SandCraft Adds Multimedia Extensions

New SR1-GX Core Aims at Next-Generation Set-Top Boxes

by Tom R. Halfhill

Microprocessors without multimedia extensions are becoming as rare as unemployed engineers in Silicon Valley. Equally rare are embedded-processor companies that don't have a system on a chip (SOC) and "post-PC" strategy. One of the latest companies to swell the tide is SandCraft, which is introducing a new MIPS-compatible embedded CPU core with digital-signal-processing (DSP) and single-instruction, multiple-data (SIMD) extensions.

Although the new SR1-GX is compatible with the MIPS-IV instruction set, SandCraft is not a MIPS licensee. SandCraft's first customer for the core, LSI Logic, does have a MIPS license. LSI is integrating the SR1-GX in an SOC that a consumer-electronics company has commissioned for an advanced digital set-top box.

Neither SandCraft nor LSI will reveal anything more about the customer, but the ability to run 3D video games appears to be a key part of the specification. It's unlikely that the customer is Nintendo, Sony, or Sega—those companies have already settled on IBM, Toshiba, and Hitachi, respectively, to supply the CPUs for their next-generation game consoles. So until later this year, SandCraft's first design win for the SR1-GX will remain a mystery.

FPU Is Optimized for 3D Graphics

The SR1-GX is an enhanced version of the SR-1 core that SandCraft unveiled last fall (see MPR 12/7/98, p. 10). It's a superscalar, out-of-order machine that can dispatch as many as four integer and two floating-point instructions per cycle. It has dynamic branch prediction and configurable L1 caches that can range in size from 8K to 64K. The caches can be direct mapped or two-, four-, or eight-way set-associative.

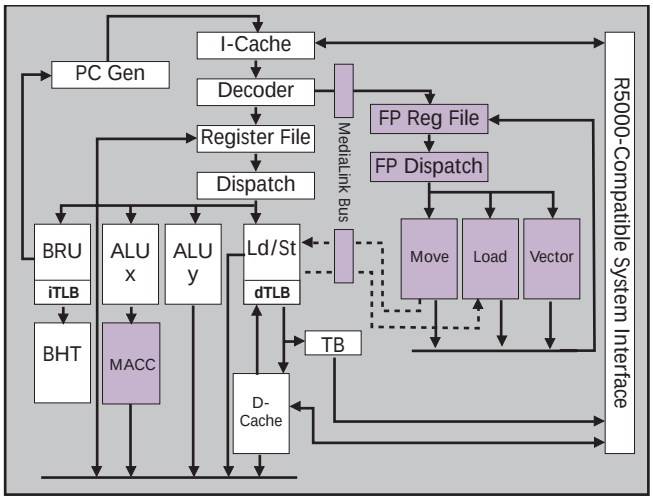

Figure 1. The SR1-GX is built around a two-way superscalar core and an FPU that uses SIMD instructions to execute 1.6 GFLOPS at 400 MHz. It doubles the number of registers available for single-precision floating-point values to a total of 64.

SandCraft says the customer originally wanted an embedded processor core that could run at 500–600 MHz to achieve the desired level of performance. Instead, SandCraft produced simulations to demonstrate that extensions to the SR1 core could deliver the same performance at 400 MHz while reducing costs and power requirements. As Figure 1 shows, SandCraft added an integer multiply-accumulate (MAC) unit, 16 new instructions for fixed-point DSP operations, a 64-bit FPU, 32 extra registers for single-precision floating-point numbers, and several new 32-bit SIMD instructions known as the Vector3D extensions.

The pipelined MAC unit can execute a $16 \times 16 \rightarrow 64$-bit MAC instruction in three cycles with single-cycle throughput, or a $32 \times 32 \rightarrow 64$-bit MAC in four cycles with a repeat rate of two cycles. It can multiply 32-bit integers with a latency of four cycles (repeated every two cycles) and multiply 64-bit integers with a latency of six cycles (repeated every four cycles). Additional instructions rotate 32- and 64-bit integers, count leading zeroes and ones (for data normalization), and perform saturating arithmetic. Although the SR1-GX certainly isn't competition for a high-end DSP that can execute multiple MACs per cycle, the new instructions compare favorably with similar extensions added to other CPU architectures, such as Intel's MMX.

On every clock cycle, the FPU can dispatch any two of the following: a move, a load, or a Vector3D instruction. The Vector3D instructions can perform a multiply and an add on two single-precision floating-point numbers per cycle—a total of 4 FLOPS per cycle, or 1.6 GFLOPS at 400 MHz. That's the same number of FLOPS per cycle as the leading desktop PC processors, such as the Pentium III with SSE or the AMD K6-2 with 3DNow. And like Intel and AMD, SandCraft has expanded the register file to avoid resource conflicts when the FPU is crunching all that data. The SR1-GX has 64 single-precision floating-point registers, or twice the number defined in the MIPS-IV architecture, without adding any architectural state that would affect OS compatibility. It's apparent that SandCraft optimized this core for the single-precision matrix math that's a mainstay of 3D games. That a set-top box could have the computational horsepower of a desktop PC is impressive indeed.

Even so, the SR1-GX doesn't come close to the performance of the Emotion Engine chip that Sony and Toshiba designed for the next-generation Sony PlayStation. The Emotion Engine (see MPR 4/19/99, p. 1) can crunch 6.2 GFLOPS at

Price & Availability

SandCraft says it will tape out the SR1-GX this summer, enabling customers such as LSI Logic to begin producing system-on-a-chip devices with the core by early next year. Pricing depends on the licensing agreement. For more information, go to *www.sandcraft.com*.

300 MHz—almost four times the performance of the SR1-GX at a 25% slower clock speed. The Hitachi SH7750 in Sega's Dreamcast can execute 1.2 GFLOPS at 167 MHz, which would scale to about 180% of the performance of the SR1-GX at a comparable clock frequency.

Obviously, the SandCraft core wasn't designed to the same steroidal proportions as CPUs optimized for video games; it's a general-purpose core for SOCs in set-top boxes, as Figure 2 shows. SandCraft estimates the core's die size, including 32K of L1 cache, will be 21–29 mm^2 in a 0.18-micron four-layer-metal process. Projected power consumption at 1.8 V is 1.4 W at 400 MHz. Compare that to the Emotion Engine's 240-mm^2 die (albeit in a larger 0.25-micron process) and 15 W at 1.8 V. Considering the vast disparity in die size and power consumption, the SR1-GX acquits itself well in very fast company.

Data in the Fast Lane

Pumping up the FPU does little good if the processor can't keep it fed with the vast amounts of data in those 3D polygon matrices, so SandCraft also improved the core's dataflow. The 133-MHz data bus is still 64 bits wide, but the bus between the data cache and the cache buffer is 256 bits wide. At its peak transfer rate, the cache buffer can stream 32 bytes of data into and out of the cache in one clock cycle.

An internal bus that SandCraft calls the MediaLink decouples the FPU from the integer core. The 64-bit MediaLink runs at the core frequency and resembles the internal coprocessor bus in MIPS processors. Although the SR1-GX hangs the FPU on this bus, SOC designers can use it to add their own coprocessors or optimized function units.

Bucking a recent trend, SandCraft is supplying the SR1-GX as a hard macro, not as a synthesizable soft core. The latest Jade cores from Mips Technologies will be available in both forms (see MPR 5/31/99, p. 18), and Lexra plans to deliver its mostly MIPS-compatible LX5280 as a soft core, too (see MPR 5/10/99, p. 5). Synthesizable cores are easier to customize for specific applications.

Hard cores often deliver greater performance, however. Mips expects the Jade 4Kc core to reach 270 Dhrystone MIPS at 225 MHz, but that's far short of the SR1-GX's 800 Dhrystone MIPS at 400 MHz. Mips had to "detune" the Jade pipeline to make it compatible with synthesis tools. A future hard core from Mips that's based on the new MIPS64 architecture is expected to exceed 1,000 Dhrystone MIPS.

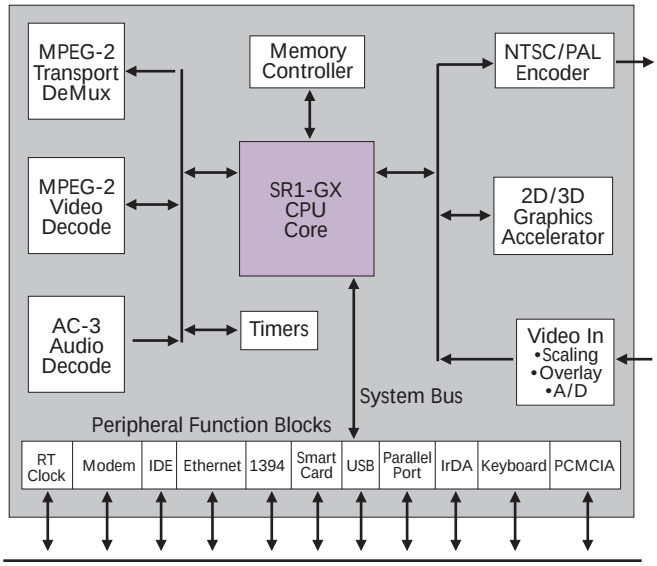

Figure 2. SandCraft's conception of a system on a chip for a next-generation set-top box—though it's unlikely a single chip would include every peripheral block shown here.

SandCraft's DSP extensions resemble the 36 new Radiax instructions in Lexra's LX5280. Both do 16- and 32-bit MACs, multiplies, and saturating arithmetic. An important difference is that Lexra is giving away the Radiax extensions for free, hoping to establish a standard in the MIPS community. Although the SR1-GX offers more performance than the LX5280, SandCraft will have to guard against losing business to competitors that offer soft cores with more flexible design options. The SR1-GX is a good alternative for those who value performance over configurability.

Redefining the Set-Top Box

When customers demand cores like the SR1-GX for their set-top boxes, they're clearly building something more than a simple channel switcher or pay-per-view decoder. Perhaps some company besides the triumvirate of Nintendo, Sony, and Sega is looking hungrily at the home video-game market—with good reason. Sales in the U.S. alone reached $6.5 billion last year. A single video game, Mario Kart, made more money than all of last year's Oscar-winning movies put together.

Is there room for another major competitor? Sony successfully muscled in on a market that was once dominated by Nintendo and Sega. To imitate Sony's success, newcomers will have to compete against next-generation game consoles that offer truly astonishing performance. SandCraft's SR1-GX is merely impressive, not astonishing.

Still, it's likely that gaming will become an accessory feature of advanced set-top boxes, if not the main ingredient. Because the boxes already are tethered to the cable network, interactive online games at cable-modem speeds could be their differentiation. Indeed, games could even be delivered by cable, eliminating the need for discs and ROM cartridges. With a strong customer, SandCraft might find itself in the right place at the right time with the SR1-GX. M