P6 Reaches All Market Segments

High-End, Low-End, Mobile Parts Leave No Room for Pentium

by Linley Gwennap

With a wide-ranging set of announcements, Intel has thrust its P6 processor family into all of its PC market segments: basic (low-end), performance (high-end), and mobile PCs. Although a few remaining gaps provide some openings for the Pentium family, these gaps will quickly close. The death of the Pentium line is clearly in sight.

The new parts include the first Celeron processor, code-named Covington. This processor is a 266-MHz version of the standard Deschutes P6 CPU, but without a level-two cache on the processor module. At the high end, Intel added 350- and 400-MHz Pentium II products, also based on the Deschutes CPU. These parts are the first to use a 100-MHz system bus, 50% faster than the current bus. The company also rolled out Mobile Deschutes processors at 233 and 266 MHz.

Not content to stop there, Intel released new chip sets (see MPR 4/20/98, p. 18) for each of the new CPUs and repriced all of its other processors. The revised pricing includes Pentium II products below $200 and the new Celeron part at $155. Although the company doesn't expect Celeron systems to reach store shelves until June, PCs using the new mobile and high-end processors are already available.

Covington Aims to Kill Socket 7

The first Celeron part has one purpose: eliminate Pentium/MMX, and therefore Socket 7, from Intel's product line as quickly as possible. This change prevents Intel's competitors from continuing to exploit Socket 7 for their own benefit. No vendor other than Intel offers Slot 1 processors today, and AMD in particular is contractually barred from Slot 1, so Intel is motivated to make this changeover happen.

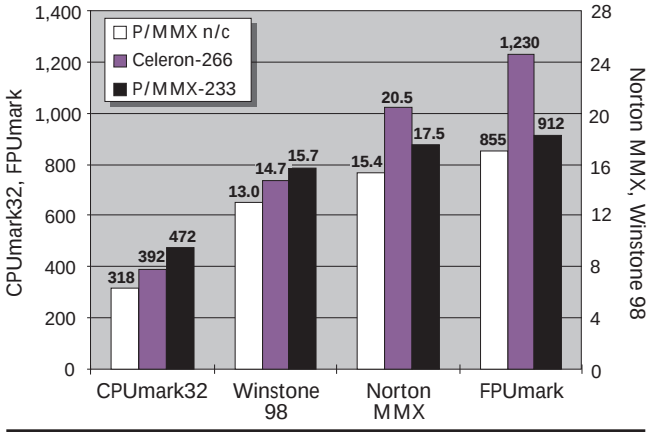

Figure 1. The Celeron-266 is 6% slower than a typical Pentium/MMX-233 system on standard business applications but does better on FP- and MMX-intensive programs. See sidebar, page 16, for configuration details. n/c=no L2 cache (Data source: Intel)

Intel had previously expected the Slot 1 transition to occur naturally during 2H98 as market needs grew beyond the performance of the Pentium/MMX line. Growing interest in the sub-$1,000 market, however, seems to have caught Intel by surprise. Without a change in plan, Pentium/MMX might have remained a viable product in the low-end PC market into 1999.

Sometime last fall, we believe, Intel decided to create new products for low-end PCs (which the company now calls basic PCs). Under pressure to quickly create a new product, the company had no time to make significant changes to its CPU silicon. Fortunately, Intel sells its P6 processors only in a module; thus, the company could change the product simply by altering the module.

In the tradition of the 386SX and 486SX, Covington is a mainstream processor that has been crippled to make it less desirable. This technique allows Intel to charge a premium for the full-fledged Pentium II while offering Covington at a price low enough to displace Pentium/MMX from the market. To reposition Covington, Intel removed the level-two (L2) cache from the module, a change that reduces performance by 43% on CPUmark32 compared with a Pentium II at the same clock speed.

While they were at it, Intel's designers also stripped off the attractive black case from the module and simplified the design of the module's PC board. Without the outer case, the Celeron module requires different card guides than does the standard Pentium II, although both plug into the same connector. The Celeron card guides are basically the width of a PC board, whereas the Pentium II guides accept the much fatter module. In total, these changes to the module result in a modest saving of about $10 , or 15%, in per-unit manufacturing cost.

Performance Close to Pentium/MMX-233's

As Figure 1 shows, a Celeron-266 ranges from somewhat below to well above a Pentium/MMX-233 in performance, depending on the benchmark. This comparison assumes the Pentium processor has an L2 cache; a few PC makers have omitted the L2 cache from their sub-$1,000 systems, which greatly reduces their performance.

Celeron fares worse on standard Windows 95 applications, represented here by Winstone 98, but it outruns the Pentium/MMX-233 on applications that frequently use

MMX or floating-point instructions, such as multimedia and 3D games. This strength should help Celeron in the consumer market, where low-cost PCs have been most popular. But on the applications that most people use every day, the Celeron processor is slightly slower than the Pentium/MMX-233.

In all cases, the lack of an L2 cache pushes the performance of the Celeron-266 well behind that of a Pentium II-266 with 512K of L2 cache. In fact, the Celeron-266 is slower than a 233-MHz Pentium II on most benchmarks.

Future Celeron products will be based on a new CPU chip, code-named Mendocino, that includes an on-chip L2 cache. This design will greatly reduce the per-clock performance drop from Pentium II. Changes to a CPU chip, even simple ones like adding cache, take much longer than alterations to the processor module; assuming the two designs were started at the same time, this difference explains why Mendocino will not be available until late this year, about six months after Covington.

With significantly better performance than Covington, Mendocino will be an attractive part. The danger for Intel is that Covington's lack of superiority over Pentium/MMX could make a bad first impression for the new Celeron line.

Covington Acceptance Will Be Limited

Intel is initially pricing Covington at $155. This price makes Covington slightly more expensive than a Pentium/MMX-233, which now lists for $134 (see MPR 4/20/98, p. 27). The difference between these two prices is far more than the $3–$4 needed to add an L2 cache to a Pentium/MMX system, allowing it to outperform a Covington system on most applications. Even if Intel drops Covington's price to match that of the Pentium/MMX, which is likely by 3Q98, an OEM could easily save enough money to cover the cost of the L2 cache by using a non-Intel Pentium chip set.

Thus, Covington appears to be merely a useless appendage to Intel's product line, a chip for the benchmark-impaired. It is neither faster (on most applications) nor less expensive than the product it replaces. Yet we expect Covington will be accepted by many PC makers and PC buyers, for different reasons.

PC makers are attracted to Covington because it allows them to build a low-end product line around Celeron. True, the first Celeron part is not a winner, but the investment in building motherboards around the new 440EX chip set and the "skinny" Slot 1 can be leveraged to future Mendocino-based products, which will be quite competitive. The 440EX also provides AGP capability at a low price point.

Some PC makers will choose to stay with Socket 7 motherboards, at least until Mendocino is available. These vendors must choose between redesigning their boards for a Socket 7 chip set with AGP (which Intel doesn't plan to offer) or getting along without AGP. The first strategy requires creating a new motherboard with a short lifetime, and the second is less competitive in the market.

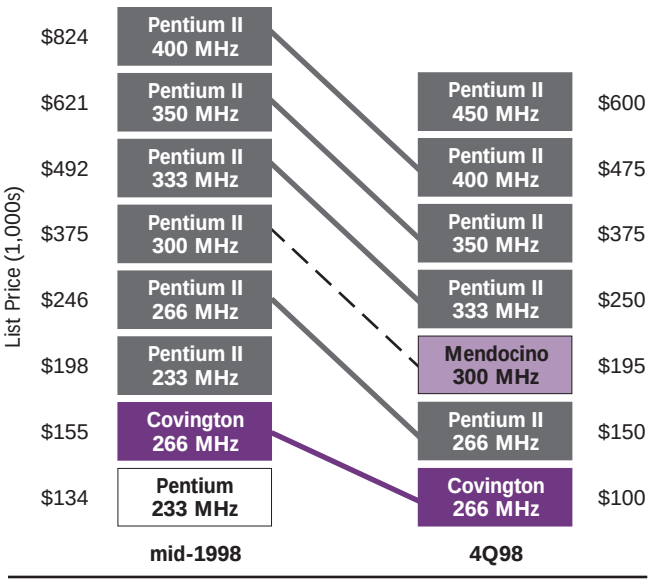

Figure 2. Repositioning Intel's product line around the new Celeron standard may require faster-than-usual price cuts in 2H98. (Source: 2Q98 prices from Intel; 4Q98 prices are MDR estimates)

We expect both Covington and Pentium/MMX will coexist in Intel's lineup, with the two splitting Intel's low-end volume roughly equally in 2H98. In the total sub-$1,000 PC market, however, Covington will probably be swamped by Socket 7 parts from Intel and others.

Knowledgeable end users should avoid Covington, but many people don't pay attention to benchmarks. They will be drawn to the Covington system by its Intel brand name and possibly the Celeron name, if Intel advertises it aggressively. Most important is the 266-MHz clock speed, which makes Covington faster than a 233-MHz Pentium/MMX in the eyes of the uninformed buyer.

Although they may help Covington, these clock-eyed buyers ultimately make Intel's life difficult. Once the 266-MHz Celeron is established in the low-end market, it will be difficult to move the Pentium II-233 into this market, as it has a lower clock speed. Thus, this speed grade is likely to fade away after Covington's release. The Pentium II-266 becomes a dicey proposition but could be positioned above the Celeron-266 with the strength of the Pentium II name.

Mendocino poses another problem. Since a 266-MHz Mendocino would also be called a Celeron-266, Intel won't be able to market Mendocino at that speed. Boosting Covington to 300 MHz makes these problems worse, so Intel's next Celeron part will probably be a 300-MHz Mendocino in 4Q98. This part should offer performance similar to that of the Pentium II-300, replacing that part in Intel's lineup. That would leave the Pentium II-333 at the bottom of the performance PC space, as Figure 2 shows.

To accomplish these changes, Intel will need to cut its prices more rapidly than usual during 2H98. This is likely to cause the company's average selling price (ASP) to drop during this period. Intel must also ensure that it has plenty of

Benchmark Details

For the data shown in Figure 1, Intel tested the Pentium/MMX with the 430TX and optional 512K L2 cache; Celeron with the 440EX. Both use 32M of SDRAM, Seagate ST32122A EIDE hard drives, and STB Velocity 128 PCI graphics cards with 4M of SGRAM in 1,024 × 768 × 16 mode.

For the data shown in Figure 3, Intel tested all the Pentium II processors with the 440BX chip set, 32M of SDRAM (64M for Winstone NT), Seagate ST34501W hard drives, and Matrox Millennium II AGP cards with 4M of SGRAM in 1,024 × 768 × 16 mode.

In this article, CPUmark refers to Ziff-Davis' CPUmark32; FPUmark is the Ziff-Davis FPU WinMark; Norton MMX is the Norton Multimedia Benchmark from Norton Utilities 3.0; and Winstone 98 is Ziff-Davis's Business Winstone 98 benchmark. These four tests were all run under Windows 95. Winstone NT refers to Ziff-Davis' High-End Winstone 98 benchmark run under Windows NT. SPECint95 and SPECfp95 are the baseline versions of the SPEC95 metrics and are run under UnixWare 2.0.

For more performance information, check Intel's Web site at *developer.intel.com/procs/perf*.

0.25-micron capacity, as this plan virtually eliminates the 0.28-micron Klamath from the product line at that time.

P6 Bus Speeds Up to 100 MHz

At the other end of the line, Intel is boosting performance by increasing the system-bus speed along with the CPU speed.

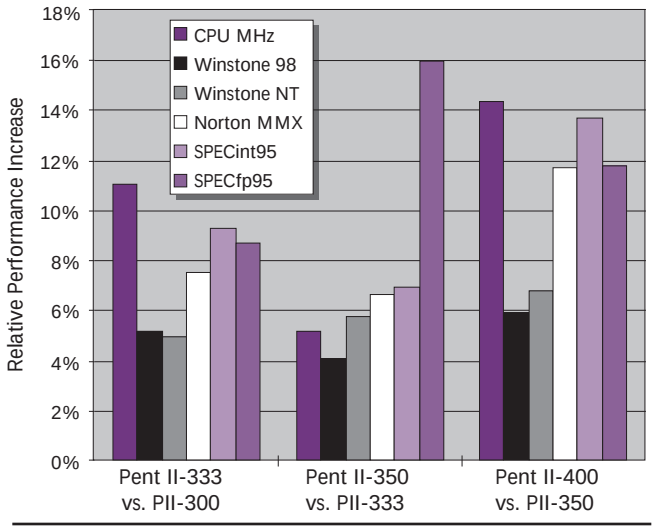

Figure 3. The 350-MHz Pentium II achieves a surprisingly large performance benefit over the 333-MHz version due to a 50% increase in system-bus speed. The gain is greater on programs that frequently access main memory. See sidebar above for configuration details. (Data source: Intel)

The shift to a 100-MHz bus increases the bandwidth to 800 Mbytes/s, boosting the performance of the processor more than the CPU speed alone would indicate.

Figure 3 shows that the performance increase from a 300-MHz Pentium II to a 333-MHz version on the Winstone 98 benchmark is about 5%, despite the 11% clock-speed increase. Moving to the 350-MHz processor and 100-MHz bus provides only a 5% clock-speed increase, but the performance gains are similar: 4% under Windows 95 and 6% on Windows NT. Thus, the faster bus allows Intel to squeeze an extra speed grade into its product line, selling both 333- and 350-MHz parts.

The impact of the 100-MHz bus varies depending on the application. The biggest gains come on programs that make the most accesses to main memory, of course; these include programs that manipulate images and other large data sets. SPECfp95, for example, increases by 16% when moving from the Pentium II-333 to the 350-MHz version.

The 400-MHz Pentium II is even faster, of course. That part achieves 15.8 SPECint95 and 11.4 SPECfp95 (base). Only Digital's 21164 and HP's PA-8200 have posted better integer scores, although Pentium II still falls well behind all the major RISCs in floating-point performance.

This performance comes with the usual costs in both dollars and watts. The 400-MHz part was introduced at a list price of $824, a bit higher than most of Intel's other new parts over the past few years. Introducing both the 350- and the 400-MHz chips at the same time allows Intel to charge a premium price for the faster product. This price is likely to fall by 40% or more in 2H98, as Figure 2 shows.

The power dissipation of the 400-MHz Pentium II processor is 28 W (maximum), including the 2.0-V Deschutes CPU and the 3.3-V SRAMs. While this is a bit higher than for the 333-MHz Deschutes, it is still much lower than the 43 W posted by the 300-MHz Klamath processor, which uses older 0.28-micron process technology.

With the new 100-MHz bus, future Pentium II products will use multiples of 50 MHz rather than 33 MHz. The 0.25-micron Deschutes will ship at 450 MHz later this year, but that chip isn't likely to reach 500 MHz. In 1999, Intel will introduce the Katmai processor, first in 0.25-micron and later in 0.18-micron CMOS, at speeds of 500 MHz and beyond.

P6 Hot for Notebooks

The Mobile Pentium II processors use the same Deschutes CPU chip as their desktop brethren but run the chip at only 233 or 266 MHz. The low clock speed is due to the reduced supply voltage: 1.7 V instead of 2.0 V. The combination of low voltage and low speed produces the low power dissipation needed for a notebook processor. At 266 MHz, the Mobile Pentium II CPU dissipates 7.8 W. In comparison, a Mobile Pentium/MMX-166 (P55C) CPU dissipates 7.7 W, although the 0.25-micron Mobile Pentium/MMX chips dissipate much less power.

Note that these power figures are Intel's thermal design power (TDP) rating and are not directly comparable to the maximum ratings of the desktop products. They represent a "typical maximum" and do not include the L2 cache.

The Mobile Pentium II processors will be sold in two packaging options: a Mobile Module compatible with the Pentium/MMX Mobile Modules (see MPR 2/17/97, p. 9) and a new minicartridge. The Mobile Module contains the Deschutes CPU, 512K of L2 cache, and the 440BX north bridge (see MPR 4/20/98, p. 18); the module has PCI and DRAM interfaces that connect to the motherboard. Because this module plugs into many existing notebook designs without modification, several vendors have already announced Pentium II notebook systems.

The minicartridge contains only the Deschutes CPU and 512K of L2 cache, making it functionally equivalent to the standard Pentium II module. The minicartridge, shown in Figure 4, is much smaller than the desktop module and smaller than even the Mobile Module, since it lacks the north bridge and many discrete components. It is also thinner, protruding 8–9 mm above the surface of the motherboard rather than 10 mm for the Mobile Module. Thus, the minicartridge can be used for smaller, thinner notebooks.

For ultrathin notebooks, such as the IBM 560, even the minicartridge is too big. The only solution for these designs is to solder the CPU chip directly to the motherboard. So far, Intel has resisted supplying the CPU chip itself to PC makers, but it may make an exception if there is no other alternative. Once Mobile Mendocino is available, Intel is likely to relent and sell the CPU chip alone, since a minicartridge would contain the CPU chip and little else.

In the minicartridge, the new Mobile Pentium II processors at 233 and 266 MHz carry a list price of $466 and $696, respectively; Intel charges $76 extra to supply the processor in a Mobile Module, a relative bargain since the module price includes the $52 BX chip set.

While Intel is charging a stiff premium for the maximum performance, the 233-MHz part is priced to begin pushing the Mobile Pentium/MMX chips out of the mobile lineup. On Winstone 98, the Pentium II-233 offers a 7% performance advantage (roughly one speed grade) over the Pentium/MMX-266 but carries only a small price premium of $43. Intel's most popular notebook chips are currently the 166-MHz and 200-MHz Pentium/MMX, which list for as little as $95, so the Mobile Pentium II parts won't displace these chips soon.

Faster Mobile Parts to Appear Slowly

CMOS circuits run more slowly at lower voltages, so Intel can't simply crank up the clock on its mobile parts to offer more performance. As a result, the desktop products deliver a 50% clock-speed advantage over the mobile versions.

As the speed yields on Deschutes improve enough for Intel to begin shipping 450-MHz desktop parts, the company should also be able to push the Mobile Pentium II to 300 MHz. At that speed, the CPU should dissipate 8.8 W, just over the 8-W limit Intel has set for previous mobile processors. This overage may prevent some notebook makers from using the 300-MHz processor unless they add more cooling to their systems. Even if Intel could yield a 333-MHz part at 1.7 V, it would be hotter yet, so Intel probably won't push Mobile Deschutes beyond 300 MHz.

Instead, the company is more likely to move Mendocino into the mobile market. Its integrated L2 cache reduces system power, since the L2 cache is smaller and doesn't need to communicate off-chip. With no external cache, Mendocino also requires less board area than Mobile Deschutes. The power savings from the L2 cache should allow Intel to offer a 333-MHz Mobile Mendocino

Price & Availability

The Mobile Pentium II processors, as well as the 350- and 400-MHz Pentium II processors, are available immediately. The Celeron-266 is currently sampling, with volume shipments expected in May. In a Mobile Module, the Pentium II-233 and -266 carry 1,000-piece list prices of $542 and $772, respectively. See table on page 27 for other pricing.

For more information on the mobile processors, check the Web at *developer.intel.com/design/mobile*; information on the new Pentium II processors is at *developer.intel.com/design/PentiumII*.

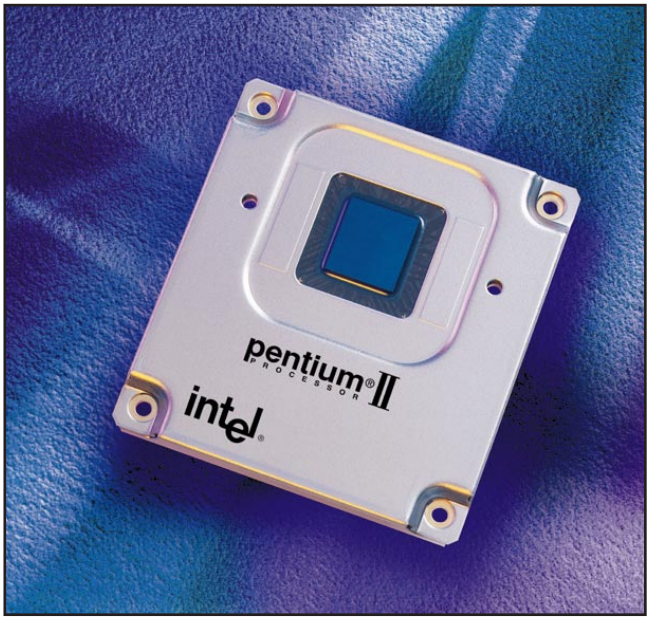

Figure 4. The minicartridge (shown here actual size) is functionally identical to the standard Pentium II module, but it measures only 60 mm × 56 mm × 7 mm, making it better suited for space-constrained mobile systems.

within the same power limit as the current mobile products. Mendocino is likely to appear in the mobile lineup in 1H99.

With only two more mobile P6 products due in the next year, it will be more difficult to erase Pentium/MMX from the mobile line than from the desktop line. Intel prefers to fill out its mobile line with four to five different speed grades at any given time, so even with the 300-MHz Pentium II available, in 2H98 Intel will probably still be shipping one or two Pentium/MMX speed grades for the low end of the notebook market. The Pentium/MMX-266, just introduced last quarter, could persist in Intel's line through 1H99, albeit at the very low end.

Price Reductions Come Early, Often

Intel chose to roll out new pricing for all of its desktop processors as part of the April 15 product introduction rather than waiting until the end of April for the usual round of price cuts. (Mobile prices will change as usual on April 27.) This seemingly small schedule change trims the average price of many parts by 4–5% for the quarter, giving OEMs a small gift. This benefit comes on the heels of an unusual midquarter price cut on the Pentium II-333 (see MPR 3/30/98, p. 5).

The 233-MHz Pentium II now carries a list price of $198, well into the sweet spot of Intel's line. As a result, we expect P6 unit shipments will exceed Pentium unit shipments in 2Q98 for the first time. The low end of Intel's desktop lineup is now the Pentium/MMX-200, at $95.

The price cuts on most of the desktop processors averaged 30% from 1Q98 prices, a bit steeper than Intel's typical price cuts. To drive Pentium/MMX and Socket 7 completely out of its desktop product line in 2H98, Intel will have to continue these rapid price cuts.

P6 Proliferation Populates PC Space

This prolific series of announcements shows Intel taking full advantage of its 0.25-micron process and the Deschutes CPU. The new process provides simultaneous benefits in speed, cost, and power. By this fall, Intel will be building virtually all of its processor products around a single CPU, using variations in clock speed, cache size, voltage, and packaging to generate several complete product lines. This strategy creates enormous economies of scale.

With the P6 taking over Intel's product lines, the end is near for the venerable Pentium CPU. Pentium will disappear from the desktop in a matter of months, but it may cling stubbornly in the mobile line for up to a year. Intel's customers shouldn't make plans for new Pentium systems. Intel's competitors, who still rely on Pentium's Socket 7, will soon find out if there is life after Intel. M