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Pentium II Debuts at 300 MHz

Better Integer Performance Than All But Fastest Alpha

by Linley Gwennap

For the first time in 18 months, Intel has introduced a new high-end processor, Pentium II (PII), now shipping at clock speeds of 233 and 266 MHz. In addition, the company plans to ship a 300-MHz version of the chip this summer, further boosting its top-of-the-line performance. Even after that, Intel won't sit still for long; a 0.25-micron version of Pentium II, code-named Deschutes and due around the end of this year, will reach speeds of at least 400 MHz, according to the company.

Pentium II, formerly known as Klamath (see MPR 2/17/97, p. 1), is based on the P6 CPU used in Pentium Pro but adds Intel's MMX multimedia extensions and features to improve performance on 16-bit code. The chip includes 16K instruction and data caches, twice the size of Pentium Pro's primary caches, but uses a slower bus than Pentium Pro does to access the external L2 cache.

The 233- and 266-MHz parts are aimed at the PC market and offer better performance than any other x86 processor. The initial pricing for the parts is high: $775 for the faster part, $636 for the 233-MHz version, both with 512K of cache. But given Intel's typical rapid price cuts, we expect the price of the 233-MHz part to fall below $500 by the end of this year (see MPR 5/12/97, p. 23), making Pentium II attractive to holiday shoppers looking for a premium PC.

Intel will sell Pentium II only on modules that contain the CPU and level-two (L2) cache; the processor will not be available as a standalone chip. The module is functionally similar to Pentium Pro but uses a PC board instead of a ceramic substrate. Earlier plans for Intel to offer 256K and 512K caches have been simplified; the company will offer only the 512K version.

Closing the Gap With RISC

The 300-MHz chip is intended mainly for workstations and carries a hefty price tag: $1,981. Although this is a record-setting price for an Intel processor, it is well within bounds for workstation CPUs, which often reach $2,000 or even $3,000. At 11.6 SPECint95 (base), the PII-300 will deliver better integer performance than any RISC processor shipping today except the 500-MHz 21164, as Figure 1 shows. By the time the 300-MHz chip ships, however, HP and Digital plan to offer faster processors. At 6.8 SPECfp95 (base), the PII-300 offers less than half the floating-point performance of most high-end RISC processors.

As Intel increases its emphasis on the workstation market, it has taken a page from the RISC vendors. Because of the bell-shaped yield curve of CMOS processors, these vendors have often announced high-end speed grades after skimming a handful of the fastest parts off the production line. In the past, Intel has been loath to follow suit, not announcing parts until it could build them in the volumes required by the PC market. This time, by setting a high price, Intel can dampen PC demand for its fastest speed grade while supplying it in the smaller quantities needed by workstation makers. This technique allows Intel to boost its peak performance by about 10% without any design or IC process changes.

With RISC workstation vendors Digital, HP, and IBM

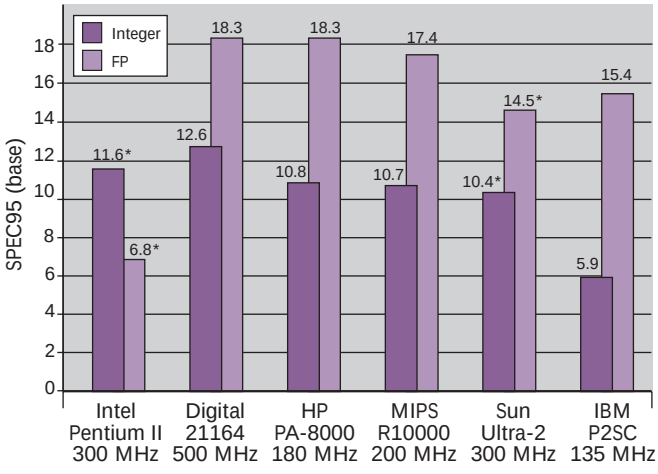

Figure 1. A 300-MHz Pentium II, with 512K of level-two cache, surpasses the integer score of most RISC processors but falls well behind on the floating-point tests. (Source: SPEC except *vendors)

joining Intergraph and Compaq in offering workstations based on Windows NT and P6 processors, we expect the market for these x86 workstations to grow considerably over the next few years. With Pentium II at 300 MHz and eventually faster, Intel can cover the needs of many low-end workstation users today, the recently disclosed FPU bug (see *www.MDRonline.com/P6/bug* for more details) notwithstanding. RISC-based systems, however, will still be needed to obtain maximum FP performance.

Half-Speed Cache Has Minimal Impact

Pentium II nestles snugly at the top of Intel's product line. According to the SYSmark tests, the PII-233 is 9% faster than a PPro-200 when running Windows NT applications, while the PII-266 is nearly 20% faster than the PPro-200, as Figure 2 shows. Due to the new chip's 16-bit enhancements, the difference on Windows 95 is more pronounced; even the PII-233 outruns the PPro-200 by 19%, while the PII-266 delivers nearly 30% more performance.

Most of this performance gain is due to the higher clock speeds. Pentium II also benefits from its 512K L2 cache; the Pentium Pro was tested with only 256K of cache. (Pentium Pro is available with a 512K cache, but this version is mainly used in servers, not PCs, due to its high price.) Pentium II loses some performance due to its half-speed L2 cache, but on these PC applications, the slower cache results in a loss of only a few percent of performance.

The effect of the slower cache is slightly greater on the SPECfp95 benchmark, where the PII-233 delivers less than 7% better performance than the PPro-200. This test contains several programs with large working sets. For most applications, however, the doubling of both the L1 and L2 caches will roughly compensate for the decrease in the bandwidth of the L2 cache bus.

For applications that take advantage of Pentium II's MMX capabilities, the increase will be much more substantial. Based on Intel's Media Benchmark, the PII-266 delivers 80% better performance than a PPro-200, which doesn't implement MMX, and 38% better performance than a 200–MHz Pentium/MMX (P55C). As Figure 3 shows, however, the increase varies widely, depending on the type of application and how much it takes advantage of MMX.

This data implies that, for non-MMX applications, a Pentium II would deliver slightly lower performance than a Pentium Pro at the same clock speed and with the same external cache. Although interesting to microarchitects, this point is otherwise moot, because Intel has no plans to release a version of Pentium II at the same 200-MHz clock speed as Pentium Pro, nor will it ship versions of Pentium II with less than 512K of external cache.

Coexisting With Pentium Pro

Although Pentium II would appear to supercede Pentium Pro, the two parts will coexist in Intel's lineup for the rest of this year. Pentium II is significantly more expensive than Pentium Pro, which today lists for $407 to $514, and will remain so for most of this year. Pentium Pro will continue to be popular in NT desktop systems and midrange servers, while Pentium/MMX serves as the mainstream PC processor throughout 1997.

Pentium II has other limitations that will prevent it from replacing Pentium Pro in high-end servers. The initial version is limited to single- and dual-processor systems. Although Pentium II, like Pentium Pro, could function properly in a four-CPU configuration, Intel feels the 66-MHz P6 bus doesn't have enough bandwidth to support the larger configuration with the faster CPUs.

Whereas the Pentium Pro cache has built-in error cor-

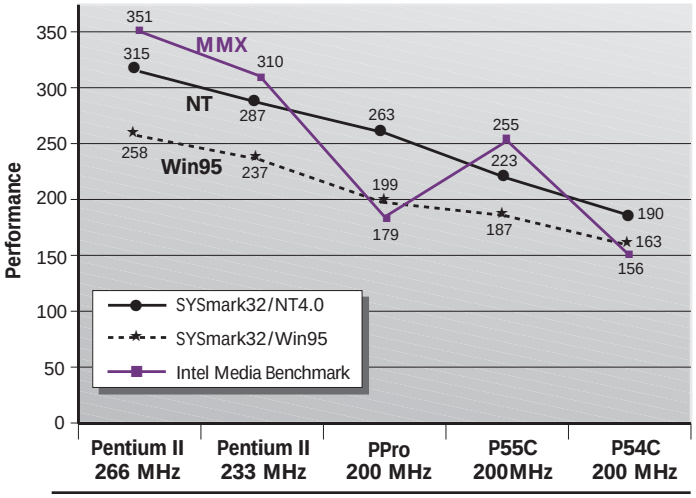

Figure 2. Even at 233 MHz, Pentium II outperforms Pentium Pro on a variety of benchmarks. Only the Intel Media Benchmark contains MMX code. All processors were tested with 512K of burst SRAM (except Pentium Pro had 256K), 32M of DRAM, a Matrox Millennium graphics card with 2M of WRAM in 1024 x 768 x 256 mode, and a Seagate ST32550W hard drive. The Pentium systems used a 430VX chip set and SDRAM; the P6 systems used a 440FX chip set with EDO DRAM. (Source: Intel)

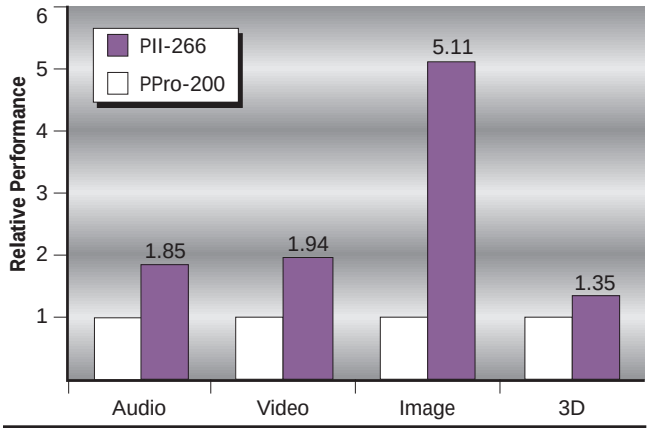

Figure 3. Individual components of the Intel Media Benchmark show a wide variation in the performance advantage of Pentium II over Pentium Pro. All but the 3D test use MMX. See Figure 2 caption for system configurations. (Source: Intel)

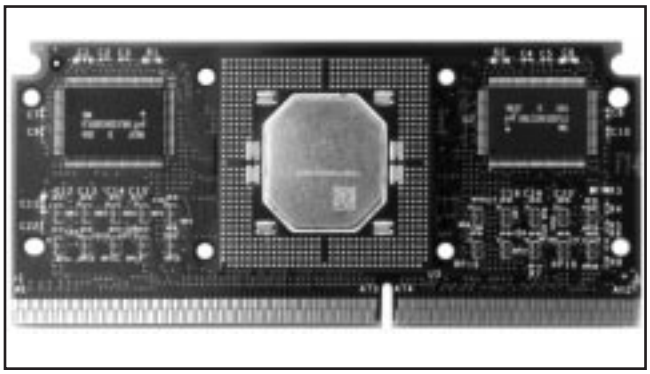

Figure 4. The Pentium II processor module contains a PC-board substrate that holds the Pentium II CPU chip, two L2 data RAMs, and various discrete components. The other side of the board has two additional L2 data RAMs and the L2 tag RAM.

Figure 5. The PC board is enclosed in a plastic case measuring 5.73 x 2.47 x 0.66 inches. The case provides physical protection, EMI shielding, and a decorative hologram. In systems, a large heat sink will be mounted onto a metal plate on the rear (not shown).

rection (ECC), the initial Pentium II modules do not. As ECC is a popular feature in servers, Intel plans to add ECC versions to its Pentium II lineup in the near future. These modules will cost about $30 more than the non-ECC versions, however. In addition, the error checking adds a cycle to all L2 cache accesses, degrading performance by about 4% on SPECint95. Thus, most desktop systems and low-end servers will stick with the non-ECC versions.

Since Pentium Pro will continue to be used mainly in servers, Intel plans to offer its server customers a version of that part with a 1M cache; Pentium II will be limited to 512K of cache for the next several months. Faster clock speeds, however, are not in the works for Pentium Pro.

Deschutes to Reach 400 MHz

Ultimately, Pentium II will completely displace Pentium Pro. Intel has committed to delivering a future Pentium II that supports the full four-processor configuration and caches larger than 512K. We expect to see these improved parts around the end of this year.

We believe the vehicle for these improvements will be Deschutes, a 0.25-micron version of Pentium II likely to be marketed under the same name. Although Intel plans to ship its first 0.25-micron parts in Q3, these parts will be extensions to the Pentium line (see MPR 5/12/97, p. 4). The company plans to ship a 0.25-micron P6 processor around the end of this year and claims such a device will eventually reach speeds of at least 400 MHz.

We expect Deschutes will ship initially at lower speeds but should reach 400 MHz by 2H98. The 1.8-V part will also be the first P6 chip for notebook systems; as Table 1 shows, the initial Pentium II processors, at 2.8 V, dissipate up to 42 W, suitable only for desktop systems. This power level includes the CPU and L2 cache; we estimate the Pentium II CPU alone will reach a maximum of 30 W at 300 MHz.

We expect Deschutes will also support bus speeds of up to 100 MHz, providing enough bandwidth to support the faster processor in four-way configurations. Larger L2 caches will ease bus-bandwidth demands even as the CPU frequency skyrockets. Although the 100-MHz bus will provide some performance improvement in uniprocessor desktop systems, the current 66-MHz bus will be adequate for uniprocessors at 300 MHz and perhaps even higher.

Pentium II Debuts New Package

Starting with Pentium II, Intel will ship its processors in the form of a module instead of as a standalone chip. This module, shown in Figures 4 and 5, is a daughtercard that contains the Pentium II CPU chip, the cache-tag chip, and the external L2 cache chips. This package, which Intel calls the single-edge contact (SEC) cartridge (see MPR 12/9/96, p. 4), plugs into a connector that Intel calls Slot 1. (Pentium processors plug into various sockets, the most popular being Socket 7.)

The bus between the CPU and the L2 cache is entirely contained within this module. The initial Pentium II modules operate this bus at one-half the CPU speed, up to 150 MHz for the 300-MHz processor. Intel is concerned that PC makers couldn't handle these bus speeds, at least not on a four-layer motherboard. If this is true, a daughtercard is a practical necessity, and Intel believes it can supply this module at a lower price than a PC maker could build it.

This strategy has some down sides and has already generated some resentment in the PC community, although Intel claims most of its customers are satisfied. For example, the only L2 cache options for Pentium II are those offered by

	Pentium II Processor Modules				
Clock Speed	300 MHz	266 MHz	266 MHz	233 MHz	233 MHz
L2 Cache Size	512K	512K	512K	512K	512K
L2 Cache Type	ECC	ECC	No ECC	ECC	No ECC
Max Power	42 W*	38.2 W	38.2 W	34.8 W	34.8 W
SPECint95†	11.6	10.4	10.8	9.1*	9.49
SPECfp95†	6.79	6.36	6.43	5.85*	5.91
List Price	$1,981	$805	$775	$666	$636
Availability	3Q97	3Q97	Now	3Q97	Now

Table 1. The initial wave of Pentium II products includes clock speeds ranging from 233 to 300 MHz, cache sizes of 512K, and versions with either ECC or non-ECC cache. †baseline results (Source: Intel except *MDR estimates)

Price & Availability

Intel's Pentium II processor module is currently shipping in volume at 233 and 266 MHz with 512K of non-ECC cache; versions with ECC cache are expected to ship in early Q3. A 300-MHz Pentium II is now sampling, with volume production expected in 3Q97. See Table 1 for 1,000-piece list prices.

For more information, access the company's product Web site at *www.intel.com/intel/product/index.htm* or contact your local Intel sales office.

Intel, which has chosen not to supply 256K caches, only 512K. Even with this restriction, the company has two versions of the module for each clock speed: one with ECC cache and one with standard cache. Intel is motivated to keep its product line as simple as possible, so over time, OEMs wanting to offer something other than the mainstream cache solution are likely to be disappointed.

We expect the new package to meet most vendors' needs and to be widely accepted. It allows Intel to increase the speed of the L2 cache bus as needed without impacting motherboard designs, maximizing the performance of its processors. Over time, Intel could add other functions, such as system logic or graphics, to the processor module if it becomes necessary to couple them tightly with the CPU. Such a move would, however, diminish the ability of other companies to market products in these areas.

In the near future, Intel will deploy Pentium II in other types of modules. The company has committed to delivering Deschutes on a Mobile Module (see MPR 2/17/97, p. 9) for notebook systems. To support larger caches, the company may also create bigger modules for servers. Product configurations and slot numbers will undoubtedly proliferate.

Setting the Pace in the PC Market

The new package is another factor making life difficult for Intel's competitors. Other vendors would like to offer products compatible with Pentium II, but various legal restrictions will make it difficult for them sell processor modules that plug into Slot 1. Instead, processors like AMD's K6 (see MPR 3/31/97, p. 1) are designed for the Pentium-compatible Socket 7. Now that Pentium II is launched, we expect Intel to begin a campaign to convince PC makers and end users to move away from Socket 7, hampering AMD's plans to gain market share.

With its high clock speeds, the new Intel processor also raises the performance bar for PC processors. Although the 233-MHz K6 offers slightly better performance than a PPro-200, it falls well behind a PII-266. AMD plans to deliver a 0.25-micron version of the K6 by the end of this year at speeds of 300 MHz or above, but it is unlikely to reach the 400-MHz mark that Intel claims the 0.25-micron Pentium II will hit. We believe AMD will remain one or two speed grades behind Intel's fastest processors for most of the next year.

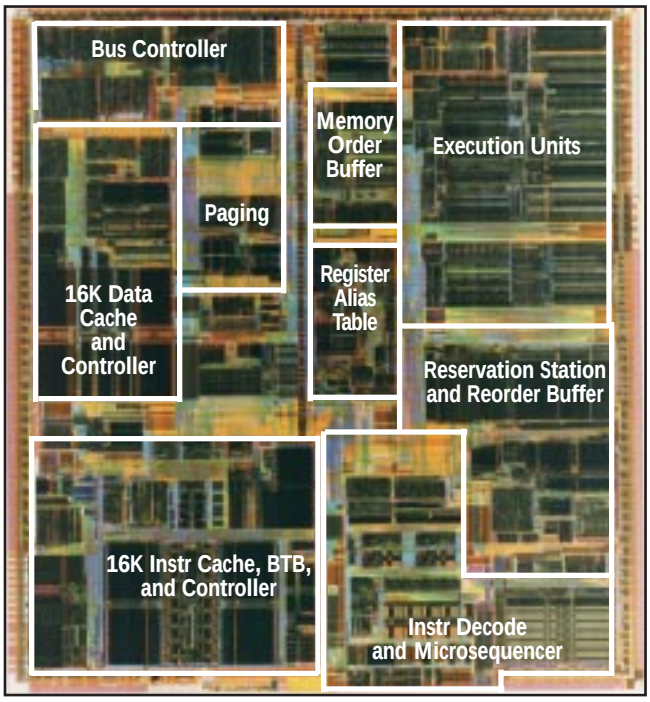

Figure 6. Intel's Pentium II CPU chip has 7.5 million transistors and measures 203 mm^2 when built in Intel's 0.28-micron four-layer-metal CMOS process.

The performance gap between Pentium II and the K6 is greater on applications that stress either floating-point or MMX instructions. Intel has put more emphasis on these areas to support emerging multimedia and 3D applications as well as the workstation market. Pentium II will also outperform the K6 when high cache and memory bandwidth is required; although Socket 7 and Slot 1 provide the same peak bandwidth, the K6 must share this bandwidth between the L2 cache and main memory, whereas Pentium II has a separate L2 cache bus and can devote the entire system bus to main-memory traffic. Thus, the K6 will not compete well in servers or for applications that have large data sets.

With prices above $500 for most of this year, Pentium II will not take the PC market by storm in 1997. The new chip will be a strong high-end offering and should quickly become the power user's processor of choice. Once the 0.25-micron version of Pentium II rolls out, we expect a rapid production ramp. During 1998, Pentium II will sweep the Pentium generation entirely out of Intel's line, with PII-233 pricing projected to fall below $150 by 4Q98. Vendors that offer Socket 7 processors beyond that date could be limited to small segments of the market. M