsushita	1	2	3	0.2	0.2	0.2
Mitsubishi	2	0	0	0.3	0	0
NEC	22	34	84	3.4	3.1	4.9
Toshiba	26	38	52	4.0	3.5	3.0
European Companies	50	57	71	7.8	5.2	4.1
GEC Plessey	7	6	3	1.1	0.6	0.2
SGS-Thomson	39	51	68	6.1	4.7	4.0
Siemens	4	0	0	0.6	0	0
Asia/Pacific Companies	0	0	0	0	0	0

Source: Dataquest (June 1996)

Table 3-15
Top 16 Companies' Factory Revenue from Shipments of 32-Bit-and-Up RISC Microprocessors Worldwide (Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Percentage Change	1995 Market Share (%)
1	1	IBM	246	525	113.0	30.5
2	2	Intel	205	231	13.0	13.4
3	3	Texas Instruments	153	180	18.0	10.5
4	12	Motorola	31	177	471.0	10.3
5	5	Hitachi	77	132	71.0	7.7
6	11	NEC	34	84	147.0	4.9
7	4	Advanced Micro Devices	81	74	-8.0	4.3
8	7	SGS-Thomson	51	68	34.0	4.0
9	9	Fujitsu	47	68	45.0	4.0
10	6	Integrated Device Technology	51	63	24.0	3.7
11	10	Toshiba	38	52	37.0	3.0
12	8	LSI Logic	51	36	-29.0	2.1
13	13	Weitek	14	20	40.0	1.1
14	16	VLSI Technology	2	4	86.0	0.2
15	14	GEC Plessey	6	3	-50.0	0.2
16	15	Matsushita	2	3	33.0	0.2
		All Others	0	0	0	0
		Americas Companies	834	1,310	57.0	76.2
		Japanese Companies	198	339	71.0	19.7
		European Companies	57	71	25.0	4.1
		Asia/Pacific Companies	0	0	0	0
		Total Market	1,089	1,720	58.0	100.0

Source: Dataquest (June 1996)

Table 3-16
Ranking of Each Company's Shipments of 32-Bit-and-Up RISC Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Hitachi	6,008	6,511	8.4	23.9
2	2	Intel	4,155	5,717	37.6	21.0
3	5	LSI Logic	900	3,100	244.4	11.4
4	10	NEC	230	2,698	1,073.0	9.9
5	3	IBM	2,000	2,121	6.1	7.8
6	4	Advanced Micro Devices	1,139	1,930	69.4	7.1
7	17	Motorola	32	1,306	3,981.3	4.8
8	6	Integrated Device Technology	603	1,000	65.8	3.7
9	7	GEC Plessey	550	686	24.7	2.5
10	9	Fujitsu	370	570	54.1	2.1
11	8	Texas Instruments	400	444	11.0	1.6
12	12	SGS-Thomson	150	350	133.3	1.3
13	11	Hewlett-Packard	175	225	28.6	0.8
14	15	Digital Equipment Corporation	65	180	176.9	0.7
15	13	VLSI Technology	109	138	27.1	0.5
16	14	Toshiba	78	130	66.7	0.5
17	16	Weitek	60	62	3.3	0.2
18	18	Mitsubishi	17	25	47.1	0.1
19	21	National Semiconductor	0	20	NM	0.1
20	19	Performance Semiconductor	15	0	-100.0	0
		All Others	0	0	0	0
		Total Market	17,056	27,212	60.0	100.0

NM = Not meaningful
Note: Hitachi's 1994 total includes devices that were reclassified as microcontrollers in the 1995 numbers.
Source: Dataquest (June 1996)

Table 3-17
Ranking of Each Company's Shipments of 32-Bit-and-Up RISC Embedded Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Hitachi	6,008	6,511	8.4	29.3
2	2	Intel	4,070	5,717	40.5	25.7
3	4	LSI Logic	900	3,100	244.4	13.9
4	10	NEC	110	2,430	2,109.1	10.9
5	3	Advanced Micro Devices	1,139	1,930	69.4	8.7
6	6	Integrated Device Technology	539	875	62.3	3.9
7	5	GEC Plessey	550	686	24.7	3.1
8	9	SGS-Thomson	150	350	133.3	1.6
9	7	Fujitsu	190	300	57.9	1.3
10	11	VLSI Technology	109	138	27.1	0.6
11	12	Weitek	50	62	24.0	0.3
12	17	Motorola	0	56	NM	0.3
13	13	Mitsubishi	17	25	47.1	0.1
14	15	Toshiba	4	25	525.0	0.1
15	18	National Semiconductor	0	20	NM	0.1
16	16	Digital Equipment Corporation	0	15	NM	0.1
17	8	Hewlett-Packard	175	0	-100.0	0
18	14	Performance Semiconductor	15	0	-100.0	0
		All Others	0	0	0	0
		Total Market	14,026	22,240	59.0	100.0

NM = Not meaningful
Note: Hitachi's 1994 total includes devices that were reclassified as microcontrollers in the 1995 numbers.
Source: Dataquest (June 1996)

Table 3-18
Ranking of Each Company's Shipments of 32-Bit-and-Up RISC Compute Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	IBM	2,000	2,121	6.1	42.6
2	9	Motorola	32	1,250	3,806.3	25.1
3	2	Texas Instruments	400	445	11.3	8.9
4	3	Fujitsu	180	270	50.0	5.4
5	4	NEC	120	268	123.3	5.4
6	11	Hewlett-Packard	0	225	NM	4.5
7	7	Digital Equipment Corporation	65	165	153.8	3.3
8	8	Integrated Device Technology	64	125	95.3	2.5
9	6	Toshiba	74	105	41.9	2.1
10	5	Intel	85	0	-100.0	0
11	10	Weitek	10	0	-100.0	0
		All Others	0	0	0	0
		Total Market	3,030	4,974	64.0	100.0

NM = Not meaningful
Source: Dataquest (June 1996)

Section 4: Microprocessor Unit Shipments—Processor Families

Table 4-1
Shipments of Microprocessors by Family Worldwide (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	x86	81,927	99,109	21.0	42.0
2	2	68K	39,632	54,446	37.4	23.1
3	3	SH	6,000	6,500	8.3	2.8
4	4	i960	4,070	5,610	37.8	2.4
5	6	MIPS	1,732	4,678	170.1	2.0
6	5	PowerPC	2,000	3,427	71.4	1.5
7	9	SPARC	780	1,015	30.1	0.4
8	10	ARM	659	822	24.8	0.3
		All Others	61,013	67,823	11.2	28.5
		Total	191,547	236,080	23.2	100.0

Source: Dataquest (June 1996)

Table 4-2
Shipments of Embedded Microprocessors by Family Worldwide (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	68K	35,334	53,333	50.9	32.4
2	2	x86	29,668	33,606	13.3	20.4
3	3	SH	6,000	6,500	8.3	4.0
4	4	i960	4,070	5,610	37.8	3.4
5	5	MIPS	1,474	4,180	183.6	2.5
6	8	ARM	659	824	25.1	0.5
7	10	SPARC	190	300	57.9	0.2
		All Others	54,565	60,138	10.2	34.9
		Total	131,960	164,492	24.7	100.0

Source: Dataquest (June 1996)

Table 4-3
Shipments of Compute Microprocessors by Family Worldwide (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	x86	52,259	65,503	25.3	91.5
2	2	PowerPC	2,000	3,371	68.6	4.7
3	3	68K	4,298	1,113	-74.1	1.6
4	4	SPARC	590	715	21.2	1.0
5	5	MIPS	258	498	93.0	0.7
6	6	PA-RISC	0	225	NM	0.3
7	7	Alpha	65	165	153.8	0.2
		All Others	117	0	-100.0	0
		Total	59,587	71,590	20.0	100.0

NM = Not meaningful
Source: Dataquest (June 1996)

Table 4-4
Shipments of CISC Microprocessors by Family Worldwide (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	x86	81,927	99,109	21.0	47.5
2	2	68K	39,632	54,446	37.4	26.1
		All Others	52,932	52,142	6.5	25.0
		Total	174,491	208,868	20.0	100.0

Source: Dataquest (June 1996)

Table 4-5
Shipments of RISC Microprocessors by Family Worldwide (Thousands of Units)

1995 Rank	1994 Rank		1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	SHX	6,000	6,500	8.3	23.9
2	2	i960	4,070	5,610	37.8	20.6
3	3	MIPS	1,732	4,678	170.1	17.2
4	4	PowerPC	2,000	3,427	71.4	12.6
5	5	SPARC	780	1,015	30.1	3.7
6	6	ARM	659	822	24.8	3.0
7	7	PA-RISC	179	229	27.9	0.8
8	8	Alpha	65	180	176.9	0.7
		All Others	1,571	4,751	202.4	17.5
		Total	17,056	27,212	60.0	100.0

Note: Hitachi's 1994 total includes devices that were reclassified as microcontrollers in the 1995 numbers.
Source: Dataquest (June 1996)

Section 5: Microprocessor Unit Shipments—x86 Processor Family

Table 5-1
Ranking of Each Company's Shipments of x86 Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Intel	50,790	58,655	15.5	59.2
2	2	Advanced Micro Devices	14,177	20,595	45.3	20.8
3	3	NEC	10,670	12,160	14.0	12.3
4	4	Cyrix	2,382	3,642	52.9	3.7
5	6	IBM	1,515	2,133	40.8	2.2
6	5	Texas Instruments	1,540	1,153	-25.1	1.2
7	7	Oki	400	340	-15.0	0.3
8	8	Harris Semiconductor	225	281	24.9	0.3
9	10	Sharp	56	140	150.0	0.1
10	11	United Microelectronics	25	10	-60.0	0
11	9	Chips & Technologies	147	0	-100.0	0
		All Others	0	0	0	0
		Total x86 Market	81,927	99,109	21.0	100.0

Source: Dataquest (June 1996)

Table 5-2
Shipments of x86 Microprocessors by Family Worldwide (Thousands of Units)

	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
Pentium Pro	0	95	NM	0.1
Pentium/Cyrix-6x86	5,040	33,214	559.0	33.5
486/Cyrix-5x86	43,587	35,235	-19.2	35.6
386	6,957	1,631	-76.6	1.6
286	444	281	-36.7	0.3
186/188	14,650	16,017	9.3	16.2
8086/88	11,249	12,636	12.3	12.7
All Others	0	0	0	0
Total	81,927	99,109	21.0	100.0

NM = Not meaningful
Source: Dataquest (June 1996)

Table 5-3
Ranking of Each Company's Shipments of 16-Bit x86 Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	NEC	10,580	12,050	13.9	41.9
2	3	Advanced Micro Devices	4,582	9,718	112.1	33.8
3	2	Intel	10,500	6,405	-39.0	22.3
4	4	Harris Semiconductor	225	281	24.9	1.0
5	5	Oki	200	160	-20.0	0.6
6	6	Sharp	56	140	150.0	0.5
		All Others	0	0	0	0
		Total 16-Bit Market	26,143	28,754	10.0	100.0

Source: Dataquest (June 1996)

Table 5-4
Ranking of Each Company's Shipments of 32-Bit x86 Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Intel	40,290	52,250	29.7	74.5
2	2	Advanced Micro Devices	9,595	10,877	13.4	15.5
3	3	Cyrix	2,382	3,642	52.9	5.2
4	5	IBM	1,515	2,133	40.8	3.0
5	4	Texas Instruments	1,540	1,153	-25.1	1.6
6	7	NEC	90	110	22.2	0.2
7	8	United Microelectronics	25	10	-60.0	0
8	6	Chips & Technologies	147	0	-100.0	0
		All Others	0	0	0	0
		Total 32-Bit Market	55,584	70,175	26.0	100.0

Source: Dataquest (June 1996)

Section 6: Microprocessor Unit Shipments—68K Processor Family

Table 6-1
Ranking of Each Company's Shipments of 68K Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Motorola	36,157	50,315	39.2	92.4
2	2	Hitachi	1,550	1,900	22.6	3.5
3	3	Toshiba	1,250	1,600	28.0	2.9
4	4	SGS-Thomson	650	600	-7.7	1.1
5	5	TCS	25	31	24.0	0.1
		All Others	0	0	0	0
		Total 68K Market	39,632	54,446	37.0	100.0

Source: Dataquest (June 1996)

Section 7: Microprocessor Unit Shipments—RISC Processor Families

Table 7-1
Ranking of Each Company's Shipments of SPARC Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	2	Fujitsu	370	570	54.1	56.2
2	1	Texas Instruments	400	445	11.3	43.8
3	3	Weitek	10	0	-100.0	0
		All Others	0	0	0	0
		Total SPARC Market	780	1,015	30.0	100.0

Source: Dataquest (June 1996)

Table 7-2
Ranking of Each Company's Shipments of MIPS Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	LSI Logic	900	3,100	244.4	66.3
2	2	Integrated Device Technology	603	1,000	65.8	21.4
3	3	NEC	140	448	220.0	9.6
4	4	Toshiba	74	130	75.7	2.8
5	5	Performance Semiconductor	15	0	-100.0	0
		All Others	0	0	0	0
		Total MIPS Market	1,732	4,678	170.0	100.0

Source: Dataquest (June 1996)

Section 8: Microprocessor Unit Shipments—8-Bit and 16-Bit Embedded Processors

Table 8-1
Ranking of Each Company's Shipments of 8-Bit Embedded Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	Zilog	21,780	25,411	16.7	48.7
2	2	Toshiba	6,200	9,580	54.5	18.4
3	3	Hitachi	5,060	4,420	-12.6	8.5
4	4	SGS-Thomson	4,510	3,350	-25.7	6.4
5	5	Sharp	2,180	2,630	20.6	5.0
6	6	Motorola	1,891	1,049	-44.5	2.0
7	7	Oki	1,200	1,030	-14.2	2.0
8	9	LG Semicon	1,000	950	-5.0	1.8
9	10	Intel	700	875	25.0	1.7
10	8	Ricoh	1,000	750	-25.0	1.4
11	13	California Micro Devices	400	500	25.0	1.0
12	11	Rockwell	567	484	-14.6	0.9
13	12	NEC	540	440	-18.5	0.8
14	16	National Semiconductor	219	262	19.6	0.5
15	15	Mitsubishi	255	210	-17.6	0.4
16	17	Hughes	93	116	24.7	0.2
17	19	Harris Semiconductor	50	62	24.0	0.1
18	14	Texas Instruments	260	6	-97.7	0
19	18	Fujitsu	85	0	-100.0	0
		All Others	0	0	0	0
		Total Market	47,990	52,125	9.0	100.0

Source: Dataquest (June 1996)

Table 8-2
Ranking of Each Company's Shipments of 16-Bit Embedded Microprocessors Worldwide (Thousands of Units)

1995 Rank	1994 Rank	Company	1994 Units	1995 Units	Percentage Change	1995 Market Share (%)
1	1	NEC	10,580	12,050	13.9	40.7
2	3	Advanced Micro Devices	4,582	9,718	112.1	32.8
3	2	Intel	10,500	6,405	-39.0	21.6
4	4	Hitachi	400	400	NM	1.4
5	7	Harris Semiconductor	225	281	24.9	0.9
6	5	SGS-Thomson	350	200	-42.9	0.7
7	9	Zilog	155	193	24.5	0.7
8	8	Oki	200	160	-20.0	0.5
9	10	Sharp	56	140	150.0	0.5
10	6	Matsushita	340	60	-82.4	0.2
11	11	Performance Semiconductor	15	0	-100.0	0
		All Others	0	0	0	0
		Total Market	27,403	29,607	8.0	100.0

NM = Not meaningful
Source: Dataquest (June 1996)

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