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TOSHIBA'S NEW MIPS64 FAMILY

TX99-Series Chips Aim for High-Performance Embedded Systems

By Tom R. Halfhill {7/26/04-02}

It's been a relatively quiet year for MIPS-compatible processors, but Toshiba is making waves with a new family of high-performance embedded processors based on an enhanced MIPS64 core. The first member of the family is the TX9956CXBG, which has Toshiba's new TX99/H4 64-bit core, jointly developed with MIPS Technologies.

Sampling now, with production scheduled to start in November, the TX9956CXBG is a standard-product chip for multifunction printers, high-end set-top boxes, automotive information systems, and other high-performance embedded applications. It's a step up from Toshiba's existing 64-bit MIPS processors, because the TX99/H4 is Toshiba's first MIPS64-compatible core with superscalar pipelines and clock speeds beyond 500MHz. It's also the first chip in its class, from any vendor, to be manufactured in a 90nm IC process, which gives the TX9956CXBG an advantage in power consumption and power-performance ratios.

In line with Toshiba's historical practice, the TX9956CXBG—as the first member of a new family of standard products—is not a highly integrated chip. Instead, it's a general-purpose processor designed to work with companion ASICs over its MIPS-compatible 32/64-bit System Address/Data (SysAD) bus. Future members of the TX99 family will be much more integrated. Toshiba plans to add such features as a PCI/PCI Express controller, memory controller, Gigabit Ethernet controller, NAND/NOR flash controller, cryptography accelerators, video ports, UARTs, timers, and other peripheral logic. Different members of the TX99 family will have different levels of integration, depending on their intended applications.

Although Toshiba derived the TX99 core from the MIPS 25Kf hard core—essentially, it's a 90nm port of the 25Kf—neither the TX99 nor the 25Kf is available for general licensing. Toshiba reserves the TX99 for its own standard products and for custom SoCs designed for specific customers. (Two of those SoCs—one for an office-automation product, the other for an automotive application—are in production, but the customers prefer to remain nameless.) MIPS hasn't ruled out licensing the 25Kf if a customer commits to large enough volumes, but, as a rule, MIPS has refocused its business on synthesizable processor cores instead of less-portable hard cores. Toshiba says it took two years to port the full-custom 25Kf to the 90nm H4 process.

Enhanced Core Boosts Performance

The TX99 core boasts several improvements over Toshiba's existing MIPS64 TX49 core, which is found in processors like the TMPR4956CXBG. To begin with, the TX99 has a two-way superscalar pipeline instead of a simple uniscalar pipe. Also, the superscalar pipeline is deeper (seven stages vs. five), so the TX99 can reach significantly higher clock frequencies than the TX49. Toshiba says the TX99 can hit 800MHz in the 90nm process and is actually running at that speed in a custom SoC now in production for a customer. In comparison, the fastest Toshiba processor based on the older TX49 core (the TMPR4956CXBG) runs at only 450MHz in the same 90nm process.

However, Toshiba isn't pushing the TX99 core to its maximum clock frequency in the TX9956CXBG. For now, at least, Toshiba will limit that processor to speeds of 533MHz

and 666MHz. Toshiba says that running the chip below its maximum-possible clock frequency will achieve a better balance of cost, performance, and power consumption. At 533MHz and 666MHz, the superscalar TX9956CXBG should be fast enough for its target applications.

Another performance boost comes from the TX99's integrated Level 2 (L2) cache, a first for Toshiba. The TX9956CXBG has 256KB of L2 cache on chip, which supplements the four-way set-associative 32KB instruction and data caches. In addition, the TX99 has the MIPS-3D Application-Specific Extensions (ASE), which include 13 instructions for matrix multiplication, image clipping, lighting, and other tasks. (See *MPR 8/23/99-1311en*, "MIPS Adds a New Dimension to MIPS64.") The MIPS-3D ASE will be useful for printing and imaging in multifunction peripherals.

Toshiba says early production samples of the TX9956CXBG are running at 533MHz. Typical power consumption at that clock rate is 2.4W, and worst-case power consumption is 4.5W. Future bin-sorts will allow the company to offer production parts at 666MHz. Toshiba hopes to publish certified EEMBC benchmark results in the future; for now, however, the only performance ratings are hoary Dhrystone 2.1 benchmarks: 1,173 mips at 533MHz and 1,466 mips at 666MHz. That's not much to go on, because the Dhrystone program hardly exercises the memory bus in a processor with such large caches.

How does the TX9956CXBG stack up against the competition? Almost all of Toshiba's competitors already offer deeply pipelined superscalar processors with larger-scale integration and faster clock speeds, despite the handicap of using older fabrication technology. Consider PMC-Sierra's new RM7900, which has several similarities with the TX9956CXBG: an enhanced MIPS64 core; a seven-stage, two-way superscalar pipeline; 256KB of L2 cache; and a double-precision FPU. The RM7900 runs at higher clock speeds (up to 900MHz), even though it's manufactured in an older 0.13-micron process. It also has an integrated L3 cache controller, a feature not found in the TX9956CXBG. Toshiba's L1 caches are twice as large (32KB vs. 16KB), but the PMC-Sierra chip has a faster memory bus (200MHz vs. 133MHz).

Toshiba's advantages are better price-performance and power-performance ratios. At 533MHz, the TX9956CXBG typically consumes 2.4W and will cost $30 in 10,000-unit volumes. In contrast, PMC-Sierra's RM7900 typically consumes 4W at 750MHz, and the 668MHz part costs $103 in 10,000-unit volumes. Therefore, the TX9956CXBG delivers 150% more megahertz per dollar and 18% more megahertz per watt than the RM7900—advantages almost certainly attributable to Toshiba's next-generation process technology. Usually, direct clock-frequency comparisons of different processors from different vendors are misleading, but in this case, both processors have almost identical MIPS64-compatible microarchitectures.

Other high-performance embedded processors from AMCC, Freescale, IBM, and Intrinsity often beat the TX9956CXBG in core clock frequency, bus frequency, L2 cache, or

Feature	Toshiba TX9956CXBG	Toshiba TMPR4956CXBG	AMCC 440GX	IBM 750GX	Intrinsity FastMath	Freescale MPC7447A	PMC-Sierra RM7900
Architecture	Enhanced MIPS64	MIPS64	PowerPC Book E	PowerPC G3	MIPS32	PowerPC G4+	Enhanced MIPS64
Core Freq	533–666MHz	400–450MHz	533–800MHz	733MHz–1.0GHz	1.0–2.5GHz	1.0–1.4GHz	668–900MHz
Bus Freq	133MHz	133MHz	166MHz	200MHz	500MHz	167MHz	200MHz
Cache (I/D)	32K/32K	32K/32K	32K/32K	32K/32K	16K/16K	32K/32K	16K/16K
Level 2 Cache	256K	—	256K	1MB	1MB	512K	256K
FPU	Yes	Yes	No	Yes	No	Yes	Yes
Pipeline Stages	7	5	7	4	7–13	7	7
Instr/Clock	2	1	2	2	1	3+branch	2
Special Features	TX99/H4 core, SysAD bus, MIPS-3D ASE	TX49/H4 core, SysAD bus, 1-cycle MAC	GbE, TCP/IP h/w, PCI-X, I^2O messaging	L2 cache locking, deep bus pipelining	RapidIO, 4x4 SIMD	AltiVec	L3 ctrl, L2 ECC
Voltage (core)	1.25V	1.2V	1.5V	1.5V	0.85–1.2V	1.1–1.3V	1.3V
Power (typ)	2.4W (533MHz)	0.4W (400MHz)	4.5W (533MHz)	8.8W (1.0GHz)	6.0–24W (1.0–2.5GHz)	9.3W (1.2GHz)	4W (750MHz)
Transistors	32.3M	5.4M	n/a	63M	68M	58M	21.5M
IC Process	90nm	90nm	0.13µ	0.13µ SOI	0.13µ	0.13µ SOI	0.13µ (LV)
Die Size	n/a	n/a	n/a	51mm^2	122mm^2	75mm^2	n/a
Availability	July/August	Now	Now	Now	Now	Now	2Q04
Price (10K)	$30 (533MHz)	$18 (400MHz)	$68 (533MHz)	$98 (800MHz)	$349 (2.0GHz)	$245 (1.4GHz)	$103 (668MHz)
Price/MHz	$0.06	$0.05	$0.13	$0.12	$0.17	$0.18	$0.15
MHz/Watt	222	1,000	118	114	167	129	188

Table 1. All these RISC processors are suitable for high-performance embedded systems, and nearly all are superscalar designs. Some are focused on communications and networking, so they integrate specialized features, such as Gigabit Ethernet (GbE) and packet-processing hardware. Toshiba's first TX99-series processor is designed to work with companion chips; future members of the family will have more integrated features. (n/a: not available)

feature integration, but they don't match Toshiba's price-performance and power-performance ratios. Table 1 compares the TX9956CXBG with Toshiba's existing TMPR4956CXBG, AMCC's PowerPC 440GX (recently acquired from IBM Microelectronics), IBM's PowerPC 750GX, Intrinsity's FastMath, Freescale's MPC7447A, and PMC-Sierra's RM7900.

Grasping for High-Hanging Fruit at 90nm

Although Toshiba obviously gained some advantages by porting the 25Kf core to the 90nm H4 process, the TX99's performance isn't earth-shaking for a full-custom processor core manufactured in the latest fabrication technology. Even if Toshiba pushes the TX99 core to its maximum clock frequency of 800MHz, it's still slower than some competing cores manufactured in older 0.13-micron technology, such as the nearly identical PMC-Sierra RM7900. That's one reason Toshiba isn't promoting the TX9956CXBG for high-end communications and networking applications. Another reason, as noted above, is the lack of integrated controllers and communications interfaces in this first member of the TX99 family.

In power consumption, Toshiba's 90nm technology delivers a greater payoff. The TX9956CXBG typically consumes 2.4W at 533MHz, about half as much power as AMCC's PowerPC 440GX at the same clock frequency in a 0.13-micron process. Toshiba says the TX9956CXBG will consume a little less power with 2.5V I/O instead of 3.3V I/O.

Of course, the PowerPC 440GX is a much more integrated part, with an on-chip Gigabit Ethernet controller, a PCI-X controller, and hardware acceleration for TCP/IP packet processing. The TX9956CXBG would require a companion chip to match those features, if a customer tried to use it for the same applications. The PowerPC 440GX also has a faster memory bus (166MHz vs. 133MHz). In counterbalance, the TX9956CXBG has a 64-bit architecture, an FPU, and a much lower price ($30 vs. $68). When the more highly integrated members of the TX99 family appear, it will be interesting to see how their extra baggage affects Toshiba's power-consumption/price advantage over the 440GX and other competing processors.

Toshiba may be battling the same challenges that Intel discovered after moving the Pentium 4 to a next-generation 90nm process. (See *MPR 2/2/04-01*, "Prescott Pushes Pipelining Limits.") Static current leakage and other problems with deep-submicron technology are diluting the usual advantages of a process shrink. At least Toshiba's processors are consuming *less* power than their predecessors did, not more power, even if they aren't setting new records for clock speeds. As Toshiba gains experience with its H4 process, future chips in the TX99 family should bear more fruits of that labor.

Price & Availability

The first member of Toshiba's TX99/H4 family is the TX9956CXBG, sampling in July or August at 533MHz. Samples will cost $45 in 100-unit quantities. Samples at 666MHz should be available in August. Volume production is scheduled to commence in November 2004; the 533MHz part will cost $30 in 10,000-unit quantities. For more information, see *www.toshiba.com/taec/cgi-bin/display.cgi?table=Category&CategoryID=7271*.