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Intel Will Customize Atom

New TSMC Collaboration Will Produce Customer-Specific x86 SoCs

By Tom R. Halfhill {3/30/09-01}

Intel and TSMC have announced a new collaboration in which Intel will design customer-specific SoCs based on the Atom microprocessor core. TSMC will offer peripheral blocks for the SoC designs and manufacture the chips in its fabs. For Intel, it's the first step toward x86 licensing since the 1980s, when the company sold second-source licenses to AMD and other suppliers.

Make no mistake: this deal is aimed squarely at ARM. Intel wants to push the x86 architecture into smartphones and other low-power embedded systems, which ARM dominates. ARM's 32-bit architecture is by far the most popular in the world. Yet ARM doesn't manufacture a single chip, preferring instead to license its CPU cores to other chipmakers. Although Intel isn't close to adopting a licensing model as open as ARM's, this is still a big step for a company that guards the x86 like a family heirloom.

Microprocessor Report has expected Intel to make such a move. As we noted in our in-depth Atom coverage last year, low-power embedded systems need SoCs, not discrete processors. Systems with separate processors, peripheral chips, and interface chips simply can't match the compactness, power efficiency, and economy of systems built with highly integrated SoCs. Atom chips are great for small PCs and some other applications, but not for truly pocketable devices like smartphones. (See *MPR 4/7/08-01*, "Intel's Tiny Atom.")

Intel has been trying to meet the obvious need for SoCs by introducing new product lines of semicustom chips. These standard parts are broadly designed for networking, communications, consumer, and industrial applications. However, the first generation of Intel's SoCs doesn't yet incorporate the lower-power Atom core and is burdened with some power-hungry legacy logic. As we reported last summer, these chips will have trouble competing with sleeker SoCs designed for specific applications by chipmakers with more experience in those markets. (See *MPR 8/18/08-01*, "Intel's New SoCs.")

Meanwhile, the trend in personal computing is swinging away from desktop PCs toward highly mobile devices, such as netbooks and smartphones. Intel's x86 architecture dominates the new netbook category but is conspicuously absent in smaller systems. To keep up, Intel must adapt the x86 to the new era. It's impractical for Intel to design and manufacture standard-part SoCs for every conceivable purpose, so bringing customers closer to the design process is a logical move. For all these reasons (and more), *MPR* has anticipated the need for an x86 licensing program for several years. Apparently, Intel is inching toward the same conclusion. (See *MPR 7/31/06-01*, "Intel's Embedded Future.")

Not Quite Licensing—At Least, Not Yet

Intel and TSMC haven't disclosed some pertinent details of their collaboration. Indeed, their March 2 press conference merely announced a "memorandum of understanding" between the companies, with many important aspects yet to be disclosed or even negotiated. Much could change before the program actually begins. The overall picture emerging is a very cautious approach to custom design services that falls well short of ARM's licensing model but is significant for Intel.

Indeed, the Intel-TSMC joint announcement was rather vague and open to interpretation. At first, *MPR* and other

Price & Availability

Intel and TSMC have not announced when their custom-SoC program will begin or the costs for customers. Intel and TSMC have posted joint announcements on their respective websites:

- *www.intel.com/pressroom/archive/releases/20090302corp_a.htm*
- *www.tsmc.com/tsmcdotcom/PRListingNewsAction.do?action=detail&newsid=3441&language=E*

observers believed that Intel was announcing a true licensing program that would make the Atom processor core available to third-party SoC developers through TSMC. Intel president and CEO Paul Otellini seemed to suggest this interpretation in the joint press release, which quotes him as saying, "We believe this effort will make it easier for customers with significant design expertise to take advantage of benefits of the Intel [x86] Architecture in a manner that allows them to customize the implementation precisely to their needs."

Later, Intel clarified that "customers" refers to system OEMs, not third-party SoC developers—and that Intel, not third-party developers, will most likely "customize the implementation." In other words, OEMs that need an application-specific SoC can ask Intel to design a custom chip around the Atom core. The OEM will provide specifications and the additional semiconductor intellectual property (IP) required, some of which may be licensed from TSMC.

Already, TSMC licenses a great deal of IP to its foundry customers, including the peripheral blocks that typically surround processor cores in SoCs. Much of this IP comes from other companies that use TSMC as a licensing clearing house. The IP is preverified for TSMC's fabrication processes, saving developers time and trouble. Although Intel uses similar IP internally, it's probably not in a packaged form suitable for outside licensing.

Intel will design the chips for the OEM customers and outsource the manufacturing to TSMC. Of course, Intel has plenty of fab capacity of its own, including a derivative of its 45nm process specifically tuned for SoCs. However, outsourcing lower-volume custom chips to TSMC probably makes more sense for Intel, especially if much of the peripheral IP is already verified for TSMC's processes. *MPR* gets the impression that Intel would rather not be bothered with the nitty-gritty details of IP licensing and foundry manufacturing, which is understandable. Even some companies more comfortable with licensing—Freescale Semiconductor, for example—prefer to outsource the customer service to independent clearing houses. (See *MPR 2/11/08-01*, "Buy SoC IP Like MP3s.")

Unlike ARM, Intel won't license its CPU core to anyone with a purse and a pulse. Suitors must seek approval for their SoCs from Intel, which wants to create new opportunities for Atom without creating additional competition for its own SoCs or standard-part microprocessors. Indeed, Intel won't accept proposals for Atom-based processors that aren't SoCs for embedded systems. And the wariness goes both ways: Intel's customers must consider the risk that a successful SoC will later attract Intel to the same market with a standard part, potentially cannibalizing the customer's business. Because ARM doesn't make chips, it has no such conflicts with its customers.

In some respects, Intel's program resembles a design-services initiative that Freescale announced last year. Freescale will design SoCs to customer specifications, using Freescale CPUs and peripheral cores augmented with customer-provided IP. Overall, Freescale's program is more flexible than Intel's. (See *MPR 11/17/08-01*, "Freescale's Designer SoCs.")

Foundry and Process Options Are Limited

Intel's designer-SoC program for Atom has several technical drawbacks. One is that Atom currently exists only as a hard core, not as synthesizable RTL. True, hard cores save time by eliminating the steps of synthesis, layout, and process-specific verification. However, they are less flexible than soft cores, especially when integrating the CPU with peripheral IP and on-chip interconnects. The widespread preference for soft cores persuaded ARM and other processor-IP vendors to offer most of their CPUs in synthesizable formats years ago.

Another consideration is that Intel's foundry arrangement is exclusively with TSMC. As things stand now, customers won't be able to take the SoC design to another foundry. Certainly, there's nothing wrong with TSMC. It's one of the best foundries in the world, and its fabrication technology is second only to Intel's and IBM's. (Intel's collaboration with TSMC doesn't include sharing fabrication technology.) Nevertheless, virtually all other processor-IP vendors allow licensees to take their chip designs to any foundry for manufacturing.

Because Atom is a hard core and the SoCs will be manufactured exclusively at TSMC, Intel and TSMC must port the core to TSMC's design flows and fabrication processes, which differ from Intel's own technology. The expense of porting the core may limit Atom to one or two process options—probably a leading-edge process and a node-minus-one process. Which ones? Intel hasn't announced when the custom-SoC program will begin, and process technology is a moving target. Depending on the timing, *MPR* expects the options will be 32nm and 45nm, or perhaps 45nm and 65nm.

In contrast, CPU cores licensed from ARM and other processor-IP vendors are portable to numerous fabrication processes at any foundry. These processes include state-of-the-art technologies, such as the 28nm and 32nm high-*k* metal-gate processes developed by the Common Platform,

an IBM-led technology alliance involving ARM, Chartered, and Samsung. At the opposite end of the spectrum, some microcontroller vendors save money by using ancient fabrication processes as large as 250nm (0.25 micron).

MPR suspects that Intel will impose still another limitation: customers won't be able to request multicore designs exceeding Intel's level of multicore integration with Atom. Right now, Intel offers single- and dual-core versions of standard-part Atom processors. Starting with those cores, it's unlikely that Intel will design a custom SoC with four or more Atom cores. The fixed interfaces and other inflexible features of a hard core would make larger-scale multicore designs difficult to implement. In contrast, developers are using synthesizable CPU cores from ARM and others to build multicore designs with dozens or even hundreds of cores.

Forget About Architectural Licenses

Intel will surely restrict the range of customization options, too. *MPR* expects Intel will design Atom-based SoCs with almost any peripheral blocks around the core but will balk at modifying the CPU core itself. In other words, it's almost inconceivable that Intel will grant anyone the equivalent of an architectural license, which would allow the customer to specify a new implementation of the x86 architecture.

History explains why. In 1981, IBM coerced Intel into licensing AMD as a second-source supplier for x86 processors in IBM PCs. Although IBM's adoption of the x86 helped make Intel an industry leader, the last thing Intel wants is to spawn another competitor like AMD. (See *MPR 2/17/09-01*, "How Intel Got Big.")

Architectural licenses from ARM and other processor-IP vendors are uncommon (partly because of their much higher price), but they do exist. Although ARM won't publicly disclose all its architectural licensees, the confirmed list includes Freescale, Marvell, Qualcomm, and—ironically—Intel (which inherited its license by acquiring DEC's StrongARM product line). Samsung is a rumored member of this exclusive club. Last summer, ARM announced the sale of an architectural license to an unnamed cellular handset manufacturer, widely rumored to be Apple.

Finally, another drawback of Intel's custom-SoC program is the lack of variety. Intel will offer only one processor core—Atom. ARM's catalog lists 23 processor cores—and even more, counting variations. For example, the ARM Cortex-R4 is available with or without an FPU, as are some other ARM cores. (See *MPR 10/30/06-01*, "ARM Thumbs a Ride.") ARC International, MIPS Technologies, and Tensilica have thick product catalogs, too. In addition, most of their licensable processors are customizable, effectively granting the near-equivalent of an architectural license to every licensee.

Variety is much more important for SoCs than it is for Intel's traditional market, PC processors. Licensable processor cores from ARM and other vendors range from extremely small, low-power cores to high-performance CPUs with superscalar execution, multithreading, and multicore-ready features. At the low end, ARM has the new Cortex-M0, a processor core with a minimum usable configuration of only 12,000 gates. (See *MPR 3/2/09-01*, "ARM's Smallest Thumb.") At the high end, ARM claims the Cortex-A9 MPCore is faster than Atom and consumes less power, when both processors are fabricated in the same technology. In addition, ARM's partners have developed ARM cores using exotic technologies, such as Fast14 logic and asynchronous logic. (See *MPR 9/24/07-01*, "Cortex-R4X: Extreme Makeover," and *MPR 2/21/06-01*, "Can ARM Beat the Clock?") Without offering synthesizable cores and architectural licenses, Intel can't match this variety.

Table 1 sums up the differences between the Intel/TSMC custom-design program and ARM's licensing model. Note that ARM's model is representative of processor-IP licensing in general. Other vendors—such as ARC, MIPS, and Tensilica—have very similar models. We're singling out ARM because it's the most popular licensable CPU architecture and is Intel's chief competitor in the embedded world.

Intel's Ace: the x86

All these differences between Intel's custom-SoC program and the licensing models of established processor-IP vendors might seem to doom Atom to rapid decay. However, as noted in our Atom report last year, Intel's perky little processor has something those other vendors can't match—the x86 architecture. If an SoC requires x86 compatibility, no one licenses a leading-edge x86 core. It's an Intel-designed chip or nothing.

Whether that difference matters remains to be seen. Largely, it depends on the application. Already, Intel is

	ARM	Intel
Open CPU Licensing	Yes, since 1990	Not quite yet
CPU Architecture Offered	32-bit ARM	64-bit Intel x86
Number of CPU Cores Offered	23	1 (Atom)
Types of Available CPUs	Mostly soft cores, some hard	Hard core only
Architectural Licenses	Available at extra cost	Highly unlikely
Chip Fabrication	Any foundry	TSMC
Fabrication Process	Any process	Undisclosed
Multicore SoCs	Any number of CPUs per chip	Undisclosed, probably limited
Peripheral IP Vendors	Any IP vendor, including ARM	Any vendor, mainly TSMC
SoC Project Approval Required	No	Yes, by Intel
Licensing Fees & Royalties	Not publicly disclosed	Not publicly disclosed

Table 1. The new Intel/TSMC custom-SoC program for Atom differs markedly from processor-IP licensing models, as exemplified by ARM.

conquering netbooks by storm. A few attempts to sell netbooks with MIPS-compatible processors have encountered stiff resistance from consumers, mainly because the non-x86 netbooks run Linux instead of Windows. ARM-based netbooks—including future models built around chips from Freescale, Qualcomm, and Texas Instruments—will face the same hurdle. With AMD absent from the netbook segment (so far), Intel's only serious competitor in netbooks is VIA Technologies. VIA sells x86-compatible processors, but not x86-based SoCs or licensable x86 cores. (See *MPR 3/10/08-01*, "VIA's Speedy Isaiah.")

Of course, the vast majority of users care nothing about CPU architecture—except when it visibly affects the product they're using. When the operating system is in-your-face visible, as it is with netbooks, few users stray from their comfort zone. In a mobile computer that's still perceived as a PC, they overwhelmingly prefer Windows over Linux, to the dismay of Linux partisans and everyone else who appreciates efficient system software.

When a device presents a friendly user interface and needn't run legacy software, most people are oblivious to the operating system. And when the operating system doesn't matter to users, neither does the CPU architecture. Apple's iPhone illustrates this case. It has a great user interface and is unencumbered with legacy software, so it can dispense with Windows. Performance and battery life are the vital requirements. Apple is free to use any CPU architecture that best meets those requirements—and right now, it's ARM, not the x86.

To compete on those terms, Intel must develop new Atom cores that reduce power consumption and die size still further. And, at some point, Intel may have to license the x86 under broader terms. But the collaboration with TSMC is an important step that further demonstrates Intel's desire to push the x86 into the embedded-processor market. ◇