MICROPROCESSOR REPORT

CIRRUS LOGIC GROWS TEN ARMs

ARM9-Based Processors Extend Consumer/Industrial Maverick Family

By Tom R. Halfhill {3/1/04-01}

Encouraged by the reception of its first ARM9-based processor in 2001, Cirrus Logic is rolling out 10 more chips with an ARM920T core. All are highly integrated system-on-chip (SoC) devices with impressive features and on-chip peripherals, but the feature creep isn't coming at a price—even the new high-end chip costs 37% less than Cirrus Logic's first ARM9 processor from three years ago.

The new standard parts in Cirrus Logic's Maverick family of 32-bit embedded processors range from the EP9301 at the low end to the EP9315 at the high end. In between are the EP9303, EP9304, EP9305, EP9306, EP9307, EP9309, EP9310, and EP9311. They will join the EP9312, Cirrus Logic's first ARM9 processor, which was announced in June 2000 and shipped in early 2001.

Even at the low end of this line, the EP9301 is a well-integrated SoC with a 166MHz core and such luxuries as a 10–100Mb/s Ethernet controller, dual USB 2.0 host controllers, internal boot ROM, 12-channel DMA, 12-bit analog-to-digital converter (ADC), I^2S stereo audio, and multiple timers. The higher-end models run at 200MHz and add many more features. Because all these chips use the ARM920T core, they also have 16KB instruction and data caches, Thumb-1 instructions, and an MMU. The last feature allows them to run more-sophisticated embedded operating systems, such as Linux and Windows CE.NET.

Two of the new processors are available now: the low-end EP9301 and the high-end EP9315. The latter chip is pin compatible with the existing EP9312, while the others have smaller packages with reduced pin counts to cut costs. Cirrus Logic says the remaining chips will sample next quarter and ship in 3Q04. Prices for the new processors range from $8.96 to $24.01 in 10,000-unit quantities.

Peripherals Make the Difference

By introducing so many similar processors, Cirrus Logic is trying to convince consumer-electronics manufacturers and industrial customers that purchasing an off-the-shelf standard part makes more sense than developing a custom ASIC or SoC. The advantage of a custom chip, of course, is that the architects can fine-tune the design for a specific application, omitting unnecessary features to keep costs low. Standard parts often carry unneeded baggage. The disadvantage of a custom chip is that it requires a risky one- or two-year development project costing millions of dollars. Re-spins at the foundry to debug the design can prolong the project for months and cause a product to miss its critical time-to-market window.

Cirrus Logic is tempting customers into bypassing a custom-chip project by offering them 11 processors with nearly identical cores and a closely spaced selection of features and peripherals. Ideally, a customer will be able to find at least one processor in this lineup that has everything it needs and little or nothing it doesn't need. In practice, it's unlikely that any one of these processors will exactly match a customer's shopping list of features, especially considering how well-endowed these chips are. Some features will almost certainly lie fallow in a particular application. However, when customers weigh the cost and risk of a development project against the ready availability of a standard part, they may be willing to accept some excess baggage, especially in lower-volume applications that make it difficult to justify the cost of a custom ASIC or SoC.

With that in mind, Cirrus Logic has sprinkled features and peripherals across the EP93xx chips to offer a wide range of options. Unlike less-integrated processors, these chips don't vary in price according to clock speed—it's the integrated features and peripherals that account for the almost 3-to-1 price spread. Except for the low-end EP9301, which has a 166MHz core and a 66MHz memory bus, all the other EP93xx processors run at 200MHz with a 100MHz bus.

All the processors are manufactured in the same 0.18-micron CMOS process at UMC in Taiwan. Several of them are based on the same chip design, with different bonding and packaging options to differentiate their features. If a particular part proves exceptionally popular, Cirrus Logic may optimize the design by trimming off the disabled features.

The EP9301 is obviously intended for bargain hunters. In addition to being the slowest processor in the line, it's the only one with 16-bit SDRAM and flash-memory interfaces; all the other chips have 32-bit memory interfaces. (Internally, the EP9301 has the same 32-bit datapaths between the memory interfaces and the processor core as other EP93xx chips have, so it needs two bus cycles to translate between 16- and 32-bit words.) Another notable omission from the EP9301 is an FPU; all other EP93xx chips have Cirrus Logic's

MaverickCrunch Engine, a 32/64-bit floating-point coprocessor tightly coupled to the ARM920T core. However, because of its narrower buses, the EP9301 has only 208 pins, compared with 272 pins for most other EP93xx chips and 352 pins for the high-end EP9312 and EP9315. The reduced pin count and smaller package help the EP9301 achieve its entry-level price of just under $9.

Even so, the EP9301 is hardly a no-frills economy model. With its 10–100Mb/s Ethernet media-access controller (MAC), dual USB host controllers, I^{2}S stereo audio, boot ROM, 12-bit ADC, and other features, it's suitable for many embedded applications that need Internet or network connectivity. For example, it might find a home in a portable MP3 audio player. The USB ports would allow connections to a PC for downloading audio files, and the flash-memory bus provides a glueless interface to mass storage.

The EP9301 even has provisions for digital rights management (DRM). All EP93xx processors have Cirrus Logic's MaverickKey security technology, which fuses a unique 32-bit identification number and a 128-bit random number into the circuitry of each chip. Used separately or in combination, these immutable numbers make it possible to verify the identity of individual devices or users. Microsoft is asking vendors of portable consumer-electronics products to include such a unique identification number as part of its Trustworthy Computing initiative.

Luxury Model Adds Rich Features

At the opposite end of the spectrum is the EP9315, which becomes the new top of Cirrus Logic's ARM9 line. It has the MaverickCrunch FPU and 32-bit memory interfaces that are missing from the EP9301 and the same 10–100Mb/s Ethernet MAC. In addition, it has several step-up features: a PCMCIA interface, an extra USB 2.0 controller (three total), a two-channel EIDE interface, six-channel I^{2}S audio with 24-bit resolution, an extra UART (three total), 2D graphics acceleration, a video/LCD display controller, an 8 × 8 keypad interface, and an eight-wire touch-screen interface. Figure 1 is a block diagram of the EP9315.

Extra features make the EP9315 suitable for a much broader variety of embedded applications. For example, the six-channel I^{2}S audio interface means the EP9315 can handle 5.1 surround sound (five discrete channels plus a subwoofer) or simultaneously feed two-channel stereo sound to three different locations. With 24-bit audio resolution, it also delivers higher fidelity than the 16-bit I^{2}S interfaces on all other EP93xx chips but the EP9312. In an MP3 player patterned after Apple's popular iPod, the EP9315's EIDE interface would provide an easy connection to a hard drive as an alternative to flash memory for mass storage. The integrated video/LCD controller eliminates the need for a separate chip to drive the display, and the keypad interface allows a direct connection to user-input controls.

In higher-end embedded systems, such as point-of-sale terminals and kiosks, the EP9315's built-in touch-screen
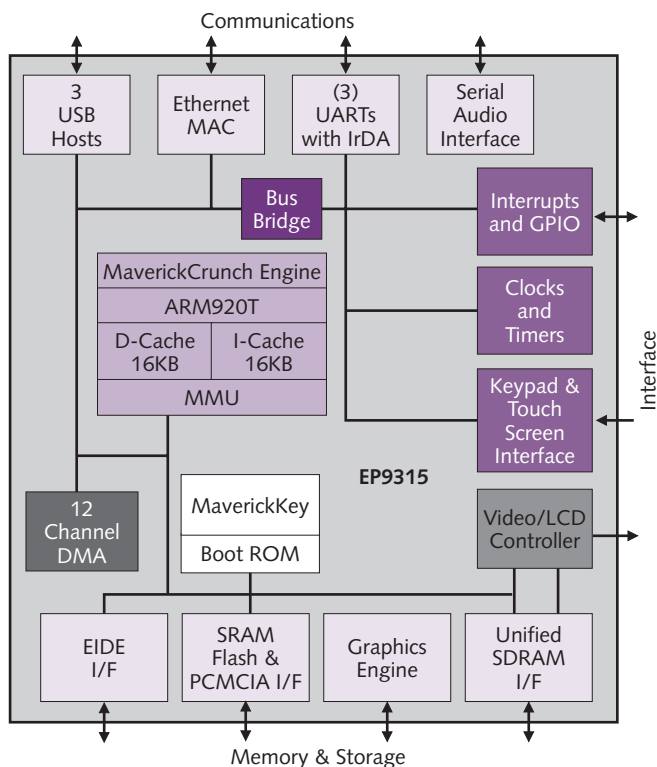
Figure 1. The EP9315 is the new high-end member of the ARM9 Maverick family. Although it runs at the same 200MHz clock frequency as most other ARM9 Maverick processors, it is more highly integrated. Note that datapaths to the left of the bus bridge are an AMBA high-speed bus (AHB), whereas datapaths to the right of the bus bridge are an AMBA peripheral bus (APB).

capability allows designers to provide a friendly user interface without adding another control chip. (For industrial applications, the eight-wire touch-screen interface can serve as a 12-bit ADC.) The EP9315's PCMCIA interface allows a system to incorporate Type I or Type II card slots for expansion. For any application that has a video display, the EP9315 provides hardware acceleration for 2D graphics primitives, such as line drawing, color mapping, block moves, block copies, and cursor movement.

Of course, the tradeoff for all the additional interfaces and wider memory buses is a larger package and higher pin count: the EP9315 comes in a 352-contact BGA compared with the 272-pin thin-format BGA packages of most other EP93xx chips. However, because the EP9315 is pin compatible with the EP9312, some customers using Cirrus Logic's former top-of-the-line ARM9 processor will be able to drop the new flagship part into the same socket. And long-time customers of the EP9312 should be pleased that the much-improved EP9315 costs only $24.01—37% less than the price of the EP9312 only three years ago. (The EP9312 is now priced at $21.83, a 43% cut.)

Naturally, the EP9315 consumes more power than its predecessor and other EP93xx chips do. Cirrus Logic rates the typical power consumption of the EP9315 at 475mW, compared with 460mW for the EP9312 and 322mW for the EP9301. Power-consumption figures for the other EP93xx processors aren't yet available, but they will fall within this range. (All EP93xx processors operate at a core voltage of 1.8V with 3.3V I/O.) The actual differences may be smaller than the typical power-consumption ratings imply, because EP93xx chips can shut down any unused peripheral blocks to conserve energy.

Between the low-end EP9301 and the high-end EP9315 are nine similar processors (counting the original member of the family, the EP9312). All run at 200MHz, all have the MaverickCrunch FPU, and all have 32-bit SDRAM and SRAM/ROM/flash memory buses. The mix of peripherals is what makes them different from each other. If Cirrus Logic

Feature	Cirrus EP9301	Cirrus EP9303	Cirrus EP9304	Cirrus EP9305	Cirrus EP9306	Cirrus EP9307	Cirrus EP9309	Cirrus EP9310	Cirrus EP9311	Cirrus EP9312	Cirrus EP9315
CPU Core	ARM920T	ARM920T	ARM920T	ARM920T	ARM920T	ARM920T	ARM920T	ARM920T	ARM920T	ARM920T	ARM920T
Core Freq	166MHz	200MHz	200MHz	200MHz	200MHz	200MHz	200MHz	200MHz	200MHz	200MHz	200MHz
Bus Freq	66MHz	100MHz	100MHz	100MHz	100MHz	100MHz	100MHz	100MHz	100MHz	100MHz	100MHz
Cache (I/D)	16K/16K	16K/16K	16K/16K	16K/16K	16K/16K	16K/16K	16K/16K	16K/16K	16K/16K	16K/16K	16K/16K
MMU	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FPU	—	32/64-bit	32/64-bit	32/64-bit	32/64-bit	32/64-bit	32/64-bit	32/64-bit	32/64-bit	32/64-bit	32/64-bit
10/100 Ethernet	Yes	—	—	—	—	Yes	Yes	Yes	Yes	Yes	Yes
PCMCIA	—	—	—	Yes	Yes	—	Yes	Yes	Yes	—	Yes
USB 2.0 Hosts	2	3	2	2	2	3	3	3	2	3	3
EIDE Channels	—	—	2	2	2	—	—	1	2	2	2
SDRAM i/f	16-bit	32-bit	32-bit	32-bit	32-bit	32-bit	32-bit	32-bit	32-bit	32-bit	32-bit
SRAM/Flash i/f	16-bit	32-bit	32-bit	32-bit	32-bit	32-bit	32-bit	32-bit	32-bit	32-bit	32-bit
DMA Channels	12	12	12	12	12	12	12	12	12	8	12
I²S Audio	2x16-bit	2x16-bit	2x16-bit	2x16-bit	2x16-bit	2x16-bit	2x16-bit	2x16-bit	2x16-bit	6x24-bit	6x24-bit
SPI	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
UARTs	2	3	3	3	3	3	3	3	2	3	3
2D Graphics	—	Yes	—	—	Yes	Yes	—	—	Yes	—	Yes
Display Ctrl	—	Yes	Yes	—	Yes	Yes	Yes	—	Yes	Yes	Yes
Keypad i/f	—	8x8	8x8	—	8x5	8x8	8x5	—	—	8x8	8x8
Touch Screen	—	8-wire	8-wire	—	8-wire	8-wire	4-wire	—	8-wire	8-wire	8-wire
MaverickKey	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
General-Purpose Timers	1x32-bit 2x16-bit watchdog	1x32-bit 2x16-bit watchdog	1x32-bit 2x16-bit watchdog	1x32-bit 2x16-bit watchdog	1x32-bit 2x16-bit watchdog	1x32-bit 2x16-bit watchdog	1x32-bit 2x16-bit watchdog	1x32-bit 2x16-bit watchdog	1x32-bit 2x16-bit watchdog	4x16-bit watchdog	1x32-bit 2x16-bit watchdog
ADC (12-bit)	Yes	Touch*	Touch*	Yes	Touch*	Touch*	Touch*	Yes	Touch*	Touch*	Touch*
Boot ROM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IC Process	0.18μm	0.18μm	0.18μm	0.18μm	0.18μm	0.18μm	0.18μm	0.18μm	0.18μm	0.18μm	0.18μm
Voltage (Core-I/O)	1.8V/ 3.3V	1.8V/ 3.3V	1.8V/ 3.3V	1.8V/ 3.3V	1.8V/ 3.3V	1.8V/ 3.3V	1.8V/ 3.3V	1.8V/ 3.3V	1.8V/ 3.3V	1.8V/ 3.3V	1.8V/ 3.3V
Power (typical)	322mW	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	460mW	475mW
Package	LQFP-208	TFBGA-272	TFBGA-272	TFBGA-272	TFBGA-272	TFBGA-272	TFBGA-272	TFBGA-272	TFBGA-272	BGA-352	BGA-352
Price (10K)	$8.96	$12	$12.75**	$13.50**	$14.25**	$15**	$15.75**	$16.50**	$17	$21.83	$24.01
Availability	Now	3Q04	3Q04	3Q04	3Q04	3Q04	3Q04	3Q04	3Q04	2001	Now

Table 1. Ten new ARM9-based processors have joined the existing EP9312 to expand the Maverick family of highly integrated SoCs. All are well equipped for consumer-electronics and industrial applications. Notably, all have an MMU, USB 2.0, dual memory buses, stereo audio, internal boot ROM, and Cirrus Logic's MaverickKey security identification. Additional features and on-chip peripherals distinguish the parts from each other. *The touch-screen interface can serve as a 12-bit ADC. **MPR estimate. n/a: not available.

offered every possible combination of peripherals, there would be thousands of chips in this family, so the company tried to combine the ingredients in some nonrandom fashion. In general, the higher the part number, the more features, but there are exceptions. Table 1 summarizes the most important characteristics of the EP93xx family.

Only Missing Feature: Memory

Considering the history of Cirrus Logic's ARM7-based processors, the prospects for the new ARM9 chips look bright. In 1999, Cirrus Logic was among the first companies to recognize the potential of portable digital audio by introducing two highly integrated ARM720T-based SoCs with audio interfaces. (See *MPR 11/15/99-03*, "Cirrus Logic Makes Music With ARM.") In a 1999 year-in-review article, *MPR* wondered if the company's foresight would have it singing "I Can See For Miles" or—if the gamble didn't pay off—another song by The Who: "Don't Get Fooled Again." (See *MPR 1/17/00-01*, "Embedded Market Breaks New Ground.") After shipping a total of 34 million ARM processors since becoming one of ARM's first licensees in 1993, Cirrus Logic is singing a happy song.

The company's ARM7 Maverick chips have found their way into CD/MP3 players, automotive audio systems, Internet radios, digital jukeboxes, PDAs, global positioning systems, smart phones, and a variety of industrial systems. Design wins for the more-powerful ARM9 chips include GSM-capable PDAs, industrial PDAs, telematic navigation systems, electronic voting terminals, marine radars, textile-machine controllers, digital audio receivers, video-on-demand controllers for apartment buildings, and car stereos with MP3 jukeboxes. That's a broad range of embedded applications. Expanding the Maverick ARM9 family to 11 processors is sure to attract even more customers.

Essentially, Cirrus Logic's Maverick processors—whether they have ARM7 or ARM9 cores—are 32-bit microcontrollers, albeit with features rarely found in the 8- and 16-bit chips that commonly define the term. Maverick's main competitors are custom ASICs and SoCs, as well as other ARM-based integrated processors. Among ARM-based processors, the leading competitors are from Atmel, Hynix, Oki, Philips, and Triscend. (See *MPR 5/19/03-01*, "Philips Shows Flashy MCUs.") Maverick processors tend to have more on-chip peripherals, but some of the competitors differentiate themselves with other features, such as on-chip or in-package flash memory, or—in the case of Triscend—small amounts of reconfigurable logic. (See *MPR 9/15/03-02*, "Triscend Revs Up for Motors.") The most significant feature missing from the ARM9 Maverick processors is on-chip memory (except for the CPU caches), which prevents them from serving as true single-chip microcontrollers.

Nevertheless, Cirrus Logic is offering powerful bait to lure customers away from 8- and 16-bit chips for higher-end embedded systems, and the Maverick processors support ARM's strategy of expanding the market for 32-bit microcontrollers with ARM cores. (See *MPR 2/17/04-02*, "ARM Grabs Triscend.") As the Maverick family continues to expand and evolve, it seems only a matter of time before on-chip SRAM or flash memory completes its already impressive list of features. ◇