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INTEL'S PENTIUM M GETS EMBEDDED

Mobile Processors and Chip Sets Aim for Communications Market

By Tom R. Halfhill {5/12/03-01}

Intel's newest microprocessor for mobile PCs is hardly out the door, but already the Intel Communications Group is promoting it as a high-performance embedded processor for networking. Intel is also sketching a roadmap for future chip sets that will improve the differentiation between its embedded and PC/server platforms.

The "new" embedded processor is the Pentium M, formerly known as Banias, which Intel introduced in March as part of the Centrino mobile PC platform. (See *MPR 3/31/03-01*, "Pentium M Hits the Street.") Although the mobile market currently has six Pentium M speed grades, ranging from 900MHz to 1.6GHz, Intel is offering the embedded market only two speeds: 1.1GHz and 1.6GHz. This probably reflects Intel's intention to sell the embedded Pentium M into high-performance communications-infrastructure applications, such as core routers, server blades, and network controllers. In those kinds of applications, the embedded Pentium M will be a control-plane or applications processor that works alongside a more-specialized network processor.

Among the first embedded Pentium M products to be announced is Momentum Computer's Cheetah-A, a CompactPCI single-board computer for 6U-size racks. It's available with either the 1.1GHz or 1.6GHz Pentium M, 2GB of dual-channel DDR DRAM, two Gigabit Ethernet ports, and a 32-bit, 33MHz PCI interface.

Intel Faces Stiff Competition

The Pentium M is better suited for its new role than are other Intel x86 processors. Thanks to a unique microarchitecture, it offers an attractive combination of high performance and low power consumption for an x86 chip. Its core clock frequencies are deceptive—the Pentium M should deliver higher performance than other Intel x86 processors running at similar clock speeds. (See *MPR 11/25/02-01*, "Intel Spills the Beans About Banias.") Unfortunately, independent embedded benchmarks aren't available, and Intel isn't saying whether it will release EEMBC benchmarks for the Pentium M.

Improving the x86's performance/power-consumption ratio will help it compete with RISC processors from Broadcom, IBM, Motorola, NEC, PMC-Sierra, and other veterans of the high-performance communications market. RISC architectures like MIPS and PowerPC typically consume less power than the x86 at comparable clock frequencies. The performance/power ratio is particularly important when designing densely packed boards for server racks, routers, switches, and other big-iron communications equipment.

Two other x86 vendors eagerly pursuing the embedded market are Transmeta and VIA. Transmeta recently introduced its Crusoe SE (Special Embedded) processors, and VIA is also aiming its Centaur C3 E-Series processors and their successors at embedded applications. Like Intel's Pentium M, the x86 processors from Transmeta and VIA were originally designed as mobile PC or desktop chips, but they have been transformed into embedded processors with the wave of the magic marketing wand. (See *MPR 1/13/03-01*, "Transmeta Charges the Embedded Market," and *MPR 11/11/02-01*, "VIA Keeps It Simple.")

Transmeta's Crusoe SE consumes less power than the Pentium M at comparable clock speeds, but the trade-off is

that its performance is less than its clock speeds imply—unlike the Pentium M, which should deliver more performance relative to clock frequency. VIA's C3 E-Series processors probably fall somewhere between the Crusoe SE and Pentium M in performance. Judging from their very different microarchitectures, we believe the Pentium M would outperform the VIA C3 in most benchmark tests, but the difference would almost certainly be smaller than their price gap. The 1.1GHz, 12W Pentium M sells for $257, while the low-power version of the 1.0GHz VIA C3 (11.8W) costs only $45. (Another version of the C3 that VIA sells to the PC market costs $40 but consumes 17W.)

Intel already has a significant presence in communications, thanks to previously remarketed x86 processors and the StrongARM-based XScale chips. The Pentium M will compete against the Crusoe SE, Centaur C3, PowerPC, MIPS, and other processors for the hearts and minds of design engineers at companies like Cisco, Juniper, and Lucent. Table 1 compares Intel's latest offerings with a sampling of the competition.

Because Intel didn't specifically design Pentium M for embedded communications, it lacks some features found in a few competing processors, particularly the highly integrated chips from Broadcom. Broadcom's flagship is the BCM1250, which has dual CPU cores, three Gigabit Ethernet media-access controllers (MAC), a 400MHz data-rate DDR-SDRAM controller, two high-speed serial interfaces for T-3/OC-1 connections, a PCI interface, and two 600MHz HyperTransport channels. Despite that boatload of extra logic, the BCM1250's maximum thermal design power (TDP) for a dual-core 800MHz processor is still only 15.5W, 36% less than the 1.6GHz Pentium M's 24.5W. Broadcom also offers a single-core processor, the BCM1125 (not shown in Table 1), which consumes only about 4W. No other processor listed in Table 1 is as well equipped as the BCM1250, although the Crusoe SE and RM9000x2 do have integrated memory controllers, and the RM9000x2 has HyperTransport.

To deliver the kinds of functions built into the BCM1250, Intel's Pentium M and Pentium III require external core logic and peripheral chips. Intel offers three chip sets for Pentium M, all based on the north-bridge/south-bridge system architecture common to PC desktop, mobile, and server computers. Although none of these chip sets was designed for embedded communications, all can provide most functions Intel's target applications require.

Chip Sets Are Retargeted, Too

Intel's chip sets for the Pentium M are the E7501, 855GM, and 855PM. Of these, only the latter two are specifically designed for the new processor; the E7501 was already available as a server chip set for Intel Xeon processors. The 855GM and 855PM chip sets are nearly identical, distinguished only by integrated 3D graphics in the 855GM and AGP-4X in the 855PM. These are the same two north-bridge chips Intel pairs with the Pentium M for the mobile-PC Centrino platform. However, the embedded Pentium M uses the ICH4 I/O controller hub (south-bridge chip) instead of Centrino's newer ICH4-M. Table 2 summarizes the features of all three Pentium M chip sets.

Two major differences between the E7501 and 855-series chip sets are their support for memory subsystems and for I/O expansion. As would be expected of a server-oriented chip set, the E7501 supports dual channels of double-data-rate (DDR) DRAM and up to 16GB of physical memory, although the Pentium M is limited to 4GB because it has only 32 address lines. In contrast, the 855-series chip sets are limited to single-channel DDR DRAM and only 2GB of physical memory. Those differences will be significant for some large embedded systems.

I/O expansion differs because the E7501 and 855-series chip sets work with different south-bridge chips: the ICH3-S and ICH4, respectively. Furthermore, the E7501 has three additional hub interfaces (HI 2.0) for high-speed bus controllers such as the Intel P64H2. Each P64H2 controller can support two 64-bit PCI or PCI-X buses, so a Pentium M system with an E7501 north bridge could support up to six of those buses. The HI 2.0 interfaces can also support multiple Gigabit Ethernet MACs or UltraSCSI-320 controllers—unlike

	Intel Pentium M	Intel LV Pentium M	Intel LV Pentium III	VIA C3 E-Series	Transmeta Crusoe SE	IBM 750FX	Motorola MPC7457	PMC-Sierra RM9000x2	Broadcom BCM1250
Architecture	x86 32-bit	x86 32-bit	x86 32-bit	x86 32-bit	x86 32-bit	PowerPC 32-bit	PowerPC 32-bit	MIPS 64-bit	MIPS 64-bit
CPU Cores	1	1	1	1	1	1	1	2	2
Core Freq	1.6GHz	1.1GHz	933MHz	1.0GHz	933MHz	800MHz	1.3GHz	1.0GHz	800MHz
L2 Cache	1MB	1MB	512K	64K	512K	512K	512K	256K x 2	512K
Core Voltage	1.484V	1.18V	1.15V	1.25V	0.8–1.3V	1.4V	1.0V	1.2V	1.2V
Max TDP	24.5W	12W	12.2W	11.8W	9W	8.5W	26W	12W	15.5W
IC Process	0.13µm	0.13µm	0.13µm	0.13µm	0.13µm	0.13µm SOI	0.13µm SOI	0.13µm	0.13µm
Availability	Now	Now	Now	Now	Now	Now	4Q03	Now	Now
Price (10k)	$625	$257	$209*	$45	N/A	N/A	$189	$350	$549

Table 1. The Pentium M will easily outperform existing Pentium III chips while consuming less power at comparable performance levels. It also stacks up well against x86 processors from other vendors. RISC processors based on the PowerPC and MIPS architectures are stronger contenders. *Intel doesn't release pricing for embedded Pentium III processors, so the Pentium III price in this table is for the mobile-PC version of the same chip. N/A=not available.

the 855-series chip sets, which lack the necessary I/O bandwidth to fully use these interfaces.

The ICH3-S south-bridge chip attaches to the E7501's HI 1.5 hub interface and provides a 32-bit PCI controller, four ATA-100 interfaces for IDE hard drives, six USB 1.1 ports, a 10/100 Ethernet MAC, and a low-pin-count (LPC) interface for other peripheral devices. However, this aging south-bridge chip does not natively support the ATA-133, Serial ATA, or Hi-Speed USB 2.0 standards without additional (and less efficient) peripheral chips.

The ICH4 south bridge for the 855-series chips is less versatile than the ICH3-S but a little more up to date. It has a 32-bit, 33MHz PCI controller, two ATA-100 channels for IDE hard drives, a 10/100 Ethernet MAC, a Hi-Speed USB 2.0 host controller (supporting six USB ports), and an LPC interface. Still, there's no native support for the latest ATA-133 and 150MB/s Serial ATA standards, which would be desirable in a high-performance embedded system. Moreover, the 855/ICH4 combination is burdened with hand-me-down features from the mobile PC market; few routers and server blades need integrated 3D graphics, AGP, or AC97 audio.

Price & Availability

Intel's embedded Pentium M processors are available now, priced at $625 for the 1.6GHz part and $257 for the low-voltage 1.1GHz part in 10,000-unit quantities. The E7501, 855GM, and 855PM chip sets are also available now. For more information, visit *http://developer.intel.com/design/intarch/pentiumm/pentiumm.htm*.

Intel Needs More Differentiation

Intel's roadmap foresees new chip sets that will offer more features for the embedded market. Although Intel hasn't publicly released any details, it's obvious the chip sets need to support the latest I/O standards, such as Serial ATA, as well as future standards like Serial ATA II and PCI Express.

Future chip sets also need to support Pentium M multiprocessor configurations to compete with rival PowerPC and MIPS processors in the highest-performance applications. Intel's server-sired E7501 north bridge supports two-way multiprocessing, but with Xeon processors only. In contrast, Broadcom's dual-core BCM1250 natively supports two-way glueless multiprocessing with its 600MHz HyperTransport channels, effectively allowing designers to assemble a four-way multiprocessor configuration using only two chips.

Ideally, Intel should produce a more-integrated version of the Pentium M to compete with highly integrated communications processors like the BCM1250. When one adds up the power consumption of a comparable Pentium M configuration—the 1.6GHz processor (24.5W), the E7501 north bridge (6.2W with single-channel DDR DRAM), the ICH3-S south bridge (2.0W), and three P64H2 hub controllers (4.6W each)—the total is 46.5W, three times the power consumption of the BCM1250. That doesn't include the additional chips the Pentium M would require to support Gigabit Ethernet, which the BCM1250 also integrates. And the multichip Pentium M configuration would occupy much more board space and be more difficult to design. If Intel wants to make serious inroads into embedded communications, it may have to do more than relabel PC processors and chip sets as embedded processors and chip sets. Leveraging the high-volume PC-processor business model has its limitations.

Intel's new Enhanced SpeedStep somewhat mitigates the Pentium M's greater power consumption (relative to RISC processors). Unlike the original SpeedStep, which merely lowered the processor's supply voltage and clock frequency while a mobile PC was running on batteries, Enhanced SpeedStep has multiple voltage/frequency steps

	Intel E7501	Intel 855GM	Intel 855PM
Host CPUs	Pentium M Xeon	Pentium M	Pentium M
Multiprocessing	Dual Xeon	No	No
System Bus	400/533MHz	400MHz	400MHz
Bus Width	64-bit + 8-bit ECC	64-bit + 8-bit ECC	64-bit + 8-bit ECC
Memory System	Dual-Channel DDR	Single-Channel DDR	Single-Channel DDR
Memory Speeds	200/266MHz	200/266MHz	200/266MHz
Memory Bandwidth	4.2GB/s (dual)	2.1GB/s	2.1GB/s
DRAM Densities	128–512Mb	64–512Mb	64–512Mb
Maximum Memory	4GB (Pentium M) 16GB (Xeon)	2GB	2GB
South Bridge	ICH3-S	ICH4	ICH4
S. Bridge Bandwidth	266MB/s	266MB/s	266MB/s
Add'l Hub Interfaces	HI 2.0 x 3	No	No
Add'l Hub Bandwidth	1.066GB/s x 3	—	—
Add'l Hub Chips	P64H2 (64-bit PCI/PCI-X)	—	—
Reliability Features	RASUM*	No	No
Integrated Graphics	No	Yes	No
AGP Interface	No	No	AGP 2.0 1x–4x
Power (N. Bridge)	6.2W (1-channel DDR) 7.1W (2-channel DDR)	N/A	N/A
Power (S. Bridge)	2.0W	N/A	N/A
Package	1,005-ball FCBGA	732-ball Micro-FCBGA	593-ball Micro-FCBGA
Availability	Now	Now	Now

Table 2. Intel's mobile-PC 855-series chip sets are closely related, while the server-oriented E7501 is a completely different beast. Note that Pentium M can't use the E7501's multiprocessing capabilities. N/A=data not available. *RASUM is Intel's term for "reliability, availability, serviceability, usability, and manageability." It describes a collection of features that include error-correcting codes (ECC), autoinitialization, memory scrubbing, CPU thermal monitoring, and hot-plugging for PCI/PCI-X buses.

that can change dynamically. Both the embedded Pentium M processors support Enhanced SpeedStep with all chip sets, varying their clock frequency from a low of 600MHz to their maximum clock speed of 1.1GHz or 1.6GHz. Competing RISC processors lack this feature, although some other x86 chips have it. Transmeta pioneered dynamic voltage/frequency scaling with its Crusoe processors, which use a technology called LongRun, and VIA's x86 processors have a similar feature called LongHaul.

We expect the Pentium M's performance/power-consumption ratio to significantly improve later this year when Intel rolls out Dothan, a Pentium M fabricated in Intel's new strained-silicon 90nm-lithography process. (See *MPR 9/3/02-01*, "Intel Adopts Strained Silicon.") Dothan will push performance beyond the reach of the fastest x86 challengers from VIA and Transmeta while lowering the maximum TDP to more-favorable levels. Competing RISC architectures will probably continue to enjoy an overall power-consumption advantage, but they, too, will have difficulty matching Dothan's peak performance. If Intel can deliver new processors and chip sets that are more optimized for embedded systems, the Pentium M microarchitecture will be a formidable platform for high-performance communications.