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Shift to Pentium Begins in Earnest

486 Competition Intense, Pentium Competition Just Starting

by Michael Slater

Driven by a multifaceted campaign that included the biggest marketing blitz in the history of microprocessors, Pentium achieved a significant minority role in the PC market last year. Despite the floating-point divide fiasco, Intel's unrelenting efforts, coupled with the outstanding price/performance offered by Pentium systems, will drive the chip to a major role in 1995. Pentium's success in the consumer market has been particularly striking, marking a major shift in adoption cycles for new microprocessors.

Only one company—NexGen—shipped a Pentium competitor in 1994. Its volume, about 4,000 units, was less than 0.1% of the Pentium market, but the company is poised to become a more significant force during 1995.

Neither AMD nor Cyrix will ship its Pentium competitors in quantity until the second half of 1995. NexGen and AMD each project 1995 sales of 500,000 to 1,000,000 units; Cyrix declined to give an estimate, but shipment of more than 100,000 to 200,000 units seems unlikely. The Pentium-class processor market in 1995 will therefore remain dominated by Intel, which will hold a share greater than 90%. Not until 1996 will Intel's competitors have a chance to play a role in the Pentium-class market similar to the one they have played in the 486 business.

As Figure 1 shows, while Pentium will be the hot product this year, the 486 will continue to make up the majority of the shipments. Here, too, Intel remains a step ahead of its competitors, but this lead could disappear as Intel stops advancing the 486 and others continue to push it forward. Competition in the 486 market will be much more vigorous than in the Pentium-class market, with AMD, Cyrix, IBM, Texas Instruments, SGS-Thomson, and United Microelectronics Corp. (UMC) all shipping products. Nevertheless, Intel's hold on the vast majority of x86 processor revenue is secure; because Intel's competitors will be strongest in low-end processor segments, their dollar share of the market will be well below their share in units.

The most dramatic news of the year was Intel's alliance with Hewlett-Packard to develop a next-generation architecture. The new architecture, promised to be binary-compatible with both the x86 and PA-RISC architectures, presumably will introduce a new native-mode instruction set. Although the announcement has no near-term effects—the first chips are expected around 1998 and will be aimed at high-end systems—it is significant in that it marks the first time that Intel has acknowledged the need to shift architectures to continue the pace of performance improvement in the long term.

60-MHz Pentiums to Yield to 75-MHz Parts

Last year, Intel boosted Pentium's clock rates from 60–66 MHz to 90–100 MHz. The yield at 100 MHz was poor until late in the year, making 100-MHz chips expensive and systems using them scarce. The 90-MHz Pentiums were widely available, however, and quickly became the power user's processor of choice.

The 60- and 66-MHz Pentiums remained popular for two reasons. First, Intel priced them very aggressively, driving the price for the 60-MHz chip to $383 by the end of 1994—below the price of a 486DX2-66 at the start of that year. Intel chose to use the slower chips to drive the market transition from the 486, accepting lower margins than on its other products to achieve a strategic objective.

Second, the 60- and 66-MHz processors run at 5 V, while the faster chips run at 3.3 V. Although the lower voltage reduces power consumption, it requires 3.3-V chip sets and cache RAMs. These chips carry a price premium over 5-V chips and are less available.

Toward the end of the year, Intel rolled out the 75-MHz Pentium, the slowest clock rate to use the 0.5-micron, 3.3-V P54C design. Originally pitched for notebook systems, this chip is also likely to displace the slower versions on the desktop in the second half of 1995, eliminating the 5-V design. Intel is ramping up its 0.5-

micron fab lines in Ireland, Albuquerque (N. M.), and Santa Clara, relieving the supply constraints on chips using this process.

Intel played a dominant role in the Pentium chipset and motherboard market in 1994. While Intel will remain strong in these areas, there will be much more competition this year, further lowering system prices.

Pentium Speeds Increase

As the 75-MHz Pentium displaces the 60-MHz chip at the low end, the high end of the line will get at least two boosts during the year. Early in the spring, Intel plans to roll out a 120-MHz Pentium. This advance presumably will be made possible by a shrink of the design; given the difficulty Intel had getting decent yields at 100 MHz, combined with the narrow frequency distribution of its BiCMOS process, this frequency could not be reached without some process enhancements or tuning of speed paths.

The big boost for Pentium will come later in the year with the 150-MHz P55C, the second major revision to the Pentium design. A 133-MHz P55C is rumored as well, but Intel is not publicly committing to this speed. This chip will be fabricated in Intel's next-generation 0.35-micron process, now in development. Intel says that the P55C will be in production by the end of 1995 but declines to provide a more specific timeframe. Since the chip requires a process not yet in production, volume shipments probably won't begin until the fall.

It seems likely that the P55C will double the cache size to 32K, but Intel has declined to confirm or deny this. The P55C will be very important for Intel, as AMD, Cyrix, and NexGen seek to ship x86 processors that outperform the current Pentium. The P55C is expected to require a supply voltage of less than 3.3 V: the specification probably will be 2.9 V, according to sources.

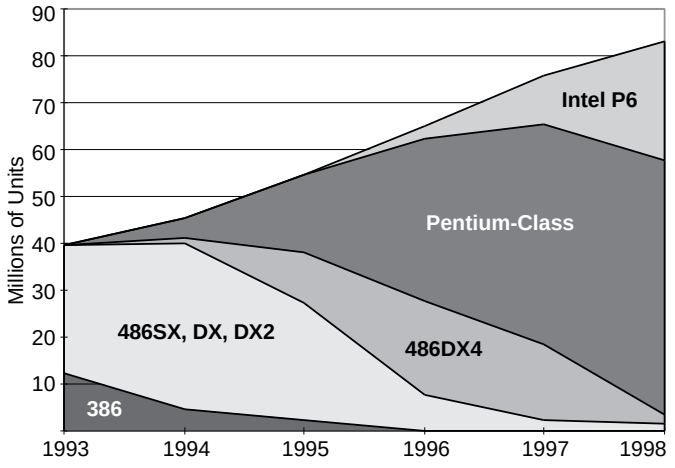

Figure 1. Estimated system shipments by processor class. Pentium-class processors will take on a bigger role this year, but they won't become the majority of the market until 1996. (Source: Computer Intelligence Infocorp)

P6 Takes the High End

At about the same time that the P55C boosts Pentium performance, the P6 will raise the high end of Intel's x86 line even further. So far, Intel has revealed few details about the P6; the first technical disclosure, but not a complete announcement, will occur at ISSCC on February 16. (We'll have details in our next issue.)

According to press reports, the P6 will be a two-chip design, with both chips packaged in a single module. This multichip package, a first for a high-volume microprocessor, would enable Intel to closely couple the processor and a second-level cache. The P6 will be produced first in 0.5-micron BiCMOS but will move quickly to a 0.35-micron technology.

The P6 presumably will use register renaming, out-of-order execution, and other modern microarchitectural techniques that have already appeared in many RISC processors and are also used, to varying degrees, in NexGen's Nx586, AMD's K5, and Cyrix's M1. The P6 probably will go further than any of these other x86 devices in its implementation of these features. It is also likely to be in production at about the same time as the K5 and M1; AMD and Cyrix, being the underdogs, have released information much further in advance than Intel has, but all three appear to be on similar schedules.

Intel declined to give a timeframe for P6 other than to say that systems with the chip will be shipped in 1995. Early samples have already been tested, however, and initial production shipments by mid-year seem possible.

With P55C providing a significant performance boost for Pentium systems without a redesign, and presumably at a much lower price than the P6, the P6 is likely to be limited to servers and very high end PCs in 1995 and early 1996.

Pentium Prices Slashed

As Figure 2 shows, Intel aggressively cut its Pentium prices during 1994 to move the chips into the mainstream. Prices on DX4 chips dropped much more slowly, leading to the anomaly of the Pentium-60 price dropping below the DX4-100 and matching the DX4-75. Steep price cuts on the 486DX2 pushed that part down to the entry level, preparing for the elimination of the SX line.

In 1995, the pace of Pentium price cuts will slow (except for the 100-MHz part, which will rapidly fall to come closer to the 90-MHz chip) while DX4 prices drop more rapidly. The new Pentium clock rates will fill in the upper end of the price spectrum, and the P6 is likely to be off the chart.

NexGen First to Offer Pentium Competitor

NexGen's Nx586 made its long-awaited debut in 1994, making the company the first to market with a

competitor to Pentium. The company gained a significant credibility boost, as well as access to high-volume, leading-edge manufacturing, by announcing an agreement with IBM to produce the chips.

NexGen's original goal was to provide higher performance than anything Intel offers, but long delays in the chip's development, combined with Intel's aggressive advancement of its Pentium line, made this impossible. The company has managed to match Intel's performance levels and to ship parts roughly a year ahead of Cyrix and AMD, earning it a place in the market.

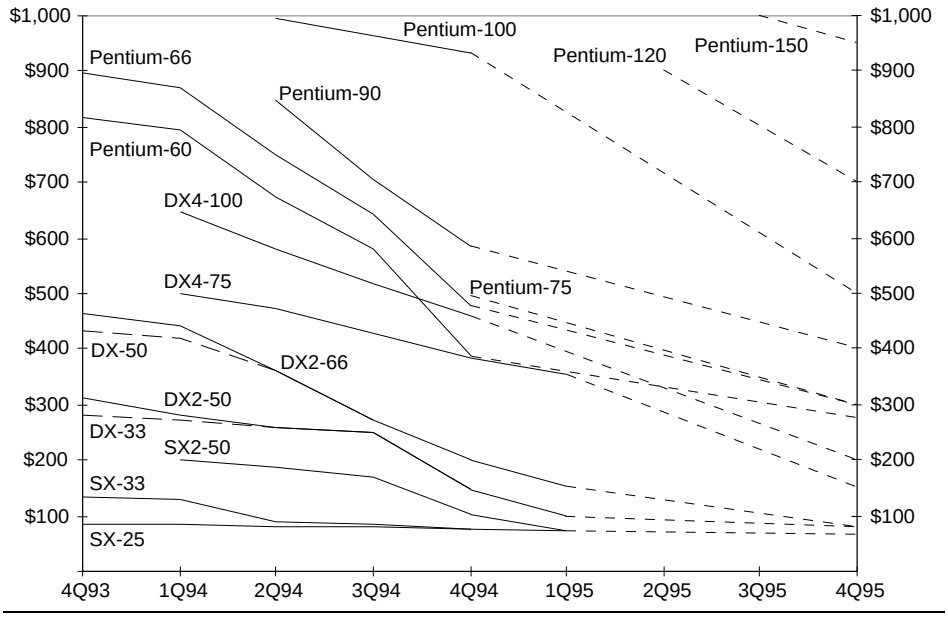

Figure 2. During 1994, Intel's 1,000-piece list prices for most Pentiums dropped sharply, while DX4 prices fell more slowly. Intel's 1Q95 prices are being announced in two phases. The January price changes affected primarily the 486 line; new prices for Pentiums will be announced in February. (Source: Intel for 1994, MPR estimates for 1995)

NexGen's design is not pin-compatible with Pentium because it uses a private bus for a second-level cache. Ultimately, this extra bus should allow NexGen to scale up in performance more readily, since second-level cache performance will not be constrained by system-bus speeds. The current 586 doesn't gain much, though; it is only about 7% faster than Pentium at the same clock rate, based on Winstone 94. The 586's maximum clock rate is 93 MHz, offering performance comparable to that of a 100-MHz Pentium processor. The private cache bus will be of greater value as core CPU clock speeds increase and as NexGen moves to its next-generation device with superscalar instruction dispatch.

The lack of pin compatibility means that the NexGen processor cannot be used with standard chip sets, forcing the company to be in the chip-set business as well and reducing the range of options for system makers. So far, NexGen has only a VL-bus chip set; first silicon of a PCI chip set was recently fabricated, and the company expects to have it in production by the end of the first quarter.

NexGen has found that its customers want a single source of supply, so—following Intel's lead—the company has been offering complete motherboards. Unlike Intel, which manufactures its motherboards in its own plants, NexGen is brokering products from third-party manufacturers. For customers buying motherboards, the pinout and chip-set issues are irrelevant.

Another handicap for the 586 is its lack of an FPU. Although the vast majority of PC users don't use any floating-point-intensive applications, this is a marketing handicap that will force NexGen to keep its prices well below Intel's. A version of the device that includes a separate FPU chip mounted in the same package, creating a module that will be pin-compatible with the current 586, is promised for midyear.

The lack of performance leadership, lack of a PCI chip set, and lack of an FPU have kept NexGen from gaining design wins beyond third-tier companies. Among the smaller companies, however, NexGen has had considerable success: it has signed up over 70 OEMs, most in the U.S., with a few in Taiwan, one in Japan, and several in Europe. NexGen executives claim that at least one top-tier PC vendor will announce a 586-based system this year. How successful these companies will be in selling the systems to customers remains to be seen, but NexGen should get a modest boost from all the negative publicity surrounding Intel's Pentium bug.

NexGen has done an impressive job of exploiting IBM's process technology to compact its chips, which could be critical to its ability to compete as Intel continues to lower Pentium prices. The initial 586 was ported from a Hewlett-Packard process to IBM's 0.65-micron, four-level-metal CMOS-5L process, but it was not optimized for the IBM process. The resulting die size is 196 mm^2—about 20% larger than Intel's 0.5-micron Pentium. (Note that IBM calls CMOS-5L a 0.5-micron process, and Intel calls its P54C process 0.6-micron, but we use the drawn channel length instead of the official nomenclature so processes can be more fairly compared.)

A redesign to optimize for the IBM process has already been completed, reducing the die size to an impressive 118 mm^2—27% smaller than the 0.5-micron Pentium. A further shrink to IBM's CMOS-5S process is under way; this redesign will reduce the die size further and boost clock rates.

P24T Finally Shipping

One device that Intel had promised for 1994, but failed to ship, is the P24T—the Pentium-based OverDrive processor. This chip is a derivative of the P54C design, with twice the on-chip cache and a 32-bit, 5-V bus interface. Making this chip compatible with the wide range of systems in which it must work has required several revisions to the silicon; last fall, Intel made one change that it thought would make the part production ready, but then a new problem showed up, preventing the promised year-end introduction.

Intel has finally announced the 63-MHz version (for upgrading systems with 25-MHz buses), priced at $449 (single-unit). There apparently are still frequency yield problems, however, possibly due to the larger cache; the 83-MHz version (for upgrading systems with 33-MHz buses) will be delayed until midyear.

Packaged in a 235-pin PGA, the P24T can be used to upgrade any PC that has the larger, 237- or 238-pin OverDrive socket. This socket is used mostly in DX2 systems but appears in some SX and DX machines.

NexGen expects to have its next-generation CPU design, the Nx686, in production by the end of the year. The microarchitecture of the 586 won't require radical changes to generate a significant performance boost; adding superscalar x86 instruction dispatch will enable the existing execution engine to be better utilized. If NexGen's plans are fulfilled, the company could yet be in a position to ship the fastest x86 processor of all. At a minimum, the company should maintain its lead over AMD and Cyrix in competing with the P6.

DX4 Takes Over 486 Market

Despite Intel's focus on Pentium, the company shipped a record number of 486 chips during 1994. Intel limited its DX4 production during 1994, allegedly so it could devote more of its 0.5-micron capacity to high-end Pentiums. The real motivation, however, was probably a desire to keep the DX4-100 from distracting the market from Pentium. Intel kept DX4 prices very high, apparently to suppress demand.

This shift in strategy led to considerable angst among PC makers, such as Compaq, that had based their midrange plans around the DX4-100. Intel's shipments of DX4 chips were primarily of the 75-MHz version, with 100-MHz parts becoming gradually more available toward the end of the year. This shortfall would have provided a fantastic opportunity for Intel's competitors, but none was ready to exploit it.

Intel's DX4 prices are likely to drop dramatically in the first half of the year, since the company's 0.5-micron production capacity has increased—and AMD will be ready with 100-MHz chips, creating a competitive situation. (AMD's DX4 will have only half the cache of Intel's chip, however, so it won't quite match its performance.) The 75–100-MHz Pentiums provide a comfortable speed gap above the DX4-100, making its position more clear-cut than when 60-MHz Pentiums were dominant.

Intel also quietly upgraded its 486DX2 last fall to provide write-back cache operation. The intent of this upgrade is to encourage low-cost systems without second-level caches; with an L2 cache, the performance boost from the write-back cache is insignificant.

AMD Gains in 486 Market

AMD made significant headway in the 486 market in 1994, with its penetration limited primarily by production capacity. The company estimates that it shipped about 4.8 million units during the year, making up about 13% of the 486 market. AMD made major strides in breaking into the top-tier PC makers, with Compaq as the key prize. Digital and Acer also began using AMD processors. AMD expects to ship more than 10 million 486 processors in 1995, hitting its 30% market share goal.

Being production-limited, AMD focused its efforts on the 486DX2, where the profits are greatest. It also sold a significant number of 486SX2 processors, primarily to Compaq. In this case, providing Compaq with a device that Intel chose not to supply (the 486SX2-66) was of sufficient strategic value to justify the allocation of some wafers to these lower-margin chips. Compaq had a short-term exclusive, which has now expired, but AMD still hasn't put the SX2 on the price list because it doesn't want any new customers for the part.

AMD signed two deals for outside foundry capacity in 1994: with Digital Equipment and with Taiwan Semiconductor Manufacturing Company (TSMC). Digital is now producing AMD 486s at its South Queensferry, (Scotland) plant, but AMD does not expect this to be a long-term source of supply because of the sale of that facility *(see **0901MSB.PDF**)*. AMD expects this fab to produce 500,000 chips per quarter during 1995. The company expects TSMC to be a much more significant supplier, starting production in mid-1995 and reaching a rate of more than two million units per quarter in 1996.

AMD is transferring its 0.5-micron CMOS process to TSMC. AMD may also have to transfer its clean-room microcode to avoid the 20% foundry limit specified by its negotiated truce with Intel *(see **0901MSB.PDF**)*.

The big boost for AMD's production will come from its new Fab 25, which is now running test wafers and is expected to reach volume production by the middle of the year. With outside foundries to handle the 486 business, AMD plans to devote almost all Fab 25 capacity to the K5 and its successors. The Submicron Development Center (SDC), which is AMD's sole internal 486 production facility, is able to produce about two million 486s per

quarter. Fab 25, when fully outfitted (which won't occur until 1997), has about eight times that capacity.

AMD Shifts 486 Line to 0.5 Micron

At the start of the fourth quarter of 1994, all AMD's 486 production was done with a 0.7-micron process. During that quarter, the company began volume production of 0.5-micron chips. The denser process yields twice as many chips per wafer, doubling AMD's 486 capacity, so the company is naturally eager to shift its customers to the new design. All new wafer starts at the SDC now use the 0.5-micron process; chips from South Queensferry will serve customers requiring the 0.7-micron design. The 0.5-micron chips use a 3.3-V supply, forcing some design changes by system makers.

AMD has been shipping the 5-V 486DX2 chips with 66- and 80-MHz clock rates. The 3.3-V device is being offered at 66, 80, and 100 MHz, with 120 MHz possible later this year. The 0.5-micron design has a new input pin that determines whether the clock is multiplied by two or by three. AMD calls its 100-MHz chip a 486DX4, even though it has half the cache of Intel's DX4. Others are likely to follow suit, calling any 486 that runs at 100 MHz with a clock tripler a DX4. This naming strategy is unfortunate in that it blurs the meaning of DX4, but marketing considerations make it inevitable.

AMD's 486 business has been confined almost entirely to desktop systems. Although the company had a version of its 486 with AMD-style system-management mode, the company sold only about 100,000 of these chips before Intel's victory in the "ICE" lawsuit forced AMD to take all its chips with SMM off the market.

AMD is now sampling a revised 486DX4 that implements Intel-compatible SMM and stop-clock features without using the ICE microcode. This chip, which is expected to be in volume production in March or April, will enable AMD to compete with Intel's DX4 in the portable market. AMD will offer the chip in both write-through and write-back cache versions.

AMD will build a 486 with a 16K cache, but its popularity (and availability) remains to be seen. Intel requires customers to go to a 16K cache to get 100-MHz operation; AMD could provide a choice of either cache size. According to AMD VP Bob McConnell, the 16K cache part would have to be priced 70% higher than the 8K cache device to produce equivalent profits, yet the performance gain is much smaller—as little as 5–10% in a system with a second-level cache. As a result, the 16K cache part may be offered to only a few customers.

K5 Begins AMD's Intel Independence

AMD stands to become a major player in the 486 market this year, but its role in the Pentium-class market will be more limited. The company says that the K5 is on track for volume production in the second half of

Key x86 Events in 1994

TI introduced Rio Grande, the first x86 processor with a PCI interface *(see **080201.PDF**)*, but dropped it before going into production *(see **0814MSB.PDF**)*.

Intel boosted the 486 and Pentium families with its 0.6-micron process, yielding the IntelDX4 and P54C Pentium *(see **080301.PDF**)*. Intel soon pulled back on the DX4 *(see **0806MSB.PDF**)*.

Intel slashed the 60-MHz Pentium price to push it into the mainstream *(see **080904.PDF**)*. The 75-MHz Pentium *(see **081503.PDF**)* marked the entry of TAB packaging into mainstream PCs.

Intel added SX2 *(see **0805MSB.PDF**)* and DX4 *(see **081503.PDF**)* OverDrive chips. It previewed the Pentium-based OverDrive processor at the Microprocessor Forum *(see **081503.PDF**)* but failed to meet the promised year-end date for the formal introduction *(see **0817MSB.PDF**)*.

Intel's obscure 486SXJ appeared in a Compaq subnotebook *(see **0806MSB.PDF**)*. Intel enhanced its 486DX2 by adding a write-back cache *(see **081503.PDF**)*.

Intel unveiled a specification for standard MP systems using its APIC *(see **080603.PDF**)* and began pitching Native Signal Processing using a new port of the SPOX OS *(see **0815MSB.PDF**)*.

Intel and HP entered into a landmark agreement to jointly develop a next-generation architecture *(see **080801.PDF**)* but announced no details of their plans.

Intel achieved first silicon on the P6 *(see **0816MSB.PDF**)*, which could be Intel's last pure x86 CPU core.

A floating-point bug in Intel's Pentium created the company's biggest PR nightmare ever *(see **0817ED.PDF** and **081702.PDF**)* and will result in the replacement of large numbers of Pentium chips.

NexGen unveiled its long-awaited Nx586 *(see **080403.PDF**)*, announced a manufacturing agreement with IBM *(see **0808MSB.PDF**)*, and added higher clock rates when it began shipping chips in the fall *(see **0813MSB.PDF**)*.

AMD gained Compaq as a customer *(see **0802MSB.PDF**)* and became the first vendor to offer a 486SX2 *(see **0803MSB.PDF**)*—an offering Intel matched weeks later *(see **0804MSB.PDF**)*.

AMD added an 80-MHz 486DX2 *(see **0812MSB.PDF**)* and sampled 100-MHz chips *(see **0813MSB.PDF**)*.

AMD described its K5 at the Microprocessor Forum *(see **081401.PDF**)* and achieved first silicon by Thanksgiving *(see **0816MSB.PDF**)*.

Cyrix announced a five-year foundry and alternate-source agreement with IBM *(see **080602.PDF**)*, and IBM announced the Cx486DX2 as the IBM BL486DX2 *(see **0808MSB.PDF**)*. The M1 taped out in October *(see **081601.PDF**)*. The cost-reduced M9 version was described at financial conferences but not formally disclosed *(see **0817MSB.PDF**)*.

UMC announced its 486SX-compatible processor in Taiwan *(see **080702.PDF**)*.

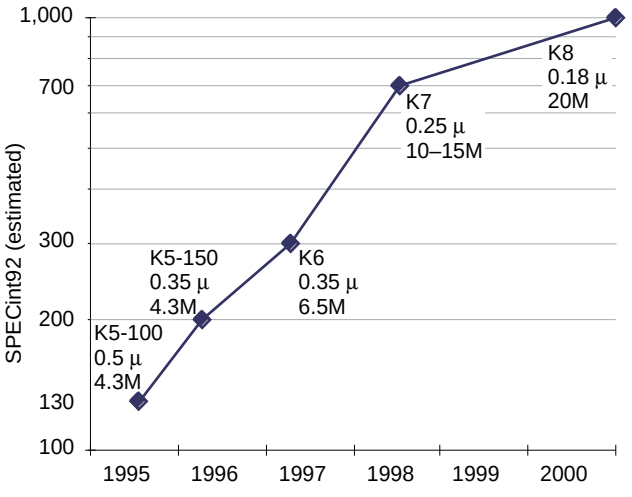

Figure 3. AMD's roadmap for its K86 microprocessor line, showing the expected production date, process technology, and estimated transistor count for each version. (Source data: AMD)

the year, but it expects to ship only 500,000 to 1,000,000 chips in 1995. The K5 will be much more important in 1996, when AMD will have ramped up production in its new Fab 25 facility and will be able to ship millions of the chips. AMD expects to shrink the K5 to a 0.35-micron process by early 1996, boosting production capacity and enabling a 150-MHz clock rate. It could take until 1997, however, for AMD to approach its desired 25–30% market share for this product category.

Even though the K5 will be a small part of the PC market this year, it is a vitally important product for AMD because it establishes the company's independence from Intel's designs and provides a path to future generations. This independence should minimize new litigation, and even more important, it allows AMD to proceed with its design process without waiting for Intel to release its next generation of devices.

Figure 3 shows AMD's roadmap for its K86 devices. AMD expects the K5 to outperform Pentium by at least 30% at the same clock rate, so the company has rated it at an estimated 130 SPECint92 at 100 MHz. (This does not take into account Intel's latest, improved SPEC results, but AMD should benefit from the same software enhancements.) The 150-MHz version will give the K5 a significant performance boost in 1996, and AMD plans introduce its next generation—the K6—by the end of that year. Production is planned for 1997, putting AMD perhaps 18 months behind Intel's P6.

AMD officials say that the K6 will follow the general microarchitecture of the K5. A new microarchitecture will be introduced with the K7, promised for introduction in 1997 and production in 1998. Whether AMD can maintain this aggressive pace of a new chip generation every year remains to be seen. AMD's roadmap then shows a relatively long span before the K8 emerges in 2001. At that distance into the future, the roadmap represents little more than a general vision.

Sole Survivor in Integrated 386 Market

With the demise of the Intel/VLSI Polar chip set, AMD's Élan (officially the Am386SC300) has become the only high-integration 386 device for PCs. (Intel also has an integrated 386 but is marketing it only for embedded applications.) The Rev A version of the chip is now in production and is being used in a variety of vertical-market handheld computers, mostly running DOS with various extensions. GeoWorks also has been ported to the chip. A WinPad port was in progress as well, along with a version of the chip with enhanced graphics for WinPad, but the demise of the first generation of WinPad software put an end to these efforts.

AMD is now sampling the Rev B silicon, which improves the power-management capabilities and slashes the standby current. This reduction is important for long battery life when the system is "asleep" most of the time. Existing devices have a typical standby current of approximately 50 µA; AMD expects to get this down to 15 µA with the Rev B version.

Microsoft expects a reborn WinPad to be released sometime in 1996—the same timeframe in which AMD plans to have a 486-based member of the Élan family.

Cyrix Falls Behind in 486 Race

Cyrix had a very good year, in some ways, in 1994. Its pact with IBM Microelectronics gave the company access to leading-edge foundry capacity, significantly improving the credibility of its efforts to become a major player. IBM's decision to market the Cyrix parts under its own name further enhanced Cyrix's credibility, and while this creates a competitor for Cyrix, it also adds a royalty stream.

Cyrix made substantial cash payments to IBM to guarantee a capacity of 128,000 8" wafers for its processors—half to be sold by IBM, and half to be sold by Cyrix. The MPR Cost Model estimates that Cyrix's 486DX2 yields about 125 good die per wafer, so 128,000 wafers would equate to about 16,000,000 chips. A significant number of these wafers will go to Pentium-class parts, but Cyrix also is getting chips from its original foundry, SGS-Thomson. In any case, it is clear that Cyrix has the foundry capacity to sell several million 486s in 1995.

Cyrix also gained its first customer among the top-10 PC makers: AST. The legal front had more good news for Cyrix, as well—IBM's Intel patent license was ruled to protect Cyrix, and Intel's efforts to seek royalties from Cyrix's OEM customers, based on the "Crawford" '338 patent, failed. Cyrix settled its dispute with Texas Instruments, denying TI rights to the M1. The company also collected more than $20 million in payments from TI and Intel as part of its legal settlements.

Cyrix did not fare as well on product execution, however. The 486DX2 chips that IBM has been building for Cyrix have not been optimized for IBM's process technology, leading to disappointing results. The first chips used 5" wafers and a 0.8-micron, two-level-metal process. The chip was shrunk to a 0.65-micron process last fall, using 8" wafers, but still with only two metal layers.

Not only is the chip large (115 mm^2 in the new process, down from 148 mm^2), but yields have been disappointing. With a 3.3-V supply, yield at 66 MHz has been marginal, leading Cyrix and IBM to offer parts with slightly higher voltage specs as well. In an effort to get decent yield at 80 MHz, the supply-voltage specification was raised to 4.0 V for that clock rate, but other problems cropped up that made 80-MHz yield very poor even at that voltage. A design change was made late last year to address the 80-MHz problem, and IBM has recently fabricated wafers that show much improved yield at this clock rate. Whether the change will yield 100-MHz chips remains to be seen.

M1 Heads for 2H95 Production

Cyrix's future will be determined largely by the degree of success its forthcoming M1 processor enjoys. Like most processors, the chip has been subject to a series of schedule slips. When the company first disclosed the design in the fall of 1993, it promised system shipments in 1994, but development delays made this impossible.

At Comdex in November 1994, the chip had just taped out, and the company claimed that it would have its first production chips by the end of 1Q95. Cyrix now concedes that only samples will be delivered in the first quarter, and the M1 will not produce significant revenue until the second half—the date that we would expect, given the normal 12-month period from tape-out to volume system shipments.

Sources indicate that the first silicon of the M1 is performing well, and that the recent delays have not been caused by any unexpected degree of trouble with the chip. Rather, it seems that Cyrix realized it had set expectations too high, and that it was better to disappoint now and have a better chance of delivering on its promises—and possibly even doing a bit better.

Cyrix seems to have overindulged in positive-thinking exercises, setting unrealistic goals and expectations in the hope of beating the odds. The company's Comdex slogans—"The race is on, and we have a winner" and "Who's building the world's fastest 586 chip? Cyrix"—were premature and may turn out to have been overly ambitious; by the time the M1 ships, AMD, NexGen, and Intel itself will all be contending for this position, and it is far from clear who the winner will be.

Until benchmark results are available, it is impossible to say just how fast the M1 will be. One thing is clear, however: it is the largest commercial microprocessor ever manufactured. With a die size of 394 mm^2, producing millions of chips is nearly impossible. This design is handicapped by having been crafted to be built by either IBM or SGS-Thomson using only three layers of metal and a process with 0.8-micron metal geometries (but 0.65-micron transistors). Two shrinks are planned: a quick optical shrink, which could be completed in time to boost production capacity in the fall, and a redesign for IBM's 0.5-micron CMOS-5S process. This redesign will make use of five layers of metal with smaller geometries to cut the die size by perhaps 50%. If all goes well, this shrunk version should be in production by the end of 1995, and it is this chip that will give Cyrix the opportunity for a volume role in the Pentium-class market.

M9 to Fill Gap

Because of the M1's large die size, Cyrix and IBM are likely to focus it on the high end of the Pentium market. To compete with mainstream 60–75-MHz Pentiums, Cyrix will use a chip code-named the M9 (also called the M1SC). This is a scalar version of the M1 core, which can also be viewed as a high-end 486-type (single-

x86 Legal Events in 1994

Despite one victory against AMD, it was another bad year in court for Intel, forcing the company to settle its long-running lawsuits against AMD *(see **0901MSB.PDF**)*.

The most far-reaching legal event of the year was the U.S. Supreme Court's decision not to hear Intel's appeal of its suit against ULSI System Technology *(see **080202.PDF**)*, establishing the precedent that a foundry's patent license protects chips built for its customers. Intel's attempt to challenge IBM's right to build Cyrix's chips using its Intel license failed as well *(see **0817MSB.PDF**)*.

Intel also lost in its efforts to enforce the '338 patent against Cyrix's customers *(see **080202.PDF**)*, a decision that was upheld on appeal *(see **0817MSB.PDF**)*.

The most significant victory for AMD was prevailing in the retrial of the 287 microcode case *(see **080402.PDF**)*, establishing AMD's right to Intel's microcode.

AMD's big loss for the year was in the ICE module of the 486 copyright case *(see **0814MSB.PDF**)*. The resulting preliminary injunction pulled AMD's 486 chips with SMM off the market *(see **0815MSB.PDF**)*.

Cyrix and Texas Instruments reached an out-of-court settlement days before their dispute was scheduled to go to trial *(see **0817MSB.PDF**)*, ending the relationship but allowing TI to continue using the original Cyrix core and to get one other design, but not the M1.

On the last working day of the year, the California Supreme Court upheld the arbitrator's right to award AMD an implied license to the 386 microprocessor, reinstating the challenged award *(see **0901MSB.PDF**)*.

pipeline) design but, based on performance, will surely be positioned as a 586-class product.

Cyrix plans to offer the M9 in the DX4 pinout for portable systems and in a Pentium-compatible pinout for desktop systems. In a DX4 pinout, this chip could do for 486 systems what Cyrix's original 486SLC did for 386SX systems: provide an easy upgrade for OEMs to enhance systems with a next-generation CPU core.

Cyrix has refused to officially acknowledge the M9, even though the company's CEO has hyped the chip at financial conferences. It is said to be about two months behind the M1, suggesting that volume system shipments are unlikely before the fourth quarter.

IBM Takes Aggressive x86 Role

IBM Microelectronics became a significant force in the x86 market in 1994, serving as a foundry for both NexGen and Cyrix and marketing the Cyrix designs under its own name. The combination of an Intel patent license, high-volume leading-edge fab capacity, and a determination to become a major microprocessor manufacturer makes IBM a formidable contender.

IBM began shipping the Cyrix 486DX2 late in 1994 as the Blue Lightning 486DX2. IBM, of course, is subject to the same speed constraints as Cyrix, and therefore will be limited to the low end of the market until the chip is redesigned for IBM's technology.

IBM will also offer the M1 and M9 in the second half of the year. IBM sees the M9 as its biggest opportunity in 1995, both because of its smaller die size and because it will be offered in a DX4 pinout, enabling it to serve as a bridge for 486 systems to use next-generation CPU technology.

IBM's original Blue Lightning processor, now called the Blue Lightning 486SX3, is still being sold at a module or motherboard level but cannot be sold as a standalone chip due to agreements with Intel. IBM presumably will focus its efforts on the Cyrix design, which does not have this limitation. IBM Microelectronics continues to make Intel-designed 486DX2 processors for the IBM PC Company, but the PC Company has not yet publicly committed to using Cyrix-designed chips.

TI Serves Low End with 486SXL

While Cyrix faces a difficult transition in 1995, its position looks positively rosy compared with that of its former partner, Texas Instruments. The ill-fated relationship between the two companies collapsed privately in early 1993 and provoked lawsuits in December of that year. The companies later settled out of court, ending their relationship and giving TI the right to continue selling chips based on the original Cyrix core. On March 1, TI will also get one more Cyrix design, which has not been disclosed other than to say that it is *not* the M1 or a derivative; the 486DX2 is a good possibility.

TI's lack of an FPU has limited the company to the SX-class market, an arena that other vendors have avoided because of its low margins. For TI, the lack of interest from other players makes this a reasonable opportunity; the company has competitive manufacturing costs and is accustomed to selling chips with small margins. TI has set for itself a modest, but achievable, goal for 1995: to be the number-one supplier of 486SX2-class processors. The company certainly has the fab capacity: it claims to be able to produce 50 million 486s per year, far more than the demand for low-end 486 chips.

Although interest is weak in the U.S., TI has found a significant market for its 486SXL (the Cyrix core with an 8K write-through cache in a 486SX pinout, but without burst mode) in developing countries. While anemic compared with the DX4 and Pentium processors that are taking over the mainstream market, the 486SXL remains an attractive upgrade for low-end users whose alternative is a 386. The company is pitching the chip at "$1 per MHz," a new low for 486-class processors. Nearly all 1994 production was of 40-MHz 486SXL and 50-MHz 486SXL2 chips; the company has sampled a 486SXL2-66 and expects volume production this quarter.

TI's most innovative foray was its Rio Grande chip set, which included the first x86 microprocessor with an on-chip PCI interface. Alas, the processor was stillborn. The targeted subnotebook market was slow to develop, and TI had a hard time convincing mainstream notebook makers to create a Rio Grande motherboard without having a range of processors to plug into it. In this sense, TI's inability to get access to Cyrix's FPU may have hastened Rio Grande's demise.

While TI will be bottom-fishing during most of 1995, the company is developing its own next-generation x86 CPU core with a focus on the value-oriented consumer and small office markets. This effort, though not given much visibility, is claimed to be the biggest design project currently under way at the company. Its fruit is unlikely to appear until 1996, when TI hopes to take a more aggressive position in the x86 market.

SGS-Thomson Selling Cyrix-Designed Chips

Cyrix-designed 486 processors are also being sold by SGS-Thomson, which was the company's original foundry and still provides chips to Cyrix. SGS obtained the right to market the chips under its own name as part of a deal with Cyrix that guaranteed the fabless chip maker a certain amount of fab capacity. In a world where alternate sourcing seems like an old-fashioned idea, the Cyrix 486DX2 is actually available from three sources: Cyrix, IBM, and SGS. The M1 and M9 should be available from all three sources as well. As Cyrix optimizes its designs for IBM's process technology, however, SGS will be left with much larger die unless Cyrix also creates designs optimized for the SGS process.

Last April, SGS-Thomson announced plans for a "New Ventures" group to market x86 processors, but little has been said since then. SGS has approached the market quietly so far, seeking out a few key customers rather than investing in a broad marketing and sales campaign. It is also investing $600 million in its 8" fab in Phoenix to serve the x86 market, both as a foundry to Cyrix and for its own products.

In addition to Cyrix's original 486SLC and DLC designs, SGS has been offering 50- and 66-MHz 486DX2 processors, and it has plans for 486DX2-80 chips as well as clock-tripler DX4 chips (with 8K cache) at speeds up to 120 MHz. A DX4-100 has been promised for production in July.

Despite its quiet approach, SGS appears to be serious about the x86 market, and it will have the fab capacity to be a significant player. Not only is the company expecting to produce Cyrix's full CPU line, but it also plans to develop a high-integration program to combine the Cyrix-designed cores with application-specific peripherals. First samples of core products are expected by midyear, with production in 1996.

UMC First Asian 486 Supplier

Taiwan-based UMC became the first Asian supplier of 486 microprocessors with the debut of its 486SX-compatible processor, the U5SX, last spring. Based on a core licensed from design house Meridian Semiconductor (Irvine, Calif.), the processor has a more aggressive microarchitecture than Intel's 486 and achieves about 30% better performance (according to UMC) at the same clock rate.

UMC has been shipping 33- and 40-MHz SX processors. In 2Q95, the company plans to add 486SX2-50 and SX2-66 versions, as well as a 486DX-50 and a DX2-66. UMC does not market its chips in the U.S.

UMC's shipment rate, according to the company, is approaching one million units per year. Like TI, UMC is serving the low end of the market. UMC's location puts it in a prime position to seek business throughout Asia, and the company is marketing in Europe as well.

Room for Everyone

As the length of this article attests, the number of competitors and products in the x86 microprocessor market continues to expand rapidly. The barriers to entry for Intel's competitors have fallen dramatically, with many of the legal issues resolved and compatibility concerns largely put to rest.

Intel's competitors have been buoyed by the desire of companies such as Compaq, AST, and IBM to create a competitive x86 microprocessor market. Microsoft too has been supportive of alternative processor vendors, lending its Windows-compatible logo and avoiding Intel-specific software optimizations. The widely felt resentment of Intel's dominance of the PC business, the huge profits it has earned there, and the way it conducts its business also boosts the opportunities for Intel's competitors. Dell and Gateway 2000 remain the largest Intel loyalists—and even they may go multivendor in 1995.

Intel's profit margins have already begun to shrink, and they will fall further before they stabilize. Intel's market share is likely to decline at the same time. These changes probably will be slow enough, however, that the overall growth of the market will more than compensate, resulting in continued growth for Intel.

Despite Intel's vulnerabilities, none of Intel's competitors will unseat the giant chip maker as the dominant x86 supplier, at least not in the next few years. But this market is big enough for many to prosper—with a total size of well over $10 billion, just a few percent of market share is plenty to keep companies such as Cyrix and NexGen happy. This market can have tremendous potential for smaller companies without cutting significantly into Intel's market share.

AMD has considerably grander ambitions, with a goal of a 25–30% market share. AMD seems likely to achieve this share, in units, but only as products age; in 1995, for example, AMD may achieve a 30% share of the 486 market, but it is likely to be well into 1996 or even 1997 before the company has a chance to come close to this share in the Pentium-class market. Because AMD won't achieve this market share until the products have moved past their higher price points, its share in dollars will be considerably less than in units.

The role of other large semiconductor makers has been constrained by a lack of leading-edge designs. IBM was hobbled at first by its inability to sell chips it designed using Intel's intellectual property; the company is now being held back by delays with fast 486 chips and the M1 from Cyrix. Texas Instruments is stuck at the low end of the market because of the collapse of its relationship with Cyrix, at least until it completes its own core design. SGS is just getting started selling x86 chips under its own name, and it could emerge as a major player.

Competition in the 486 market will be heated this year, and Intel's competitors could grab close to half the market. Intel will slash the prices of its DX4 processor, but AMD and others will respond even more aggressively with 100-MHz 486 chips (but with 8K caches).

The Pentium-class market will belong mostly to Intel in 1995, with NexGen as the only company competing there from the first of the year. AMD, Cyrix, IBM, and SGS-Thomson will join in the second half, but their chips will be early in their life cycle and won't play a major role this year. In 1996, however, the Pentium challengers will be ready for prime time, and by 1997, the Pentium market will look a lot like the 486 market does today.

By then, of course, Intel will be focusing on its P6 processor, and the cycle will begin again. This time, however, the competitors expect to be nipping closer to Intel's heels, and Intel will have to keep running fast to hold on to its market dominance in the waning years of the millennium. Ultimately, Intel's lead in manufacturing capacity may be the advantage that protects its market share, but it may have to accept much lower profit margins to hold on to its share.

As the P6 begins to fade, the PC microprocessor market will get even more dynamic. Intel's hopes to retain its higher margins rest with its new architecture, being developed with HP, while a hoard of x86 suppliers will try to keep the old architecture alive as long as possible. At the same time, PowerPC (and any other surviving RISCs) will be in a stronger position to make a play for the mainstream PC market because of lower memory costs and Microsoft's plan to make its portable OS mainstream. Wild as today's x86 market looks, it will only get more complex in the coming years. ♦

