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PC PROCESSOR COMPETITION CONSOLIDATES

From Five Companies to Three; AMD's Athlon Intensifies Challenge

By Michael Slater {01/17/00-05}

The past year has been a roller-coaster ride for the PC processor business. Intel started the year with a bang by slashing Celeron prices while boosting its clock rate, signaling that it did not intend to abdicate the low-cost PC market to its competitors. Intel succeeded in regaining considerable share, pushing AMD into its biggest loss of recent times and driving National to exit the PC processor business by selling Cyrix.

Taiwan-based VIA jumped into the market with both feet, buying Cyrix as well as IDT's x86 subsidiary, Centaur. Rise Technology, stuck with a part that was too slow for the PC market, never shipped significant volumes of its mP6, and the company decided in November to pull the plug on its PC processor efforts and shift its focus to information appliances.

Intel raised the bar in the performance processor market by shifting from Pentium II to Pentium III, first in a 0.25-micron version that added nothing but the SSE instructions and then with the 0.18-micron Coppermine, bringing on-chip L2 cache to the performance processor segment and boosting clock speeds to 800 MHz by year-end.

The biggest change in market dynamics came from AMD's Athlon. Although AMD shipped only about one million Athlon processors, most of them in the fourth quarter, the emergence of competition for the high end of Intel's line was a watershed event that could have far-reaching implications.

In 2000, Intel will face just two established x86 competitors: AMD and VIA. AMD will compete across the full breadth of Intel's PC processor product line. VIA, meanwhile, will focus on the low end of Intel's line, primarily serving price points below the bottom of Intel's range.

Table 1 summarizes the current PC processors.

Company	Intel			AMD				VIA-Cyrix
Product	Celeron	Pentium III		K6-2	K6-III	Athlon		M II
Code Name	Mendocino	Katmai	Coppermine		Sharptooth	K7	K75	
Process	0.25µ	0.25µ	0.18µ	0.25µ	0.25µ	0.25µ	0.18µ	0.18µ
Max. Speed	500 MHz	600 MHz	800 MHz	533 MHz	450 MHz	700 MHz	800 MHz	PR433
Interface	Socket 370	Slot 1	Socket 370	Socket 7	Socket 7	Slot A	Slot A	Socket 7
L1 Cache	32K	32K	32K	64K	64K	128K	128K	64K
L2 Cache	128K	512K*	256K	none	256K	512K*	512K*	none
Die Size	154 mm^2	128 mm^2	103 mm^2	78 mm^2	118 mm^2	184 mm^2	102 mm^2	88 mm^2
Transistors	19 million	9.5 million	23 million	9.3 million	21.3 million	22 million	22 million	6.5 million
Price Range	$64–$167	$173–$465	$284–$851	$61–$167	$163–$173	$209–$699	$799-$849	$28–$49

Table 1. In today's PC processor market, only Intel is using the P6 bus interface, in the form of Slot 1 and Socket 370. AMD's Athlon is the first non-Intel processor to compete in the same speed and price band as Intel's high-end offerings. * L2 cache is off chip, on the processor module.

Table 2, presented later in this article, describes the processors expected in 2000.

As Figure 1 shows, Intel gained a few percentage points in 1999, as Cyrix's share plummeted. For the year overall, AMD managed to gain a couple of points, but it remains below the share it held in the fourth quarter of 1998. PowerPC's share (i.e., Macintosh) crept up slightly.

Intel Attacks Entry Level

Intel's resurgence in entry-level PC processors required no new products; Celeron has always had the capability to run at higher speeds but was held back by Intel's need to differentiate it from Pentium II. Intel boosted Celeron to 400 MHz in January and 433 MHz in March, when the top Pentium II speed was only 450 MHz. Now that Pentium III has reached 800 MHz, Celeron has been boosted to 533 MHz—higher than Pentium II ever reached, but still comfortably below the Coppermine range.

Intel has restricted Celeron to a 66-MHz bus, leaving the higher bus speeds as a differentiator for Pentium III. As the Pentium III market moves to a 133-MHz bus (which is available today but is only a small part of the current market), Intel presumably will allow Celeron to use the 100-MHz speed.

Aside from clock and bus speeds, Pentium III is distinguished by its SSE instruction set extensions. As Intel ramps up production in its 0.18-micron process, the aging Mendocino design will be replaced by a defeatured version of Coppermine for the Celeron market. If history is a guide, the Celeron version is likely to have 128K of on-chip L2 cache, whereas Coppermine has 256K. Using a 0.18-micron process, Intel will be able to increase Celeron's clock speeds to as high as it dares (or the market demands). If the market allows it, Intel would no doubt prefer to keep Celeron processors limited to speeds below those of Pentium III, maintaining clear separation, but some overlap is likely. The smaller L2 cache and slower bus speeds will continue to provide differentiation.

As Figure 2 shows, Intel's aggressive Celeron push was quite successful. Intel's market share in the U.S. retail channel, which dipped below 35% early in the year, began climbing soon after the Celeron boost and broke the 60% level in August and September.

Pentium III Adds SSE, On-Chip Cache

Intel revitalized its high-end line with Pentium III, which is based on the same P6 CPU core as Pentium II but with the SSE instruction set extensions. SSE provides a nice boost for 3D graphics and a few other applications. Intel promoted SSE heavily as improving the Internet experience, but there is very little substance behind this claim today.

Even though SSE does little for most PC users, the performance-oriented market switched quickly from Pentium II to Pentium III. This transition was driven not by the architectural enhancements in Pentium III but by its higher clock speeds and aggressive pricing of the lower speeds. As Figure 3 shows, Pentium II sales in U.S. retail plummeted in the first half of the year as Pentium III took over the high end and Celeron more than doubled its share of Intel's shipments in this channel. (Note that Celeron's rise in Intel's overall product mix was not nearly so dramatic, since corporate buyers largely stuck with the Pentium II/III line.)

Intel's most important new product in 1999 was the Coppermine version of Pentium III. Built in a 0.18-micron process, this chip enables higher speeds with lower power consumption. By bringing a 256K L2 cache on-chip, Pentium III eliminates the need for the Slot 1 module. Although the chip is offered in the Slot 1 form factor for compatibility with older system designs, its future is in the Socket 370 package pioneered by Celeron. After a three-year diversion into mod-

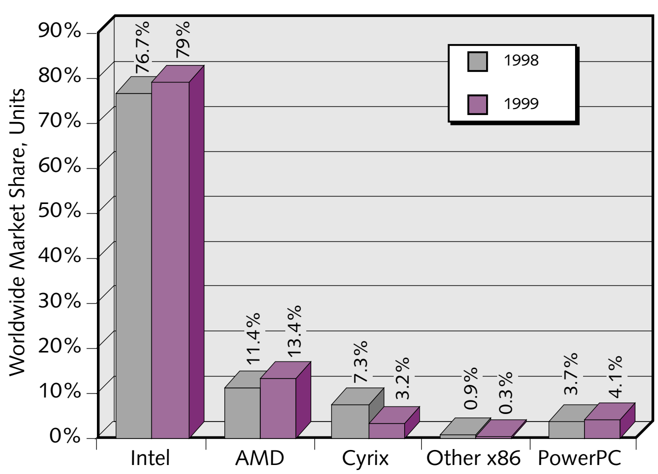

Figure 1. Intel and AMD each gained a couple of points of market share in 1999, as Cyrix's share plummeted. (Source: MDR)

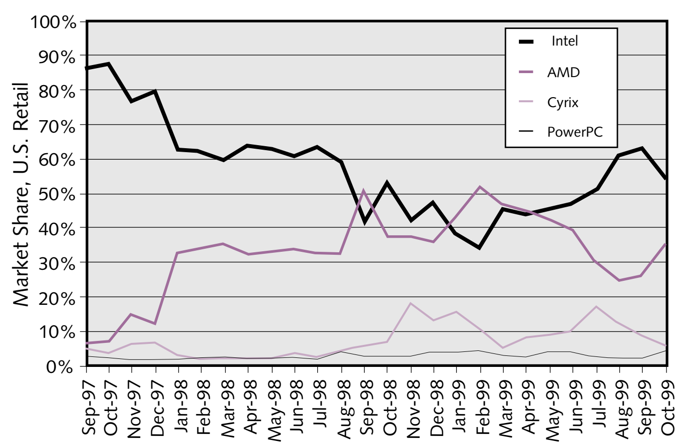

Figure 2. Following the boost in Celeron speeds in early 1999, Intel's share of the U.S. retail channel began rising after an 18-month decline. AMD's share plummeted and only recently began rebounding. Cyrix's share likewise fell; it had another peak midyear, due to a fire-sale of National's inventory, but then resumed a steady decline. (Source: NPD Intelect)

ules, Intel's product line has returned to the simpler packaging of earlier days. Modules, once pitched as the wave of the future, are now revealed as nothing more than a fad, covering the period between Intel's decision to add a back-side L2 cache and the inclusion of the L2 on the processor die.

Coppermine is not the first PC processor to integrate the L2 cache—Celeron has that distinction—but it is the first to optimize the L2 cache interface. The Celeron design simply bolted the on-chip cache onto an interface designed for an off-chip cache, keeping the 64-bit data width. In Coppermine, Intel quadrupled the bus width to the L2 cache to 256 bits. The cache runs at only one-half the CPU speed, making it easier to continue scaling the clock rate, but because of the wider bus, it still delivers twice the L2 bandwidth of Celeron and four times the bandwidth of the off-chip cache in Pentium II and Katmai. The latency was also decreased. Because of these enhancements, the 256K L2 in Coppermine outperforms the off-chip 512K cache in Katmai.

AMD Breaks Through With Athlon

The K6-2 accounted for the lion's share of AMD's shipments in 1999. The K6-III has remained a niche processor; it delivers much better performance at the same clock speed, but the cost-sensitive retail customers that are the focus of the K6 family tend to buy on clock speed alone, making the higher cost of the K6-III a net disadvantage for PC makers.

By far the most significant event for AMD in 1999 was its introduction of Athlon. AMD shipped only 200,000 Athlons in the third quarter and more than 800,000 in the fourth quarter, compared with more than four million K6-family processors in each quarter, but the average selling price was far higher. As the Athlon family broadens in 2000 and increases in volume, it will become the heart of AMD's PC processor line—and, in fact, the basis of the company's future. AMD has already sold off its programmable logic business and, in need of cash to support its PC processor efforts, has put its networking and communication business up for sale, leaving the company with PC processors and flash memory as its primary product lines.

Athlon is of tremendous significance to AMD because it has enabled the company to go beyond the economy-PC market. Whereas K6-family processors typically appear in systems selling for less than $1,000, Athlon systems start above that level and go well above $2,000. The K6-2 competes with Celeron, while Athlon competes with Pentium III. This allows AMD to enjoy the same high price points that Intel achieves for its premium processors. Intel cut Celeron prices aggressively to compete with AMD's K6-2 while protecting its revenue base by keeping Pentium III prices high. To fight against Athlon on price, on the other hand, would be enormously damaging to Intel's profits.

Most of the Athlon processors shipped in 1999 were built in a 0.25-micron process. AMD introduced Athlon at 550, 600, and 650 MHz, and then quickly added a 700-MHz version, staying ahead of Intel until the debut of Coppermine. Late in the year, AMD began shipping 0.18-micron parts, which run much cooler (the 0.25-micron Athlon is the most power-hungry chip in the PC market today) and achieve higher speeds. AMD's top speed reached 750 MHz, edging ahead of Pentium III's 733-MHz top speed at the time. In the final days of 1999, Intel stretched Pentium III to 800 MHz in an unusual Christmas-week announcement, and AMD matched that speed in the first week of January.

Athlon has a more advanced microarchitecture than Pentium III, with three symmetric instruction decoders, the ability to handle more in-flight instructions, faster floating-point units, and a faster bus. It also reached 700 MHz in 0.25-micron technology, while Intel's Pentium III topped out at 600 MHz. For these reasons, and because it is the first non-Intel product ever to seriously challenge Intel's high-end PC processors, we have awarded Athlon our Analyst's Choice award for the **Best PC Processor of 1999**.

When compared with Katmai, Athlon has a clear performance lead at the same clock speed. Coppermine boosts Pentium III's performance at a given clock rate because of its superior cache architecture, enabling it to pull ahead of Athlon in many cases (depending on the system configuration and benchmark). One can argue about which processor is the better performer, but the differences are modest; Athlon is clearly in the same ballpark as Intel's fastest processors, something that has never before been achieved, except very briefly, by AMD or any other Intel competitor.

Furthermore, whereas Coppermine is presumably the end of the line for the P6 architecture, Athlon will gain another boost by shifting to on-chip L2 cache. Athlon also appears to have plenty of frequency headroom, having started at 750 MHz in the 0.18-micron process. Another

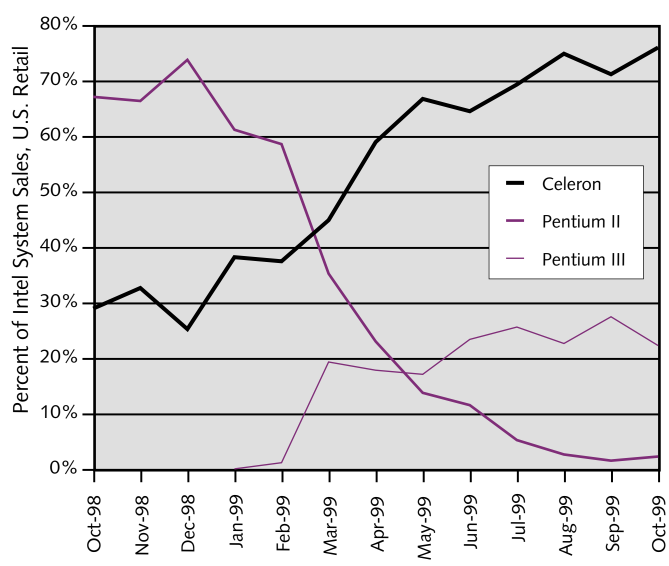

Figure 3. Pentium II declined rapidly during the year as Celeron accounted for an increasing portion of Intel's sales in the U.S. retail channel and Pentium III took over the peformance-oriented segment. (Source: NPD Intelect)

process boost is in store when AMD begins shipping chips using copper metallization from its Dresden fab, due midyear. At about the same time, however, Intel will launch Willamette, raising the bar.

VIA Consolidates Cyrix and Centaur

The biggest surprise of 1999 was the aggressive move into the PC processor market by Taiwanese chip-set maker VIA Technologies, which bought not one but two low-end processor makers. With Rise's withdrawal from this market, VIA has become the only alternative other than AMD. With anticipated 1999 revenues of $265 million, VIA has about one-tenth the revenue of AMD and generated only 1% of Intel's revenue. The 800-employee company expects to ship about 24 million PC chip sets in 1999, showing that being tiny doesn't preclude gaining significant share in certain segments.

VIA first acquired Cyrix from National, which had decided to exit the PC processor market after seeing that Intel was not, after all, going to leave the entry-level market to competitors. Even before completing the acquisition of Cyrix, VIA added IDT's Centaur subsidiary to its collection. IDT had decided to get out of the PC processor business when its process technology proved inadequate to deliver competitive clock rates. With Centaur planning to use non-IDT fabs, and price competition making the business a lot less attractive, IDT couldn't justify continuing the effort.

VIA apparently found Centaur's design approach and lean structure to be more to its liking and a better fit for its long-term goals, while Cyrix provided a stronger near-term product and a more widely recognized brand. VIA has dropped the WinChip product line and for now is selling just the M II. Cyrix is now a brand name rather than a company name, and the WinChip name has been retired. VIA is using primarily the Centaur team to develop next-generation products that will debut later in the year.

The M II is an aging design; it has been in the market longer than any of its competitors. It lacks any 3D (SIMD FP) instruction set extensions, such as SSE or 3DNow, and it lags Intel and AMD in clock speed. It is also the only part to be marketed on the basis of its performance rating rather than its clock speed. These limitations have restricted the M II to the lowest reaches of the PC market.

VIA and Intel are in litigation regarding VIA's P6 chipset license, which, in Intel's view, did not permit VIA to support 133-MHz operation. VIA has sidestepped the issue for now by having National manufacture the chip set in question, and it plans to continue having National manufacture the Cyrix processors for the same reason. VIA wants to use Taiwanese foundries, however; it may attempt to continue using National for patent protection by contracting with National to make the chips, with National then subcontracting to a foundry. It is a good bet that Intel will challenge such an obviously contrived arrangement, but VIA appears prepared to fight it out. VIA acquired some x86-related patents along with Cyrix and Centaur, which it may use to counterattack if Intel tries to interfere with its x86 business.

Low-Cost Landscape in 2000

The processor choices for low-end PCs will change completely during 2000. Table 2 summarizes the key features of the chips that will serve this market.

Intel will add a Celeron processor with SSE, as described previously, using a reduced-cache version of Coppermine. Mendocino will continue to serve the lower speed grades, while the Coppermine-derived Celeron will extend the speed range. By the end of the year, however, Mendocino is likely to be phased out.

Filling in at the low end of Intel's line will be the processor code-named Timna—Intel's first highly integrated processor since the ill-fated 486SL. We expect Timna to combine the equivalent of a Celeron processor, probably based on the cache-reduced Coppermine design, with system logic and graphics similar to that those in Intel's 810 chip set. The design reportedly will include an RDRAM memory controller, although Intel may be forced to revisit that choice unless RDRAM prices drop sharply.

AMD, although much of its attention is on Athlon, is moving both the K6-2 and the K6-III into its 0.18-micron process, creating the K6-2+ and K6-III+. The K6-2+ will add an on-chip 128K L2 cache, making it, in essence, a cost-reduced version of the K6-III. The K6-III+ will retain the same 256K cache as the current K6-III. Both chips will implement AMD's Gemini technology, which provides the same dual-voltage support as Intel's SpeedStep and allows mobile systems to operate in either a low-power or a high-performance mode (see sidebar).

Later in the year, AMD will bring an Athlon derivative into the value market. Code-named Spitfire, this chip will presumably have a small on-chip L2 cache. It will plug into the new Socket A, a socket-based equivalent of Slot A. This chip is likely to sit above the K6-2+ during 2000, serving the upper reaches of the value market, and move into the true entry-level domain in 2001. AMD's K6-III+ will be focused on the mobile market.

Company	Intel		AMD			VIA	
Product	Celeron/SSE	Timna	K6-2+	K6-3+	Spitfire	Joshua	Samuel
CPU Core	P6/SSE	P6/SSE	K6-2	K6-2	K7	Cayenne	C5
Interface	Socket 370	Integrated	Super 7	Super 7	Socket A	Socket 370	Socket 370
L1 Cache	32K	32K?	64K	64K	128K?	64K	128K
L2 Cache	128K	128K?	128K	256K	?	256K	None
Availability	1H00	2H00	1Q00	1Q00	2H00	1Q00	3Q00

Table 2. Makers of low-cost PCs will have an entirely new assortment of processors to choose from in 2000, including the first non-Intel Socket 370 chip and Intel's first highly integrated processor.

Mobile Processors Get Hungrier, Faster

Intel continues to dominate the overall mobile processor market, but AMD came on strong in the retail segment with the K6-2P and K6-IIIP in 1999. Tipped off by the fact that some PC makers were using its less-expensive desktop processors in consumer notebooks, AMD introduced the "P" (for performance) line of mobile chips with higher power consumption—a maximum of 16 W, instead of the traditional 10-W ceiling. These processors were so successful that AMD dropped its lower-powered mobile line. AMD's Athlon, the most power-hungry of all PC processors, is far out of the mobile range; there won't be any mobile Athlon processors until late in 2000.

Intel's Mobile Celeron processors likewise moved to higher power levels, needed to support increasing clock speeds. The Katmai version of Pentium III was too power-hungry for mobile applications, even with the expanded envelope, but with Coppermine Intel was able to introduce Mobile Pentium III chips. Power consumption limits constrained these chips to 500 MHz, however.

Escalating power consumption is a fact of life with high-performance microprocessors; decreasing power-supply voltages, even with the square-law effect, aren't enough to offset increasing transistor counts, clock speeds, and capacitance. On the desktop, higher power is a pain, but it can be dealt with. In mobile applications, high power consumption creates problems both in dissipating the heat and with battery life. Further lowering the supply voltage reduces the power consumption but also cuts the top frequency.

In 2000, both Intel and AMD will attack part of this problem by supporting dual-voltage operation. Using an approach that Intel calls SpeedStep (formerly known by the code-name Geyserville) and that AMD has code-named Gemini, mobile processors will have two modes of operation: a lower-voltage, lower-power, lower-frequency mode for mobile use, and a higher-voltage, higher-power, higher-frequency mode for use when the system is plugged in. This approach will allow notebook systems to get closer to desktop speeds when, as is often the case, the notebook is plugged in and battery life is not an issue. The thermal limits of the smaller notebook systems remain, however, even when these systems are plugged into the wall, so some gap will continue to exist.

When Intel begins shipping Pentium III processors with SpeedStep in the first half of the year, there will be a large apparent speed boost. Note, however, that these processors are likely to be marketed by their higher-power speed; when they are operating on battery power, the speed boost will be less dramatic. AMD will support dual-voltage operation, starting in the first quarter, with its K6-2+ and K6-III+ processors; its first mobile Athlon processor isn't due until the second half.

Startup Transmeta is one wild card in the mobile area; its processor is expected to deliver good performance with very low power. We'll have more on Transmeta next week.

AMD's K6-2+ and K6-III+ are likely to be the last processors to support the venerable Socket 7 interface. VIA plans to begin shipping its Joshua processor, formerly known as Gobi and Jedi, in the first quarter of 2000. The company plans to market the chip as the VIA Cyrix III. This chip combines an enhanced version of the M II CPU core, code-named Cayenne, with a 256K on-chip L2 cache and a Socket 370 interface. The enhanced CPU core has a faster floating-point unit, dual-issue MMX, and 3DNow support, bringing it up to the level of the K6-2 and K6-III.

The emergence of a pin-compatible Celeron competitor could have a considerable effect on the market if VIA is able to achieve comparable speeds. Unlike Intel, VIA doesn't have a high-end line to protect, so it will support bus speeds of up to 133 MHz; Intel has, so far, limited Celeron to a plodding 66-MHz bus and isn't likely to go beyond 100 MHz in 2000.

Joshua appears to be the end of the line for processors from the Cyrix design team. VIA laid off most of the team working on the next-generation Jalapeno core, which is now very unlikely ever to reach the market. In the second half of the year, VIA plans to launch its first chip to come from the Centaur team, code-named Samuel (formerly known as the C5 at Centaur). This processor is based on the core once known as the WinChip 4, which is a deeply pipelined version of the WinChip 3 (which was, in turn, a large-cache version of WinChip 2). Unlike the stillborn WinChip 4, however, which was to use a Socket 7 interface, Samuel will be mated to Socket 370. Because it has a more streamlined CPU core and uses a large L1 cache instead of an on-chip L2, Samuel will have a much smaller die size than Joshua. A small die is essential for reaching the low price points where VIA is most likely to succeed.

VIA also plans to begin sampling its first highly integrated processor by the end of 2000. Designed to compete with Timna, this processor presumably will combine the Samuel processor with one of VIA's integrated system-logic/graphics chips. This chip probably will not be in volume production until 2001.

Advancing the High End

The big event of 2000 at the high end will be Intel's introduction of its next-generation PC processor, code-named Willamette. This is the only entirely new CPU core likely to hit this market in 2000. So far, little has been revealed about

PowerPC's Big Event: G4

The world of Macintosh processors is a lot simpler than the x86 world, with only two suppliers selling largely the same parts—and with only one customer. After being anchored by the 750 (G3) processor for some time, the Mac got a big boost from the G4, which Apple began shipping in August. IBM, which opted out of Somerset and did not initially have rights to the G4, continued to supply Apple with G3 processors but appeared ready to phase out of the Mac processor market. Then, presumably encouraged by Apple's suprising robustness and by Motorola's difficulty in yielding high-speed G4 processors, IBM struck a deal with Motorola to gain rights to the G4 processor, which it will begin shipping early in 2000.

Largely because of its short pipeline, the G4 lags Pentium III and Athlon clock speeds: Apple's top clock speed is only 450 MHz, barely more than half of the 800-MHz top speed achieved by both Athlon and Pentium III. Of course, it is performance, not clock speed, that really matters, but this is hard to communicate to consumers. Furthermore, despite the greater performance per cycle of the G4 processor, on most applications this efficiency is not enough to overcome the large lag in clock speed.

The PowerPC G3 processor does well in notebooks, where its low power consumption enables it to achieve nearly the same speeds as on the desktop while delivering excellent battery life; Apple offers a 400-MHz G3 notebook, matching the top speed of the G3-based iMac. No G4 notebooks have yet appeared, however.

In 2000, Motorola will roll out an enhanced G4 processor with a deeper pipeline that should enable significantly higher clock speeds. In addition, IBM's process technology edge should enable it to deliver faster processors than Motorola has been able to yield.

this processor, other than the fact that it is an entirely new core and is intended to achieve both higher clock speeds and higher performance at a given speed.

Until Willamette is ready, Intel will have to depend on Coppermine. The limited availability of 733-MHz Pentium III processors suggests that Intel has had yield problems at the high end of the speed range; it appears that Intel pushed harder than it otherwise would have in response to Athlon's speed edge. During Christmas week, Intel launched 750- and 800-MHz Pentium III processors, but availability of systems lagged. Intel apparently couldn't stand to let AMD end the year with a higher top clock speed, even if Intel's top speed was essentially unavailable at the time. AMD seems to have more headroom, but Intel is an old master at tweaking chip designs and processes for higher clock speeds. The company disclosed at IEDM a notched-poly enhancement to its 0.18-micron process that should enable another round of speed increases, and it will disclose a higher-speed version of Pentium III at ISSCC.

AMD won't have a new core until 2001, but it plans to roll out two enhancements to the Athlon line in 2000. The first, code-named Thunderbird, is due midyear and will be the first Athlon processor to incorporate an on-chip L2 cache. Later in the year, AMD plans to deliver another version, code-named Mustang, which will be tuned for the copper process and should deliver another clock-speed boost. Mustang will also incorporate various power-reduction refinements and will implement the Gemini technology, enabling the first mobile Athlon processor.

AMD's original K8 project appears to have been scrapped, with the next-generation SledgeHammer processor being derived from the Athlon design. When it debuts in 2001, SledgeHammer will mark the debut of AMD's 64-bit extensions to the x86 instruction set, widening the architecture split that began with 3DNow and SSE.

Dividing Up the Pie

The outcome of the speed race between Intel and AMD is impossible to predict, but it is likely the two will stay very close in performance. AMD is starting out with a strong product and a small market share at the high end, leaving plenty of room for growth. The 0.18-micron Athlon, already in production, should hold its own very well against Coppermine; the next question is how Thunderbird and Mustang will fare against Willamette.

AMD continues to strive for 30% market share by the end of 2001, a goal that is not impossible but is certainly a huge challenge. If it can keep its ASP up, the company should be nicely profitable with a 20% share. Unless AMD runs into problems with its 0.18-micron process or the ramp of the Dresden fab, it should have the capacity to reach a 30% share; the bigger concern is how many high-end PC buyers, especially in businesses, will buy AMD-based systems.

The value market will become considerably more complex in 2000. VIA plans to treat its PC-processor business just like the chip-set business, leveraging close foundry and motherboard-maker relationships and operating with thin profit margins. VIA hopes to be the economy processor leader—a role it could play, if all goes well, but one that is not without its challenges. So far, Intel seems content not to participate in the market for under-$50 processors—but it is worth remembering that Intel surprised many in the industry when it did not abdicate the market for $60-to-$90 processors. Just what role Timna will play remains to be seen, but it is likely to be a significant factor in at least part of the value space.

VIA's primary competition is more likely to come from AMD than from Intel. In the unlikely event that AMD is capacity constrained, it will focus its wafers on the much more profitable Athlon. But unless something goes terribly wrong with its fabs, AMD should have plenty of capacity as

PC Processor Events of 1999

Intel began the year by introducing 366- and 400-MHz versions of Celeron and slashing prices (*MPR 1/25/99-04*, p. 18). It followed by increasing the top speed to 433 MHz (*MPR 3/29/99-msb*, p. 4) and then 500 MHz (*MPR 8/2/99-msb*, p. 5). Intel cut prices even more frequently than usual in 1999 (*MPR 2/15/99-msb*, p. 4; *MPR 5/31/99-msb*, p. 4; *MPR 8/2/99-msb*, p. 5; *MPR 9/13/99-msb*, p. 5; *MPR 11/15/99-msb*, p. 13; and MPR *12/27/99-msb*, p. 4). Intel settled with the FTC (*MPR 3/29/99-ed*, p. 3), at least for now.

Intel introduced Dixon as Mobile Pentium II at 266 to 366 MHz and, with half the cache disabled, as Mobile Celeron at 266 and 300 MHz (*MPR 1/25/99-05*, p. 20). Mobile Celeron was boosted to 333 MHz (*MPR 4/19/99-msb*, p. 4), and then to 400 MHz (*MPR 6/21/99-msb*, p. 4) and 466 MHz (*MPR 10/6/99-msb*, p. 4). Mobile Pentium II also increased to 400 MHz (*MPR 6/21/99-msb*, p. 4), its final speed.

Intel rolled out Katmai as Pentium III at 450 and 500 MHz (*MPR 3/8/99-01*, p. 1) and later raised the top speed to 550 MHz (*MPR 5/31/99-msb*, p. 4) and 600 MHz (*MPR 8/2/99-msb*, p. 5). The Coppermine version debuted at speeds up to 733 MHz (*MPR 10/25/99-01*, p. 1) and made a year-end push to 800 MHz (*MPR 12/27/99-msb*, p. 4). Coppermine also yielded the first Mobile Pentium III, at speeds of up to 500 MHz (*MPR 10/25/99-01*, p. 1). Coppermine was struck by a startup bug that briefly halted shipments by at least one PC maker (*MPR 12/27/99-msb*, p. 4).

Intel disclosed details of its 0.18-micron process (*MPR 1/25/99-06*, p. 22), and used Dixon as its first production vehicle (*MPR 6/21/99-msb*, p. 4).

AMD introduced the mobile K6-2 at 333 MHz (*MPR 1/25/99-msb*, p. 4) and then introduced the “P” version at up to 380 MHz (*MPR 3/29/99-msb*, p. 4). The top speed was later boosted to 450 MHz (*MPR 10/6/99-msb*, p. 4). AMD’s desktop K6-2 was raised to a top speed of 475 MHz (*MPR 4/19/99-msb*, p. 4) and then 533 MHz (*MPR 12/6/99-msb*, p. 4).

AMD rolled out the K6-III at 400 and 450 MHz (*MPR 3/8/99-05*, p. 22) and added mobile versions at up to 380 MHz (*MPR 6/21/99-msb*, p. 4) and later 450 MHz (*MPR 10/6/99-msb*, p. 4).

AMD announced the K7 as Athlon at speeds to 600 MHz (*MPR 7/12/99-01*, p. 1); when it began shipping the chip (*MPR 8/23/99-01*, p. 1), the top speed was raised to 650 MHz. AMD followed up with 700-MHz (*MPR 10/6/99-msb*, p. 4) and 750-MHz (*MPR 12/6/99-msb*, p. 4) versions of Athlon.

AMD revealed plans for server versions in 2000 and disclosed that the K8, now known as SledgeHammer, will implement 64-bit extensions to the x86 instruction set (*MPR 10/25/99-06*, p. 24). AMD later disclosed its roadmap for 2000 (*MPR 12/6/99-msb*, p. 4).

IDT announced the long-delayed WinChip 2 and a detailed roadmap (*MPR 3/29/99-00*, p. 1), though few parts ever shipped and IDT subsequently decided to get out of the PC processor business (*MPR 8/2/99-msb*, p. 4).

Cyrix raised the M II speed to PR366 (*MPR 5/10/99-msb*, p. 4). **National** decided to sell Cyrix (*MPR 5/31/99-02*, p. 12) just as Cyrix unveiled a new roadmap (*MPR 5/31/99-02*, p. 13).

VIA Technologies bought Cyrix (*MPR 7/12/99-02*, p. 5) and then IDT’s **Centaur** subsidiary (*MPR 8/23/99-msb*, p. 4; and *MPR 9/13/99-ed*, p. 3).

Rise Technology laid out a new roadmap for reaching the mainstream PC market (*MPR 5/31/99-03*, p. 15) and licensed its mP6 core to SiS (*MPR 11/15/99-msb*, p. 4) but pulled the plug on future PC processors.

Motorola disclosed plans for a second-generation G4 processor (*MPR 10/25/99-02*, p. 10). **IBM**, after initially passing on manufacturing the G4, decided to make the chips for Apple after all (*MPR 11/15/99-msb*, p. 5).

Fab 25 converts to 0.18-micron and Fab 30 ramps up. Given this capacity, AMD could be very aggressive at the low end with the K6-2+, which will be a much smaller die than Joshua. VIA will have the advantage of compatibility with Intel’s Socket 370 interface, but it is unclear that Joshua will be able to match Celeron’s performance points; it almost surely will not match Celeron’s clock speeds.

One of the biggest challenges facing the PC processor industry in the long run is that the processors have outpaced the needs of the vast majority of users. New applications will continue to benefit from faster processors, but for the vast majority of users, last year’s microprocessors—i.e., this year’s economy processors—are totally adequate. This trend plays into VIA’s strengths.

The saving grace for the processor business would be compelling new software with widespread appeal that makes even the fastest processors seem slow, but no such software is on the horizon (outside of certain games and content creation, which don’t have truly widespread appeal). In the absence of such software, it will be hard to maintain high-end processor demand in the long term. For at least a year or two, however, Intel no doubt will be able to keep the performance processor market propped up with advertising; after all, consumers’ purchases are mostly based on what they have been emotionally manipulated to want, not on their actual needs.

Although the PC processor industry has consolidated from five vendors to three, it remains vigorously competitive.

As long as Intel has at least one strong competitor, the industry will benefit from the lower prices and more aggressive product roadmaps that inevitably result. If either AMD or VIA executes well, Intel could see its market share dip a few percent in 2000, but it is likely to feel a larger financial effect from price competition and weakening high-end demand than from loss of share. ◇

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