New Pentiums for Notebooks, 486 Upgrades

TAB Package Slashes Size—75-MHz Clock Keeps Power Modest

by Michael Slater

Intel has introduced its long-awaited 75-MHz Pentium processor, destined to serve as the heart of 1995's high-end notebook systems. Adding to the range of Pentium processors, Intel also disclosed at last month's Microprocessor Forum the key specifications for the P24T, the Pentium-based OverDrive processor.

Although the 75-MHz chip is itself no different from today's 90- and 100-MHz Pentium (P54C), the new package cuts weight from 55 grams to less than 1 gram. At the 75-MHz clock rate, the chip dissipates 3–4 W (typical)—less than a 486DX2-66.

According to Intel's results on various benchmarks, the Pentium-75 is almost twice as fast as today's top-of-the-line notebook processor, the DX4-75. On both CPUmark16 and SPECint92, the Pentium-75 rates 82% faster than a DX4-75 and a third faster than a DX4-100. Tests on system benchmarks, such as Winstone and SYSmark93, have not yet been published and are likely to show more modest gains because disk and graphics performance are included. On floating-point applications, the Pentium-75 shows a three times increase over the DX4-75, as Figure 1 shows.

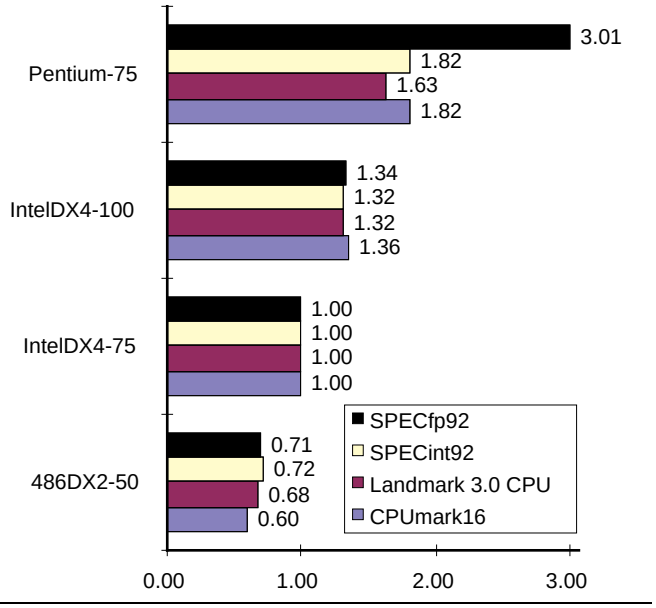

Figure 1. Performance relative to the DX4-75. Note that CPUmark16 is the renamed and scaled version of ZD's PC Bench Processor Test, so it produces the same relative results. The Pentium-75 and DX4-100 systems have 256K L2 caches; the others have none.

The performance delivered will vary with the system design. In some systems, the Pentium-75 will be used without any level-two cache—something that has been unheard of in Pentium systems so far. Using fast EDO (extended data out) DRAMs, such systems perform nearly as well as those with a secondary cache and standard DRAM, said Intel's Fred Pollack.

Power Dissipation Less Than 486DX2-66

Because the P54C's dynamic power management automatically powers down unused parts of the chip on a cycle-by-cycle basis *(see **080301.PDF**)*, the chip's power consumption is highly software-dependent. Power consumption is more than 8 W in a truly worst-case sense, but Intel says that, when running application software, the maximum is 6.5 W and the average is 3–4 W. Instantaneous power consumption when running the Winstone benchmark suite varies from 4 to 6 W, but Windows 3.1 idle power is only 1.25 W.

Intel recommends that 6.5 W be used as a thermal design guide, with a temperature sensor to slow down or shut down the processor should the temperature rise too high. This could occur if the processor gets stuck in a pathological loop that increases the power to the 8-W maximum, or if the ambient temperature is too high.

The bus runs at two-thirds of the CPU clock, or 50 MHz. Despite widespread press reports and other information to the contrary, Intel insists that a 25-MHz bus speed was never seriously considered. Such a bus would make existing notebook designs easier to adapt but would compromise too much on performance.

TCP Breaks New Ground in x86 Packaging

The 320-pin tape carrier package (TCP) uses a lead pitch of 0.25 mm to pack all the leads into a package barely over an inch on a side. (TCP is Intel's name for what is more commonly called TAB, for tape automated bonding) *(see **071304.PDF**)*. The package design, as Figure 2 shows, adds minimal mass to the die itself, unlike the massive PGA it replaces.

Before the package is mounted, a spot of thermally conductive paste is put on the board. The chip is pressed into this paste while hot metal bars in the placement device push the leads down onto the solder-coated board.

Under the chip, the circuit board is filled with an array of plated-through holes, forming thermal vias. The heat is drawn out from the back of the board to a heat sink or heat pipe. Newer notebook designs use heat pipes to transfer the heat from the processor to a larger area

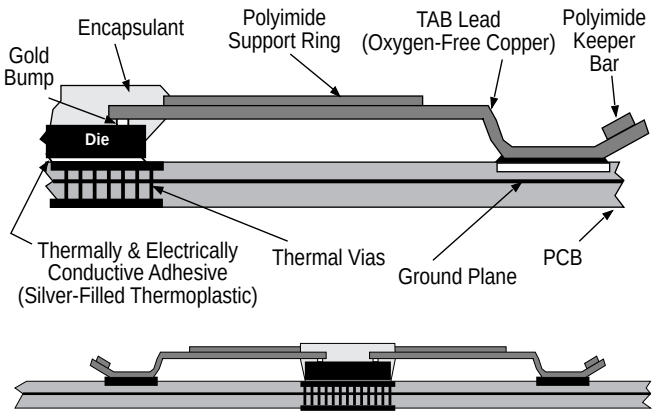

Figure 2. Intel's TCP uses very little space and provides good heat transfer. The lower drawing shows the entire package cross-section; the upper illustration shows the detail on one side of the package (not to scale).

that is exposed to the outside. Although not necessary for the Pentium-75, the heat pipe eliminates the "hot spot" that is otherwise apparent in high-end notebooks.

Only one other commercial microprocessor—Sun's MicroSparc—has used TAB. In the past, concerns about the availability of TAB board manufacturing technology have limited its appeal, but this appears to be changing—at least at the larger manufacturers. Motorola prefers ball grid array (BGA) packages, which have been used for years in cellular phones and are now being used for high-end PowerPC chips.

The 75-MHz Pentium does not bond out nine signals that are provided on the 90- and 100-MHz Pentiums. Features not supported by the TCP package are dual-processor support, functional redundancy checking (master/checker pair operation), and two signals for optimizing high-performance L2 cache operation.

With good thermal design, the 75-MHz Pentium is well below the thermal limits of the TCP package, and the die inside is the same one that Intel has been selling with 90 MHz as the slowest speed grade. It therefore seems likely that a 90-MHz TCP chip will follow in 1995, pushing high-end notebooks up one more notch.

New Lineup Drops 486SX

With the Pentium-75 taking over the high end of the notebook market, the DX4-75 becomes the midrange, leaving the DX2-50 as the low end. The 486SX, still popular today, will fade rapidly during 1995. Intel projects that Pentium-based notebooks will shift nearly half of the mobile market away from the 486 by the end of 1995. This might be possible if Intel were the only x86 CPU supplier, but with AMD, Cyrix, and IBM gearing up new enhanced 486 products, the transition won't be as quick as Intel would like.

The first system to be announced with the 75-MHz Pentium, Toshiba's T4900CT, has a list price of $7,500, illustrating how notebook vendors initially will use the new chip for fully configured, premium-priced systems: Toshiba's notebook includes a 772M hard drive and a 10.4" active-matrix color display as standard features. At prices like this, Pentium notebooks will be limited to the high-end fringe.

As more systems are introduced, prices for Pentium notebooks are sure to fall sharply, making Pentium a mainstream notebook choice by the end of 1995. Intel also has plenty of room to lower the price of the chip over the course of the year. Pentium-90 notebooks should be possible by late 1995, using the same TCP packaging.

During 1995, when AMD and Cyrix/IBM are struggling to establish their Pentium-class processors, Intel's Pentium competitors are likely to remain focused on the desktop market. In 1996, the competition may deploy portable versions of their Pentium-class processors—at least a year behind Intel. This delay may not be significant, however, because it will take this long for Pentium-class notebooks to become a major part of the market.

The biggest competition for the Pentium-75 in 1995 will come from high-end 486 chips, such as Intel's own DX4 and similar chips due from AMD and Cyrix/IBM. Intel has kept its DX4 prices very high, but DX4-100 processors from AMD and Cyrix will be significantly less expensive than Pentium-75 (at least until Intel slashes its price).

The Pentium-75 has a performance advantage, but it is only 33% faster than a DX4-100. (AMD's current DX4 has only an 8K cache, so the Pentium-75's performance edge is probably closer to 40%, but versions with larger caches and clock rates to 120 MHz are expected from AMD next year.) The system design is also less expensive because of the 32-bit 33-MHz bus. Systems using DX4-class processors could become the economy-minded power-user's notebook, while Pentium holds the high end.

The 75-MHz Pentium could also displace the 60-MHz version in mainstream desktop systems. Today, Intel charges a premium of almost $150 for the 75-MHz part (assuming PGA packaging for both), but this spread is likely to shrink next year as Intel has more 0.6-micron production capacity. Intel's manufacturing cost for the

Price & Availability

The 75-MHz Pentium processor is in production now and is priced at $495 for the TCP version or $535 in a staggered PGA (SPGA) package, both in 1,000s. For literature, call 800.548.4725 or contact Intel sales at 800.628.8686.

Price and availability for the Pentium OverDrive processor (P24T) have not been announced but Intel promises a formal introduction by year-end.

75-MHz chip is lower than for the much larger 60-MHz die, so there is plenty of room to drop the 75-MHz price. Desktop systems based on the Pentium-75 are already appearing and could obsolete the 60- and 66-MHz Pentiums by the middle of next year. This would shift the entire Pentium market to 3.3-V designs.

Intel Reveals P24T Specifications

Intel also disclosed at the Microprocessor Forum the specifications for the long-awaited P24T, the Pentium-based upgrade chip for 486 systems. The chip will be formally introduced by the end of the year.

Officially called the Pentium OverDrive processor, the chip will be sold as an end-user product for upgrading 486-based PCs that provide the extended OverDrive socket. This socket has an extra row of pins all the way around, as compared to the original OverDrive socket defined by the 487SX. These extra pins provide additional power and ground pins and six new signals to support the on-chip write-back cache.

The Pentium OverDrive processor was originally expected much earlier this year, but a variety of problems have delayed it. Originally, Intel expected to use the 0.8-micron P5 design as the basis for the OverDrive chip, which must operate in 5-V systems. Power dissipation and performance issues made this impractical, however, forcing a shift to the 0.6-micron 3.3-V P54C version. This shift added challenges, however, since it required mating the 3.3-V chip to 5-V systems. Other factors contributing to the delay include the development of exotic cooling and packaging technology and the need to make sure the chip will work in a wide range of system designs.

CLARENCE TOWERS

Intel's Fred Pollack describes the 75-MHz Pentium and P24T Pentium OverDrive processors at the Microprocessor Forum.

Technology issues aside, Intel may have chosen to delay the introduction of the P24T in support of its Pentium push. Intel would like users to buy Pentium systems from the outset; the availability of the P24T will make it more attractive for some users to buy a 486DX2 system, knowing that they can upgrade it later should their needs increase.

According to Intel's benchmark results, application performance (as measured by SYSmark93) in a 66-MHz 486DX2 system with the Pentium OverDrive processor installed is increased by about 50%. This improvement makes the upgraded PC comparable to a Pentium-60 system and about 10–15% faster than a DX4-100 system on integer applications. Floating-point applications will see a much bigger boost.

In addition to a special package, several changes were made to the P54C die. The only surprise was that the P24T has twice the cache of other Pentium processors: 16K each for instructions and data. This change was made to mitigate the effects of the slow, 32-bit bus interface required for compatibility with 486 systems.

Pollack said that the larger cache resulted in a 25% die-size increase. According to the MPR Cost Model *(see **081203.PDF**)*, this boosts the manufacturing cost from $120 to $165. The exotic package and related components will raise the cost further, making the P24T today's most expensive x86 processor to produce.

The Pentium OverDrive processor runs the CPU core at 2.5 times the bus speed, yielding core speeds of 83.3 MHz in 33-MHz (DX2-66) systems and 63.25 MHz in 25-MHz (DX2-50) systems. The chip's peak bus bandwidth is about one-fourth that of other Pentium chips, which use a 64-bit bus clocked at 60 or 66 MHz.

Although other Pentium processors use a write-back data cache, the OverDrive processor can operate in either write-through or write-back mode. Write-through mode is needed because some PCs include the required socket for the chip but don't provide the additional signals to support write-back cache operation. Those systems that provide the write-back support signals will get a bigger boost from the OverDrive upgrade than systems that force the chip to operate in write-through mode. The emergence of DX2 processors with write-back caches (see sidebar below) will make chip sets with write-back support more common.

In addition to the larger cache and slower bus, the Pentium OverDrive processor required changes in both the chip design and the package to deal with differing supply voltages. To enable the 3.3-V chip to be used in 5-V 486 systems, a custom linear voltage regulator is surface-mounted on top of the ceramic PGA package, along with four capacitors. Unlike the P54C, which requires 3.3-V logic levels (and therefore 3.3-V chip sets and cache RAMs), the P24T includes 5-V–tolerant I/O buffers.

Keeping OverDrive from Overheating

Cooling issues have long plagued the P24T. At first, Intel told PC makers what the airflow requirements would be for the OverDrive chip with a heat sink. Some system makers provided the required airflow—several times that required by a 486 system with an empty OverDrive socket—but many cut costs by providing much less airflow. Intel has since revised its specifications and instituted a verification program for PCs.

To support the widest range of PCs and save 486 system makers the cost of providing high airflow even

Intel Adds Write-Back DX2

Although it has escaped most press notice, Intel has enhanced its 486DX2 processors to support write-back cache operation. (The announcement was so low key that we heard about it only secondhand, and then had a hard time finding someone at Intel who knew about it!) The new device goes by the catchy name of Write-Back Enhanced IntelDX2; for the sake of brevity, we'll call it the DX2WB. Surprisingly, a write-back option still is not offered for the DX4.

Intel pitches the DX2WB as enabling system makers to drop the second-level cache, cutting system costs as the DX2 moves down to the entry level. Performance of the DX2WB-66 on SPECint92 in a system without an L2 cache is 31.5, 11% higher than in a write-through system with no L2 cache but still 20% below the 39.6 rating of a write-through DX2-66 with an L2 cache. SYSmark93 shows similar results. The CPUmark16 rating for the DX2WB-66 without an L2 cache is 36.4, 15% above the write-through version.

Four additional signals were added to support the write-back protocol (including burst writes) using pins that were previously "no connect." One pin enables write-back or write-through mode, and this pin is internally pulled up to select write-through. This allows the DX2WB to be used in write-through system designs, where it will act the same as an original DX2. Chip sets supporting the write-back signals are already common because of the need to support this capability for the P24T, Pentium, and Cyrix's 486DX processors.

The die size of the DX2WB is about 10% larger than the standard DX2, increasing the estimated manufacturing cost by a dollar or two. Thus, Intel's margins will be slightly lower for the new device, but with prices of $149 (50 MHz) to $199 (66 MHz) and manufacturing costs of $15–$30 (depending on package type), the decrease in margin is insignificant.

The emergence of the DX2WB puts increasing pressure on AMD to add this capability, which both Intel and Cyrix/IBM now offer.

Intel has priced the DX2WB, which is in production now, identically to the standard DX2, effectively obsoleting the original design. Intel will continue to produce the old version for those customers preferring to stick with that design.

DX4 Offers OverDrive Option

Although the P24T remains in the future, Intel has announced and begun shipping a DX4-based OverDrive processor. Because of its lower power consumption, this chip does not require the fan used in the Pentium OverDrive, and it is also much less expensive to produce. The DX4 OverDrive processor is recommended for upgrading 486SX and DX systems; the Pentium OverDrive is recommended for DX2 system upgrades.

Like the Pentium OverDrive, the DX4 OverDrive processor uses a package-mounted voltage regulator to mate the 3.3-V, 0.6-micron technology to a 5-V system design. Because the DX4 already includes 5-V–tolerant I/O, no changes to the die were required.

The DX4 OverDrive processor triples the performance of code that runs entirely from the on-chip cache, but even the 16K cache is not enough to fully offset the limitations of the slow bus on real applications—or even on decent benchmarks. A 486DX-33 system upgraded with a DX4 OverDrive processor runs CPUmark16 (the newly named and rescaled version of the ZD Bench Processor Test) at 2.3 times the speed of the unmodified system. The application-based SYSmark93 suite shows a 2.2 times increase; specific applications benchmarked by Intel showed performance increases ranging from 1.8 to 2.6. SPECint92 is increased by a factor of 2.2, from 20.0 to 44.8. (Request Intel's document number 297130-007 for complete benchmark results.)

The DX4 OverDrive processor is available now; it is priced at $549 for the 75-MHz version (for upgrading 486DX-25 systems) or $699 for the 100-MHz version (for upgrading 486DX-33 systems). Since these are retail products, prices are quoted for single-unit quantities.

when the system has not been upgraded, Intel has created a novel fan-heatsink combination that is attached to the package. A small fan, powered from contacts built into the top of the PGA package, delivers ample cooling for the chip even in systems with minimal airflow, as long as the air surrounding the device is below 55°C.

Intel developed a special high-reliability fan and expects fan failures to be less than 1% after 10 years of use. Should the fan fail, it can be replaced without replacing the chip. To make the chip fail-safe, the processor senses the fan speed, and if it falls below the expected rate, the CPU core reverts to a nonmultiplied clock, cutting the power consumption by more than a factor of two.

Keeping Up the Heat

As Intel's competitors inch closer to the high end of Intel's product line, Intel is fighting back with lower prices and a broader range of products. A key point of attack for Intel's competitors has been in the mobile arena, where Intel's position has been weakest. With the Pentium-75, Intel has an effective weapon to fight back against competitive high-end 486 chips—if system makers cooperate by introducing Pentium notebooks at reasonable prices.

The value of the OverDrive processor is less clear. History has shown that although the existence of processor upgrades is appealing to system purchasers, few actually buy the upgrade. The P24T is likely to be an expensive upgrade chip, and with falling Pentium system prices, buying a new system will be more attractive for most consumers. ♦

