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Intel Boosts Pentium Pro to 200 MHz

Integer Performance Beats the Best RISCs

by Michael Slater

After nearly a year of buildup, Intel has formally announced its Pentium Pro processor and demonstrated performance that makes it the clear leader for integer applications. For the first time in the history of the x86 architecture, Intel is in a performance leadership position, creating a renewed challenge for its struggling RISC competitors.

Table 1 (see below) summarizes the five initial versions of Pentium Pro (PPro). The 150- and 180-MHz parts, intended primarily for workstations, will come with a 256K L2 cache; the 166-MHz chip, designed for servers, will be coupled only with a 512K cache; and the 200-MHz part will be available with either cache size. Intel has dropped plans for a 133-MHz version, originally disclosed in February *(see **090201.PDF**)*.

The company expects about 30 vendors to ship systems this year. At the introduction, Intel demonstrated systems from Acer, Compaq, Dell, Digital, Gateway 2000, Hewlett-Packard, and Intergraph. Systems shipping this year, priced as low as $4,000 will primarily be uni- and dual-processor systems using the 150-MHz chips, although 200-MHz system shipments are promised by year-end.

Four-way multiprocessor systems will be delayed until 1Q96 due to problems with the supporting chip set, which will be corrected in a version shipping next month. Desktop systems will move fairly rapidly to the 180-MHz processor, with entry-level servers using the 166-MHz chip and high-end servers waiting for the 200-MHz/512K version. The larger cache will be especially valuable in multiprocessor systems, in which bus contention is a key issue.

Die Shrink Boosts Speed, Cuts Cost

Only the slowest version, 150 MHz, is built in 0.5-micron BiCMOS technology; 166-, 180-, and 200-MHz chips are built in Intel's 0.35-micron BiCMOS process. The shrunk die is only 196 mm^2, 64% of the size of the 0.5-micron, 308-mm^2 version. Both versions are functionally identical. Intel's decision to introduce the 0.35-micron parts now, along with steep price cuts on 0.35-micron Pentium chips, indicates that the company's capacity in this advanced process has increased rapidly.

The 256K L2 cache chip is implemented in 0.5-micron technology, while the 512K chip requires the 0.35-micron process. At 242 mm^2, the 31-million-transistor 512K cache chip is larger than the processor chip. Processors with the 512K cache chip, which are positioned for the relatively cost-insensitive server market, carry a steep price premium.

According to the MDR Cost Model, the total manufacturing cost of the 150-MHz/256K PPro is about $330, dropping to $250 for the 0.35-micron versions with the smaller cache and rising back to $330 when the larger cache is added. List prices range from just under $1,000 for the 150-MHz chip to nearly $2,000 for the 200-MHz/512K part. Recent Pentium price cuts *(see **0915MSB.PDF**)* make even the entry-level PPro almost twice as expensive as a top-of-the-line Pentium; in addition, Intel's initial PPro chip set carries a price premium of more than $200 beyond a Pentium chip set. These prices clearly position PPro for the workstation and server markets, at least for now, but are competitive for those markets.

Outstanding 32-Bit Integer Performance

As reported previously *(see **091001.PDF**)*, Pentium Pro performance on 16-bit code is lackluster. Not surprisingly, Intel has chosen to ignore 16-bit performance altogether, focusing its performance data entirely on 32-bit benchmarks.

Ziff-Davis' CPUmark32 benchmark provides an indication of how PPro fares, relative to Pentium and Cyrix's 6x86, on CPU-intensive 32-bit Windows-like code. As Figure 1 shows, the 150-MHz PPro beats a 133-MHz Pentium by 48% if the Pentium has a typical 256K cache, or by 27% if compared with a high-end Pentium system with a 1M L2 cache.

Figure 1 shows clearly that Cyrix's 6x86 is a Pentium-class device, despite its sixth-generation designation, when it comes to 32-bit code. When compared to Intel systems with similar 1M L2 caches, the 6x86 falls between the 120- and 133-MHz chips. Unfortunately, no CPUmark32 results have been published for NexGen's 586 or 686 or AMD's K5.

It is easy to see why Intel chose not to publish CPUmark16 ratings, which reflect performance on 16-bit code: tests done by PC Magazine Labs show that the 150-MHz PPro turns in a rating of about 270, slightly below a Micron Pentium-133 system. The faster PPro chips will deliver leadership performance even on 16-bit code, but they won't be a cost-effective solution for this environment.

Windows 95, being a hybrid of 16- and 32-bit code, delivers an intermediate result: according to Intel's benchmarks, the PPro-150 outperforms Pentium-133 by 15% to 30% on 32-bit versions of Excel, Word, PowerPoint, and Freelance. For Windows 95, the high-end PPro-200 outruns a Pentium-133 by a respectable 50%.

Windows NT Performance Shines

BAPCo's SYSmark for Windows NT (SYSmark/NT) shows that Pentium Pro does extremely well in a pure 32-bit application environment. As Figure 2 shows, the slowest Pentium Pro comes close to the fastest RISC system, and the faster Pentium Pros take the lead. A 200-MHz R4400 system, for example, delivers just over half the performance of the Pentium Pro-166. Unfortunately, the SYSmark suite does not yet support PowerPC, but SPEC results suggest that today's PowerPC systems won't fare well against Pentium Pro on Windows NT applications; even next year's PowerPC systems will struggle to catch up.

Performance varies considerably from one application to another. Alpha is relatively strong on the CAD component of the suite, Orcad's MaxEDA PC layout program. On this portion of the suite, even the 200-MHz Pentium can't top Alpha's performance. Other applications with more FP content would show off Alpha's capabilities more clearly. Digital expects to be shipping the considerably faster 21164A in the second half of next year; this chip will widen Alpha's FP lead but isn't likely to be significantly faster than the high-end Pentium Pro on integer applications. (Benchmark results for the 200-MHz/512K Pentium Pro are not yet available. Depending on the application, we expect this chip to offer a 5–10% boost over the 256K cache version.)

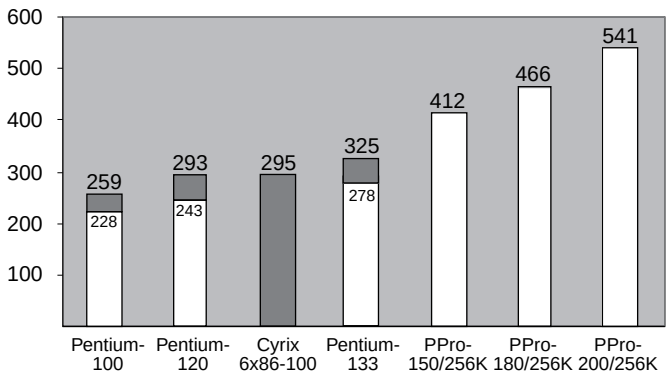

Figure 1. On CPUmark32, the slowest Pentium Pro delivers 33% greater performance than the best Pentium-133 systems. Dark gray bars show Intel's Xtended Xpress Pentium systems with 1M L2 caches; the white bars represent Gateway systems with 256K L2 caches. The Pentium Pro ratings are for Intel's "Alder" server platform; Cyrix's 6x86 rating is for Cyrix's "reference system" with a 1M L2 cache. (Source: vendors)

Clock Speed	150 MHz	166 MHz	180 MHz	200 MHz	200 MHz
Bus Speed	60 MHz	66 MHz	60 MHz	66 MHz	66 MHz
L2 Cache	256K	512K	256K	256K	512K
Typ. Power	23.2 W	23.4 W	25.3 W	28.1 W	tbd
Max. Power	29.2 W	29.4 W	31.7 W	35.0 W	tbd
Samples	Now	Now	Now	Now	1Q96
Production	4Q95	1Q96	4Q95	4Q95	2Q96
Price (1,000)	$974	$1,682	$1,075	$1,325	$1,989

Table 1. Key specifications for the five versions of Pentium Pro. The server-oriented versions with 512K L2 caches carry premium prices. All are 4Q95 prices except the 200-MHz/512K price, which is for 2Q96. tbd=to be determined (Source: Intel)

On SYSmark/NT, the 150-MHz Pentium Pro is 58% faster than a 133-MHz Pentium, and the 200-MHz PPro is twice as fast as the Pentium-133. When performing a Gaussian blur in Photoshop—a highly parallelizable, FP-intensive application—tests by PC Magazine Labs showed that the PPro-150 delivered an impressive 2.5 times the performance of a Pentium-133. Adding a second processor boosted this to 4.1 times, yielding a 64% gain from the second CPU. On Excel, Word, and AutoCAD, however, the second processor provided virtually no benefit.

Thus, for Windows NT users, PPro systems will provide a satisfying speed increase over the fastest Pentiums. Early next year, Pentium will move to 150 and 166 MHz, but the 180- and 200-MHz PPro versions will maintain a comfortable gap.

Integer Leads, FP Lags RISC Chips

On SPECint95, as Figure 3 shows, the 150-MHz Pentium Pro delivers a 47% gain over a Pentium-133. Table 2 (see below) shows the detailed breakdown of Intel's SPEC95 results. The 200-MHz Pentium Pro delivers almost twice the integer performance of a Pentium-133—an achievement that makes it faster than any other processor shipping today.

Floating-point performance is a different story. The Pentium Pro has taken x86 FP to new levels, but the chip remains handicapped by its awkward stack architecture and modest FPU. Several RISCs, including Digi-

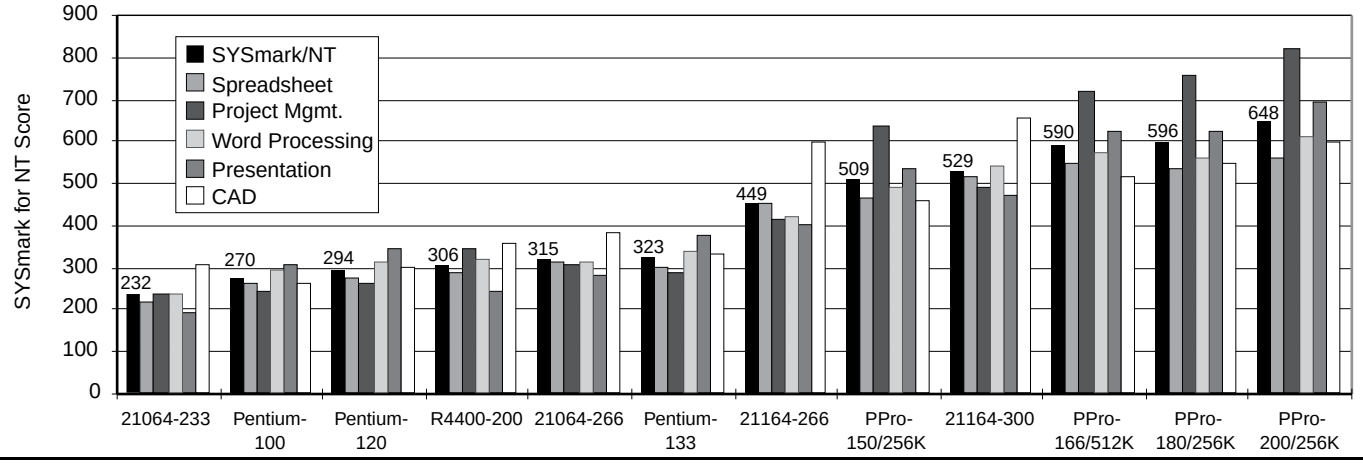

Figure 2. On SYSmark for Windows NT, Pentium Pro beats all other processors for which results have been reported. The Pentium ratings use Gateway P5 systems with a 256K write-back L2 cache; the PPro ratings are for Intel's "Alder" platform. Both use 64M DRAM (EDO for Pentium), an Adaptec SCSI/PCI disk controller, and a Matrox Millennium PCI graphics card. The 21164-300 system is a high-end configuration with 4M of L2 cache and 64M of DRAM. (Source: BAPCo)

tal's 21164 Alpha processor, IBM's multichip Power2, and HP's PA-7200, outdistance Pentium Pro on FP code by nearly a factor of two.

SPEC92 shows Pentium Pro in a similar position. The 200-MHz/256K part is rated at 366 SPECint92 and 283 SPECfp92, while the 150-MHz version is rated at 276 SPECint92 and 220 SPECfp92.

Interestingly, the 180-MHz PPro is slightly slower than the 166-MHz part on FP benchmarks. This is because the 166-MHz part has the larger cache and also runs its bus at 66 instead of 60 MHz, better supporting the larger data sets of the SPECfp95 programs.

The 150-MHz PPro matches almost exactly the projected performance of the recently disclosed PowerPC 604e-166, which will be the high-end desktop part for the PowerPC line in the first half of 1996. Higher-speed Pentium Pro versions will provide formidable competition for PowerPC workstations and make it hard for any PowerPC product to stake out an exciting performance position. PowerPC chips are likely to be less expensive for similar performance levels, but this cost advantage has proven difficult to deliver at the system level.

One area where Pentium Pro is likely to significantly expand Intel's role is in transaction-processing server applications, but TPC benchmarks are not yet available and will probably await shipment of four-processor systems.

Hardware Design Supports Upgrades

Pentium Pro has been designed from the outset to enable OEMs and end users to upgrade systems as faster chips arrive. This approach has already paid off for OEMs, as Intel upgraded the clock frequencies it promised customers even before the chip's formal debut.

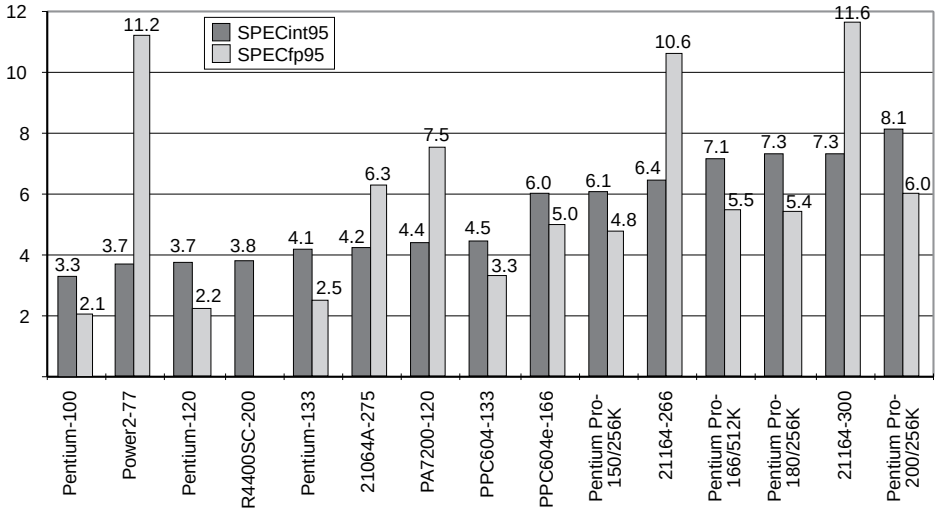

Figure 3. SPEC95 ratings for Pentium, Pentium Pro, and various RISCs show that Pentium Pro beats the best RISCs on integer code but falls short on floating-point. (Source: vendors)

The chip supports a pin-selectable range of ratios between the bus and CPU speeds. The initial chips all use a ratio of 2.5 or 3 to achieve bus speeds of 60 MHz for the 150- and 180-MHz chips and 66 MHz for the 166- and 200-MHz versions. The design also supports ratios of 3.5, 4, 4.5, 5, and 5.5, allowing future core clock rates as high as 366 MHz with a 66-MHz bus.

As clock rates continue to increase, it is likely that the maximum bus speed will be boosted to 75 MHz or higher, especially for servers. Pentium's TTL-level bus isn't likely to go beyond 66 MHz, but the GTL+ design of the PPro bus *(see **090701.PDF**)* should make higher

Processor	Intel Pentium Pro	Intel Pentium Pro	Intel Pentium Pro	Intel Pentium Pro
System	Intel "Alder"	Intel "Alder"	Intel "Alder"	Intel "Alder"
Clock Rate	150 MHz	166 MHz	180 MHz	200 MHz
Cache (L1/L2)	16K/256K	16K/512K	16K/256K	16K/256K
099.go	6.01	6.98	7.27	8.11
124.m88Ksim	5.85	6.51	7.02	7.81
126.gcc	5.76	6.55	6.91	7.65
129.compress	5.24	7.45	6.29	6.99
130.li	6.47	7.68	7.80	8.62
132.ijpeg	6.35	7.10	7.58	8.43
134.perl	6.15	6.84	7.38	8.21
147.vortex	6.93	7.93	8.26	9.14
SPECint95b	6.08	7.11	7.29	8.09
101.tomcatv	7.92	8.92	8.69	9.64
102.swim	9.74	10.9	11.1	12.3
103.su2cor	3.10	3.92	3.35	3.70
104.hydro2d	3.50	3.92	3.74	4.16
107.mgrid	2.57	2.93	2.89	3.22
110.applu	2.54	2.83	2.96	3.29
125.turb3d	4.59	5.12	5.34	5.93
141.apsi	5.22	6.34	5.96	6.64
145.fpppp	7.87	8.79	9.49	10.6
146.wave5	5.85	6.75	6.81	7.41
SPECfp95b	4.76	5.47	5.40	5.99

Table 2. Detailed breakdown of Intel's SPEC95 baseline results. Intel's "Alder" system is a server platform benchmarked in a uniprocessor configuration. The systems are running UnixWare 2.0 and use version 2.2 beta of Intel's compilers, promised for shipment in 2/96. (Source: Intel)

clock rates achievable.

As process technology advances, supply voltages will continue to fall. With Pentium, the shift from a 5-V to a 3.3-V supply required motherboard changes. The Pentium Pro design eliminates the need for motherboard modifications to support supply voltage variations. Four pins on the chip provide a four-bit output code that specifies the desired core supply voltage in 0.1-volt increments, from 2.1 to 3.5 volts. (I/O levels remain constant.) The initial 150-MHz PPro uses a 3.1-V supply; the faster versions run at 3.3 V, even though they use a more advanced process. (The 0.5-micron chip's supply voltage was increased from the 2.9 V originally planned to support the higher clock rate.) We expect Intel to shift Pentium to a 2.5-V CMOS process next year, and PPro is likely to follow. The voltages defined by PPro's automatic selection scheme suggest that Intel does not foresee voltages below 2.1 V in the next few years.

System OEMs can provide automatic support for processors at various voltages by using a programmable voltage regulator. Since some vendors may not want to go to this expense—especially for second, third, and fourth upgrade sockets—Intel has defined a standard voltage regulator module that plugs into a connector on the motherboard. Intel plans to ship a matching voltage regulator module with end-user upgrade processors.

Price & Availability

See Table 1 for price and availability for Pentium Pro processors.

The 82450GX PCIset (for servers, with up to four processors) is priced at $291.60, while the KX (for desktops or low-end servers with up to two processors) is $209 (both in PQFP packages). A version of either chip set using ball-grid-array packaging for the PCI bridge and data path chips is $303.71. The KX is in production now, while the GX is sampling with production planned by year-end.

For more information, call Intel at 800.548.4725 or access the Web at *www.intel.com.*

Intel hopes to avoid the Pentium OverDrive fiasco, in which many 486 PC makers built systems that lacked the cooling needed for the OverDrive processor. The company says that most PPro systems are being designed for a maximum power dissipation of 35 W per processor socket—enabling the systems to use the fastest PPro chips that Intel envisions producing, including future OverDrive processors. Note that the 200-MHz part already dissipates 35 W maximum, so Intel's recommendation of a 35-W allowance suggests that future processors at higher clock rates will use lower supply voltages to remain within this thermal envelope.

Although some Pentium systems can support an OverDrive processor as a second active CPU, most simply disable the original CPU when an OverDrive chip is added. Pentium Pro systems with upgrade sockets, on the other hand, will universally allow multiprocessor operation. Users will be able to upgrade the base processor to a higher clock rate instead of, or in addition to, adding more processors.

A Niche Now, Mainstream Later

Because of its unexciting price/performance on 16-bit code, Pentium Pro won't be a major factor in the Windows 95 market in the next year or so. Although the faster versions of Pentium Pro will provide leading-edge Windows 95 performance, they will do so at a premium cost for both the processor and the chip set. The forthcoming P55C version of Pentium is likely to deliver a more cost-effective upgrade for most Windows 95 users.

For Windows NT and OS/2 users, however, Pentium Pro will provide a compelling performance increase over Pentium. It will be especially appealing for servers, where its multiprocessing support will prove valuable. Pentium Pro's outstanding performance on Windows NT applications will force RISC vendors to focus solely on FP-intensive applications to find a performance leadership position.

Pentium Pro will also give a big boost to Intel's posi-

tion in the workstation market, running either Windows NT or Unix. (SunSoft announced Solaris 2.5 at the PPro launch event, showing that Sun's software division won't be timid about pushing the advantages of PPro.) With integer performance comparable to the best RISCs, Pentium Pro workstations will be attractive for many users. Although these x86 systems don't offer leading-edge FP performance, their relatively low prices will deliver outstanding price/performance.

For example, Intergraph has launched a line of PPro systems with workstation-class accelerated 3D graphics systems, aiming directly at Silicon Graphics, with systems starting at $14,000. With strong FP performance, PPro systems deliver impressive visualization capabilities even without expensive graphics accelerators. Today, RISC CPUs have more workstation applications than x86 systems, but PPro will fuel additional porting efforts that will reverse this situation.

PPro's performance, combined with the ease of designing four-processor servers with it, will enable Intel to make far greater inroads into enterprise-class servers than has previously been possible. Having conquered the PC market and threatened to move into workstation territory, Intel is now poised to take on the big iron.

By the end of 1996, the existing Pentium Pro design should be boosted to clock rates of 233 MHz, or possibly even 266 MHz. To make its move into the mainstream, however, we expect Intel to shift away from the two-chip package with the integrated L2 cache in 1997, introducing an enhanced version of Pentium Pro with a dedicated bus for an external L2 cache. This version will also presumably incorporate the multimedia extensions that will debut next year in the P55C and will probably include enhancements to boost performance on 16-bit code. It is likely to be fabricated in pure CMOS, rather than BiCMOS, enabling lower supply voltages and reduced power consumption. By 1998, as this version reaches high-volume production, Pentium Pro technology will move into the PC mainstream. ♦

Two Chip Sets Support PPro

Along with the debut of Pentium Pro, Intel introduced two chip sets to support it. Previously known by the code name Orion *(see **090701.PDF**)*, the 82450 PCIset is available in two versions: the 82450KX for workstations or low-end servers and the 82450GX for high-end servers. Each chip set consists of a 304-lead PCI bridge chip plus a memory controller that is split among six chips: the 208-lead DRAM controller, 240-lead datapath chip, and a simple 144-lead multiplexer chip (of which four are required). These are high-end chip sets; a new design tuned for volume desktops is expected next year. The chips sets use 0.5-micron CMOS technology.

The memory controller has a four-cache-line buffer and reorders reads around writes to maximize performance. Up to eight transactions can be outstanding.

The PCI interface operates at 3.3 V but is 5-V tolerant, supporting PCI boards running at either voltage. The bridge has a two-deep buffer for deferred responses from PCI target devices and a four-deep buffer for pending requests from PCI bus masters.

The two chip sets are very similar. The GX version has a few additional signals and is tested with more loads on the processor bus. The server-oriented GX version supports four processors, while the workstation-focused KX supports only two. The GX also allows two PCI bridges and four memory controllers, while the KX supports only one of each. Both chip sets offer ECC for the DRAM; the GX also provides ECC protection for the data bus. Both chip sets support noninterleaved or two-way-interleaved DRAM; the GX also supports four-way interleaving for maximum memory performance.

With 16-Mbit DRAMs, the chip sets allow up to 256M of DRAM in the KX version, or 1G of DRAM on each of up to four memory controllers for the GX version; 64-Mbit DRAMs will quadruple these capacities. Assuming a 66-MHz bus and 60-ns DRAM, memory read timing on a page hit is a minimum of 8 cycles for the first transaction, 11 cycles on a page miss, or 14 cycles on a page miss with precharge. A noninterleaved memory system has a 16M minimum size and delivers data every four cycles after the first access. A two-way interleaved system must be 32M or larger and delivers data every other cycle. A full-speed, four-way interleaved system has a 64M granularity and delivers data every cycle; it is cost-effective only in high-end multiprocessor systems.

