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Intel Adds Low-Power Features to Every i486

More Choices for Notebook Designers—Desktops Turn "Green"

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Unveiling its much-discussed "S-Series," Intel announced that it will roll its entire 486 product line to a new design that includes power-management features such as system-management mode (SMM), static operation, and other features previously found only in the 486SL chip. The new chips, which are otherwise identical to current 486 processors, will not carry a price premium for the added functions.

Intel evaluated several names, including staying with the S-Series code name, before settling on a mouthful: "SL-Enhanced Intel 486 CPUs." The enhanced chips inherit the same 486SX and 486DX part numbers as their predecessors; after a short transition period during which the company will sell both versions, all 486 production will shift to the enhanced design.

Because many observers associate the "SL" name with the integrated system logic of the 486SL, the new usage may engender some confusion, since the enhanced chips include no system logic. Intel is betting that most end users think of "SL" as meaning "better notebooks," helping them to quickly understand the thrust of this announcement.

The announcement signals the end of the line for the 486SL family and endorses the strategy pioneered by AMD and Cyrix of including power-management features as part of the basic processor feature set. Intel will continue to sell the 486SL but does not plan to develop any new versions. The enhanced 486 chips offer more flexibility and higher performance for notebook systems and can also be used in energy-saving "green PCs."

Power-Management Features for Free

The enhanced design will be used in all 486SX, 486DX, and 486DX2 chips. Like the 486SL and its predecessor, the 386SL, the new design incorporates SMM (see µPR 10/31/90, p. 12), allowing a hardware timer to assert SMI# (system-management interrupt) and trigger the execution of power-management software. The static design enables the clock input to be greatly slowed or even stopped without losing the contents of internal registers and caches.

The enhanced chips have several low-power modes. The HALT instruction places the CPU into "Auto Halt" mode, reducing power consumption to under 275 mW (or less, depending on the clock rate). Any interrupt or reset will return the processor to normal operation.

External logic can put the chip into "Stop Grant" mode by asserting the new STPCLK# signal. This mode has the same power rating as Auto Halt, but only reset or deassertion of STPCLK# will resume normal operation. In either of these two modes, the processor will automatically power up for one cycle to service cache snoop requests.

Once in Stop Grant mode, the external clock can be stopped completely, further reducing power to 1 mW. In "Stop Clock" mode, however, the processor cannot respond to snoop requests or interrupts. These features are very similar to the Cyrix "suspend" and "standby" modes.

Shifting Gears Requires "Clutch"

Stop Grant mode allows the system to lower the clock frequency and later speed up again, but it is not as easy as it sounds. All standard 486 chips have a built-in PLL (phase-locked loop) circuit that generates a 2× internal clock called CLK2. This should not be confused with the DX2's "clock doubler," which actually changes the frequency of the CPU clock; CLK2 is simply used to synchronize internal circuitry.

While PLL circuits simplify system design by eliminating the need for a high-speed clock, their downside is an inability to quickly change speeds. To change the clock rate with the enhanced chips, the CPU must first be placed into Stop Grant mode. The input clock can then be switched to the desired frequency, but the CPU will be unavailable for about 1 millisecond while the PLL locks onto the new clock. After that period, the CPU re-enters Stop Grant mode and can be returned to normal operation at the new clock speed. In effect, one must hold down the clutch long enough to cleanly shift gears.

For systems that wish to change clock speed "on the fly," Intel will provide a slightly modified version of the SX and DX design that accepts CLK2 directly from the system, bypassing the PLL. This allows the system to change clock speeds at any time, without using Stop Grant mode. Because this feature is not available on DX2 parts, however, such systems would not be upgradeable to OverDrive processors. These "CLK2" chips will use the same part numbers as standard 486 CPUs but will be identified by a special ordering code.

Power Management Handled Externally

The enhanced parts do not have complete power-management capability; the timers and other hardware that actually triggers SMI# are not included on the CPU. VLSI Technology has licensed Intel's 486SL power-management hardware for its new Scamp IV system-logic chip set. This $57 chip set allows vendors to design a PC that uses the same power-management software as a 486SL system.

Other system-logic vendors are developing their own power-management chip sets to work with the new Intel CPUs. Both OPTi *(see **0704MSB.PDF**)* and Eteq *(see **0705MSB.PDF**)* have already announced single-chip system-logic designs, selling for about $25, that offer all of the system interfaces and power-management capabilities of the 486SL chip set. Since these products are not register-compatible with Intel's chip, however, they require new power-management software.

One power-saving feature that is invisible to software is called Auto Idle. Available only on the DX2, it cuts the internal clock rate in half whenever the CPU is waiting for memory or I/O. Intel estimates that this feature alone will reduce processor power by up to 10% without impacting performance or system design.

Except for the Auto Idle feature, active power consumption for the new design is identical to that of current 486 chips. The maximum power specification for the 33-MHz 486DX has been reduced from 4.5 W to 3.2 W because the enhanced DX parts will be produced solely on Intel's 0.8-micron process; the higher power rating was for 1.0-micron chips.

40-MHz 486DX2 Available at 3.3V

Intel expanded its 3.3V offerings from the current 25-MHz 486SX to include a 33-MHz SX, a 33-MHz DX, and the new top of the line, a 40-MHz (internal) 486DX2. The latter chip sets a new low in DX2 clock rates. The company also expects to ship a 50-MHz 486DX2 at 3.3V by the end of the year. The 3.3V parts have the same "SL enhanced" feature set.

All of the 3.3V parts will be available in a "slim" (SQFP) package. The SQFP uses a 0.5-mm pin pitch, smaller than the standard PQFP, to reduce the overall package size. It is intended for notebooks and other systems with limited space requirements. Intel will also sell the 3.3V chips in a PQFP as a special order.

The original 3.3V parts were limited in speed because Intel had simply recharacterized its 5V design at the lower voltage, resulting in relatively poor performance. Since the new design is intended to work well at either voltage, it allows the clock speed at 3.3V to approach the current 66-MHz maximum of the 486DX2. Even with the redesign, however, it is unlikely that Intel will be able to offer a 66-MHz 486 at 3.3V using its current 0.8-micron CMOS process.

The company's 0.6-micron process, due to reach production around the end of this year, operates at 3.3V only, meaning that Intel's fastest CPUs in 1994—including Pentium and the 100-MHz 486—will be available at that voltage. The company may choose not to move the 66-MHz 486DX2 to the new process, however, which may ultimately leave a small hole in an otherwise complete family of 3.3V processors.

This announcement satisfies Intel's promise to include power-management features on all new processors. Pentium, announced earlier this year, includes SMM and a static design but does not include STPCLK# and thus cannot enter Stop Grant mode; Intel expects to add STPCLK# to future Pentium processors. The complete "SL Enhanced" feature set will become part of all future implementations.

Green PCs Save Electricity

The term "Green PC" has recently been created for a new class of personal computers designed to save power. Unlike portable systems, which cut power usage to extend battery life, these desktop systems are designed to reduce electric bills, both for the system itself and for the air conditioning needed to cool it. Such power-wise PCs use fewer natural resources, thus earning the "green" sobriquet.

The US Environmental Protection Agency (EPA) estimates that computers account for 5% of all electricity consumed by the commercial sector, a figure that could swell to 10% by the end of the decade. If all the PCs in the US were redesigned to cut power usage in half, the country could save over a billion dollars per year in energy costs, cutting down on pollution and the natural resources needed to generate that power.

Given this situation, the EPA created the "Energy Star" program to encourage the development of power-saving computers. The program asks vendors to build systems that consume less than 30 watts when in "sleep mode" and that automatically enter sleep mode when not in use. These systems can display an Energy Star logo. To add further incentive, President Clinton has declared a goal for the US government to buy only PCs that qualify for this program. Many businesses are expected to follow suit simply for the energy cost savings.

Part Number	Vcc	Package	2Q93	3Q93*	Change
i486SX-25	5V	PQFP	$89	$87	-2.2%
i486SX-25	3.3V	SQFP	n/a	$92	n/a
i486SX-25	5V	PGA	$116	$113	-2.6%
i486SX-33	5V	PQFP	$168	$163	-1.8%
i486SX-33	3.3V	SQFP	n/a	$171	n/a
i486SX-33	5V	PGA	$193	$188	-2.6%
i486DX-33	5V	PQFP	n/a	$290	n/a
i486DX-33	3.3V	SQFP	n/a	$324	n/a
i486DX-33	5V	PGA	$306	$294	-3.9%
i486DX-50	5V	PGA	$457	$444	-2.8%
i486DX2-40	3.3V	SQFP	n/a	$406	n/a
i486DX2-50	5V	PGA	$417	$406	-2.6%
i486DX2-66	5V	PGA	$542	$515	-5.0%

Table 1. Pricing for Intel's "SL Enhanced" 486 processors (denoted by the asterisk) compared to current 486 pricing, all in quantities of 1000. (Source: Intel)

The new features add approximately 30,000 transistors to the current 486 designs, increasing die sizes slightly. For example, the new 486DX2 chip measures 7.0 mm × 12.1 mm, or 84 mm^2, a 2.5% increase over the current 82 mm^2 version. While Intel says it is not charging a premium for the power-saving features, Table 1 shows that the drop in prices between 2Q93 and 3Q93 is only 2%–3% for most products, less than Intel's usual quarterly price cuts.

New Strategy for Notebooks

The new chips open a wealth of options for notebook system designers. Until recently, designers who wanted 486 performance with the advantages of SMM had to use the 486SL, which was introduced last fall at 25 MHz, or else switch to Cyrix's hybrid 486SLC or DLC. Although Intel recently began shipping a 33-MHz 486SL, this is still a far cry from the performance of the top-of-the-line 486DX2 at 66 MHz. Thus, notebook users have been forced to accept lower performance than desktop users.

This trade-off was acceptable when notebooks were used only occasionally, and typically for less-demanding character-based applications. But today, many people are using their portable systems more frequently or even as their primary machine, and they want to run the same graphical (GUI) software as on the desktop. These notebook users demand desktop performance.

The new chips allow notebook designers to choose any of Intel's 486 CPUs for use in a low-power design. Thus, a wide range of price/performance and battery-life/performance tradeoffs can be made. Another new option is the enhanced 486SX chip, which reduces cost by leaving out the math coprocessor.

End of the Road for 486SL

Although many notebook vendors are excited about the new possibilities, others are disappointed that Intel has abandoned its previous 486SL strategy. The original SL design includes system logic, such as a memory interface and ISA bus interface, on the CPU chip itself. A companion chip provides peripherals and a set of registers and timers to detect and control system activity. This met notebook vendors' demands for a highly integrated solution with power management.

Intel was not as satisfied with this solution as its customers. Integrating all of these features onto the 486 increased its die size from 82 mm^2 to 167 mm^2, more than doubling the manufacturing cost of the chip. In the meantime, however, intense competition among system-logic chip vendors drove the cost of the added features as low as $25 in an external chip set. Thus, Intel is able to charge only $311 for a 33-MHz 486SL, compared to $294 for a 33-MHz 486DX that uses the same core CPU.

The crux of the problem is that Intel's profit margins on its CPUs are far higher than the profits available for system-logic functions. Integrating these functions onto its processors forced the company to accept a lower profit—not a popular choice at Intel, particularly since the company currently has no excess factory capacity for lower-profit chips. The new strategy forces the system-logic functions back onto an external chip set, permitting Intel to retain its high margins.

There are other problems with the original 486SL concept. As mentioned, it does not allow portable users the same performance levels and flexibility as desktop systems. Also, with its on-board ISA interface, the 486SL does not fit into Intel's PCI strategy. Intel would have had to create a full line of 486SL products, with both PCI and ISA versions, to meet these demands; such a strategy would have increased design costs, manufacturing overhead, and customer confusion.

The 486SL—with its limited performance, limited configuration options, and high manufacturing cost—is also a poor match for the forthcoming "Green PC" products (see sidebar). These new PCs implement power-management capabilities in desktop systems and require access to the full spectrum of Intel processor offerings. The enhanced 486 chips allow system vendors to build power-wise PCs without any additional CPU cost. In addition, low-end and mid-range systems can cut CPU power in half, without a performance penalty, by using 3.3V processors.

Intel Reacts to AMD, Cyrix

Intel's enhanced CPUs match up well against 486 chips from AMD and Cyrix. AMD has used a static design in all of its 386 and 486 products and recently announced its 486DXLV, which incorporates SMM and runs at 3.3V *(see **070601.PDF**)*. A few weeks later, Cyrix unveiled its 486S family *(see **070704.PDF**)*. All of the new Cyrix parts have a static design and SMM; some 3.3V versions are also available. With its 40-MHz 486DX2,

Intel has one-upped its competitors; both AMD and Cyrix are limited to 33 MHz in their 3.3V families.

Intel's announcement prevents its competitors from using power management to carve out a protected niche. Neither AMD nor Cyrix has priced its parts particularly aggressively and both must continue to search for new opportunities that Intel has not exploited.

One possibility for x86 competitors is to pick up where Intel's 486SL left off. There may still be opportunities for more integrated processors in the PC market if these chips make the appropriate tradeoffs between adding functions and manufacturing cost; several RISC vendors are doing exactly that *(see **0708ED.PDF**)*. Highly integrated processors are also desirable for handheld systems such as PDAs.

Intel, of course, will bring its mighty R&D budget to bear on any market opportunity that looks promising. For example, the microprocessor giant has a joint development program with VLSI Technology to address the PDA market. AMD, Cyrix, and other x86 players must quickly and correctly identify new opportunities to get ahead in the microprocessor game. ♦

Price and Availability

All of the "SL Enhanced i486 CPUs," including the 3.3V 40-MHz 486DX2, are currently sampling and will be in production in 3Q93. See Table 1 for pricing. For more information, contact your local Intel sales office or request packet #241283-001 from the Intel Literature Center, PO Box 7641, Mt. Prospect, IL 60056; 800/548-4725.

