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Intel, Cyrix Reach P200 Level

Pentium Ships First But 6x86 Has Slight Performance Edge

by Linley Gwennap

Underscoring the tight performance race between the two vendors, Intel and Cyrix extended the performance of their mainstream processors to the P200 level at nearly the same time. Intel's 200-MHz Pentium processor is available in volume immediately, offering a 7–9% performance boost over the Pentium-166, as Figure 1 shows. Cyrix's 150-MHz 6x86, which the company sells as the 6x86-P200+, will ship in limited quantities later this month, with volume production slated for August. Testing at MDR Labs revealed the Cyrix chip outperforms the newest Pentium by 3–5% on Ziff-Davis's Winstone 96 and Winstone 32 benchmarks.

Intel, of course, has been shipping 200-MHz Pentium Pro processors for several months, but given PPro's problems with 16-bit code, the new chips outperform PPro on the Winstone 96 benchmark, which includes popular 16-bit applications running under Windows 95. Although PPro is still the fastest processor on 32-bit applications, the Cyrix 6x86 delivers the most performance within the popular P54C pinout, giving PC makers an easy upgrade for their current systems.

Intel Takes P54C to the Limit

The 200-MHz speed grade represents the end of the line for the two-year-old P54C design, which recently surpassed Intel's 486DX2 as the best-selling PC processor of all time. Starting with the original 0.5-micron BiCMOS versions at 90 and 100 MHz, the company pushed the clock speed higher and higher over time through circuit tuning and a shrink to 0.35-micron BiCMOS, producing a version known as P54CS.

Getting the part to yield at 200 MHz was no small task. While a CMOS design will yield a small number of parts well above the center point of the clock-speed curve, BiCMOS parts have a narrower yield curve. Most of Intel's parts have been yielding at 150 to 166 MHz.

To reach 200 MHz, Intel has taken several steps. First, a combination of a few circuit changes to speed critical paths with some process improvements to reduce the effective gate length moved the speed curve slightly higher. To further improve the operating frequency, Intel revived the VRE voltage specification for the Pentium-200, which requires a 3.45-V supply. This specification was used to improve the yield of early Pentium-100 chips. Increasing the voltage by 5% provides a similar improvement in clock speed.

A new plastic PGA package also helps the clock frequency. Instead of using the traditional ceramic substrate, the PPGA mounts the die on a standard PCB. The heat sink attaches to a heat slug mounted directly on the die, providing better thermal characteristics than a typical CPGA package, which has a layer of ceramic between the heat sink and die. With this arrangement, the die can operate at a higher temperature and thus tolerate a higher clock speed. Because it uses copper traces on FR4 rather than tungsten through ceramic, the PPGA has better electrical characteristics as well. Thus, the chip can run slightly faster. We believe the new package also reduces Intel's manufacturing costs.

The PPGA package fits into the same socket as the

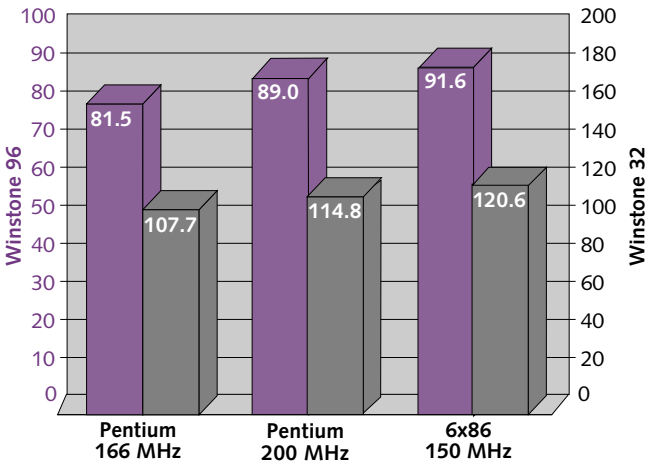

Figure 1. On two PC benchmarks, the new 200-MHz Pentium outscores the Pentium-166 by 7–9%. Cyrix's new 150-MHz chip, dubbed the 6x86-P200+, is 3–5% faster than the Pentium-200. See article text for configurations. (Source: MDR Labs)

CPGA Pentium and uses similar heat sinks, so board makers should be able to interchange the two parts. One proviso: the board must be designed to deliver the VRE voltage level, which is tolerable to non-VRE Pentiums as well. Intel will offer the 200-MHz Pentium only in the PPGA package; the Pentium-166 will be offered in the PPGA as well as the standard CPGA. Intel is likely to use the new package for other high-speed parts in the future.

The 200-MHz clock speed pushes power dissipation to 15.5 W (maximum) at 3.45 V. The faster clock also improves performance to 5.5 SPECint95 and 2.9 SPECfp95 (base). This integer score is slightly better than that of the 200-MHz 603e *(see* **100703.PDF** *)*, but the FP score lags the PowerPC chip's.

Bandwidth Problem Looms

Achieving even higher clock speeds from the current Pentium design will not be possible. Intel's next process shrink is to a 0.28-micron process *(see* **090905.PDF** *)*, but this process eliminates bipolar devices, requiring a pure CMOS design. Intel is working on a new design, the P55C, that utilizes the 0.28-micron CMOS process, but it is not expected to ship until late this year. It isn't clear whether even the P55C will exceed 200 MHz, as the missing bipolar transistors may offset the gain from the gate shrink and the new process makes no improvements to the critical metal layers.

The P55C addresses one key problem with the P54C design: the current chip has run out of bus bandwidth. The 200-MHz Pentium runs at three times the clock speed of the original Pentium yet uses the same 66-MHz bus. This bottleneck has been exacerbated over the past few years by the increased size and complexity of typical application software. As a result, the Pentium-200 scores just 9% better than a Pentium-166 on Winstone 96 despite a 20% faster clock. A 180-MHz Pentium, with just a 60-MHz bus, would do worse than a Pentium-166, which is why Intel skipped that speed grade.

The P55C doubles the size of the on-chip caches, to 16K for instruction and 16K for data, reducing the number of external cache accesses. This change, combined with minor improvements over the P54C pipeline, will give the P55C-200 about 15% better performance than the Pentium-200, according to Intel. The performance improvement at lower clock speeds may be less.

Short Lifespan for Pentium-200

Intel is selling the Pentium-200 for $599 in quantities of 1,000, a 20% premium over the Pentium-166 despite the relatively modest increase in performance. We expect this price to drop to about $450 by the end of the year. Once the P55C is available, the Pentium-200 will disappear fairly quickly, perhaps as soon as mid-1997.

We expect Intel to offer aggressive pricing on the P55C, phasing out the Pentium-200, for two reasons. First, the P55C includes Intel's new MMX multimedia instructions *(see* **100301.PDF** *)*, which the company wishes to move into the PC mainstream as quickly as possible. Second, we do not believe the speed yields on the P54C design at 200 MHz are adequate to support the volumes required to move that device into the sub-$300 portion of the market. Thus, the Pentium-200 is simply a bridge product filling the gap between the Pentium-166 introduction in January and P55C production late this year.

Cyrix Improves Bandwidth with 75-MHz Bus

Due to its more efficient microarchitecture, Cyrix's new part exceeds the performance of the Pentium-200 while operating at just 150 MHz. To achieve this performance, Cyrix has pushed the bus speed of its part to 75 MHz; Pentium, in contrast, is limited to 66 MHz. This change improves the bandwidth to the rest of the system by 14%, easing the bottleneck seen by the 200-MHz Pentium.

Cranking up the bus speed, however, can make life more difficult for the motherboard designer. Cyrix is working closely with chip-set and motherboard vendors to enable the 75-MHz bus speed. VLSI Technology announced that its Lynx chip set, available today, will support the 75-MHz bus. This chip set operates the PCI bus asynchronously, allowing it to remain at 33 MHz. The faster bus speed, however, requires more expensive cache SRAMs.

Cyrix expects Opti, SiS, and VIA to add 75-MHz system-bus support to their Pentium chip sets in the near future; none of these vendors has committed to this plan. Motherboards supporting the 75-MHz bus are available from Diamond Flower, Inc. (DFI), with First International Computer (FIC) expected to become a second source.

The 150-MHz 6x86 does not support the 2.5× clocking mode found in Pentium, which would have allowed a 60-MHz bus. It does support a 3× clocking mode, but Cyrix is discouraging its use, as this configuration would not match a Pentium-200 in performance. Thus, potential 6x86-P200+ customers are limited to a single chip set and a single motherboard vendor today, with the possibility of a small number of vendors in the future.

The company is investigating pushing the bus speed even further, to 83 MHz. This increase would support a 166-MHz 6x86 that could be deployed in 4Q96, maintaining the 2× ratio. Without the faster bus speed, however, the 166-MHz version would offer no better performance than the 150-MHz part, so there would be little point in offering it. An 83-MHz system bus is challenging but possible.

Cyrix Reaches 0.44 Microns

To achieve 150 MHz operation, Cyrix, along with fab partner IBM, developed a 0.44-micron version of the 6x86 built in a variant of IBM's CMOS-5S process called CMOS-5S2. This device is a 10% optical shrink of the 0.5-micron version currently shipping at 133 MHz *(see* **100202.PDF** *)*. The new die measures 169 mm^2, 18% smaller than the previous version. The MDR Cost Model estimates the new manufacturing cost at $75, 12% less than before.

Cyrix plans to move most of its production to the shrunk part, which also improves yield at the lower frequencies while reducing cost. The 6x86 remains far more expensive to produce than Pentium, which we estimate costs just $40 to manufacture. By focusing its efforts on products that sell for $300 and up, however, Cyrix makes this cost difference acceptable.

Cyrix has priced its 6x86-P200+ at $499 in quantities of 1,000. IBM is also selling the P200+ under its own label, at a 1,000-piece list price of $479. These prices are 20% or more below Intel's Pentium-200 price, but this gap is not really meaningful. Intel is scheduled to reduce its prices on July 29, about the time the P200+ reaches volume production; we expect the Pentium-200 will be much closer to Cyrix's $499 price by the time most vendors can buy the 6x86.

Cyrix is also working with its second foundry partner, SGS-Thomson, which has not yet been able to ship any 6x86 parts in volume. SGS-Thomson's Phoenix (Ariz.) fab is now producing samples of the 6x86, and the vendor expects to put these parts into production in 2H96.

As part of its system effort *(see* **1005MSB.PDF** *)*, Cyrix is selling 6x86-P200+ PCs, promising shipments by the end of this month. The base price for these systems is $2,699 in a configuration that includes a 256K pipeline-burst cache, 16M of EDO memory, a Matrox Millennium graphics card with 2M of WRAM, 2.5G hard drive, 8× CD-ROM, 15-inch monitor, speakers, and Windows 95.

Cyrix measured a high-end configuration, which included a 4G SCSI-2 disk with 64M of cache, at 100.5 on the Winstone 96 benchmark. This score is the highest ever published on that metric, including ratings for Pentium and Pentium Pro systems, although Pentium Pro might do better if tested with such a disk controller. Cyrix's record-breaking configuration is on the price list at $4,999.

Cyrix M2 to Duel Klamath

In early 1997, Cyrix plans to debut its next design, code-named M2. This device will retain the proven 6x86 processor core but quadruple the size of that chip's unified L1 cache to 64K, twice as much on-chip cache as the P55C. The greatly expanded cache will help overcome the bandwidth limitations of the Pentium bus.

Combined with the greater efficiency of the 6x86 CPU core, the new cache should help the M2 achieve better performance than the P55C. Sticking with the current pinout provides PC makers the option of extending the lifetime of their Pentium-based motherboards by moving to the M2.

The M2 will debut in IBM's 0.35-micron CMOS-5X process, which should allow clock frequencies of 180 and 200 MHz. We expect a subsequent shrink to the 0.27-micron CMOS-6S process in 2H97, boosting M2 speeds to 225 and 250 MHz; these parts would use a 75- and 83-MHz bus, respectively, for best performance. If Cyrix can deliver parts on this timetable, the M2 should be comparable in 16- and 32-bit integer performance to Intel's Klamath, a P6-family part expected to roll out early next year.

We believe the performance of the 6x86 core will begin to suffer at speeds above 200 MHz, even with the larger cache, due to the limited bus bandwidth. Cyrix, within the Pentium pinout, will find it difficult to match the performance of Intel's 300-MHz P6 (code-named Deschutes), expected to ship by the end of 1997. The 6x86 core might deliver better performance by moving to a new pinout, perhaps retaining the Pentium bus interface but adding a new L2 cache bus. Cyrix, however, does not expect to adopt a new pinout until its M3 processor, due in 1998.

Price & Availability

Intel's 200-MHz Pentium is available now at a 1,000-piece list price of $599. For more information, contact your local Intel sales office or check the World Wide Web at *www.intel.com*. For specific information on the plastic PGA package, request document 243103-001 from the Intel Literature Center at 800.548.4725.

The 6x86-P200+ is available in limited quantities now, with volume production slated for early August from both Cyrix and IBM. Cyrix's list price is $499 in quantities of 1,000. IBM's price is $479 in the same quantities.

Contact Cyrix (Richardson, Texas) at 214.968.8388; fax 214.699.9857 or check the Web at *www.cyrix.com*. Contact IBM Microelectronics through its fax-back service at 415.855.4121 or via the Web at *www.chips.ibm.com.*

Cyrix Adopts MMX

A key enhancement of Klamath over Pentium Pro is the addition of MMX support. To match Klamath, Cyrix has added MMX to the M2 as well. The company had initially developed its own set of multimedia instructions for M2, but when both Intel and AMD adopted MMX, Cyrix realized it had no choice but to offer compatible instructions. The company says converting to MMX added only 30–60 days to the M2 schedule, a small price to pay for compatibility.

Unlike AMD, Cyrix has not licensed MMX from Intel. From a legal standpoint, Cyrix's ability to implement these instructions should be no different from its current implementation of other x86 instructions. Presumably, its use of Intel-licensed foundries—IBM and SGS-Thomson—should protect its MMX designs.

Cyrix based its MMX implementation on public information about the new instructions. It remains to be seen whether this implementation will be fully compatible with Intel's. When Cyrix delivered its first Intel-compatible processor, the x86 instruction set had been relatively well documented for years. The startup discovered several "holes" in this documentation only through extensive testing of Intel's own processors, and since then the Cyrix designs have had no significant compatibility issues.

	Intel Pentium		P200 vs. P166	6x86 150 MHz	6x86 vs. P200
	166 MHz	200 MHz			
Winstone 96	**81.5**	**89.0**	**9.2%**	**91.6**	**2.9%**
Graphics	8.0	8.6	7.5%	8.7	1.2%
Database	9.3	10.2	9.7%	10.5	3.6%
Spreadsheet	7.5	8.2	9.3%	8.5	3.7%
Word Proc.	8.2	9.0	9.8%	9.3	3.0%
Winstone 32	**107.7**	**114.8**	**6.6%**	**120.6**	**5.1%**
Graphics	9.3	9.7	4.3%	9.9	1.7%
Database	13.5	14.7	8.9%	15.4	4.3%
WP/SS	10.6	11.4	7.5%	12.2	6.4%

Table 1. Cyrix's 6x86-P200+, which runs at 150 MHz, slightly outperforms Intel's Pentium-200 on PC application benchmarks. See article text for configuration details. (Source: MDR Labs)

Bringing out its MMX processors just a few months after Intel's raises the level of risk. Cyrix will have little, if any, opportunity to test Intel's MMX processors before finalizing the M2. Without this testing, the possibility of a compatibility problem is greater. MMX is much simpler than the rest of the x86 architecture, however, minimizing this risk.

Another issue for Cyrix is that it will have no MMX-enabled part that matches well against the P55C. The M2 should exceed the performance of the P55C, positioning it against Klamath. That would leave the current 6x86 to take on the P55C. If the market demands MMX at the P55C price points, Cyrix may choose to offer low-speed versions of the M2 instead. By 2H97, however, P55C prices will fall below $300, removing this problem from Cyrix's radar screen.

Cyrix Gains on 16-Bit and 32-Bit Applications

MDR Labs measured the performance of both the 200-MHz Pentium and 150-MHz 6x86 on two PC application suites: Ziff-Davis's Winstone 96 and new Winstone 32. Winstone 96 is a popular metric that consists of a variety of 16-bit PC applications that we ran under Windows 95. Winstone 32, which we also ran under Windows 95, contains only 32-bit (Win32) PC applications.

Because the two chips use different system bus speeds, it was impossible to run them in the same motherboard for the best comparison. We tested the 6x86 in a DFI board using the Lynx chip set, which is the only available chip set that supports a 75-MHz bus. Although this board can be configured at 66 MHz for the Pentium-200, we measured the Intel chip in a Tyan motherboard using Intel's 430HX (Triton II) chip set, which delivers better performance than Lynx for the Pentium processor. For comparison, we also tested a Pentium-166 in the same Tyan motherboard.

Other than these differences, the two test systems were as identical as possible. They both included 256K of pipeline-burst cache, 32M of EDO DRAM, a Seagate Barracuda 2G disk connected through an Adaptec SCSI adapter, and a Matrox Millennium graphics card with 2M of WRAM. Measurements were taken with the graphics card set for 1024 × 768 × 8-bit resolution.

The data in Table 1 shows the 150-MHz 6x86 outperforms the 200-MHz Pentium by 2.9% on Winstone 96 and 5.1% on Winstone 32. The Cyrix chip consistently outscores the Pentium, coming out ahead on every component of each metric. Except for the business-graphics component in both suites, the Cyrix chip wins by 3.0–6.4%. (A complete report is on the Web at *www.chipanalyst.com*.) None of these tests contains significant amounts of floating-point code, on which the 6x86 is slower than Pentium.

End users are unlikely to perceive such small differences in performance. But given the relatively small gap between the performance of the Pentium-200 and the Pentium-166, the 6x86's edge appears more significant, particularly on 32-bit code.

Cyrix Strategy Raises Socket Issues

Over the past few months, Cyrix has demonstrated that its 6x86 can match Intel's fastest Pentium on mainstream PC applications, and the company has responded well to Intel's first attempt to restore a performance gap. We expect Cyrix to continue to stay close to the PC application performance (except for 3D graphics) of Intel's top parts for at least the next year, moving to the M2 as Intel moves to Klamath.

A key difference between these two P6-class parts will be the pinout. Both Cyrix and AMD will try to extend the performance range, and thus the life, of the P55C socket with the M2 and K6, respectively. Staying with the P55C socket will help PC makers in the short term, but moving to the Klamath pinout will provide much more performance headroom in the long term. Intel's competitors were successful with the 486 pinout in 1995 but not 1996; we expect the P55C pinout to be successful in 1997 but less so in 1998.

Although matching Intel's fastest Pentium is a big PR boost for Cyrix, the most important effect of the new version of the 6x86 is increasing yield and reducing the cost of the P133+, P150+, and P166+ versions, which sell into segments of the market with higher volumes than the P200+. Even as the P200+ declines in price, we do not foresee significant sales, even by Cyrix standards. Although the P200+ is nominally pin-compatible with Pentium, its 75-MHz bus makes it incompatible with all current Pentium motherboards. We expect few vendors to redesign boards for the 6x86-P200+, limiting its adoption.

In contrast, the Pentium-200 offers an easy upgrade to existing motherboards. For the next several months, the new clock speed will be the high end for consumers and others who don't want Pentium Pro. In fact, Intel doesn't expect P55C systems to be in stores in time for Christmas, leaving the Pentium-200 as the premium model through the holiday buying season. Once P55C ships in volume, however, the Pentium-200 will be a quickly fading memory. MR