Reed Electronics Group

MICROPROCESSOR REPORT

www.MPRonline.com

THE INSIDER'S GUIDE TO MICROPROCESSOR HARDWARE

# PowerPC Ain't Dead Yet

## *Freescale's New 90nm MPC7448 Scores Highest EEMBC Benchmarks*

*By Tom R. Halfhill {7/5/05-01}*

Although Apple is abandoning PowerPC for the sleek efficiency of the x86 (ahem), it doesn't mean the PowerPC architecture is doomed to follow the AMD 29000, DEC Alpha, or Motorola 88000. PowerPC still has legs, especially in the high-performance embedded market, and its main opponent is now the MIPS architecture, another RISC refugee from the desktop.

Until now, the fastest single-core embedded processor was arguably Freescale Semiconductor's PowerPC MPC7447A, which boasted the highest EEMBC benchmark scores of any microprocessor chip. (Some specially customized versions of configurable processor cores have achieved higher EEMBC scores in simulation.) To defend its high ground, Freescale has unveiled an even faster microprocessor, the MPC7448—previously announced but without vital details. As newly certified EEMBC scores in Table 1 show, the 1.7GHz MPC7448 easily beats the 1.42GHz MPC7447A.

The MPC7448 bumps up the maximum clock frequency of the CPU core to 1.7GHz, increases the bus frequency to 200MHz, doubles the size of the internal L2 cache to 1MB, improves the efficiency of AltiVec pipelining, and debuts on Freescale's 90nm copper silicon-on-insulator (SOI) process, which will help hold the line on power consumption.

Otherwise, the MPC7448 is almost identical to the MPC7447A, sharing the same PowerPC e600 processor core and general microarchitecture. Indeed, the MPC7448 is pin compatible with the MPC7447A and with all previous versions of this basic design since the MPC7440, introduced in 2001. Freescale is sampling the MPC7448 now and says production quantities will be available in October.

### Going Mano a Mano With Ninety Nano

Most high-performance embedded processors are still manufactured in 0.13-micron processes, which surrenders a power-performance advantage to the MPC7448, at least for a short while. The existing 0.13-micron MPC7447A peaks at 1.42GHz, a clock frequency already 30–40% higher than that of most competing chips. The 90nm MPC7448 bolts out of the gate at 1.7GHz. It's remarkable that a processor with a relatively short seven-stage pipeline can scale to clock speeds from 600MHz to 1.7GHz, even with the advantage of the latest fabrication technology.

But don't be swayed by high clock frequencies. Remember that these chips are for power-minded embedded systems, not for ovenlike PCs, which sometimes have more fans than a movie star. Freescale is using its advanced 90nm SOI process and other techniques not just to pursue high clock rates but also to keep the MPC7448's power consumption in the same 10W range as other high-performance embedded processors with a single core. That's why the MPC7448 doesn't rely exclusively on clock frequency to boost performance.

Doubling the size of the integrated L2 cache to 1MB was a relatively easy way of improving overall throughput without altering the core microarchitecture and incurring the higher power cost of additional logic transistors. However, there were some trade-offs. The L2 cache now requires two clock cycles to transfer a 32-byte line instead of one

### Price & Availability

Freescale's PowerPC MPC7448 is sampling now, and production quantities are scheduled to be available in October. Freescale hasn't announced pricing for all speed grades up to 1.7GHz but says the 1.0GHz parts will cost less than $100 in 2006. For more information, visit *www.freescale.com/webapp/sps/site/overview.jsp?code=DRPPCDUALCORE*.

cycle, and the latency has increased from 9 cycles to 11 cycles (12 cycles with ECC). Even so, the higher hit rate of the larger cache should improve performance in most cases.

Another improvement is the faster system bus (Freescale's MPX bus), which now runs at 133-, 167-, or 200MHz. In contrast, the MPC7447A is limited to 133MHz or 167MHz. The faster bus is a welcome change, but a 1.7GHz processor like the MPC7448 deserves something even faster, especially because the MPX bus is the chip's only system interface.

The AltiVec vector-processing engine in the MPC7448 has been enhanced and is now capable of executing instructions out of program order. Dynamic out-of-order instruction scheduling should relieve some pipeline bottlenecks and boost throughput at a small cost in die area and power. However, AltiVec is already such a highly tuned engine that this enhancement has a relatively minor impact on overall performance.

EEMBC benchmarks tell the story. To take full advantage of AltiVec's 128-bit-wide SIMD instructions and enormous register file, programmers must vectorize the source code, which usually requires some hand optimization. (See *MPR 5/11/98-01*, "AltiVec Vectorizes PowerPC.") EEMBC forbids source-code modifications for out-of-the-box benchmarking but allows it for so-called full-fury or optimized benchmarking. Freescale has generously invested this extra effort when benchmarking both the MPC7448 and the MPC7447A. As Table 1 shows, the optimized benchmark scores are generally in line with the MPC7448's 20% higher clock speed—except for the DENmark scores. In the Digital Entertainment suite that DENmark represents, AltiVec optimizations make a bigger difference for the MPC7448 than they do for the MPC7447A. This suite is especially heavy with data-intensive media-processing tests (see *MPR 2/22/05-01*, "EEMBC Expands Benchmarks"), and apparently the out-of-order AltiVec scheduling is a greater benefit.

| EEMBC Benchmark | Freescale MPC7448 1.70GHz | Freescale MPC7447A 1.42GHz | Speedup |
|---|---|---|---|
| AutoMark | 1,883.80 | 1,564.10 | 1.20x |
| ConsumerMark | 251.5 | 197.2 | 1.28x |
| Office Automation | 2,162.80 | 1,793.70 | 1.21x |
| TCPmark | 1,097 | 819.8 | 1.34x |
| IPmark | 389.5 | 245.1 | 1.59x |
| TeleMark | 50.4 | 41.4 | 1.22x |
| TeleMark Optimized | 601.4 | 500.6 | 1.20x |
| NetMark | 55.2 | 46.7 | 1.18x |
| NetMark Optimized | 159.4 | 135 | 1.18x |
| DENmark | 350.8 | 257.6 | 1.36x |
| DENmark Optimized | 762 | 537.8 | 1.42x |

**Table 1.** Freescale's new 1.7GHz MPC7448 is the world's fastest embedded microprocessor chip, according to the latest EEMBC benchmarks. Its clock frequency is about 20% higher than that of the former champion, the 1.42GHz MPC7447A, and some scores (particularly IPmark and DENmark) surpass that difference.

To contain power consumption, Freescale has improved the dynamic voltage-frequency scaling used in the MPC7448. In response to system commands, the processor can adjust its core clock frequency from 600MHz to 1.7GHz in 200MHz increments. Voltage scaling is less flexible, owing to the inherently low voltage of the 90nm SOI process. Freescale estimates the core voltage will vary from 1.0V to 1.3V. Though narrow, that range has a relatively greater effect than clock-frequency scaling, because voltage is a squared term in the power equation. ($W=CV^2F/2$, where W is watts, C is capacitance, $V^2$ is voltage squared, and F is frequency.) Of course, the MPC7448 has other power-management features, too, such as sleep and nap modes and an on-chip diode that monitors the die-junction temperature ($T_j$).

### Multicore Chips Are the Next Challenge

Freescale's competitors for high-performance embedded processors are legion. They include Applied Micro Circuits Corp. (AMCC), AMD, Broadcom, IBM Microelectronics, Intel, PMC-Sierra, and VIA. Two of those rivals—AMCC and IBM—are fellow PowerPC vendors, whereas Broadcom and PMC-Sierra favor the MIPS architecture. AMD, Intel, and VIA back the x86, of course, and Intel also has the ARM-compatible XScale family. Sun Microsystems competes on the fringe with SPARC, and several other architectures have cult followings.

That summary makes the high-performance embedded-processor market seem more diverse than it really is. In the dominant applications—networking and communications—MIPS has a commanding presence, trailed by PowerPC. Broadcom and PMC-Sierra are solid MIPS licensees, and the latest multicore processors from upstarts like Cavium Networks and Raza Microelectronics (RMI) are highly customized MIPS-based designs. In contrast, embedded x86 processors are mostly rebranded PC chips created for an entirely different market, and they have trouble competing against the entrenched RISC architectures.

In addition to CPU architecture, the second distinguishing feature among high-performance embedded processors is their level of system integration. Some chips integrate numerous system peripherals—mainly I/O controllers (Ethernet, HyperTransport, IDE, PCI, PCI-X, PCI Express, RapidIO, Serial ATA, USB) and, more recently,

security accelerators. Other chips are traditional microprocessors, general purpose in nature. The MPC7448 is definitely in the latter camp, lacking even a DRAM controller. Its only interface to the outside world is the MPX bus, which must connect to a system controller like Tundra Semiconductor's new Tsi-108, which supports DDR2 DRAM, Gigabit Ethernet, High-Speed USB 2.0, 133MHz/64-bit PCI-X, 66MHz/64-bit PCI, Serial ATA, RS-232, and flash memory. Freescale's answer for customers seeking system integration on a single chip is the ubiquitous PowerQUICC family. (See *MPR 3/21/05-01*, "Freescale Quickens PowerQUICC.")

Consequently, the MPC744x line is becoming less attractive for networking applications targeted by specialized chips, although it's still useful for embedded applications that demand high performance and can do without high integration. One of Freescale's ambitions is to go beyond networking and communications to find more design wins in consumer electronics, such as home entertainment. The MPC7448 can certainly deliver enough throughput, especially if programmers optimize their code for AltiVec. And if Freescale achieves its goal of holding power consumption below 10W, the MPC7448 will offer a compelling power-performance ratio. In the long run, however, cost-conscious consumer-electronics OEMs—like networking customers—tend to favor integrated chips that reduce the component count.

General-purpose microprocessors like the MPC7448 are jacks of all trades and masters of none, which is why Freescale announced the MPC8641 and MPC8641D at last year's Fall Processor Forum. Essentially, the MPC8641 is an MPC7448 with the system-integration features of the PowerQUICC III MPC8548. The MPC8641D is a dual-core version of the same chip—Freescale's first multicore PowerPC processor. (See *MPR 10/25/04-01*, "Embedded CPUs Zoom at FPF.")

For customers, it's a buffet. They can choose the barebones MPC7448, the well-integrated MPC8641, or the dual-core *and* integrated MPC8641D—all built on the same high-performance PowerPC e600 CPU. Table 2 compares the MPC7448 with the existing MPC7447A, the MPC8641/D, and some competitors: AMCC's PowerPC 440GX, Broadcom's BCM1250, IBM's PowerPC 750GX, and PMC-Sierra's RM9000x2GL.

The MPC7448 is a worthy addition to the MPC744x line, but the future of these nonintegrated processors appears limited. Apple switched from PowerPC to the x86 partly because neither Freescale nor IBM could justify the costly development of low-power, high-performance, general-purpose processors for Apple's laptops, which sell about two million units a year. Evidently, the embedded market for such processors isn't large enough to justify their development, either. Otherwise, Freescale or IBM would have

| Feature | Freescale MPC7448 | Freescale MPC7447A | Freescale MPC8641/D | AMCC PPC 440GX | Broadcom BCM1250 | IBM PPC 750GX | PMC-Sierra RM9000x2GL |
|---|---|---|---|---|---|---|---|
| Architecture | PowerPC e600 (G4+) | PowerPC e600 (G4+) | PowerPC e600 (G4+) | PowerPC Book E | SiByte MIPS64 | PowerPC G3 | Enhanced MIPS64 |
| CPU Cores | 1 | 1 | 1 or 2 | 1 | 2 | 1 | 2 |
| Core Freq | 600MHz–1.7GHz | 600MHz–1.4GHz | >1.5GHz | 533–800 | 600MHz–1.0GHz | 733MHz–1.1GHz | 800MHz–1.0GHz |
| Bus Freq | 133–200MHz | 133–167MHz | 667MHz | 166MHz | Up to 400MHz | Up to 200MHz | 200MHz |
| L1 Cache (I/D) | 32K/32K | 32K/32K | 32K/32K | 32K/32K | 32K/32K | 32K/32K | 16K/16K |
| L2 Cache | 1MB | 512K | 1MB/core | 256K | 512K | 1MB | 256K per CPU |
| FPU | 1 | 1 | 1 or 2 | — | 2 | 1 | 2 |
| ALU Pipeline | 7 stages | 7 stages | 7 stages | 7 stages | 9 stages | 4 stages | 7 stages |
| Superscalar | 4-way | 4-way | 4-way | 2-way | 4-way | 2-way | 2-way |
| Special Features | AltiVec, improved voltage/freq scaling | AltiVec, voltage/freq scaling | AltiVec, 4xGbE, PCI Express, RapidIO | GbE, TCP/IP h/w, PCI-X, $I^2O$ msg | 3xGbE, PCI, HyperT, PCI, 2xDDR | L2 locking, deep bus pipelining | HyperT, GbE, PCI, DDR, SysAD |
| Voltage (core) | 1.0–1.3V* | 1.1–1.3V | 1.0–1.1V* | 1.5V | 1.2V | 1.45V | 1.2V |
| Power (typical) | <10W* (1.4–1.5GHz) | 9.3W (1.2GHz) | 10–25W* | 4.5W (533MHz) | 8W–10W (800MHz) | 8.8W (1.0GHz) | <12W |
| IC Process | 90nm SOI | 0.13µm SOI | 90nm SOI | 0.13µm | 0.13µm | 0.13µm SOI | 0.13µm (LV) |
| Package | BGA/LGA-360 | BGA/LGA-360 | BGA/LGA-1023 | CBGA-552 | BGA-860 | CBGA-292 | 672–896 pins |
| Production Availability | Oct 2005* (Sampling now) | Now | 1H06 | Now | Now | Now | Now |
| Price (10K) | <$100* 1.0GHz | $245 1.4GHz | n/a | $65 533MHz | $300–$400 600MHz–1.0GHz | $154 (1K) 1.0GHz | $321 800MHz |

**Table 2.** Freescale's new MPC7448 offers strong performance against the current crop of high-performance embedded processors, largely because it's fabricated in a 90nm SOI process, whereas competing chips are still using older 0.13-micron processes. That advantage will diminish next year, when competitors make the same transition. Furthermore, competitors like Broadcom are leaping to multicore processors with four or more CPU cores, whereas Freescale won't introduce its first dual-core PowerPC processor until next year. The general trend in the networking and communications market is toward higher system integration, which is why Freescale is introducing the MPC8641 and MPC8641D, which essentially add I/O controllers and other on-chip peripherals to the MPC7448. *Freescale estimate. n/a: data not available.

designed a low-power G5-class chip and amortized the development cost across both markets.

Instead, Apple has defected to Intel, and Freescale is using process shrinks and multicore designs to keep the performance of its G4-class chips competitive. In time, integrated chips like Freescale's PowerQUICC family and competing products will dominate networking and communications, leaving general-purpose processors like the MPC7448 to fill niches too new or too small to attract specialized designs.