6 MOS MPU, MCU, AND PERIPHERALS MARKET TRENDS

OVERVIEW

MOS microcomponents include MPUs, MCUs—including DSP devices—and microperipheral devices that are microcomputer related. The quarterly growth of this market beginning in 1990 is shown in Figure 6-1. Except for a slight leveling off period in the 1991-1992 time period, the microcomponent market has shown steady growth since 1Q90. Beginning in the second half of 1994, the microcomponent market grew rapidly as sales of less costly 486 and hot-selling Pentium MPUs took off. Solid market growth continued through 1995. ICE estimates the 1995 microcomponent market grew 39 percent. This follows two years of excellent market growth (25 percent in 1994 and 37 percent in 1993).

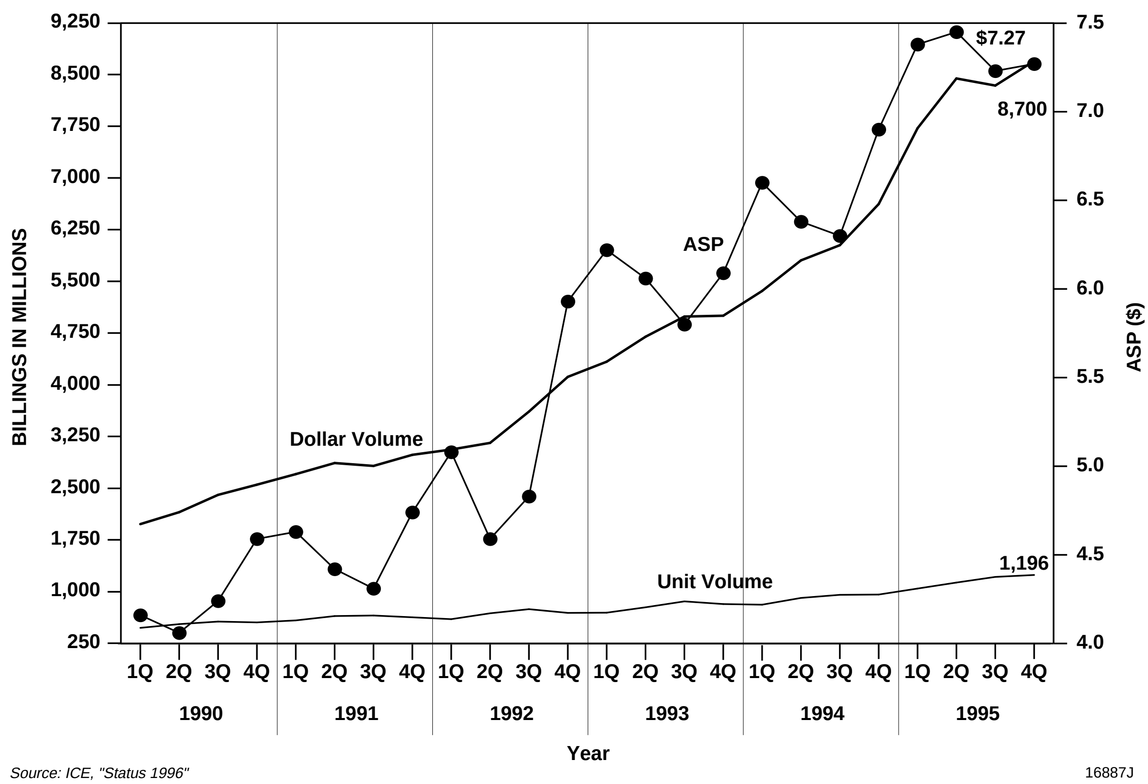


Figure 6-1. MOS MPU, MCU, and MPR Market Trends (Dollars and Units in Millions)

The dramatic increase in ASP in late 1992 is very apparent. A similar pattern of dips and increases in ASPs occurred each following year. This was due in part to seasonality and in part to high initial prices of new MPUs such as Intel's Pentium and the IBM/Motorola PowerPC chip.

Figure 6-2 shows unit volume and ASP details for the major segments of the microcomponent market. Severe price erosion on 486s and Pentiums contributed to a 13 percent decline in ASPs for the 32-/64-bit MPU segment, even though unit volume increased 49 percent. Competitive pressures resulting in more number crunching, video, graphics, and audio capabilities of "new-generation" computers and associated software plus numerous embedded applications will continue to keep 32-bit processor demand strong.

Product	1993 ASP ($)	1993/1992 Percent Change In ASP	1993/1992 Unit Volume Percent Change	1994 ASP ($)	1994/1993 Percent Change In ASP	1994/1993 Unit Volume Percent Change	1995 ASP ($)	1995/1994 Percent Change In ASP	1995/1994 Unit Volume Percent Change
MPUs									
8-bit	3.10	2	4	3.52	14	–11	3.85	9	–11
16-bit	10.29	–45	–7	9.88	–4	–12	8.70	–12	9
32-bit/64-bit	150.19	–2	88	150.51	—	31	131.45	–13	49
Total MPU	51.50	35	16	64.60	25	2	69.65	8	19
MCUs									
4-bit	1.64	1	6	1.62	–1	5	1.72	6	–7
8-bit	3.45	2	27	3.33	–3	28	3.46	4	20
16-bit/32-bit	8.13	10	30	7.86	–3	100	8.72	11	63
Total MCU*	2.71	6	16	2.82	–4	19	3.21	14	11
MPRs	5.04	8	13	5.61	11	4	6.20	11	64
Total Micro	6.02	18	16	6.54	9	15	7.34	12	24

***Not including DSP**

Source: ICE, "Status 1996"

16888J

Figure 6-2. Microcomponent ASPs and Unit Volume Change

Besides the 32-/64-bit MPU segment, microperipheral units also grew substantially (64 percent) in 1995. Growth in the form of communications, graphics, voice, and other support functions for PCs surged. Overall, ICE estimates that ASPs in the MOS microcomponent segment increased 12 percent in 1995 and unit volume increased 24 percent.

Figure 6-3 shows the microcomponent market growth rates from 1993-1995. Total market growth figures for the MPU, MCU, and MPR categories were very strong for 1995. Enjoying the highest percentage increases were 16-/32-bit MCUs, DSP devices, and MPRs. As a whole, MOS microcomponent sales grew 39 percent in 1995. Details are provided later in this section, but ICE forecasts these segments to perform well again in 1996.

PRODUCT	1993 ($M)	1993/1992 Percent Change	1994 ($M)	1994/1993 Percent Change	1995 ($M, EST)	1995/1994 Percent Change
MPUs						
8-bit	200	7	200	—	195	–3
16-bit	520	49	440	–15	420	–5
32/64-bit	7,870	70	10,355	32	13,475	30
Total MPU	8,590	—	10,995	28	14,090	28
MCUs						
4-bit	1,700	6	1,770	4	1,740	–2
8-bit	3,700	29	4,565	23	5,705	25
16/32-bit	485	42	940	94	1,710	82
DSPs	675	51	1,000	48	1,710	71
Total MCU	6,560	23	8,275	26	10,865	31
MPRs	3,920	22	4,550	16	8,255	81
Total Microcomponent	19,070	—	23,820	25	33,210	39

Source: ICE, "Status 1996" 17204H

Figure 6-3. 1993-1995 Microcomponent Market

Another perspective of the MOS MPU, MCU, and peripherals markets is shown in Figure 6-4. In 1995, the microperipherals segment grew three percentage points to command 25 percent of the microcomponent market. As mentioned earlier, growth in this category was due to the abundant number of value-added functions delivered with or added to new computer systems.

Figure 6-5 shows consumption of MOS microcomponents by geographic region for 1995. It seems hard to believe that in 1991, Japan and North America consumed the same percentage of microcomponents. Since then, things have changed dramatically. With 39 percent of the market, North America was the clear microcomponent consumption leader in 1995, although by a slightly smaller margin than the previous year.

Figure 6-6 lists the quarterly microcomponent market by region. Despite a few dips or leveling-off periods, all regional markets participated in the growth of microcomponents during the two-year period. Japan and the Asia-Pacific region each led the way with over 40 percent growth in 1995.

Figure 6-7 shows the regional microcomponent production. North American companies were the main suppliers to the microcomponent market, with Intel accounting for a very sizable portion of this production. On the other hand, ROW and European companies had fairly insignificant microcomponent marketshare.

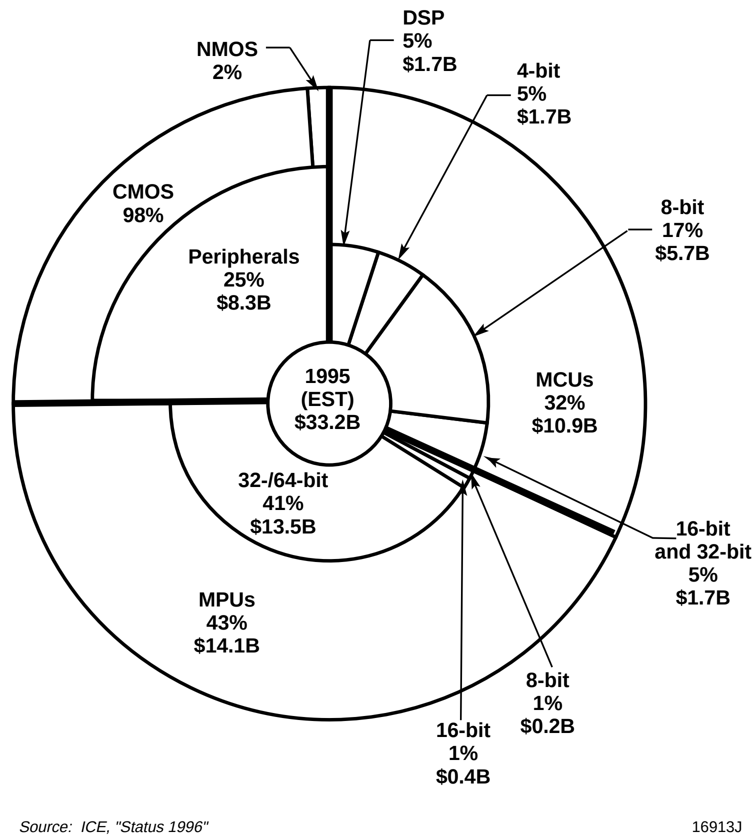


Figure 6-4. 1995 MOS MPU, MCU, and Peripherals Market

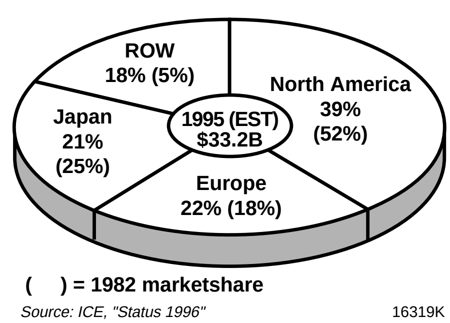


Figure 6-5. 1995 MOS Microcomponent Consumption

TOP TEN MANUFACTURERS

ICE's ranking of the top ten MOS microcomponent suppliers for 1995 is shown in Figure 6-8. Combined, these top suppliers accounted for the vast majority of the microcomponent market in 1995.

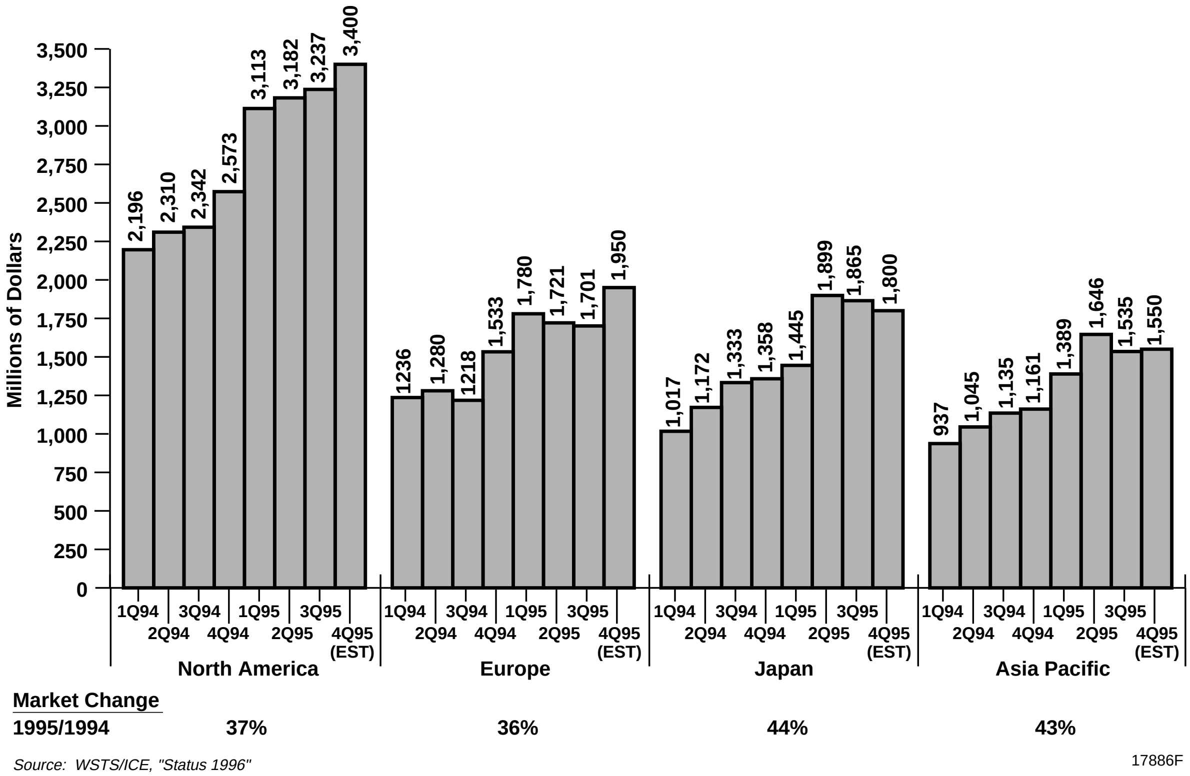


Figure 6-6. Quarterly Microcomponent Geographic Market Trends

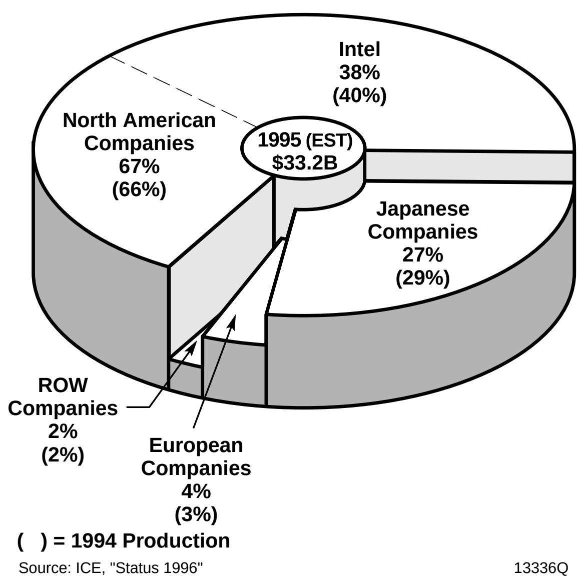


Figure 6-7. 1995 MOS MPU, MCU, and Peripherals Production

1995 Rank	Company	1994 Sales ($M)	1995 Sales ($M, EST)	1995/1994 Percent Change
1	Intel	9,450	12,730	35
2	Motorola	2,365	2,935	24
3	NEC	1,775	2,235	26
4	Hitachi	1,000	1,515	52
5	TI	1,005	1,290	28
6	Cirrus Logic	777	1,235	59
7	Mitsubishi	710	1,012	43
8	Toshiba	735	990	35
9	AMD	1,030	935	–9
10	IBM	300	640	113
	Total	19,147	25,517	33

Source: ICE, "Status 1996" 16316K

Figure 6-8. 1995 Top Ten MOS Microcomponent Sales Leaders

It comes as no surprise that Intel was again the leading microcomponent supplier in 1995. Its microcomponent sales far exceeded those of its nearest competitors. Intel's domination lies in sales of its various MPUs and MCUs. The company has the top selling CISC (Pentium) and RISC (i960) MPUs. Moreover, it is strengthening its peripheral product line up to be a bigger contender in that arena. Through its fine R&D work, careful planning, and creative marketing strategies, Intel has remained a formidable manufacturer of microcomponents. Of course, having a slew of litigation experts on hand to snuff out competitive challenges hasn't hurt the company's position either.

Strong microperipheral demand propelled Cirrus Logic's sales up an estimated 59 percent in 1995. Also, IBM, with more sales in the merchant market, made its first appearance in the top micro-component suppliers' list. IBM manufactures MPUs for NexGen, Cyrix, and Motorola besides building devices for sale under its own name.

MICROCOMPONENT FORECAST

ICE's forecast of the microcomponent market in the year 2000 is shown in Figure 6-9. In the year 2000, ICE does not anticipate any dramatic market swings to occur among MPUs, MCUs, or peripherals. However, there will likely be a noticeable shift toward higher density devices. Nearly all MPU sales will be 32- and 64-bit devices. Meanwhile, MCU sales will still be dominated by the ubiquitous 8-bit device. Compared to 1995, however, the market presence of 16-and 32-bit MCU devices will be greater in the year 2000.

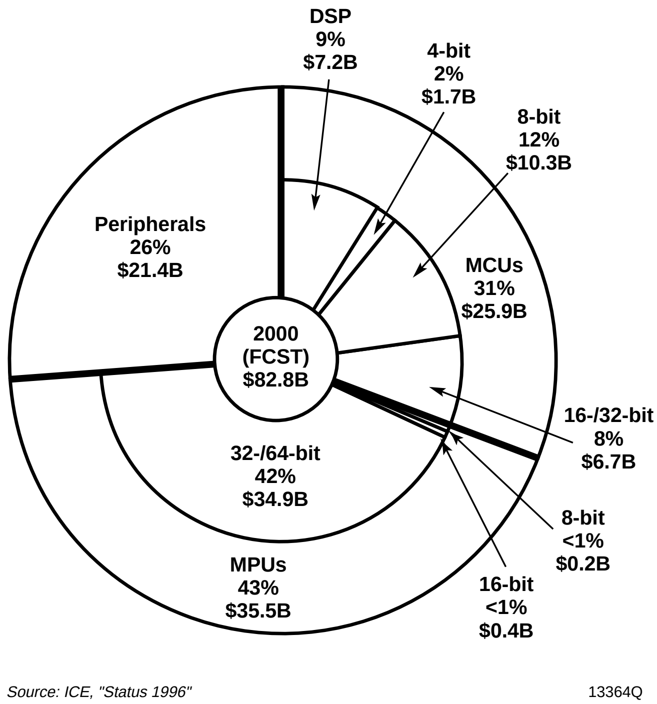


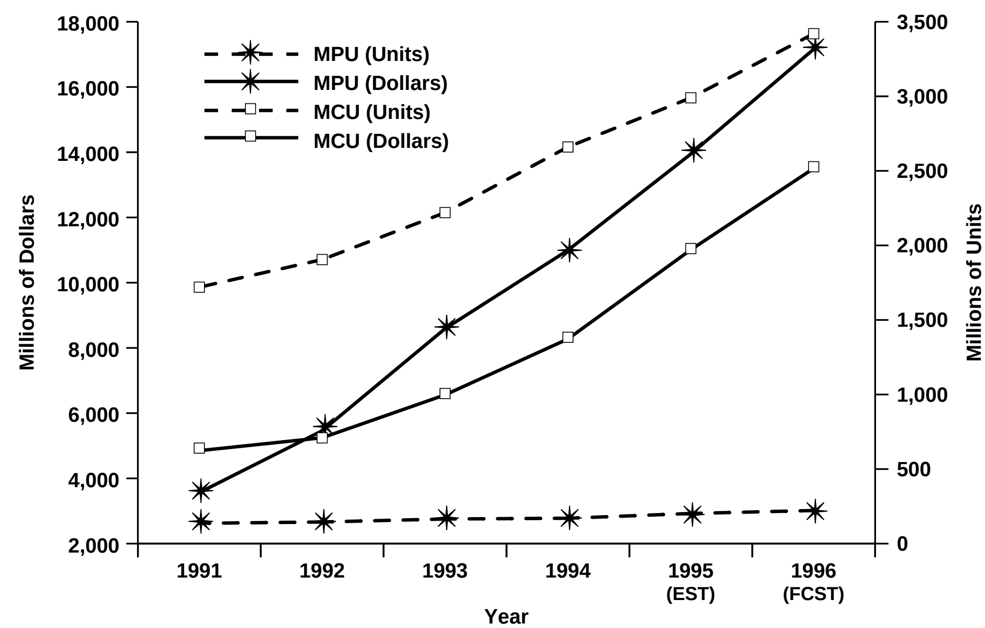
Figure 6-9. MOS MPU, MCU, and Peripherals Market Forecast

The microperipherals market is also forecast to possess a greater share of the microcomponent market in the year 2000. In future days, one chip will not hold all the information necessary to meet the needs of greater system complexity and sophistication. Microperipherals will be called upon to handle extra chores that will be required of tomorrow's MPUs, MCUs, and DSP devices.

THE MCU MARKET

As defined by WSTS, a microcontroller is a stand alone device that performs dedicated or embedded computer functions within an overall electronic system without the need of other support circuits. Unlike MPUs, microcontrollers contain some form of on-chip memory—usually ROM, EPROM, or EEPROM—that is programmed to store customer-supplied instructions.

Many times, news from the MCU market is brushed aside in favor of attention-grabbing headlines from the world of microprocessors. Despite continuous performance improvements, MCUs are often overshadowed by their MPU cousins. In terms of dollars, microcontrollers represents a smaller market. However, MCUs outship MPUs by roughly a 15:1 margin. Figure 6-10 compares the market and unit shipments figures of the MPU and MCU segments.



Units (M)						
MCU	1,720	1,905	2,220	2,660	2,990	3,420
MPU	136	145	165	170	202	222
Dollars ($M)						
MCU	4,850	5,245	6,560	8,275	10,865	13,505
MPU	3,565	5,460	8,590	10,995	14,090	17,160

Source: ICE, "Status 1996" 20318A

Figure 6-10. Comparison of the MCU and MPU Markets

Strange though it may seem, the three-billion microcontrollers shipped in 1995 remained rather well concealed. Though they often go unnoticed, the average person comes into contact each day with more microcontrollers (as many as 50) than people. Clearly, MCUs have become extremely pervasive.

MCU growth is being driven by three key sectors: automobiles, office electronics, and consumer electronics. Inexpensive cars from Korea have from five to ten MCUs each, while many luxury cars use 30 to 40. 1996 S-class cars from Mercedes-Benz use 50 MCUs throughout the vehicle. Meanwhile, the average office has about 20 MCUs, and the typical home has as many as 100 microcontrollers! In recent years, these areas have contributed significantly to the rise in the MCU market and unit growth.

Figure 6-11 projects the number of MCU devices expected to make their way into new cars, homes, and offices through the end of the decade. There is great potential in these three applications. The figure shows that MCUs in the home are forecast to grow to an average of 226 in the year 2000!

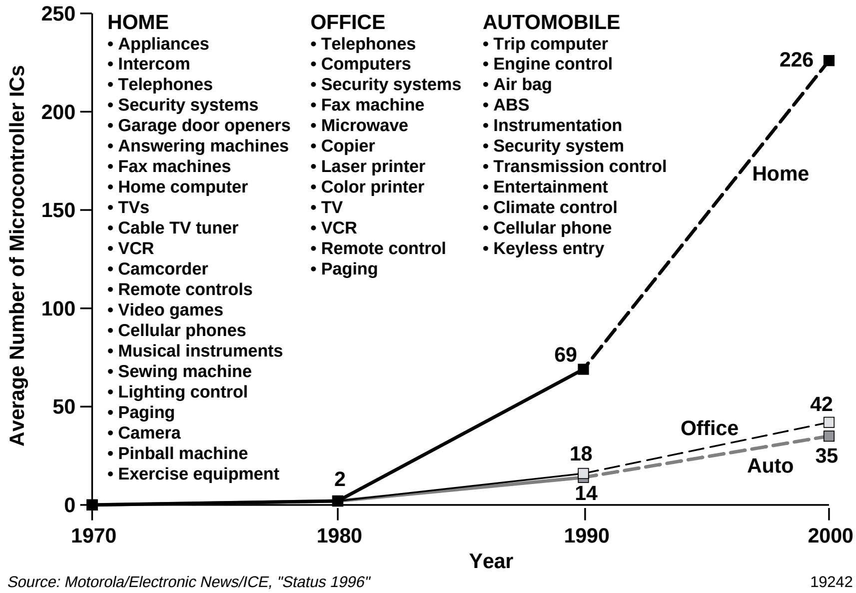


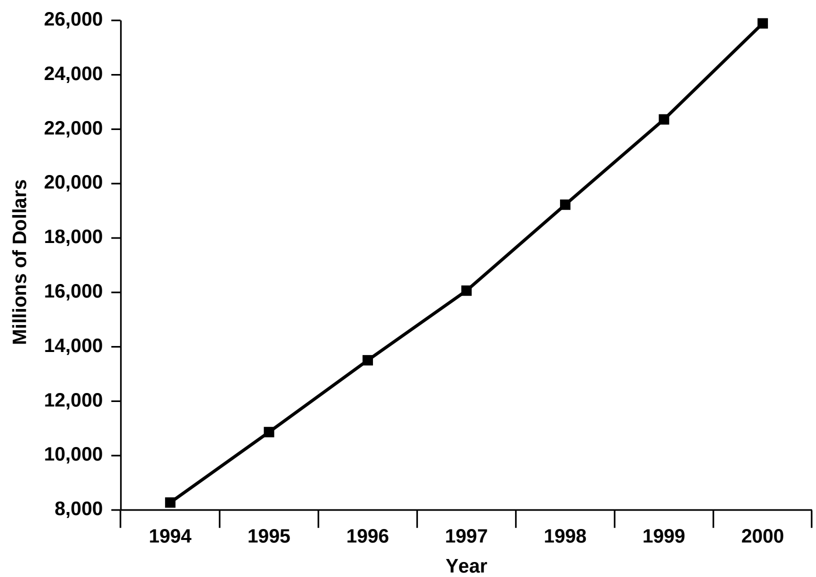
Figure 6-11. Numerous Applications Spur MCU Growth

Numerous applications will allow the MCU market to grow nicely through the end of the decade—a rate nearly that of the overall IC market. ICE projects 19 percent average annual growth from 1995-2000, when the MCU market is forecast to be $25.9 billion (Figure 6-12).

MCUs are typically available in 4-, 8-, and 16-bit configurations. A few 32-bit devices have shipped as well. Figure 6-13 shows the percentage of dollars that each density contributed to the MCU market. In this chart, DSPs are included as part of the microcontroller market. However, the DSP market is covered more fully later in this section. 8-bit MCUs were at the heart of numerous applications, old and new. As a result, ICE estimates that 52 percent of the MCU market was attributed to 8-bit controllers in 1995.

Steady gains by ≥16-bit MCUs and DSPs will continue to occur throughout the balance of the decade. OEMs are using these devices in a wide variety of complex, embedded system applications in which there is a drive for more computing muscle. In many cases, the target is consumer-oriented markets such as laser printers, cellular phones, cameras, and personal digital assistants.

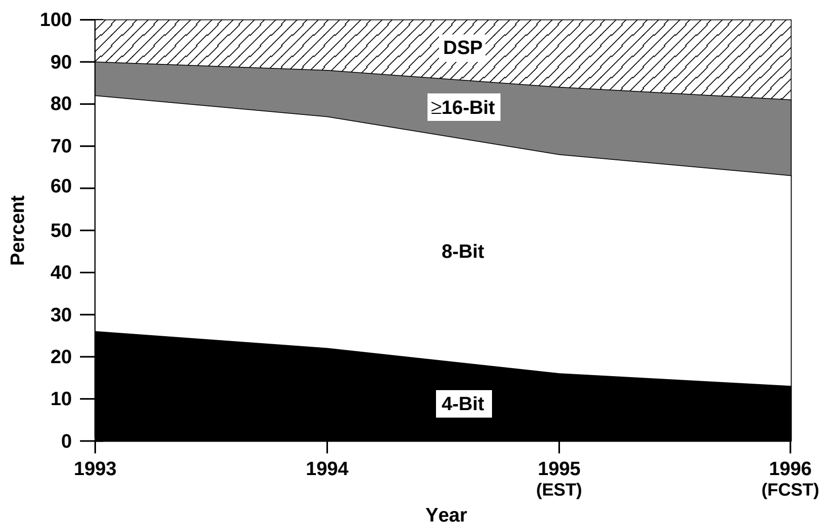
In terms of units, 8-bit MCUs reign supreme. They shipped more than half of the total unit volume of MCUs in 1995 (Figure 6-14). ICE believes that 8-bit MCUs will continue to dominate unit shipments through the end of the century. Shown in Figure 6-15 are a few of the reasons that suppliers are bullish on the future of MCUs, especially low-end devices.



MCU ($M)	8,275	10,865	13,505	16,065	19,225	22,360	25,890

Source: ICE, "Status 1996" 20438

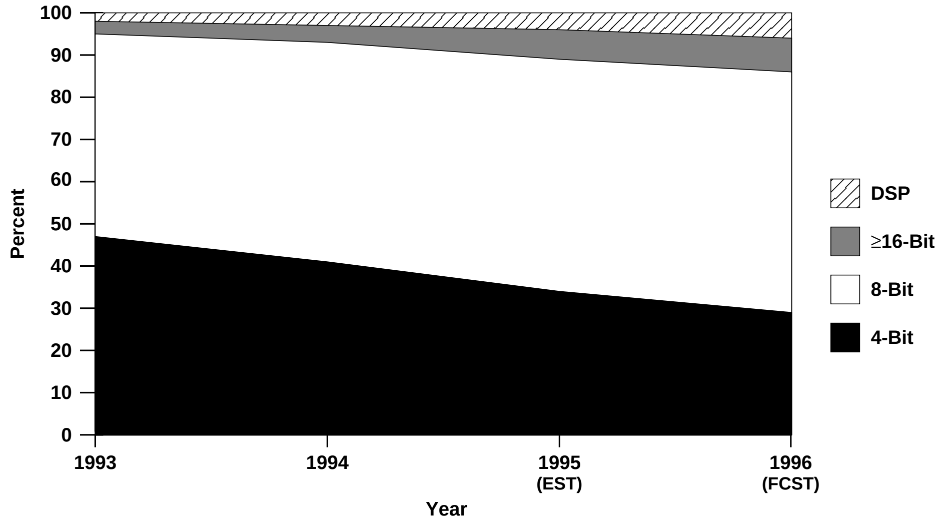
Figure 6-12. MCU Market Trends



MCU Market (%)	1993	1994	1995 (EST)	1996 (FCST)
4-Bit	26	22	16	13
8-Bit	56	55	52	50
≥16-Bit	8	11	16	18
DSPs	10	12	16	19
Total ($M)	6,560	8,275	10,865	13,505
Percent Change	25	26	31	24

Source: ICE, "Status 1996" 20319A

Figure 6-13. The MCU Market by Configuration



MCU Market (%)	1993	1994	1995 (EST)	1996 (FCST)
4-Bit	47	41	34	29
8-Bit	48	52	55	57
≥16-Bit	3	4	7	8
DSPs	2	3	4	6
Total (M)	2,220	2,660	2,990	3,420
Percent Change	17	20	12	14

Source: ICE, "Status 1996" 20320A

Figure 6-14. MCU Unit Shipments by Configuration

- **Rapid integration of MCU-related functions**
- **Easier-to-operate user interfaces**
- **Move from electromechanical to more reliable electronic systems**
- **Portability in equipment such as cordless/cellular phones and pagers**
- **Need for low-cost solutions**

Source: ICE, "Status 1996" 19234A

Figure 6-15. Elements of the 8-Bit MCU's Success

Even though it is in the mature phase of its product life cycle, there continues to be new developments and technical innovations in the 8-bit MCU market. 1995 witnessed the introduction of many families of super-8-bit MCUs, low-cost chips that compete in performance with many older 16-bit designs.

Microchip Technology introduced a new series of devices that are targeted for the low-end to high-end of the 8-bit MCU market (Figure 6-16). The PIC16CXX represents a new entrant into the mid-range 8-bit MCU market. Microchip also expanded its high-end 8-bit family with the introduction of the PIC17CXX family. Applications for the MCUs, with 160ns instruction execution speed at 25MHz, include industrial control, manufacturing equipment, robotics, appliances, copiers, fuel pump controllers, instrumentation, anti-lock braking systems, cellular phone security, modems, motor control, and network switches.

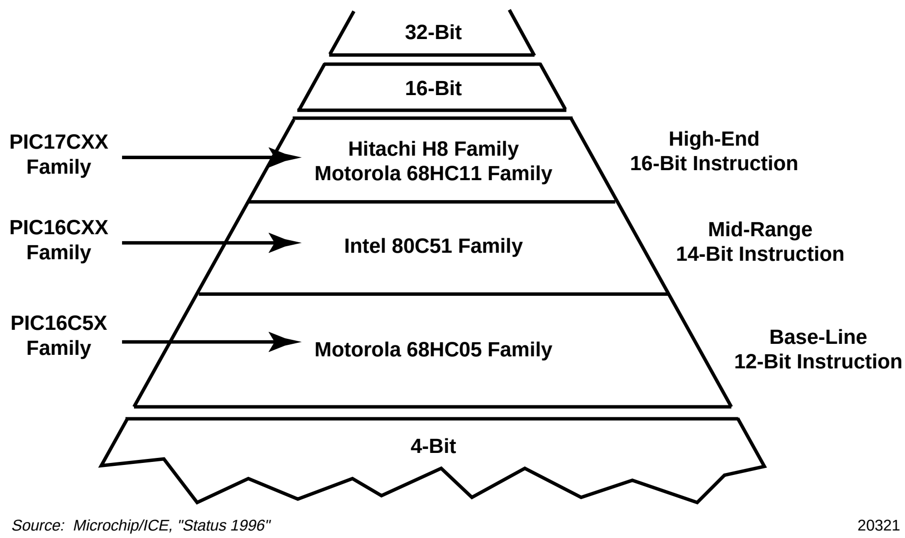
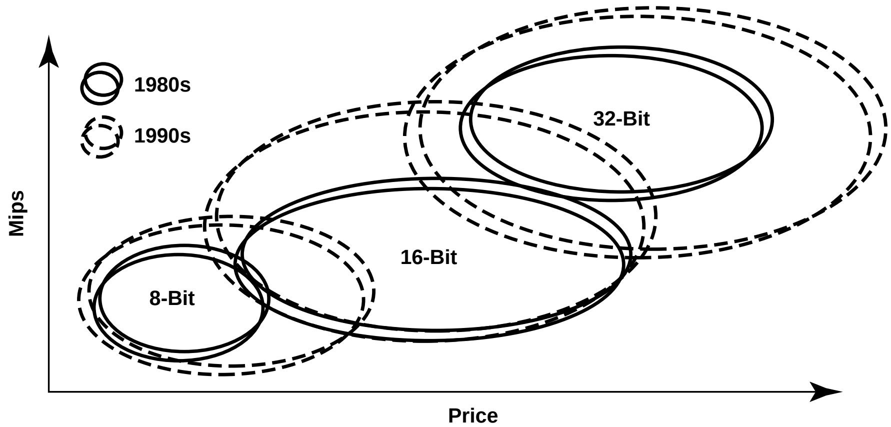


Figure 6-16. Microchip Adds New 8-Bit MCUs

As depicted in Figure 6-17, the microcontroller business has become more intertwined during the 1990's, as 8-bit MCUs offer comparable performance to 16-bit designs, as low-end 16-bit devices become cost-competitive with high-end 8-bit devices, and as 32-bit MCUs migrate down to 16-bit high-end performance.

Despite the size of the market, the variety of available options, and the solid base of customers, 8-bit MCU suppliers are increasingly faced with a dilemma—how to give their customers a clear performance upgrade path (to 16-bit MCUs and beyond) while sparing them the associated costs of new code development and expensive new components.

The designer's decision to upgrade or not upgrade is especially critical in the embedded-control market. Considerations such as architectural and performance issues must be weighed with silicon costs and the cost of software and training. Figure 6-18 shows a few of the advantages and disadvantages of migrating upward within a chosen MCU family.



Source: SGS-Thomson/ICE, "Status 1996" 20322

Figure 6-17. Relative MCU Performance

Advantages

- **Little loss of time or money.**
- **No need to learn new development tools, software packages, or peripheral functionality.**
- **No reinvestment in support structure.**
- **Code development and software preservation.**

Disadvantages

- **Future migration of silicon does not always match migration path of system design.**
- **Sometimes not "backward compatible." Low-cost version of initial product is easier when migrating within a product family. Backward compatibility of hardware and software is important.**

Source: ICE, "Status 1996" 20323

Figure 6-18. Factors Influencing Migrating Within an MCU Family

The leading MCU suppliers of 1995 are shown in Figure 6-19. Motorola, a long-time leading MCU supplier, strives to offer high integration with low cost. In doing so, it has built an extensive product portfolio. By working closely with system designers, it has been able to design in specific functions that improve a system while eliminating unnecessary features. Following this methodology, Motorola has gained considerable esteem for its MCUs designed for communications and printer applications.

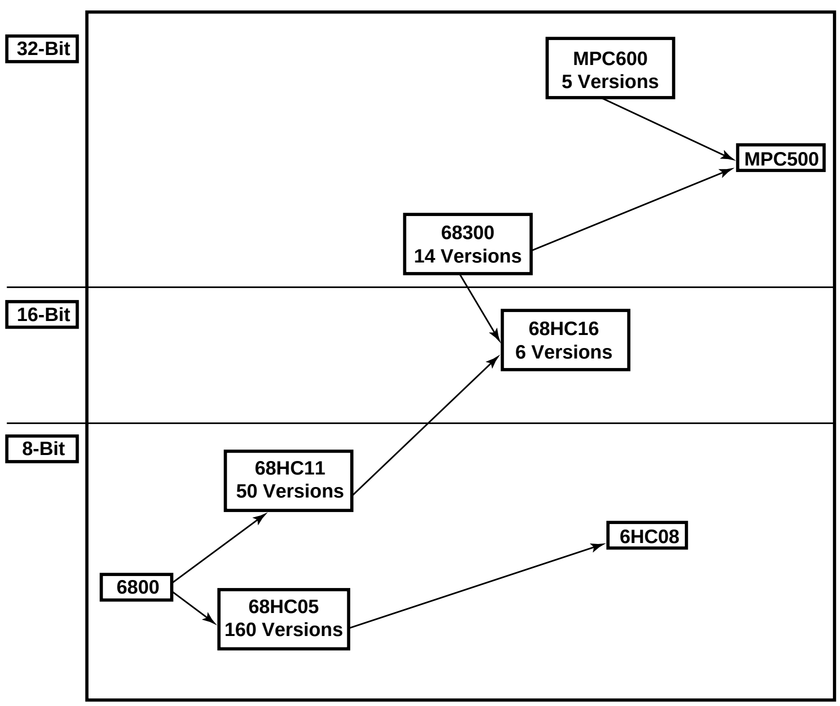
1995 Rank	MCU* Leaders	1995 (EST) Percent Marketshare
1	Motorola	20
2	Intel	14
3	NEC	12
4	Hitachi	10
5	Mitsubishi	10
6	Toshiba	7
7	Matsushita	7
8	Philips	5
9	SGS-Thomson	3
10	Fujitsu	2
	Others	10
	Total	$9.2B

***Does not include DSP sales**

Source: ICE, "Status 1996" 19233C

Figure 6-19. Leading MCU Suppliers*

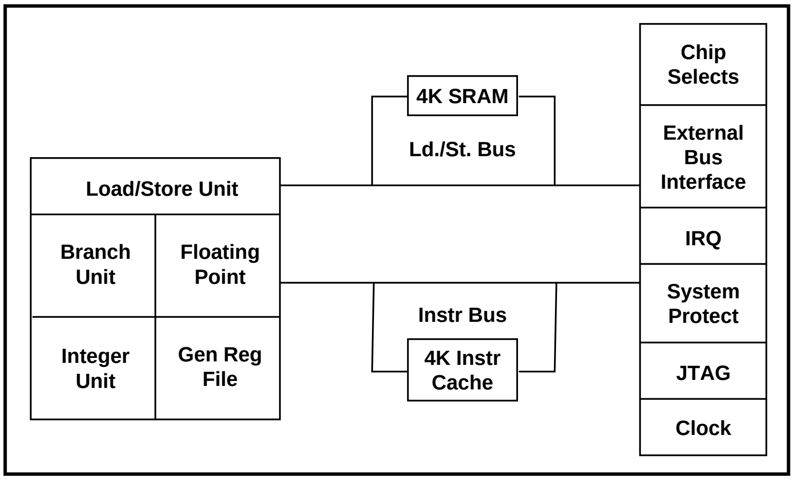
Shown in Figure 6-20 is Motorola's roadmap for MCUs. Beginning with its 8-bit 6800 family in 1975 and culminating in the RISC MPC500 family (introduced in 1994), Motorola's MCU story is one of hardware and software strength.



Source: Motorola/ICE, "Status 1996" 20324

Figure 6-20. Motorola's MCU Roadmap

The MPC505 controller is Motorola's most powerful new product for the embedded market. It represents the first embedded controller to come from the PowerPC family. A block diagram of this device is shown in Figure 6-21.



Source: Motorola/ICE, "Status 1996" 20325

Figure 6-21. MPC505 Block Diagram

Motorola is generally regarded as having the greatest share of the automotive MCU market. It has teamed with the "big three" auto makers to meet their MCU needs. Motorola supplies its 68HC11, 68HC16, and 68300 for modern applications ranging from pollution control, emission reduction, fuel injection, and engine control to anti-lock brakes.

While much of the forward march of microcontrollers is predictable, new applications will keep the market attractive to large and small suppliers through the end of the decade.

Selected highlights from the microcontroller world are listed below.

- Four leading Japanese MCU suppliers plan to significantly raise their MCU output in 1996. Mitsubishi announced plans to increase MCU production 50 percent, NEC approximately 40 percent, and Fujitsu plans to double its output. Hitachi, whose 16-bit MCU production accounts for 20 percent of its total MCU output, plans to expand 16-bit shipments 75 percent in 1996.

- GEC Plessey launched a series of 32-bit MCUs for the embedded applications business. The aim is to leverage the company's RF expertise and long-established ties in the communications component business to quickly build sales in applications such as wireless communications, networking, digital cable, and satellite TV set-top boxes.

- IBM announced a new member of its PowerPC Embedded Controller Series—the PowerPC 403GB, a 32-bit, 28MHz device designed for printers, digital scanners, set-top boxes, and X terminals for host-based systems and client/server applications.

- Intel introduced a new addition to its MCS96 MCU family. The 87C196CB, which features 1M of external addressing and integrated Controller Area Network (CAN 2.0) protocol, will support automotive and industrial applications. CAN, often referred to as multiplexing, reduces the complexity of wiring in vehicles by providing a single data path, or bus, for all electronic data transfers.

- Philips introduced its 16-bit extension of the venerable, 8-bit 8051. Philips' 8051XA targets not only 8-bit MCU users but also such 16-bit design slots as those filled by Intel's 80196 and Motorola's 68000 derivatives, which dominate the 16-bit segment.

- Oki introduced its QuickCore application-specific MCUs together with an automated design service. The methodology gives designers the flexibility to pick and choose from a variety of pre-characterized Oki nX series microcontroller peripherals and memory sizes, and to add user-defined logic via an ASIC-like environment.

- SGS-Thomson ramped production of its ST20 family of 32-bit dedicated microcontrollers in 4Q95. The ST20450 is targeted for applications including laser printers, set-top boxes, disk drives, and telecommunications infrastructure.

- Texas Instruments signed a long-term agreement to provide ITT Automotive (Frankfurt, Germany) with customized microcontrollers for anti-lock braking systems (ABS). ITT Automotive owns more than 35 percent of the worldwide market for ABS in passenger vehicles. Under terms of the agreement, TI will ship more than eight million of its 370 series MCUs per year to ITT by 1997 and up to 10 million a year by the year 2000.

- WSI Inc. (formerly WaferScale Integration) introduced a new family of 5V and 2.7V microcontrollers that offer improvements in power savings over discrete, memory-laden peripheral solutions for MCUs. The new products target complex portable applications such as cellular phones, notebook computers, and handheld equipment.

THE DIGITAL SIGNAL PROCESSOR MARKET

Digital signal processing (DSP) is a segment of the IC industry where advanced digital and analog technologies merge (Figure 6-22). The typical function of the DSP device is to perform real-time processing of a digitized analog signal, changing that signal using arithmetic algorithms, and passing the signal on. The process to accomplish this is quite complicated (Figure 6-23). In fact, finding and retaining competent DSP designers and programmers remains a challenge for many DSP manufacturers.

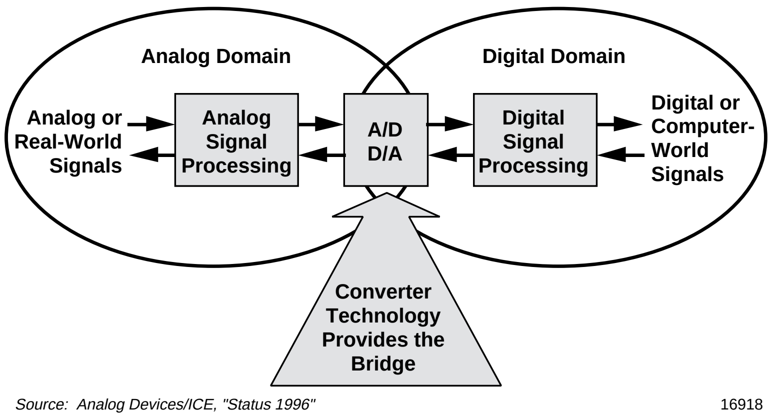


Figure 6-22. Real-World Signal Processing

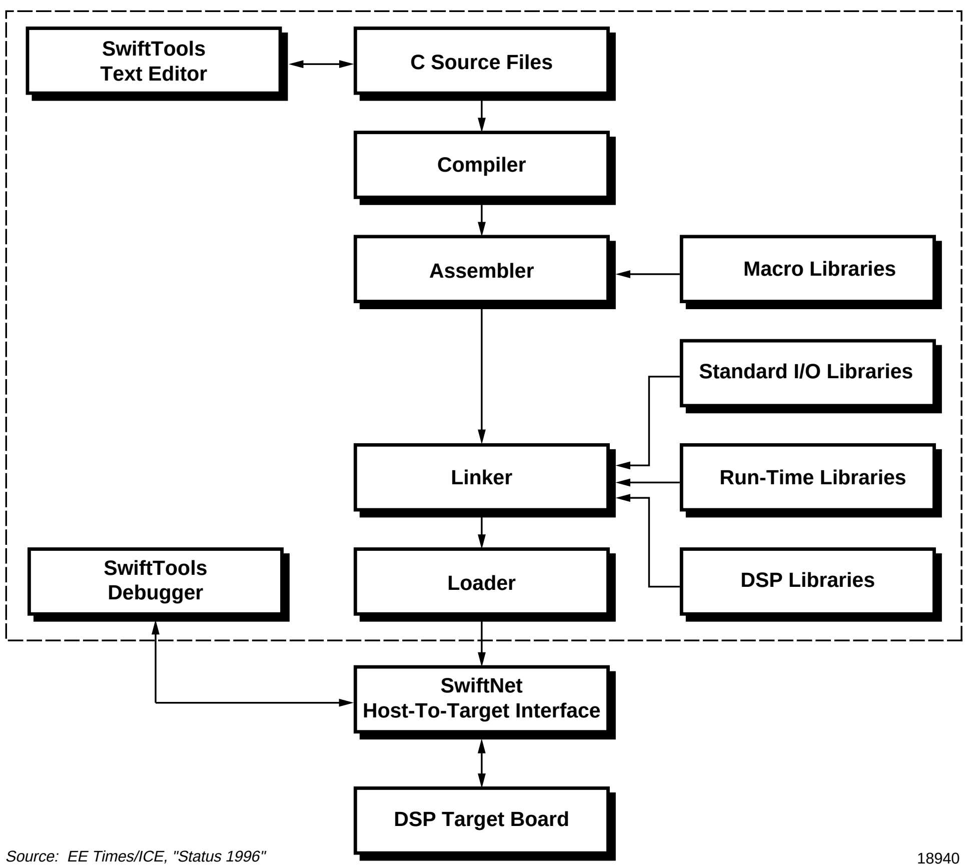


Figure 6-23. DSP Programming is a Difficult, Multi-step Operation

Texas Instruments first pioneered the DSP in 1982. Since then, it has improved the technology to give itself market leadership in this field. Figure 6-24 shows how far DSP devices have progressed since 1982 and where their performance is projected to be by the year 2002.

1982	1992	2002
75K mil^2	85K mil^2	85K mil^2
3.0 micron	0.8 micron	0.25 micron
5 Mips	40 Mips	400 Mips
20MHz	80MHz	200MHz
144-word RAM	1K-word RAM	16K-word RAM
1.5K-word ROM	4K-word ROM	64K-word ROM
$150	$15	$1.50
50mA/Mips	2.5mA/Mips	0.1mA/Mips
50K transistors	500K transistors	5M transistors
3-inch wafer	6-inch wafer	12-inch wafer

Source: TI/EE Times/ICE, "Status 1996" 19530

Figure 6-24. DSP Technology Rapidly Advances

TI and several other digital signal processor vendors have a vision of the networked society of the future. They believe the world's citizens can be better educated, healthier, more productive, more informed, better entertained, and more communicative because of technology. Naturally, at the core of this networked society are DSP devices. Several trends within the DSP industry indicate that DSPs will become more prevalent in the coming years (Figure 6-25). Whether through more competitive pricing, new technology, or improved manufacturing, many factors are working together to increase the consumption of DSP chips.

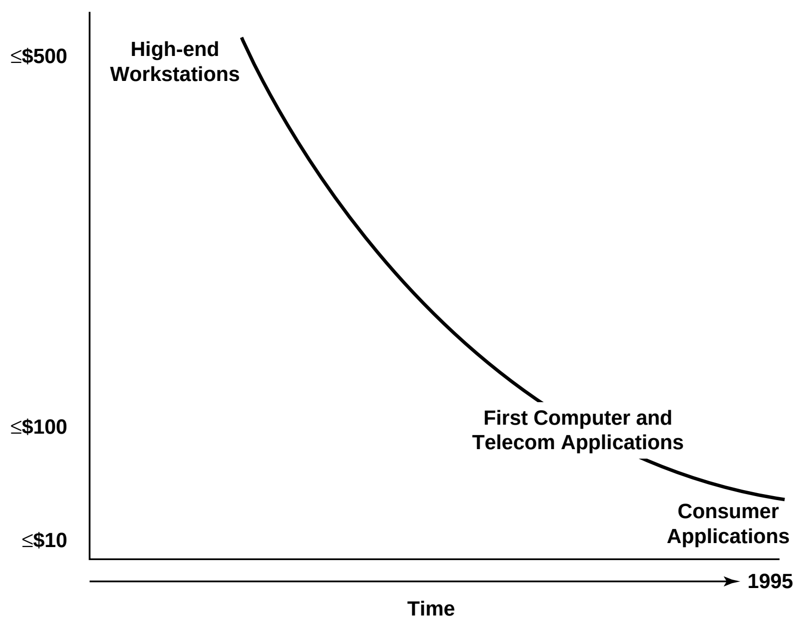
DSP consumption soared in 1995 mainly because applications emerged that were not envisioned even a year or two ago. This is particularly true in the communications markets. Lower pricing—accomplished through die shrinks, low-cost packages, and streamlined testing techniques—sparked demand. Displayed in Figure 6-26 is a relative time line showing how DSP devices have emerged in widespread applications as unit prices have declined.

Whenever a DSP supplier is able to pass along cost savings to the customer, new demand emerges for DSP-based products, which in turn triggers lower prices. At the end of 1995, DSP prices ranged from approximately $3 for simple low-end, high-volume devices to several hundred dollars for the most complex, highly integrated devices. Shown in Figure 6-27 are a few examples of how leading DSP vendors are reducing DSP prices.

Pricing	Heading lower in U.S., Taiwan, and Europe as makers put more functions on single silicon chip.
Technology	More application-specific devices. Trend is to mix more circuitry – such as MCU – on board with the DSP.
Manufacturing	High-performance is preference. Half-micron (and smaller) processes used to manufacture wide range of fixed-point and floating point models.
Other	Manufacturers offering mixed-signal DSPs that combine digital functions with application-specific analog functions.

Source: ICE, "Status 1996" 20432

Figure 6-25. DSP Trends



Source: ICE, "Status 1996" 20433

Figure 6-26. As Price Drops, DSP Applications Increase

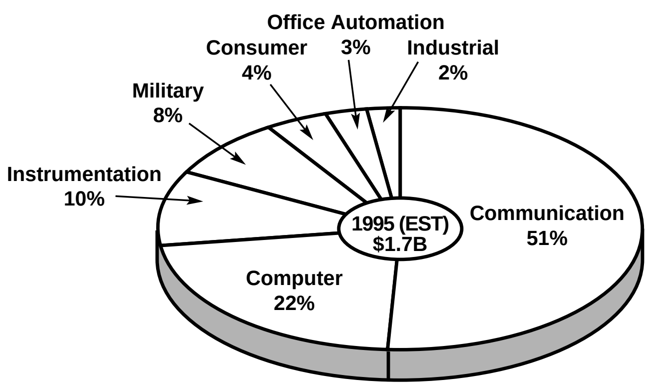
With an estimated 51 percent share of the market, the communications segment represented the largest DSP application in 1995 (Figure 6-28). Though communications will continue to be the dominant application for the next several years, suppliers are branching into other less noticeable applications. For instance, DSP devices are used for pattern recognition and image compression in computers, for special effects such as surround sound in audio applications, and for speech recognition and text-to-speech conversion applications. Whether in the home, office, at school, or in mobile applications, DSPs are certain to play a vital role in future technological advancements (Figure 6-29).

Company	Product	Type	How Cost is Being Cut
Analog Devices	ADSP-2105 ADSP-2115	16-bit, fixed-point 16-bit, fixed-point	0.6-micron process, optimized chip layout, high yields, packaging
AT&T	DSP1605	16-bit, fixed-point	0.6-micron process, optimized architecture
Motorola	56002	24-bit, fixed-point	0.8-micron process, packaging, test flow
Philips	TriMedia*	32-bit, floating-point	Stable mfg. process, 0.35-micron process, packaging
Texas Instruments	TMS320C32	32-bit, floating-point	Reduced on-chip RAM 512 words, 0.7-micron process, three-level metal, plastic packaging
	TMS320C44	32-bit, floating-point	0.7-micron process, plastic packaging, reduced die size for low power consumption

*Sampling in late 1995

Source: Electronic Business Buyer/ICE, "Status 1996" 20338

Figure 6-27. Selected DSPs are Driving Cost Down



Source: Forward Concepts/ICE, "Status 1996" 15631L

Figure 6-28. DSP Market by Application

Most DSP activity has been focused in the North American region. However, companies worldwide have taken steps to become more significant players in the worldwide DSP market. Figure 6-30 provides a brief review of the DSP activity taking place in different markets around the world.

At Home
- Moves on demand
- Direct satellite television
- Virtual reality games
- Hundreds of cable channels
- Reference book with full-motion pictures
- Dishwashers that sense when dishes are clean then turn off automatically

At the Office
- Hard disk drives that store hundreds of gigabytes
- Voice and data communications simultaneously over the same telephone line
- Desktop videoconferencing with displays from multiple locations
- Intelligent copiers - Copy, then route to appropriate file
- Fast networks - Instant access to information around the world

At School
- Interactive video classrooms that allow teachers to work with students individually
- Learning systems that remember each student's strengths and weaknesses and tailor lesson plans accordingly
- Desktop video clips to explain subjects in detail
- Instant access to library materials

On the Road
- Cellular phones that obey voice commands
- Airport phones that recognize your voice
- Portable wireless fax/modems
- Auto shock absorbers that sense road bumps and cancel them
- Video maps that display your location and the best route to your destination

Source: Texas Instruments/ICE, "Status 1996" 20341

Figure 6-29. DSP Application Explosion

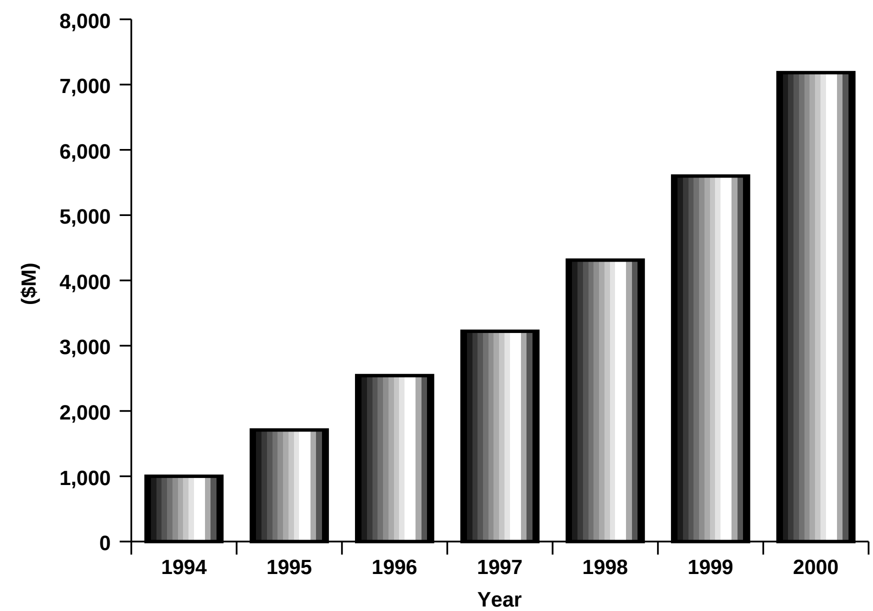
Major suppliers of DSP devices enjoyed a year of record DSP sales in 1995. Together, they helped the DSP market to grow an estimated 71 percent (Figure 6-31). As stated earlier, the overwhelming factor in the growth of the DSP market was the increased number of applications.

ICE estimates that, again in 1995, Texas Instruments was the leading producer of DSP devices (Figure 6-32). In fact, ICE estimates that TI was one of the few producers that actually increased its marketshare during the year. In 3Q95, TI stopped much of its EPROM production in Lubbock, Texas, in order to clear additional capacity for DSP parts. The added capacity helped the company to stay ahead of the growing list of aggressive competitors including the likes of AT&T and Analog Devices, whose DSP orders more than doubled through the first three quarters of 1995 versus the same period in 1994. Each introduced DSP parts that will compete in the mass market against TI.

North America	Lower prices, higher performance DSPs targeting ever-increasing number of applications. Telecom (wireless applications, infrastructure, etc.) and computers are especially hot.
Japan	Focusing on incorporation of DSPs into MCUs and MPUs-including DSP cores that can be built into semi-custom and custom chips.
Europe	Adopting application-specific approach to DSP production. DSPs are designed as part of a core that can be used in an ASIC or to develop ASSPs.
Taiwan	DSP market in Taiwan dominated by multinational companies such as Rockwell, TI, AT&T, Motorola, and ADI, making it very difficult for Taiwan's small- and medium-scale IC manufacturers to compete.

Source: ICE, "Status 1996" 20434

Figure 6-30. DSP Markets Around the World



Source: ICE, "Status 1996" 20435

Figure 6-31. DSP Market Trends ($M)

Motorola, for example, released new DSP cores in 2H95 that will likely spawn numerous derivatives. Motorola will move into the high-end digital-cellular territory with its 24-bit 56300 DSP core (code named Onyx). The core will initially deliver 66 MIPS with plans eventually slated for 100 MIPS performance.

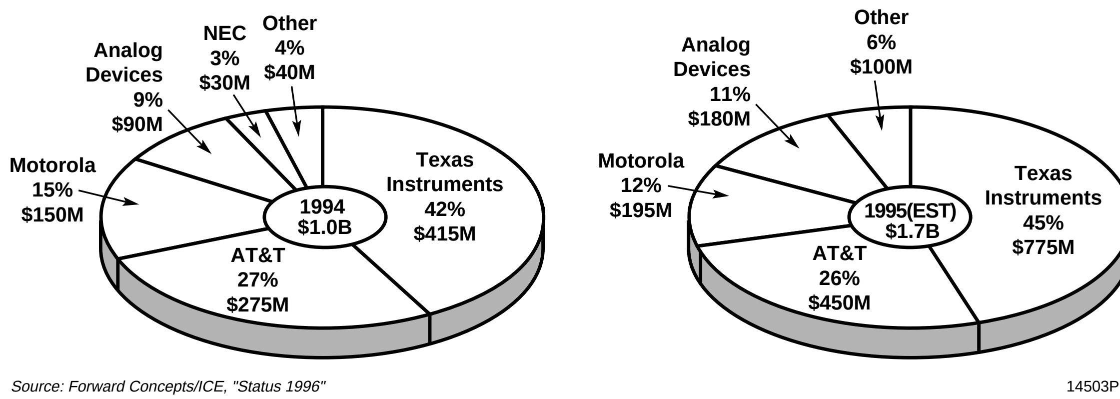


Figure 6-32. Worldwide Sales of Single-Chip DSPs

The Onyx will be followed by a 16-bit 56800 core (code named Hawk) that is intended for cost-sensitive applications such as pagers and wireless handsets. Hawk will become the heart of new devices that deliver 20 MIPS performance at 3V. Shown in Figure 6-33 are some of the derivatives from Motorola's DSP cores.

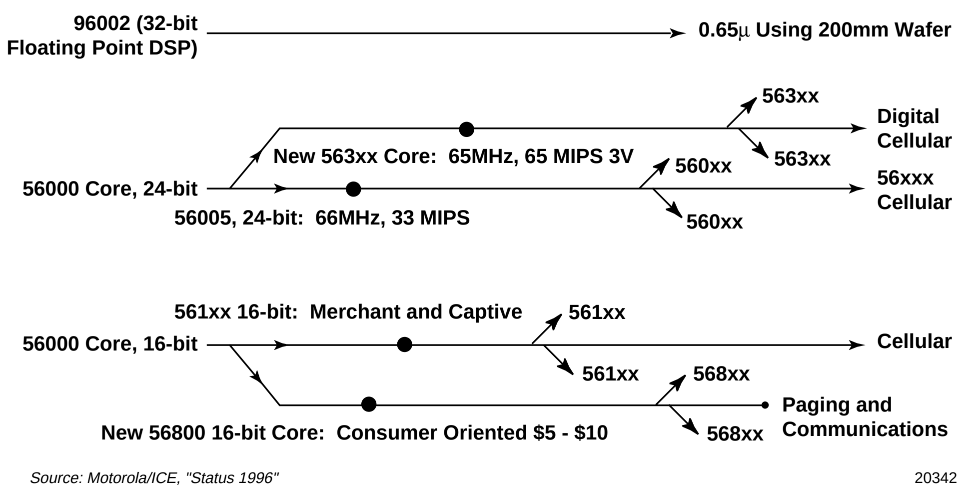
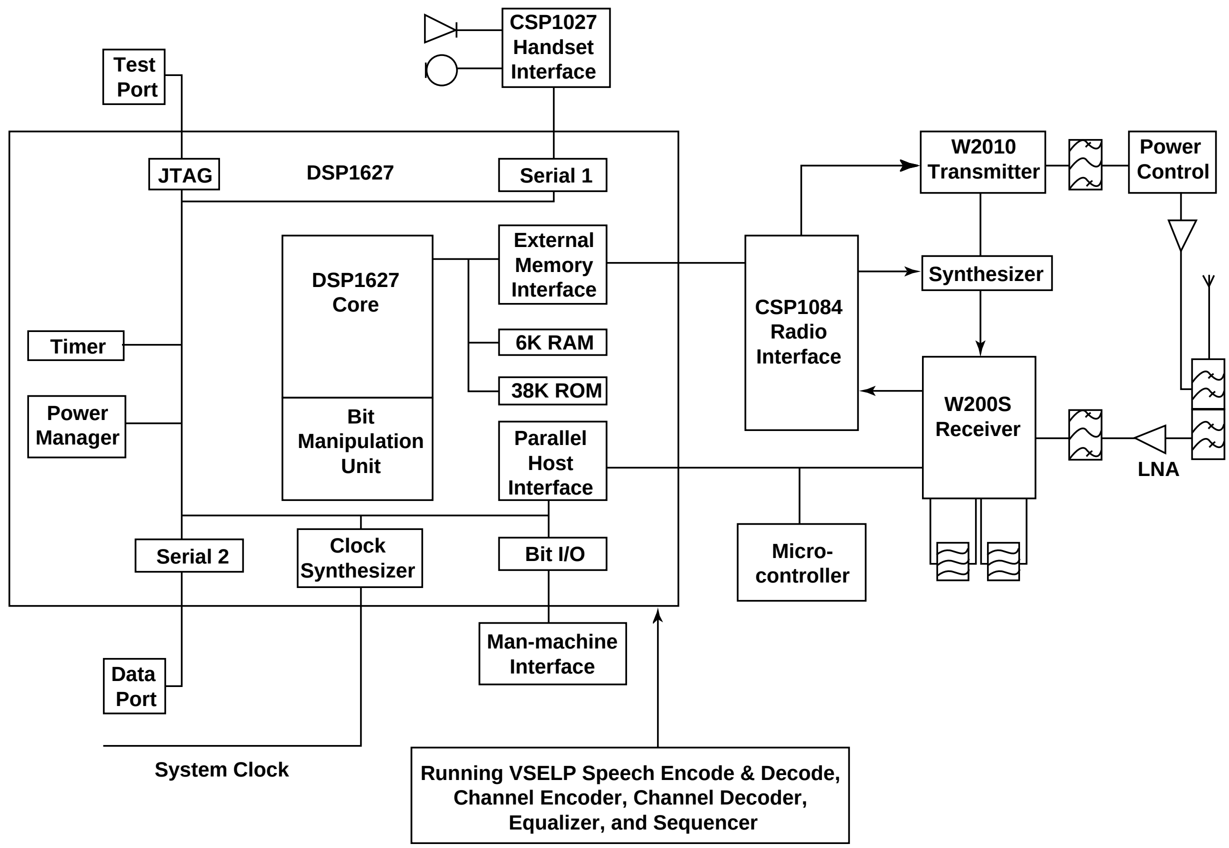


Figure 6-33. Motorola DSP Cores Spawn Derivatives

AT&T focused its attention on many of the same applications as Motorola. It released its latest device for the digital cellular market—a 2.7V, 50 MIPS DSP manufactured in the company's 0.5µm process. The DSP1627's 50 MIPS performance will enable phone designs with a single DSP to meet North American digital standards. The device also features an on-chip clock synthesizer and an 8-bit parallel host interface (Figure 6-34). AT&T is also developing new architectures and cores and shrinking its process geometries to 0.35µm to achieve higher levels of integration.



Source: AT&T/ICE, "Status 1996"

20340

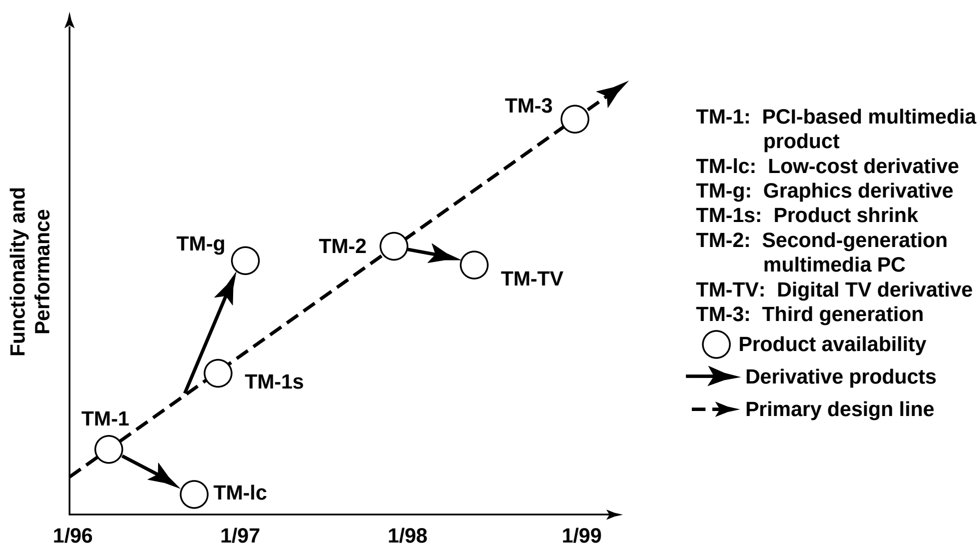
Figure 6-34. AT&T's DSP1627

Meanwhile, Analog Devices Inc. (ADI) continued to aggressively pursue TI's floating-point DSP business with its Sharc line while exploiting its vast experience in codecs and other signal-processing components. The good news for ADI was that overall customer demand for the Sharc device was two to three times higher than originally forecast. In the defense sector, demand for the Sharc DSP in high-end military and aerospace electronics applications was termed "explosive" in 1995. The bad news for the company, however, was that it had to delay volume shipments of the device until 2Q96 due to necessary revisions in the chip.

ADI shipped its first 16-bit fixed-point DSP device that processes multiple signals concurrently. The ADSP-21csp01 is primarily aimed at telecommunication and computer applications and is meant for use in applications such as simultaneous voice-over-data modems, cellular base stations, and computer telephony systems. By the end of the decade, ADI hopes to be a $2 billion company, largely on the strength of its DSP business.

Seeking to transform itself from a low-profile supplier of commodity chips into a multimedia powerhouse, Philips readied its DSP business for an assault on the multimedia market. Its TriMedia programmable DSP is targeted for high-end applications such as multimedia PCs, videoconferencing, TV set-top boxes, and digital video cameras.

Philips formed the TriMedia division, based in Sunnyvale, California, in 1994 to design and market its products. The very long instruction word (VLIW) TriMedia chips will first be manufactured in mid-1996 using Philips' 0.5μm technology, but will move to a 0.35μm process by the end of 1996. It is anticipated the device will have performance in the range of four billion operations per second. Despite its high performance and extensive features, the TriMedia exploits its simplified VLIW design to attain low pricing—about $50. Figure 6-35 shows a timeline and planned derivatives for Philips' TriMedia DSPs.



Source: Philips Semiconductors/ICE, "Status 1996" 20344

Figure 6-35. Philips' Trimedia Trek

Provided in Figure 6-36 is a sample of several DSP vendors and a few of the products they currently offer. Given the diversity of digital signal processing applications and the wide range of DSP processor offerings, it should be clear that there is no single "best" DSP processor.

Other highlights from the DSP market segment are provided below.

- DSP Communications Inc. announced a voice command chip that can recognize both predefined and user-defined words with 97 percent recognition rates in noisy environments. The single-chip DVC306 began sampling in 4Q95.

Vendor	Device	Type	Instruction/ Data Width	Multi-processor Support	Host Interface Port	Instruction Cache
Analog Devices	ADSP-2100	16-bit fixed	24/16	No	Parallel	16 x 24-bit
	ADSP-21020	32-bit floating	48/40	No	No	32 x 48-bit
	ADSP-2106x	32-bit floating	48/40	Yes	Parallel	32 x 48-bit
AT&T	DSP16xx	16-bit fixed	16/16	No	Serial	15 x 16-bit
	DSP32C/32xx	32-bit floating	32/32	No	Yes, direct to 680x0 or x86	No
DSP Group	Oak/Pine DSP Core	16-bit fixed	16/16	Yes	Customer option	No
IBM Microelectronics	Mwave	16-bit fixed	24/16	No	Yes	No
Motorola	DSP561xx	16-bit fixed	16/16	No	Parallel	No
	DSP56000	24-bit fixed	24/24	No	Parallel	No
	DSP96002	32-bit floating	32/32	Yes	Parallel (2)	1024 x 32-bit
NEC	µPD77C25	16-bit fixed	24/16	No	Serial	No
	µPD77017	16-bit fixed	32/16	No	Parallel and serial	No
SGS-Thomson	D950-CORE	16-bit fixed	16/16	Yes	No	No
Texas Instruments	TMS-320C1x*	16-bit fixed	16/16	No	Parallel support (some versions)	No
	TMS-320C2x	16-bit fixed	16/16	Yes	No	No
	TMS-320C3x	32-bit floating	32/32	Yes	No	64 x 32-bit
	TMS-3204x	32-bit floating	32/32	Yes	No	128 x 32-bit
	TMS-320C5x	16-bit fixed	16/16	Yes	Parallel	No
	TMS-32C80	32-bit multi-processor	64/32	Yes	Via Hold/HoldA Handshake	2kbytes/DSP, 4kbytes/RISC µP
Zilog	Z893XX	16-bit fixed	16/16	No	No	No
Zoran	ZR38001	20-bit fixed	32/20	No	Serial and parallel	16 x 32-bit

*Microchip Technology Inc (Chandler, AZ) is second-source

Source: EDN/ICE, "Status 1996" 20343

Figure 6-36. At-A-Glance DSP-Chip Rundown

	1994		1995 (EST)	
	$M	Percent Marketshare	$M	Percent Marketshare
8-bit	200	2%	195	1%
16-bit	440	4%	420	3%
32-/64-bit	10,355	94%	13,475	96%
32-bit CISC	9,635	88%	11,975	85%
32-bit RISC	720	6%	1,500	11%
Total MPU	10,995	100%	14,090	100%

Source: ICE, "Status 1996" 19269C

Figure 6-37. The 1994 and 1995 MPU Markets

- After evaluating several architectures for its next generation of DSP technology for embedded applications, National selected TI's 320C5X and C2X DSP cores. National will not compete against TI in general-purpose DSPs. Rather, it will use the cores in embedded applications such as wireless communication systems.

- Citing the fact that demand for raw performance continues to increase as the market develops more sophisticated applications, Motorola boosted the performance of its popular 24-bit 56002 to 40 MIPS at 5V. Motorola also expanded the 24-bit 56000 family by adding the DSP56005, a DSP optimized for industrial-control-oriented applications.

- Texas Instruments completed more than 50 customized DSP (cDSP) designs, including about 25 through 3Q95, and anticipates doing about 50 additional cDSP designs in 1996. The cDSP program is a strategy that combines a DSP processor with gate array logic for a custom design.

- TI announced a lower-cost version of its powerful MVP chip, the 320C80. The new 320C82 will carry a price tag under $100, less than half the price of the 'C80. The smaller chip achieves a peak rate of 1.5 billion operations per second using a 50MHz clock.

- TI unveiled the first in a planned series of DSPs designed with acoustic echo cancellation, noise suppression, and line echo cancellation—three elements that are intended to improve audio quality and make it safer and more convenient for hands-free cellular telephone use while driving.

- Xicor plans to have a prototype of a one-million-transistor device integrating its EEPROM technology with digital signal processing. The IC will be sold to portable communications equipment makers that need in-system programmability and 1.8-volt operation.

THE MPU MARKET

Microprocessors perform the basic arithmetic logic—are the miniature "brains"—of a computer. According to the Semiconductor Industry Association (SIA) definition, they execute external instructions and perform system control functions. These include the following: instruction decoder, arithmetic logic unit, registers, and additional support logic to support an assembly language. The architecture is optimized for general purpose data processing and the assembly language instructions are retrieved from external memory.

MPUs are available in 8-, 16-, 32-, and 64-bit designs. ICE estimates that 32-/64-bit MPUs accounted for 96 percent of the MPU market in 1995 (Figure 6-37). Because of its dominance in the MPU marketplace, this report will focus on the 32-bit microprocessors.

Figure 6-38 points out the market history of MPUs since 1991. In the third quarter of 1992, the market for 32-bit microprocessors began a dramatic climb. Although the growth percentage tapered since then, overall momentum of the 32-/64-bit market carried through the end of 1995. However, it should be noted that 1995's record first quarter was not surpassed in the remaining three quarters of the rest of the year.

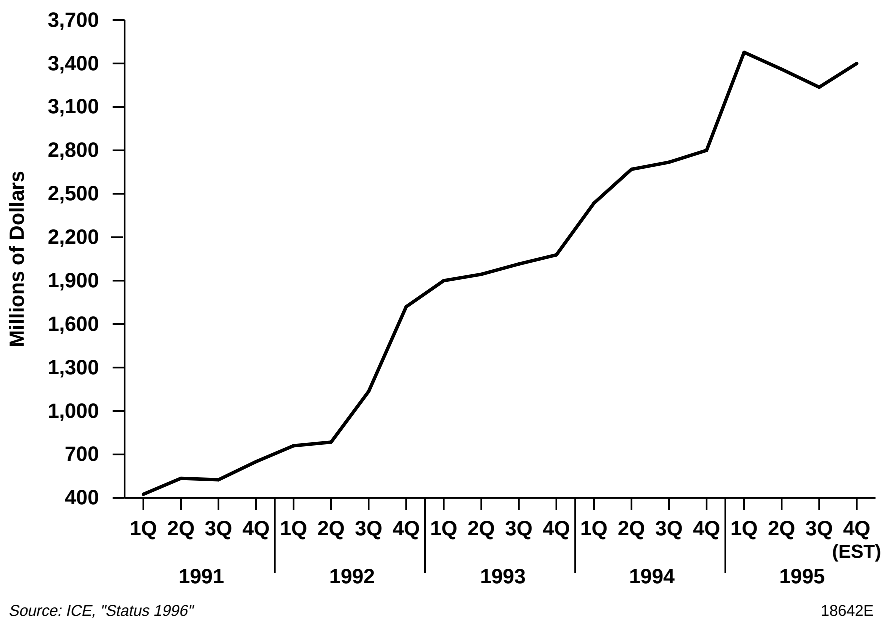
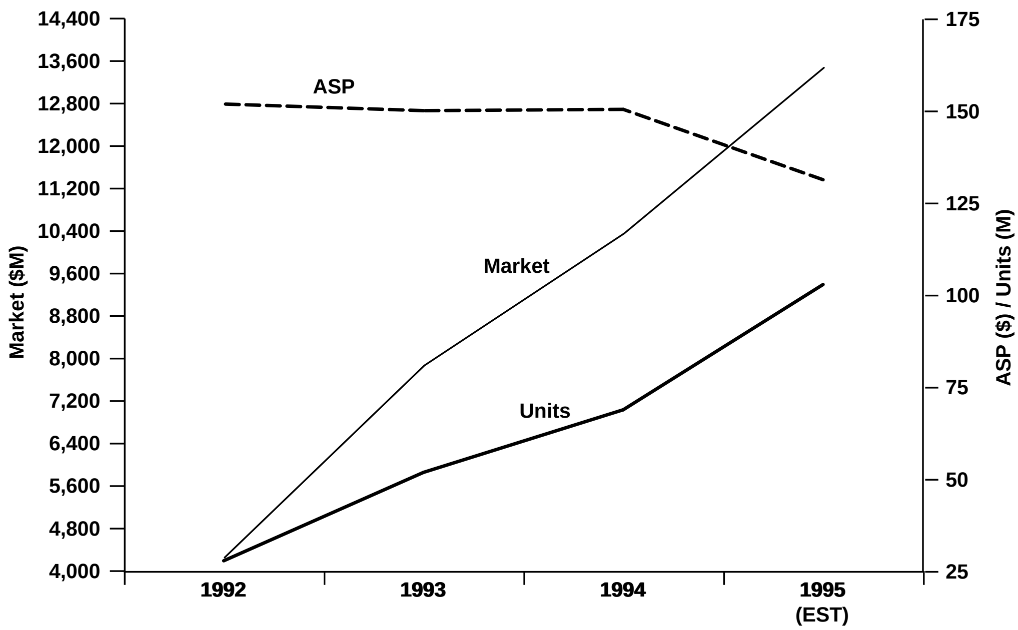


Figure 6-38. Quarterly 32-/64-Bit MPU Market

Figure 6-39 shows market growth, unit shipments and ASPs of the 32-/64-bit market over the past several years. It is interesting to note that from 1992 through 1994, ASPs were essentially flat while unit shipments increased. With more companies bringing their competitive MPUs to the 32-/64-bit MPU market in 1995, ICE estimates that shipments increased 49 percent and ASPs declined 13 percent to $131.45.



Market ($M)	4,255	7,870	10,355	13,475
Units (M)	28	52	69	103
ASP ($)	152.00	150.20	150.50	131.45

Source: ICE, "Status 1996" 20304

Figure 6-39. 1992-1995 32-/64-Bit MPU Market

Leading 32-bit MPU suppliers are shown in Figure 6-40. In terms of market size, Intel dwarfed its competition. It has dominated the 32-bit market for several years and shows no sign of weakening through the remainder of the decade. In fact, Intel may only grow stronger and more dominant as it widens the gap with its competition.

Rank	Company	1995 (EST)
1	Intel	10,370
2	AMD	910
3	IBM	640
4	Motorola	630
5	TI	295
6	Cyrix	235
—	Others	395
	Total	13,475

Source: ICE, "Status 1996" 16915H

Figure 6-40. 32-/64-Bit MPU Sales Leaders ($M)

To varying degrees, AMD, Cyrix, Hewlett-Packard, IBM, NexGen, TI and a growing group of Asia-Pacific suppliers all tried to steal away a share of the highly lucrative MPU market from Intel. In the ROW region, several companies started working on their own CISC MPU projects with hopes of becoming less reliant on outside suppliers. Samsung, Winbond, Macronix, and UMC are a few ROW firms that are developing or already have developed 32-bit MPUs. Fortunately, for buyers, the added competition represents more selection, equal or improved performance, and lower pricing.

CISC VERSUS RISC

The MPU market consists of two main architectures, CISC (complex instruction set computer) and RISC (reduced instruction set computer). The most commonly used, and the greatest number of 8-, 16-, and 32-bit processors are CISC. CISC chips include the complete x86 family (386, 486, Pentium) and Motorola's 680X0 line of MPUs.

CISC processors have long dominated the market. Although RISC's proponents predicted that they would drive CISC MPUs from the market, today, most computers are based on CISC MPUs. This is especially true in the personal computer market where over 80 percent of systems are CISC-based. Provided in Figure 6-41 is a comparison of the market size and number of unit shipments for the CISC and RISC MPUs' segments. Listed in Figure 6-42 is an overview of the shipments, ASP, and market size for the leading CISC and RISC MPU families in 1995. The 486 and Pentium processors shipped nearly equal unit amounts in 1995. In the coming year, Pentium's share will increase greatly, while the 486 will lose marketshare.

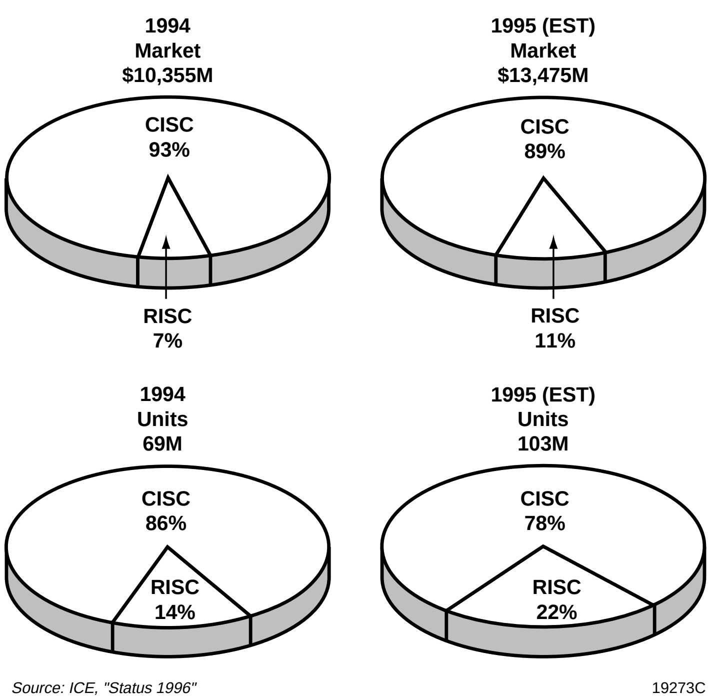


Figure 6-41. 32-/64-Bit RISC Versus CISC Comparison

Family	Unit Shipments (M)	ASP ($)	Market ($M)
386	5.6	10.00	56
486	31.8	63.70	2,026
Pentium Class	31.4	300.00	9,420
680X0	11.2	42.23	473
PowerPC	6.2	110.20	683
Other RISC	16.8	48.63	817
Total	103	131.45	13,475

Source: ICE, "Status 1996" 19271C

Figure 6-42. The 1995 32-/64-Bit MPU Market (EST)

32-BIT CISC MICROPROCESSORS

The $12.0 billion 32-/64-bit CISC market is examined in Figure 6-43. Of the 80 million CISC unit shipments, 486s accounted for 40 percent while Pentiums represented 39 percent in 1995. As mentioned previously, ICE forecasts Pentium-class processors to be the leading processor shipped in 1996. The ASP of 32-/64-bit CISC MPUs fell approximately eight percent in 1995.

	1995 (EST)
Total Market ($M)	11,975
Total Units (M)	80
ASP ($)	149.68
CISC Unit Shipments	
386	7%
486	40%
Pentium Class	39%
680X0	14%

Source: ICE, "Status 1996" 19272C

Figure 6-43. The 32-/64-Bit CISC MPU Market

Pricing of several leading 32-bit CISC MPUs is shown through 4Q95 in Figure 6-44. Intel sent shock waves through the industry early in 1995 when it slashed the price of its top products, including the 100MHz and 120MHz Pentiums. It continued bombing prices of its Pentiums through the year, resulting in the market moving to higher-speed versions. Most of its high-end Pentium family experienced price cuts at the rate of 25 percent per quarter through the year.

Processor-MHz	1Q95 ($)	2Q95 ($)	3Q95 ($)	4Q95 ($, EST)
Pentium-133	—	935	649	520
Pentium-120	935	734	581	357
Pentium-100	675	479	398	300
Pentium-90 VRT	—	—	341	272
Pentium-90	545	377	291	247
Pentium-75 VRT	—	—	204	178
Pentium-75	300	275	184	158
Pentium-66	290	260	175	135
Pentium-60	275	245	170	145
Am5X86-133	—	—	—	93
486DX4-120	—	—	165	83
486DX4-100	210	170	122	75
486DX2-80	135	110	110	50
486DX2-66	125	110	75	45

Source: Microprocessor Report/ ICE, "Status 1996" 20307A

Figure 6-44. 32-Bit CISC ASPs

Intel's pricing strategy aimed to destroy the market for high-end 486 chips from AMD, Cyrix, and others. The strategy worked quite well. Pentiums were equated with new, faster, and all-around better performance in the consumer's mind. By lowering ASPs, more system vendors made the move to a Pentium processor rather than hanging on to the 486 generation.

Process technology for microprocessors, especially at the 32-/64-bit level, has rapidly advanced. IBM, Intel, and NEC are currently shipping 0.35µm MPUs. Other vendors will soon have 0.35µm processes available to build their latest MPU devices. Furthermore, many MPU vendors expect to facilitate 0.25µm processes in 1996 and 1997. Figure 6-45 provides a summary of current and anticipated 0.35µm MPU products.

Provided in the next several pages are summaries and highlights of the CISC market suppliers from 1995.

Intel

Intel has long been the dominant player in the MPU market. It has paved the way to new technologies and advancements for MPUs. Its 80x86 family has been the backbone for astounding growth in the computer market. Figure 6-46 charts the history of Intel's microprocessor business and gives an estimate of its near-term future.

Vendor	Process Name	Example Product	First Production	Supply Voltage	Process Technology	Gate Length (Drawn)	Number of Metal Layers
AMD	CS-34	486, K5	4Q95	3.3V	CMOS	0.35µm	3-4 metal
Intel	P854	P54CS	1Q95	3.3V	BiCMOS	0.35µm	4 metal
Intel	P854	P55C	1Q96	2.5V	CMOS	0.28µm	4 metal
IBM	CMOS-5S	PPC 620	4Q94	3.3V	CMOS	0.44µm	4-5 metal
IBM	CMOS-5X	PPC 601+	4Q94	2.5V	CMOS	0.33µm	5 metal
IBM	CMOS-6S	PPC 604+	2Q96	2.5V	CMOS	0.27µm	5 metal
TI	EPIC-3	UltraSparc	3Q95	3.3V	CMOS	0.47µm	3-4 metal
TI	EPIC-3	486DX4	4Q95	3.3V	CMOS	0.42µm	3-4 metal
TI	EPIC-4	UltraSparc-2	1H96	2.5V	CMOS	0.29µm	4-5 metal
Hitachi	"0.35µ"	SH-4	2Q96	3.3V	CMOS	0.38µm	3-5 metal
Digital	CMOS-6	21164A	1Q96	2.5V	CMOS	0.33µm	3-4 metal
Digital	CMOS-6	N/A	N/A	2.5V	CMOS	0.33µm	4-5 metal
Fujitsu	CS-55	Hal CPU	2Q95	3.3V	CMOS	0.40µm	3-4 metal
Fujitsu	CS-60ALE	N/A	1Q96	3.3V	CMOS	0.35µm	3-5 metal
IDT	CEMOS 8+	R4400-200	1Q95	3.3V	CMOS	0.30µm	3 metal
NEC	"0.35µ"	R4400-200	4Q94	3.3V	CMOS	0.35µm	3-5 metal

Source: Microprocessor Report/ICE, "Status 1996" 20311

Figure 6-45. MPU Vendors Ready 0.35µm Devices

Intel Code: Other Names:	P2 286	P3 386	P4 486	P5 Pentium	P6 Pentium Pro	P7 ?
Start of Design Work	1978	1982	1986	1989	1990	1993
Formal Introduction	Feb. 1982	Oct. 1985	Apr. 1989	Mar. 1993	Q3 1995	1997 or 1998*
Volume Shipments	1983	1986	1990	1994	1996	1998 or 1999
Number of Transistors	134,000	275,000	1.2 million	3.1 million	5.5 million	10+ million
Initial Speed in MIPS	1	5	20	100	250*	500*
Peak Sales Year	1989	1992	1995*	1997*	1999*	2002*

* Estimates

Source: Business Week/ICE, "Status 1996" 20309A

Figure 6-46. Intel's MPU Development History

When plotted logrithmically, the number of transistors has increased along a steadily sloping line during the past 25 years (Figure 6-47). As shown in the graph, the Pentium Pro (P6) processor, released in 2H95, contains 5.5 million transistors. That amount considers only the number of transistors on the central processing unit (CPU). The complete Pentium Pro package (Figure 6-48), with 15 million additional transistors from a separate level-2 cache chip, contains a total of 21 million transistors.

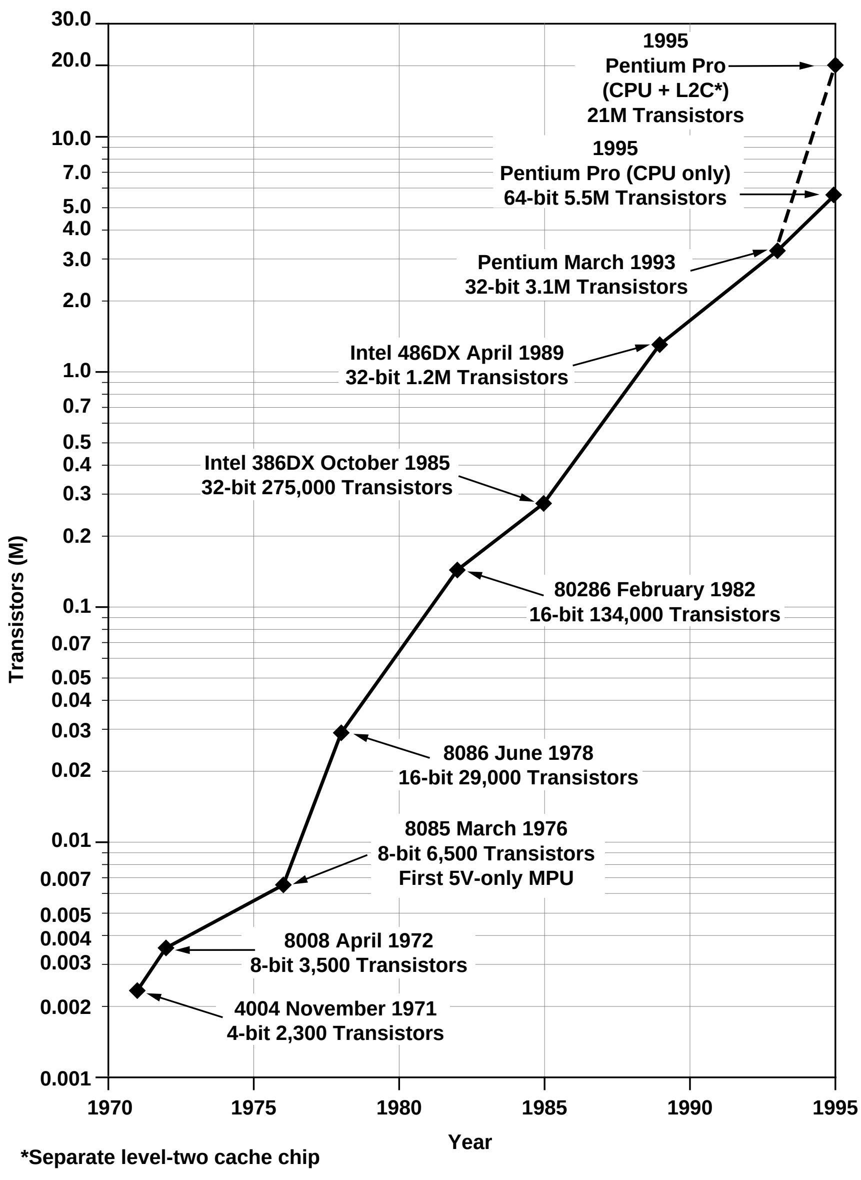
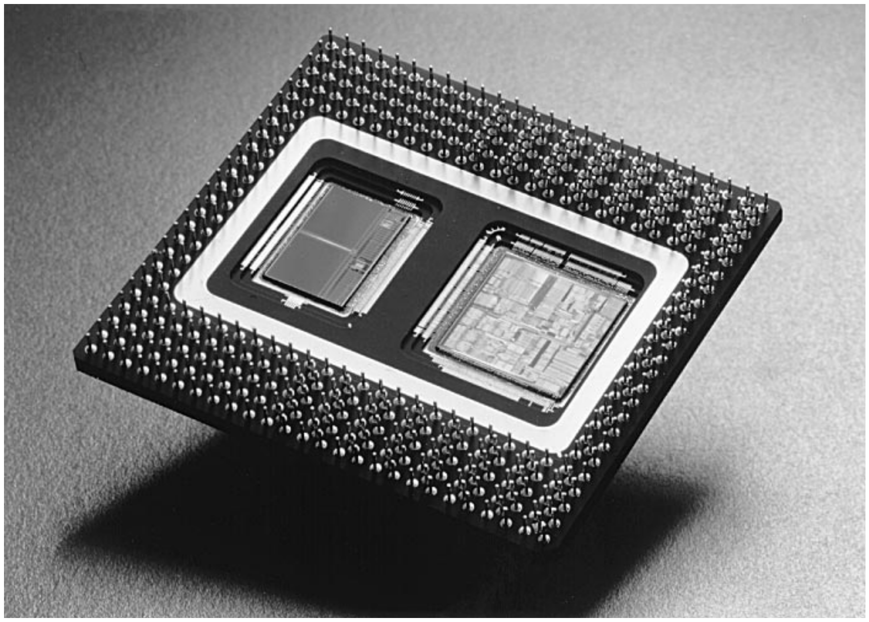


Figure 6-47. Intel MPU Introduction Dates



Source: Intel/ICE, "Status 1996" 20116

Figure 6-48. Pentium Pro Processor

Since the introduction of Intel's 4004 in 1971, the number of transistors per processor has increased nearly 40 percent per year through the Pentium. The introduction of the BiCMOS-built Pentium Pro throws that steady growth percent out of line. The main reason is that, as stated, the product is two chips (the CPU and a cache memory chip) in one package.

Even with all the "hoop-la" surrounding the Pentium Pro, Intel advanced the performance of its Pentium processor while lowering the prices on this family as well. The Pentium P54CS was among the first microprocessors built using a 0.35μm process. The advanced process reduces power consumption (10W) despite the higher clock frequency (120MHz). The P54CS has the same die area as its predecessor, but a much smaller CPU core size (Figure 6-49).

With advanced Pentiums and the Pentium Pro added to its line-up, Intel rapidly withdrew from the 486 market, forcing OEMs either to make a rapid transition to Pentiums or seek alternative sources of 486 MPUs. In fact, at less than three years, the crossover from the 486 to the Pentium was the fastest yet in any of Intel's x86 processors. Intel was almost entirely out of the 486 market at the end of 1995.

Advanced Micro Devices (AMD)

AMD remained in the lower-margin and rapidly shrinking 486 chip market in 1995. Although it had lofty plans to bring its K5 Pentium-class competitor chip to market, delays extended the start of production to mid-1996. Unable to keep pace with Intel's market-leading moves, AMD purchased NexGen for approximately $850 million and immediately leapfrogged to Pentium-class contention. AMD's manufacturing muscle combined with NexGen's MPU designs created a formidable force that is intended to give customers a high-volume alternative to Intel's Pentium Pro.

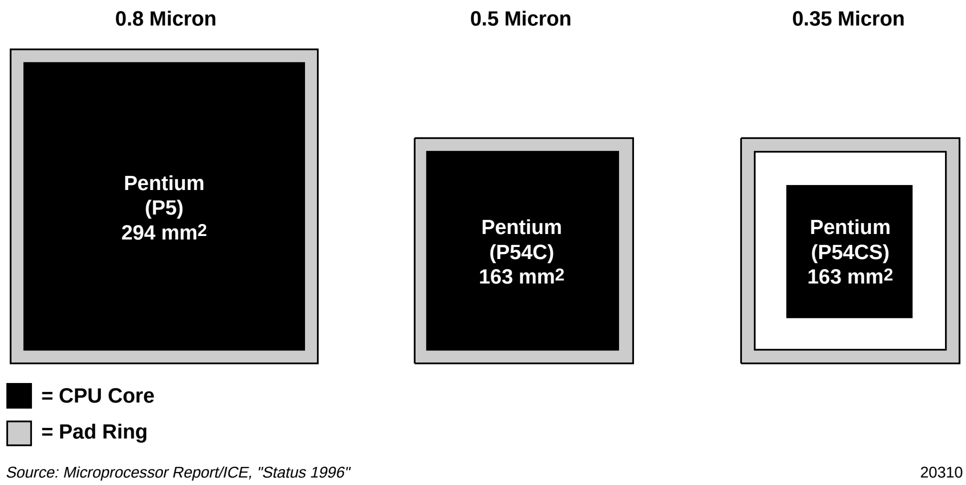


Figure 6-49. Intel Shrinks Pentium

Under terms of the agreement, NexGen will operate as a wholly owned subsidiary of AMD, which will provide production capacity at its new Fab 25 for NexGen's Nx686 and follow-on processors. AMD will cancel its K6 MPU and instead market the NexGen product under the AMD label. AMD still intends to introduce its delayed K5 processor and a scaled-down version of that product in 1996.

Aside from the AMD/NexGen announcement, AMD introduced a 486DX4 family in 2Q95, which was expected to account for 50 percent of its 486 sales by the end of 1995. In 4Q95, the company launched a 133MHz version of the device. For the year, total 486 shipments from AMD were estimated to be approximately 12 million units. Even with its new 486 developments, however, ASPs were below $100 and falling—not the kind of news a company needs to stay in mainstream MPU competition. With its acquisition of NexGen, AMD's 32-bit CISC microprocessor business may look quite different at the end of 1996.

A comparison of Intel's Pentium and Pentium Pro, Cyrix's 6x86 (formerly the M1), and NexGen's Nx586 is provided in Figure 6-50. In terms of CISC chips, the Pentium Pro offers "best-in-class" performance and sets a higher standard for other vendors to reach.

	Intel Pentium Pro	Cyrix M1	NexGen Nx586	Intel Pentium
Die Size	$306mm^2$	$394mm^2$	$196mm^2$	$163mm^2$
IC Process	0.5µm, 4M CMOS	0.65µm, 3M CMOS	0.65µm, CMOS	0.5µm, 4M BiCMOS
Clock Speed	133MHz	100MHz	93MHz	100MHz
Cache Size (I/D)	8K/8K	16K	16K/16K	8K/8K
Logic Transistors	4.5M	2.1M	1.6M	2.4M
Total Transistors	5.5M	3.0M	3.5M	3.3M
Power (max)	20W	10W	16W	10W
Package Type	MCM-C	CPGA	CPGA	CPGA
Availability	Now	Now	Now	Now

Source: Microprocessor Report/ICE, "Status 1996" 20299A

Figure 6-50. Comparison of Leading Processors

Other highlights from the 32-bit CISC MPU market are shown below.

- Partially out of fear and partially to ensure its future role in the computer industry, the Taiwan government has formulated a plan to back the simultaneous development of its own P6 and P7 generations of microprocessors. Seeking to have first silicon in 1997, the effort will help loosen the ties that bind the Taiwanese information-technology industry to foreign suppliers.

- Cyrix delivered its 6x86 (previously known as the M1) processor in 4Q95. The chip matches Intel's Pentium with software compatibility, hardware compatibility, and performance. Though the initial chip was a vast $394mm^2$ die, the company has reported good progress on its $210mm^2$ die-shrink version.

- NexGen secured Samsung as a second chip-set vendor and reportedly has negotiated with the Korean firm to acquire more capacity and an equity interest. NexGen previously signed VLSI Technology as a chip-set vendor.

- NexGen started sampling the first version of its Nx586 Pentium-class microprocessor that includes a floating-point unit (FPU). The company estimates it shipped 250,000 Nx586s in 1995.

- NexGen began an aggressive campaign to bring Pentium Pro performance to the market before Intel when it unveiled its Nx686 processor in 4Q95. NexGen's chip, which includes multimedia extensions, is built using 0.35μm technology. The company claims it is smaller and less costly to manufacture than Intel's Pentium Pro. Nx686 shipments are expected to begin in mid-1996.

- As part of an ongoing strategy to provide affordable performance in the PC marketplace, Texas Instruments announced it TI486DX4. The chip will be targeted at high-growth PC markets including China, Brazil, Mexico, Indonesia, Malaysia, and India.

- SGS-Thomson (ST) began shipping is 486DX4, rated at 100MHz. The chip is based on the Cyrix 486 design. ST has the right to sell Cyrix's 5x86 and 6x86 parts but had not exercised that option through the end of 1995.

THE RISC MPU MARKET

Growth in the RISC MPU market was substantial in 1995. Besides increased, though still limited, use in desktop computer systems, RISC chips further nudged their way into the embedded market, taking away marketshare from single-chip microcontrollers based on CISC cores.

The 1995 32-/64-bit RISC MPU market is displayed in Figure 6-51. Both the size of the market and the number of unit shipments jumped from 1994's results. A big increase in PowerPC shipments led to overall growth of RISC shipments. Deliveries of PowerPCs to desktop and embedded applications boosted its share of total RISC unit shipments to 27 percent.

	1994	1995 (EST)
Total Market ($M)	720	1,500
Total Units (M)	9.8	22.7
ASP ($)	73.35	66.08
RISC Unit Shipments (%)		
i960	38	34
PowerPC	11	27
MIPS	17	13
29000	10	9
ARM	12	6
PA-RISC	3	4
Sparc	5	3
Transputer	3	2
Alpha	<1	1
Other	1	1

Source: ICE, "Status 1996" 19274C

Figure 6-51. The 32-/64-Bit RISC MPU Market

Leading-edge performance has always been characteristic of the RISC MPU market. RISC's strengths, including high processing rate and memory bandwidth, are well suited for executing and processing data. Moreover, RISC's clean, straightforward architecture helps keep down chip costs.

Powerful 32-bit RISC MPUs have been well incorporated into embedded applications (Figure 6-52). RISC architecture stands out in embedded applications because of its favorable price/performance characteristics. For example, MIPS MPUs from IDT (R3041) sell for less than $15 and appear in low-cost printers and other embedded applications. Nintendo's Ultra64, Sony's PlayStation, and several arcade games all use MIPS processors. Additionally, devices such as the R4100 will soon appear in PDAs.

Category	Typical Application	RISC Processors	Comments
Data flow	Laser printers, X-terminals, communications (routers, bridges, servers), image processing	MIPS (R4600, IDT R30XX), i960, 29K, Motorola ColdFire, PowerPC (403, 505)	Processing stage. Processes data and passes it on. High memory bandwidth, high processing throughput.
Interactive/ Video/Portable (IVP)	Set-top boxes, video games, PDAs, interactive video, portable information appliances	MIPS (Toshiba R3900, NEC R4100/4300/4600, IDT 4600/4650/4700), ARM (6XX/7XX), NEC V851, Hitachi SH1/2/3	Interactive, video processing. Ranges from portables to set-top boxes. Needs low cost, low power, high throughput.
Classic Embedded	Embedded controllers, disk controllers, automotive, industrial control and monitoring	Motorola ColdFire, Hitachi SH, NEC V851, National Piranha, ARM, MIPS cores (LSI Logic)	Classic embedded world. Needs mix of CPU power, low cost, low power dissipation. RISC controllers — CPU with embedded peripherals on-chip.

Source: Computer Design/ICE, "Status 1996" 20441

Figure 6-52. Embedded RISC Applications Categories

In 2H95, Motorola and IBM together doubled the available number of embedded PowerPC chips. Their new offerings add peripheral features and boost clock speeds compared with their predecessors. IBM's 403GA is targeted for PDAs, the GB is tailored for data communications, while its GC version has been selected for a number of set-top box designs. With the 821 and 860, Motorola is following a similar strategy it used with the 68000 family, but with greater performance. With 68000 cores at the bottom, ColdFire at the mid-level, and PowerPC at the top end, users have many possibilities to customize their products using Motorola's parts (Figure 6-53). PowerPC options for embedded use are shown in Figure 6-54.

From a desktop standpoint, RISC MPUs have not been warmly embraced. In fact, the PowerPC is the first volume RISC processor used in a PC platform. Even so, aside from serving traditional Mac customers, PowerPC has failed to convert many x86/Pentium users. In fact, there is roughly an eight-to-one volume advantage of shipments of Windows over the Mac operating system. PowerPC and other RISC MPUs have a ways to go if they expect to penetrate the personal computer market. Several vendors are working on it, but few have had much success. Figure 6-55 provides a brief review of high-performance RISC MPU specs and the technologies each offers.

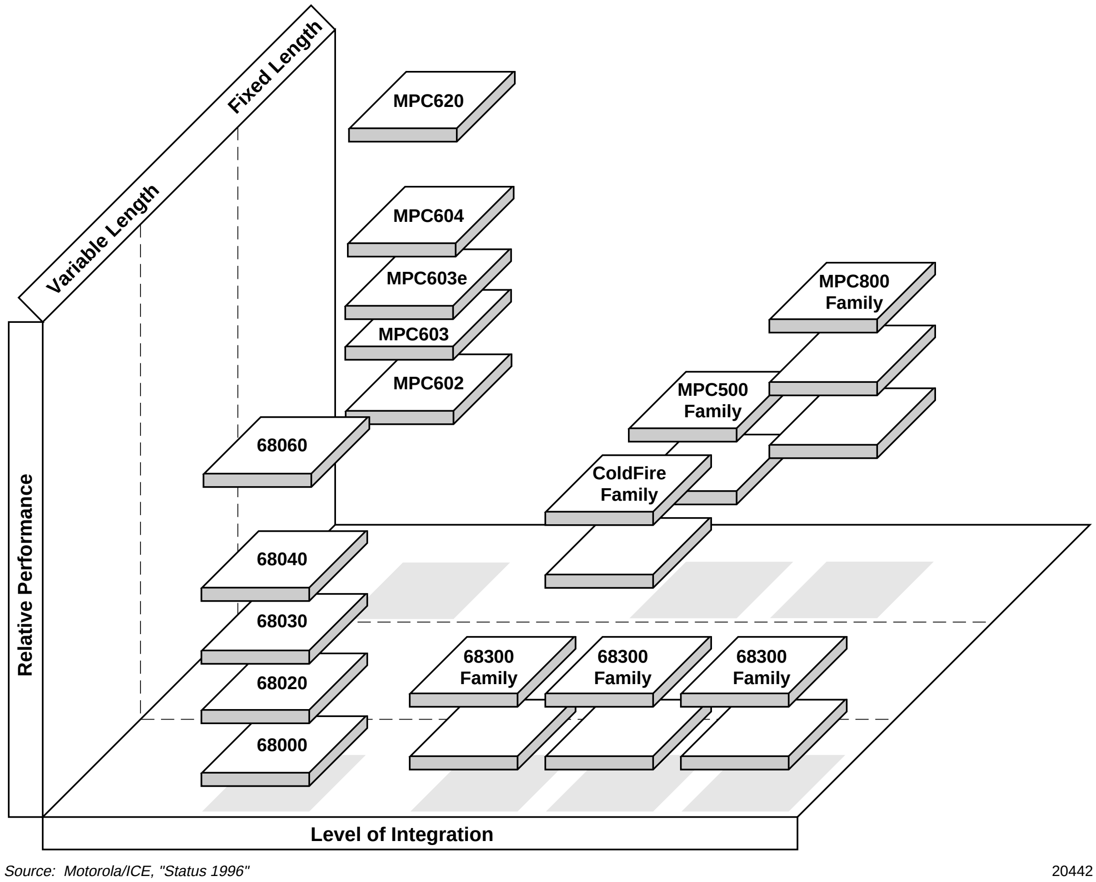


Figure 6-53. Motorola's Embedded Processor Family

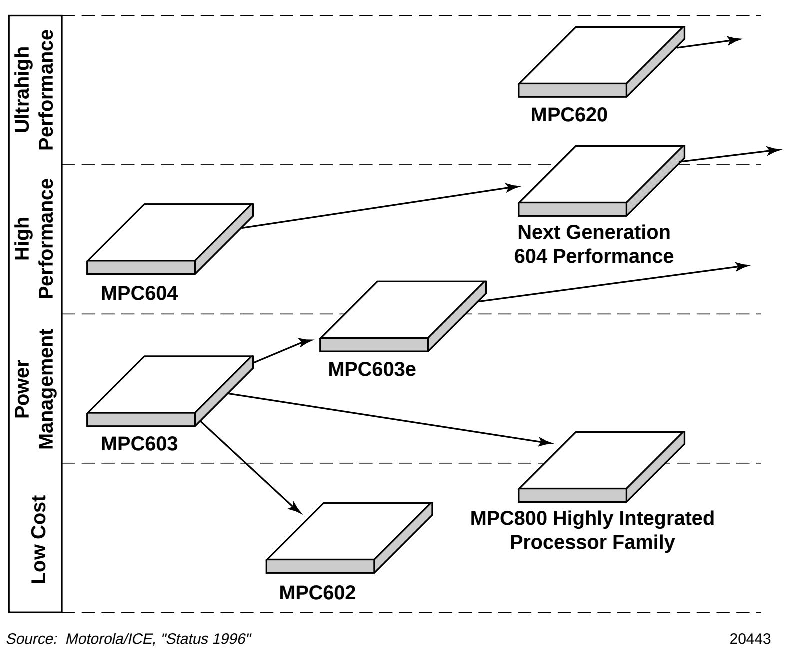


Figure 6-54. Embedded PowerPC Microprocessor Evolution

	MIPS R10000	PPC 620	SPARC UltraSparc	ALPHA 21164
Clock Speed	200MHz	133MHz	167MHz	300MHz
Cache Size	32K/32K	32K/32K	16K/16K	8K/8K/96K
Dispatch Rate	four	four	four	four
Function Units	five	six	nine	four
Predecode Bits	4 bits	7 bits	4 bits	none
Rename Regs	32 int, 32 fp	8 int, 8 fp	none	none
Branch History	512 x 2	2K x 2	512 x 2	2K x 2
Out of Order	32 instr	16 instr	none	6 loads
Ext Cach Cntl	on chip	on chip	on chip	on chip
Synch SRAM	yes	yes	yes	optional
Glueless MP	yes	yes	yes	yes
Power Usage	30W	30W	30W	50W
IC Process	0.5-micron	0.5-micron	0.5-micron	0.5-micron
Metal Layers	four	four	four	four
Logic Transistors	2.3 million	2.2 million	2.0 million	1.8 million
Total Transistors	5.9 million	6.9 million	3.8 million	9.3 million
Package Type	527-pin CPGA	625-pad CBGA	521-pin CPGA	499-pin CPGA
Die Size	298mm^2	311mm^2	315mm^2	298mm^2
Est Mfg Cost	$320	$380	$420	$430
First Silicon	4Q94 (est)	7/94	10/94	2/94
Volume Parts	4Q95 (est)	3Q95 (est)	3Q95 (est)	1Q95 (est)
SPECint92 (est)	>300 int	225 int	275 int	330 int
SPECfp92 (est)	>600 fp	305 fp	305 fp	500 fp

Source: Microprocessor Report/ICE, "Status 1996" 19547A

Figure 6-55. "Next-Generation" RISC MPU Performance Specs

Additional highlights from the RISC market are outlined below.

- Digital Equipment Corporation (DEC) announced its development of new binary translations and emulation software technology enabling x86 32-bit applications to run at near native performance on its Alpha RISC platform. The FX!32 technology will be released commercially in mid-1996.

- Digital's Alpha sales growth slowed in 1995. Alpha's initial growth came mainly from replacing VAX and MIPS machines in Digital's existing customer base. Now that transition is nearly complete, and new Alpha customers are harder to find.

- HP engineers are developing workstations built around early prototypes of Intel's P7 microprocessor. Further, HP and Intel have moved faster than anticipated on their planned Intel/HP x86/PA-RISC successor architecture they are co-developing. HP mentioned it has "proven binary capability" between Intel's x86 architecture and HP's PA-RISC architecture.

- IBM and Motorola announced that the PowerPC 620 would be delayed until at least until mid-1996 due to a re-evaluation of process options. The companies are waiting to move production to a 0.35μm process that would yield both smaller die and performance more competitive with other RISC CPUs scheduled for mid-1996 release.

- IBM is under way with its plans to develop the PowerPC 615, which has the capability to run x86 and RISC code. When running in dual mode, performance is considerably slower. However, IBM plans to resolve the problem, thus keeping the chip from reaching customers' hands until at least mid 1996. Apple has already planned many uses for the 615.

- Intel unveiled a new, single-chip i960 architecture based on the "JX" series that enhance existing servers and enable a new class of network servers to be developed. The i960 RP sampled in 4Q95 and will likely be in volume production in 1Q96.

- MIPS Technologies and NEC announced the MIPS R4300i 64-bit microprocessor. The device is optimized for interactive consumer and embedded applications. Using NEC's 0.35μm process technology, the companies claim the 100MHz processor will deliver Pentium-class performance to embedded applications for a fraction of the Pentium price.

- Mitsubishi began sampling its 64-bit MPU that is based on DEC's Alpha microprocessor. It has a top clock speed of 233MHz. In 1996, the company envisions building a core version of the device for ASICs and ASSPs for high-end embedded applications including HDTV, PDAs, and the DECT wireless phone standard.

- NEC will begin producing its T5 64-bit RISC MPU in 1996. A total of seven Japanese, U.S., and European chip makers are developing the device based on a 0.35μm process. The device is designed to challenge Intel's Pentium Pro.

- The PowerPC 604e (enhanced) debuted in 4Q95. The newest chip in the PowerPC family is built using 0.45μm technology but will migrate to 0.35μm like the rest of the PowerPC family. The 604e offers larger caches, higher clock speeds, and other improvements over the current 604.

- UltraSparc, a 64-bit version of the Sparc architecture, was unveiled and is available in clock speeds of 143MHz and 167MHz. It will compete against other leading-edge 64-bit processors including the MIPS R10000 and DEC's Alpha 21164. Meanwhile, a 200MHz version of the UltraSparc-1 MPU was demonstrated in late 1995. It is expected to compete with Intel's Pentium Pro.

- Startup company Exponential (partially funded by Apple Computer) plans to introduce BiCMOS PowerPC processors in 1997.