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Delayed Pentium Challenge to Hit in '96

Cyrix, NexGen Finally Match Fast Pentiums; AMD Aiming for 2H96

by Michael Slater

Despite high hopes at AMD, NexGen, and Cyrix, 1995 came and went without a significant challenge to Intel's overwhelming dominance of the high-performance x86 processor market. A combination of superb execution by Intel and development delays at all its competitors left Intel largely unchallenged for the Pentium market this year.

Late in the year, however, Cyrix and NexGen nipped closer to Intel's heels, shipping small quantities of processors comparable to Intel's leading edge 120- and 133-MHz Pentiums. Cyrix's 6x86 became the first shipping Pentium-pin-compatible processor, beating AMD's K5 to market and putting Cyrix in a leadership position among Intel's competitors. In 1996, Cyrix (along with its licensees IBM and SGS-Thomson) and NexGen will strive to keep pace with Intel's clock-rate increases, and AMD expects to finally begin shipping its K5—followed by the K6, acquired by swallowing NexGen. Even Texas Instruments may join the Pentium-class battle with its first original x86 core design.

These developments should give Intel's competitors a larger share of the market than they achieved in 1995 and boost their average selling prices—and profits—as well. But because of their constrained production capacity, as well as other limitations, Intel will continue to hold the vast majority of the market. Intel's already strong position will be boosted by the next-generation Pentium, P55C, which will raise the bar for its competitors. Non-Intel x86 processors will give PC makers and buyers a wider range of options, but their biggest effect may be the pressure they put on Intel to keep aggressively cutting prices and increasing performance.

Pentium Sweeps the Market

Intel began 1995 with Pentium in the headlines—thanks to the infamous FDIV bug debacle—but with chip shipments still heavily weighted to the 486. Over the course of the year, this reversed dramatically, driven by very aggressive pricing for low-end Pentium processors, copious advertising, and advances in Pentium/PCI chip sets that weren't mimicked in 486 chip sets.

By the middle of the year, Intel's unit shipments for Pentium processors exceeded its 486 shipments. At that point, the 486 still had a strong lead industry-wide, with a few million chips per quarter being shipped by a combination of AMD, Texas Instruments, Cyrix, IBM, and SGS-Thomson. By year-end, however, Pentium shipments rose above all vendors' 486 shipments.

The 486's remaining stronghold is in portable systems. During the course of 1996, the notebook market is likely to experience a conversion comparable to that which swept the desktop market this year. But 486 unit shipments will be significant in 1996, with about 15 million chips to be shipped, versus more than 50 million Pentium-class processors (including Pentium competitors, which may garner as much as a 10% share of that segment). AMD, Cyrix, IBM, and SGS-Thomson have introduced 486-pinout products they expect to produce for only six months or so—a remarkably fast microprocessor product cycle, even in the crazy PC business.

Intel has an overabundance of Pentium clock speeds in the market today. Even with the original 60- and 66-MHz chips essentially gone, the company is now shipping chips at 75, 90, 100, 120, and 133 MHz, with 150 and 166 MHz versions imminent. Seven different clock rates are surely more than the industry needs. Many of the speeds are only 10% or so above the previous one, making the performance differences modest.

We expect Intel to quickly de-emphasize the 75- and 90-MHz chips, making the 100-MHz version the entry-level standard. The 133-MHz version is likely to be more enduring than the 120-MHz part, at least on the desktop. The 150-MHz Pentium, with a 60-MHz bus, will drop into existing 120-MHz motherboard designs; the 166-MHz processor, with a 66-MHz bus, fits 133-MHz motherboards and will be the power user's choice.

Figure 1 shows how Intel's prices have been falling

throughout the year, along with our projections for price cuts to expect in 1996. In 1994, Intel steadily cut prices on the original P5 to drive out the DX4. In 1995, Intel used the aggressively priced P54C-75 to continue this role while aggressively cutting the P54C-100 price to move the mainstream up to this performance level. In 1996, we expect prices for 100-MHz and slower Pentiums to gradually stabilize around $100–$120. We expect the P55C initially to be priced at a modest premium over the P54C; over the course of 1997, this premium should vanish.

Intel has little incentive to cut Pentium Pro prices aggressively in 1996, since this chip is much more expensive to produce than the P55C, and the target workstation and server markets aren't especially price-sensitive. The price of the 180-MHz Pentium Pro is likely to be cut to match the 0.5-micron, 150-MHz version, which Intel will want to obsolete as soon as there is enough 0.35-micron capacity. The server versions, with 512K L2 caches, will continue to carry steep premiums, but there is lots of room to cut prices at the high end. Pentium Pro boosts the top of Intel's price range, which had fallen to just over $500, to nearly $2,000.

Table 1 lists all the disclosed Pentium-class chips, expected in 1996. The four vendors are expected to offer nearly 30 different devices—a number that could easily increase. Table 2 summarizes the key technical specifications for Pentium, Pentium Pro, and other Pentium-class processors.

Pentium Pro Targets Workstations, Servers

Pentium Pro captured headlines throughout 1995, but significant shipments materialized only in the final weeks of the year. Most early shipments were of 150-MHz processors, the only ones that use Intel's 0.5-micron process technology. The 150-MHz chips are likely to fade quickly, giving way to 166- or 200-MHz parts with 512K caches for servers and 180- or 200-MHz processors with 256K caches for workstations. We expect all Pentium Pro shipments to total fewer than three million units in 1996, giving it a strong start for a top-of-the-line entry and a dominant force in high-end PC ser-vers but hardly making it a major player in the overall PC market.

The coming year will be one of gathering steam for Pentium Pro. Intel is working to put in place the software and partnerships needed to make Pentium Pro systems strong competitors for technical workstations and big enterprise servers. Traditional users of Unix workstations and "big iron" servers will be slow to convert, but Pentium Pro should find ready, willing customers among high-end PC users who run Windows NT and use a few applications for which greater performance will translate directly into greater productivity. It is this workstation-like segment of the PC market that will feel Pentium Pro's impact most strongly in 1996.

Intel's decision not to add complexity to the Pentium Pro design to boost performance of 16-bit code has compromised the chip's position in the Windows 95 market. On Windows 95 applications, the best Pentium Pro processors are faster than the top Pentiums, but only by a slim margin and at a significant price premium. As a result, Intel and system OEMs have focused Pentium Pro entirely on NT, Unix, and OS/2. This has left an opening for Intel's competitors, if they can deliver a processor that is faster than Pentium on 16-bit code; for the Windows 95 market, Pentium Pro is essentially a nonevent in 1996. If many corporate users switch to NT, as seems likely, Pentium Pro could become more significant.

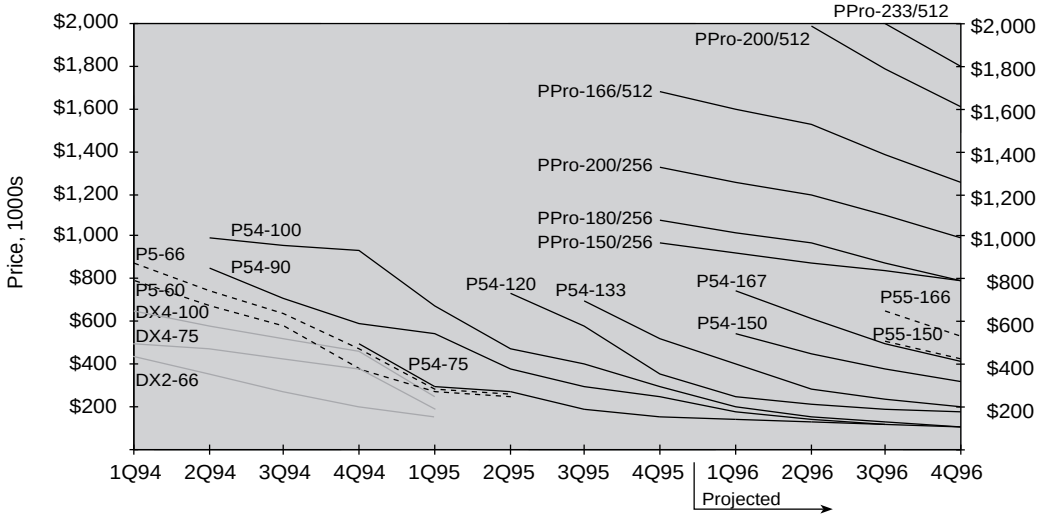

Figure 1. Intel is likely to continue steep Pentium price drops early in 1996 as competitors ramp up production, but prices are then likely to stabilize as the product matures. Pentium Pro prices should fall steadily but modestly until 1997. Intel stopped announcing quarterly 486 prices in 1995, and we dropped P5 from 1995 pricing for clarity. (Source: Intel for 1994–95, MDR estimates for 1996)

AMD Stumbles with K5, Boosts 486

The past year has been a tough one for AMD. The company's x86 processor revenue shrunk over the course of 1995, reflecting sharply lower unit prices for 486-class chips. AMD gained some important new 486 customers, including IBM, HP, NEC, Digital, and Matsushita,

and claims to have shipped more than nine million 486 chips this year. The company expects to ship more than half of all 486 processors in 1996. But with steadily declining prices, even as clock rates have increased, and a shrinking 486 market, revenue and profit growth depend on Pentium-class processors.

AMD's K5, originally expected to ship this summer, suffered two slips that pushed it out to mid-'96. AMD revealed that the K5 was not meeting its performance goal of 30% better performance than Pentium at the same clock rate. The company says that, given a few more months, it can revise the design to reach the original performance target.

To get a product to market sooner—a particularly urgent need given the rapid decline of the 486 market—the company decided to produce the original K5 design, even though it isn't any faster than Pentium at the same clock rate. The original K5 design now carries the code name of SSA/5, while the K5 name is reserved for the enhanced version to follow. With an anticipated clock rate of only 75 MHz and no per-clock advantage, the SSA/5 will serve the very low end of the Pentium market and will generate little, if any, profit. AMD says it expects to ship five million K86-family parts, which includes the SSA/5 and the K5, in the first 12 months of production, with three million in 1996.

The company also appears to have subtly backed down on its performance positioning of the K5. Originally, AMD claimed 30% better performance than Pentium at the same clock rate. Now, however, the company is talking about performance comparable to a Pentium with a 30% higher clock rate—a subtle but important distinction. A Pentium-133, for example, runs applications only about 20% faster than a Pentium-100 because of increased cache-miss penalties and the proportionally greater delays from disk and display I/O.

The revised K5 thus may be no faster than Cyrix's 6x86 at the same clock rate. Given that Cyrix expects to have 133-MHz 6x86 processors in production by the time AMD introduces its K5 at 100 MHz, AMD seems doomed to a trailing position unless it can rapidly increase the K5's clock rates. There may still be plenty of business for AMD, even with such a position, but it will be at lower margins than the company had hoped for.

To fill the gap before even the SSA/5 can be shipped in volume, AMD has boosted its 486 by adding a 16K write-back cache and a clock quadrupler and calling it the Am5x86. AMD's 5x86 is built in the company's 0.35-micron process, which is similar to that used for Intel's fastest Pentium and Pentium Pro processors. The chip runs at 133 MHz with a 33-MHz 486 bus and delivers performance similar to a 75-MHz Pentium. This is essentially the same position staked out by Cyrix's 100-MHz 5x86, which is an entirely different design, despite the identical name. Cyrix's chip has a more advanced microarchitecture that enables it to achieve comparable performance with a slower clock. AMD has demonstrated its 5x86 running at 160 MHz with a 40-MHz bus but has no current plans to introduce such a device.

Vendor	Device	Clock	Class	Voltage	Price†	Prod.
Intel	Pentium (P54C)	75 MHz	P75	3.3 V	$158	Now
				2.9 V	$178	Now
		90 MHz	P90	3.3 V	$247	Now
				2.9 V	$272	Now
		100 MHz	P100	3.3 V	$300	Now
	Pentium (P54CS)	120 MHz‡	P120	3.3 V	$357	Now
				2.9 V	$681	Now
		133 MHz	P133	3.3 V	$520	Now
		150 MHz	P150	3.3 V	tba	1Q96
		166 MHz	P166	3.3 V	tba	1Q96
	Pentium (P55C)	150 MHz*	P166*	2.5 V*	tba	2H96
		166 MHz*	P180*	2.5 V*	tba	2H96
		180 MHz*	P200*	2.5 V*	tba	2H96
AMD	5x86	133 MHz	P75	3.3 V	$93	Now
	SSA/5	75 MHz	P75	3.3 V	tba	2Q96
	K5	100 MHz	P133	3.3 V	tba	3Q96
		120 MHz	P150	3.3 V	tba	4Q96*
Cyrix	5x86	100 MHz	P75	3.3 V	$130	Now
		120 MHz	P90	3.3 V	$160	Now
	6x86	100 MHz	P120/133	3.3 V	$450	Now
		120 MHz	P150*	3.3 V	tba	1Q96
		133 MHz	P166*	3.3 V	tba	2Q96*
	5gx86	120 MHz	P90	3.3 V	tba	1H96
NexGen	586	93 MHz	P100	4.0 V	$255	Now
		120 MHz	P120	3.6 V	$303	Now
		133 MHz	P133	3.6 V	$447	Now
	586F	93 MHz	P100	4.0 V	$285	Now
		120 MHz	P120	3.6 V	tba	1Q96
		133 MHz	P133	3.6 V	tba	1Q96

Table 1. Pentium-class processors expected in 1996. All the vendors may achieve higher clock rates in the second half of the year. †List price in 1,000s ‡Both P54C and P54CS yield 120-MHz parts (Source: vendors except *MDR estimates)

Sources say that the 5x86 name had been in the works for some time. We expect the K5, when formally introduced, to be called the 5K86, so AMD stuck with the 5x86 designation for consistency even though Cyrix had co-opted the name. The SSA/5-75 probably will be called the 5K86-P75, while the K5-100 is likely to be designated the 5K86-P133. The 5K86-P100 slot could be filled by a 75-MHz K5 or a 100-MHz SSA/5.

The naming of the Am5x86, like the Cyrix 5x86, is a concession to the dictates of PC marketing. As the name of the processor has become a key element of the positioning of a PC, system makers have pushed the processor suppliers to use a "5" designation for any chip delivering Pentium-class performance, regardless of its internal design or pinout.

AMD Joins with NexGen for 6th Generation

AMD's troubles with the K5 had a ripple effect on

Vendor	Intel	Intel	Intel	Intel	AMD	AMD	Cyrix	Cyrix	Cyrix	NexGen	NexGen
Processor	Pentium P54C	Pentium P54CS	PPro P6	PPro P6S	5x86	K5 (SSA/5)	5x86 M1sc	6x86 M1	6x86 M1R	586	586 w/ FPU
Max. Clock	120 MHz	166 MHz	150 MHz	200 MHz	133 MHz	100 MHz	120 MHz	100 MHz	133 MHz	93 MHz	133 MHz
Pinout	P54C	P54C	PPro	PPro	DX4	P54C	DX4	P54C	P54C	Nx586	Nx586
Cache	8K/8K	8K/8K	8K/8K	8K/8K	16K	8K/16K	16K	16K	16K	16K/16K	16K/16K
Die Size	148 mm^2	90 mm^2	308 mm^2	196 mm^2	43 mm^2	161 mm^2	144 mm^2	394 mm^2	204 mm^2	118 mm^2	118 mm^2
Process	0.5µ, 4M	0.35µ, 4M	0.5µ, 4M	0.35µ, 4M	0.35µ, 3M	0.35µ, 3M	0.65µ, 3M	0.65µ, 3M	0.65µ, 5M	0.5µ, 5M	0.44µ, 5M
(drawn)	BiCMOS	BiCMOS	BiCMOS	BiCMOS	CMOS	CMOS	CMOS	CMOS	CMOS	CMOS	CMOS
Mfg. Cost*	$70	$60	$260†	$200†	$20	$100	$40	$270	$105	$95	$115‡
Production	Now	Now (133) 1Q96 (166)	Now	Now	Now	2Q96 (SSA) 3Q96 (K5)	Now	Now	1Q96 (120) 2Q96 (133)	Now	1Q96

Table 2. Key specifications for Pentium, Pentium Pro (PPro), and other Pentium-class chips. †Pentium Pro manufacturing cost includes 256K L2 cache chip. ‡Cost includes 36-mm^2 FPU chip. (Source: vendors except *MDR estimates)

its next-generation device, the K6. AMD's plan was to base the K6 on an enhanced version of the K5 core, while creating an entirely new microarchitecture for the K7. The delays with the K5, combined with its disappointing performance, pushed the K6 further out in time and raised questions about its ability to be competitive.

Rather than risk having its big new Fab 25 sit underutilized, AMD decided to move aggressively and acquire NexGen, which already had first silicon of its 686. With a several-year head start in the x86 game, NexGen appears to have learned many lessons from its 586 and applied them to the 686. Furthermore, the company is in the process of switching the bus interface from the proprietary design used in the 586 to a Pentium-compatible pinout. AMD expects to complete its merger with NexGen in the next month or two and to begin production of NexGen's 686—code-named Catapult and to be marketed as the AMD-K6—in the second half of 1996.

Given the amount of work involved in changing the bus interface, enhancing AMD's process technology with additional metal layers, and revising the design for the AMD process, many observers expect production of the K6 to slip into 1997. It is possible that K6 chips made by IBM Microelectronics will be shipped earlier.

NexGen Slow to Boost Speeds

NexGen's 586 has been a minor competitor during 1995 for several reasons. Because the 586 requires custom chip sets, system makers have been dependent on NexGen to develop the required support logic. Until the third quarter of 1995, NexGen had only a VL-Bus chipset available, leaving it out of step with the PCI-focused Pentium world.

NexGen's performance was limited in several ways. First, the 586 lacked an FPU version until late this year. While relatively few PC applications make much use of the FPU, its omission is still a significant marketing disadvantage. Second, NexGen was slow to boost its clock rates, which were stuck at 93 MHz—the chip NexGen calls P100—until late in the year. And even this performance point was in question; magazine reviews didn't uphold NexGen's claim that the 586-P100 delivered Pentium-100 performance. This was partly due to the fact that NexGen determined its performance ratings in the spring of 1994; after that, Pentium chip sets got significantly faster, but NexGen's performance was unchanged until the PCI chip set shipped. Even with the new chip set, the 586-P100 falls short. The 586-P120 and -P133 match Intel's clock rates and perform comparably to Pentium systems with asynchronous caches.

NexGen's 586 did as well as it did in 1995—perhaps a few hundred thousand units—because it was the only Pentium alternative available. Now it faces the 5x86 chips from AMD and Cyrix at the low end and Cyrix's 6x86 at the high end. Furthermore, now that NexGen plans to use a Pentium-compatible pinout for its next-generation device, there is no incentive for anyone to invest in new chip sets for the 586.

NexGen plans to move its 586 to IBM's CMOS-5X process in mid-'96, which should boost the clock rate to 166 and possibly 180 MHz. Whether the 586 has much life left, however, depends mostly on how AMD's K5 fares. If AMD is able to get the K5 into volume production at 100 MHz or faster in the third quarter, as the company has promised, the 586 could fade away quickly. If, on the other hand, the K5 runs into additional delays or fails to meet its performance goals, and the 586 clock rate is successfully boosted, the 586 could continue to have some life. It would be possible to adapt the 586 design to a Pentium pinout, but sources indicate that such an effort is low on AMD's priority list.

Cyrix Revamps Product Line

Like AMD, Cyrix suffered financially in 1995, with revenue and profits below 1994 levels, because of the declining 486 market. Cyrix ended the year on a stronger note than AMD, however, with the shipment of its 5x86 and 6x86.

Cyrix developed a 486DX4 (clock-tripled, 100 MHz, but with an 8K write-back cache) but never promoted the chip; IBM produced it for only a few months. Texas Instruments and SGS-Thomson continue to produce

DX4 parts based on the Cyrix core.

Cyrix let its 486 languish because it had better devices to look forward to: its 5x86 and 6x86. The Cyrix 5x86 is, in essence, an enhanced 486-style design: it has a single pipeline and a 486 pinout. It includes some features from the 6x86 microarchitecture, including branch prediction and memory bypassing, boosting its per-clock performance beyond that of any 486. The 100-MHz 5x86 is in the same performance range as the Pentium-75, while the 120-MHz version is an alternative to the Pentium-90. Because Intel has been charging a premium for its low-power VRT Pentiums, the 5x86 has a significant cost advantage, just considering the processor chip. System cost savings from using a 486 chip set and a 32-bit bus give it a further edge.

The 5x86 has already shown up in notebooks from Acer, Epson, Canon, and Sharp, as well as in low-end desktops from Epson, AST, and others. It should find modest success for a few months, but its moment in the sun will be short—both Cyrix and IBM expect to begin phasing it out by mid-'96, less than a year after ramping up production. Cyrix originally said that a version in a Pentium pinout would be offered for desktop systems but has no current plans to produce such a device.

While the 5x86 is a nice gap-filler, Cyrix's future lies primarily with its 6x86 (formerly the M1). As the first direct Pentium competitor, this chip has dramatically boosted Cyrix's prospects and proved the company's design skills. At 100 MHz, its performance ranges from that of a Pentium-120 to that of a Pentium-133, depending on the system configuration.

The 6x86 enables Cyrix to compete at the leading edge of Pentium performance. Intel's 150- and 166-MHz Pentiums will put Intel ahead again, but Cyrix's 120-MHz 6x86—due for production in the first quarter—will keep Cyrix up in the same range as Intel, and the 133-MHz part (due in the second quarter) could outperform the Pentium-166.

Cyrix's initial customers for the 6x86 are AST, Epson, and Micro Express. Cyrix showed a "technology demo" of Compaq systems with a 6x86 processor at Comdex, indicating a strong interest on Compaq's part, but Cyrix won't be able to service Compaq's volume demands until the spring.

The big question for Cyrix is capacity. During 1995, Cyrix shipped only the initial three-layer-metal 6x86 design, which is too large to be practical for volume production; only tens of thousands are likely to be shipped. Cyrix expects to begin shipping its five-layer-metal version in January.

At first, IBM will be Cyrix's only source for the five-layer-metal version, since its other foundry—SGS-Thomson—is just ramping up a comparable process. A shrink to IBM's 0.5-micron process, planned for mid-year, will boost capacity as well as clock rates. SGS-Thomson expects to begin 6x86 production in the second quarter of 1996, giving Cyrix additional capacity and providing another source for OEMs. Even so, it appears that Cyrix will need significantly more capacity to get beyond a 5–10% share of the Pentium processor market.

Cyrix executives say they are pursuing several options for additional fab capacity, and that they recognize the need for close coupling with a single vendor. They do not expect to build their own fab, at least in the near term, and are not interested in being acquired. Cyrix appears to be an attractive acquisition target, however, for a company with large, leading-edge fabs. Samsung, for example, reportedly is interested in getting into the x86 processor business and might find Cyrix attractive.

IBM Focused on 5x86 First

IBM Microelectronics has no x86 design activity of its own but serves as a fab for Cyrix and NexGen. Just how IBM's business will evolve, as Cyrix seeks a new manufacturing partner and NexGen merges with AMD, is unclear. IBM's agreements are long-term—10 years with NexGen (ending in 2004) and 5 years with Cyrix (ending in 1999)—so it isn't likely to lose its design sources soon. But if IBM wants to stay in the x86 business for the long haul, it may need to reevaluate its strategy of depending on outside design resources.

Like Cyrix, IBM is almost entirely out of the 486 business; its last 486 wafers were started last summer. IBM has announced its version of the 5x86 as the 5x86C but has chosen to wait until it can ramp up production on the five-layer-metal design before introducing the 6x86 under its own name. IBM expects the 5x86 to have a very short life and plans to slash 5x86 production as it ramps up the 6x86 in the second quarter.

IBM continues to make NexGen's 586 processors but has not marketed them under its own name, even though it has the right to do so. With the impending merger of AMD and NexGen, it seems likely that IBM will focus its efforts on the Cyrix designs. IBM does plan to build the NexGen 686 (aka the AMD K6) as well, but it remains to be seen whether AMD will cooperate.

Texas Instruments Still at Low End

TI has moved up from the 486SX market by gaining rights to Cyrix's 486DX2 and extending it to a DX4, but the market has moved forward at the same time. As a result, TI remains stuck selling processors for $70 and less—often much less. This bottom-feeding strategy is not one TI consciously chose, but one it was forced into because of the collapse of its relationship with Cyrix. While TI's x86 margins are surely modest compared with Intel's or even AMD's, they are still reasonable compared with those for other semiconductor products. By some estimates, TI was the third-largest producer of x86

processors in 1995, outshipping IBM, Cyrix, and SGS.

TI has an internal development effort under way to produce a Pentium-class processor expected to reach the market sometime in 1996. The company has revealed no details on this product, which is essential to TI's role in the PC microprocessor market beyond mid-'96. The 486 effort has served as a learning ground for TI and has enabled the company to build relationships with many third-tier PC makers. This track record could be helpful in gaining confidence with larger PC makers when the company has higher-end products to offer.

SGS-Thomson Moving Up

SGS-Thomson continues to serve as a foundry to Cyrix, as well as marketing Cyrix-designed chips under its own name. It has been selling Cyrix-designed 486 chips under its own name since the fall of 1994 but only recently began advertising them. SGS's agreement with Cyrix, like IBM's agreement, limits the number of wafers SGS can build to sell under its own name. Although details have not been disclosed, sources indicate that SGS is quite limited in the volume of 5x86 and 6x86 chips it can sell directly but is less constrained on the mature 486. The company claims to have produced more than one million 486 processors since the fall of 1994.

SGS-Thomson has aggressively priced its 486 chips and recently announced a DX4 version with clock rates up to 120 MHz *(see **0917MSB.PDF**)*. IBM and Cyrix have lost interest in this product, but SGS is apparently willing to service the lower-price segment of the market, along with former Cyrix partner Texas Instruments. Volume prices have fallen to about $0.40/MHz for 100-MHz and slower parts, while the 120-MHz chip sells for about $72, or $0.60/MHz. SGS has pioneered plastic PGA packages for 486 processors to lower its manufacturing costs.

SGS-Thomson is currently Cyrix's primary foundry for 5x86 processors, which use a three-layer-metal, 0.6-micron process, and it will begin marketing them under its own name in 1Q96. The company is now qualifying the five-layer-metal, 0.35-micron process at its Phoenix plant, and it expects to begin producing 6x86 processors using this process in 2Q96. This process is essential to the company's ability to supply 6x86 processors either to Cyrix or directly to its own customers, since the three-layer-metal version is impractically large. The Phoenix facility, which is dedicated to the x86 business, will be capable of 15,000 wafers/month when fully outfitted. Some portion of SGS's 20,000-wafer/month fab in Crolles, France, is also used for x86 processors and is now ramping up the 0.35-micron process.

The 5x86 and 6x86 will enable SGS-Thomson to move up from the low-profit 486 business. The company also expects its 486 core to have a second life as part of its ASIC library, serving as the heart of a series of "super integration" chips for embedded applications.

UMC Backing Off 486 Market

United Microelectronics Corp.'s x86 efforts appear to be faltering. The company has shipped modest quantities of its U5S 486SX-class processor in Asia and Europe, but the product was too late to fit much of the market. The company introduced 486DX and DX2 products this year but reportedly has not shipped significant quantities and is backing out of the 486 market. The company had plans to develop a Pentium-class device, but the fate of these plans is unknown.

UMC has faced a legal challenge from Intel, which has sued the company in four countries. Although UMC has launched a vigorous defense, this is an expensive and chancy proposition. With 486 prices at very low levels, fighting Intel may not be worthwhile.

P55C to Boost Pentium in 1996

The defining event of 1996 will be the debut of Intel's P55C, its fourth-generation Pentium design (following the 0.8-micron P5, 0.5-micron P54C, and 0.35-micron P54CS). Intel has so far said little about the chip, but sources indicate that it will have twice as much cache memory as current Pentiums (32K total), be built in a 0.28-micron CMOS process running at 2.5 V, include design enhancements to boost per-clock performance by better utilizing the dual pipelines, and—most important—implement the first significant additions to the x86 instruction set since the 386.

The instruction-set extensions, called MMX (MultiMedia eXtensions), have not been disclosed but are expected to be generally similar to the VIS extensions in Sun's UltraSparc *(see **081604.PDF**)*. By enabling the 64-bit ALUs to perform eight 8-bit or four 16-bit operations in parallel, UltraSparc boosts peak performance by a factor of 4–8 on many audio, video, and graphics operations. Other functions, such as saturating adds and subtracts (which don't overflow or underflow), further boost performance.

A significant performance boost is possible—solely from instruction-set extensions—on functions such as video decompression and 3D graphics rendering. This increase would be compounded by the higher clock rates the P55C should achieve and the benefits of larger on-chip caches. The P55C will therefore make Intel's native signal processing approach more attractive by enabling many more functions to be performed in software.

The P55C will also be very attractive for notebook systems. Its lower supply voltage will cut power consumption considerably at a given clock rate, supporting higher clock rates and larger caches within the same thermal envelope as current mobile Pentiums.

Just when the P55C will enter the market remains unclear. The chip had originally been expected this year, but sources indicate that the name

originally referred to a 150-MHz Pentium without the MMX features. A relatively late decision to implement MMX has pushed production of the redefined P55C into the second half of 1996. Although the P55C will be limited to the high end in 1996, we expect it to move down quickly throughout the desktop and portable markets during 1997.

Multimedia Extensions to Proliferate

The addition of multimedia extensions adds a new dimension to microprocessor performance. Two microprocessors may have comparable performance on traditional applications but radically different performance on applications using video or 3D graphics.

Based on past behavior, it would be natural to expect Intel to use MMX to raise the bar for its competitors, leaving them with yesterday's instruction set. Sources indicate, however, that Intel is considering whether to license MMX to others. Microsoft reportedly has encouraged Intel to license it and could use the threat of more limited software support to encourage this strategy. Microsoft has a track record here; the company has declined to make use of any of Pentium's Appendix H features.

If Intel doesn't decide to license MMX soon, it might be too late. The widely rumored but not officially acknowledged OpenPC (also called Sundance) group, reportedly consisting of AMD, Cyrix, IBM, and Compaq, is developing a standard of its own for multimedia instruction-set extensions. NexGen's 686, now to be AMD's K6, includes multimedia extensions that the companies have declined to discuss in detail. NexGen officials say that they have partners to drive support for their multimedia extensions but can't yet disclose who they are.

It thus appears most likely that there will be two standards for x86 multimedia instruction-set extensions: Intel's and everyone else's. These extensions will be used primarily in driver software for video decompression, 3D rendering, and audio signal processing. It is no great hardship to provide two sets of drivers for the two standards, but it does add to the burden of support for Intel's competitors, which must either create the necessary drivers or convince Microsoft to do so. Microsoft has stated its willingness to support one alternative standard for x86 extensions, but not multiple alternatives.

Unless Intel breaks new ground by licensing MMX, however, few application vendors are likely to use the extensions directly. Intel must choose between using MMX as a competitive weapon and using it to boost the entire PC industry by making it a widespread standard. A single standard would prompt wider software support that would, in turn, lead to more exciting applications and faster PC market growth—and Intel would be the biggest beneficiary of this growth.

Key x86 Events of 1995

AMD and Cyrix banded together on the OpenPIC alternative to Intel's APIC *(see **0905MSB.PDF**)*.

AMD announced a two to four-month slip in the K5 schedule in April *(see **090602.PDF**)* and another six-month slip in September *(see **0913MSB.PDF**)*, along with a new name for a gap-filler version, the SSA/5 *(see **0914MSB.PDF**)*.

AMD cranked up its 486 line, beginning with the 486DX4-120 *(see **0908MSB.PDF**)* and following with the Am5x86-133 *(see **0915MSB.PDF**)*.

AMD announced an agreement to merge with NexGen, replacing the K6 with the Nx686 *(see **091502.PDF**)*.

Cyrix announced in March that it was sampling its M1 *(see **0904MSB.PDF**)* and laid out its shrink plans. After disclosing performance data in September *(see **0912MSB.PDF**)*, the chip debuted as the 6x86 *(see **0914MSB.PDF**)*.

Cyrix revealed its much-rumored M1sc as the 5x86 *(see **090901.PDF**)* and quickly boosted the clock rate to 120 MHz *(see **0915MSB.PDF**)*.

Cyrix disclosed at the Microprocessor Forum the 5gx86, a highly integrated processor *(see **091403.PDF**)*.

IBM announced its own version of Cyrix's 5x86 as the 5x86C *(see **0915MSB.PDF**)*.

Intel and AMD abruptly ended their legal feud and settled all pending litigation *(see **0901MSB.PDF**)*.

Responding to the turmoil created by the Pentium FDIV bug fiasco, Intel decided to replace flawed Pentium chips on request *(see **0901MSB.PDF**)* and began openly publishing an updated errata list monthly *(see **0902MSB.PDF** and **090303.PDF**)*. Intel even disclosed the Pentium Pro bug list *(see **091607.PDF**)*.

Intel disclosed the P6 design *(see **090201.PDF**) and **090202.PDF**)*, followed with a description of the bus and chip set *(see **090701.PDF**)*, revealed its modest performance on 16-bit code *(see **091001.PDF**)*, christened it the Pentium Pro *(see **0913MSB.PDF**)*, and finally announced shipments at up to 200 MHz *(see **091501.PDF**)*.

Intel introduced the 0.35-micron Pentium at 120 MHz *(see **090402.PDF**)* and moved it up to 133 MHz *(see **0908MSB.PDF**)*.

Intel introduced 2.9-V notebook Pentiums at 90 MHz *(see **090702.PDF**)* and then at 120 MHz *(see **0914MSB.PDF**)*.

Intel quietly upgraded its DX4 with a write-back cache *(see **0912MSB.PDF**)* and shipped a low-power 486SX for PDAs *(see **091303.PDF**)*.

Intel shipped the long-delayed 83-MHz P24T OverDrive processor for DX2-66 systems *(see **0913MSB.PDF**)*.

NexGen disclosed its Nx686 at the Microprocessor Forum *(see **091401.PDF**)*.

NexGen boosted its 586 to 120 and 133 MHz and introduced a 100-MHz 586 with an FPU *(see **0916MSB.PDF**)*.

SGS-Thomson announced a 486DX4-100 *(see **0915MSB.PDF**)* and boosted it to 120 MHz *(see **0917MSB.PDF**)*.

Texas Instruments introduced 80-MHz 486DX2 processors based on Cyrix's design *(see **0908MSB.PDF**)* and followed up with a 486DX4-100 *(see **0915MSB.PDF**)*.

Intel sued **UMC** in four countries *(see **0909MSB.PDF**)* and UMC challenged Intel's patents *(see **0913MSB.PDF**)*.

Cyrix Makes Bold Integration Move

While numerous chips—including Cyrix's 6x86—push to higher performance levels, Cyrix is exploring another direction as well: cost reduction through higher integration. Its 5gx86, disclosed at the Microprocessor Forum this fall, combines a 5x86 CPU core with a PCI bus bridge, DRAM controller, and unified memory architecture (UMA) graphics controller. By eliminating half of the system-logic chip set, the graphics controller chip, and the frame-buffer memory, this chip could drive down the price of entry-level multimedia systems.

It remains to be seen whether this attempt at integrating peripheral functions on the processor will fare any better than previous debacles, such as the 486SL and TI's Rio Grande. That the 5gx86 can cut costs is clear, assuming that Cyrix can price the chip competitively; what is uncertain is whether the resulting performance will be too low to spark volume demand. Cyrix faces greater challenges with the 5gx86 than with any of its other chips, since it requires a custom motherboard design and driver software support.

The 5gx86 cannot escape a fundamental problem with UMA systems today: if 1M is taken away from an 8M Windows 95 system, the reduction in main memory to 7M causes a significant performance loss. Thus, UMA requires a system with 12M or 16M to be effective.

Cyrix is evaluating the performance of the initial 5gx86 silicon and probing for customer interest; the company has not committed to introducing it as a product. At a minimum, some of the technology in the 5gx86 will appear in future derivatives of the 6x86.

Setting the Stage for a Dynamic 1997

In 1996, AMD/NexGen and Cyrix/IBM/SGS should both strengthen their positions in the Pentium-class market considerably. At the same time, Intel will raise the bar with the P55C, keeping its challengers from making any easy gains. Perhaps the biggest factor boosting the competitors' positions is the desire of some PC makers—notably Compaq—to fuel a more competitive CPU market by pushing prices down and limiting Intel's dominance.

In 1997, AMD should be ramping up its K6, bringing it closer to the top of Intel's line than ever before, while Cyrix pushes the 6x86 to higher clock rates and possibly adds other enhancements. Intel will drive its P55C down to entry-level price points while introducing the next-generation P6 derivative for mainstream systems. We expect this chip to include the same MMX features as the P55C; incorporate changes to improve performance on 16-bit code; have larger on-chip caches; be built in 0.28-micron CMOS; and provide a dedicated interface for the special synchronous SRAMs that Intel is working with leading SRAM makers to supply. This incarnation of the P6 core will drive this technology into the volume market, starting in late 1997 and moving into full swing in 1998.

About that time, Intel is expected to roll out the P7 chip being jointly developed with HP; AMD should be introducing its K7; and Cyrix should be rolling out its 7x86, making for a vigorously competitive high-end market. Intel is likely to face more intense competition for high-end x86 processors in 1997–98 than ever before. And, just in time, Intel will have its new P7 architecture to give the industry a new goal. Unfortunately, Intel has said nothing of substance about the P7, and the rumors and press reports haven't been consistent enough to be credible. Intel has shown a roadmap for the transition to future processor generations that puts the P7 at less than 10% market share, even in 1999.

If all this were not enough, at least two startups are rumored to be raising funds to develop x86 processors, and the long-sleeping Asian semiconductor giants seem to be sniffing at opportunities in the x86 market.

None of Intel's competitors is close to having all the business components needed to displace Intel as the dominant PC microprocessor supplier. But there are many opportunities for them to build positions in Intel's shadow. The next two years will be a pivotal time for Intel's challengers, in which each must prove its ability to gain market share in the search for a second-place position behind Intel. A strong third-place position may make a nice business as well; others are likely to survive on a more modest scale by defending smaller niches. With the x86 processor market headed for 100 million units by the end of the decade, smaller x86 vendors can prosper without taking much market share from Intel. ♦

