Mobile Processors Begin to Grow Up

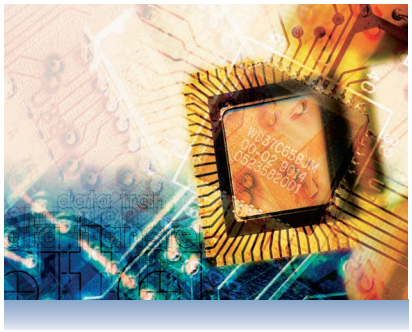
David Clark

Advances in wireless technology have increased the demand for more functional mobile devices that can take advantage of these improved capabilities. Developing better processors to power these devices is a key part of meeting that demand. More functional processors enable devices to offer the complex communications features, PC-like programs, and other advanced applications that a growing number of users want.

As the chips have improved, the mobile-processor marketplace has begun to change. Traditionally, numerous companies have designed and sold these processors. Now, wireless-device vendors are focusing on just a couple of chip architectures, and they are increasingly licensing cores and architectures predesigned by ARM Holdings. ARM licensees include Intel, Motorola, and Texas Instruments.

In fact, providing ARM-based chips is now required to compete in the marketplace, said Ed Valdez, director of wireless platform marketing for Motorola's Wireless and Broadband Systems Group.

And the importance of this marketplace is growing with the demand for smart handheld devices. The global market for the devices will have grown 43 percent annually between 1998 and the end of this year, according to market-research firm IDC. By the end of this year, IDC estimates, vendors will be shipping about 25 million devices generating about $13 billion in revenue annually.



NEW TECHNOLOGIES

Until recently, mobile applications haven't been particularly complex. At the same time, vendors have had to design mobile chips to minimize power consumption, both to make batteries last longer and to prevent heat buildup in devices that lack space for fans or other cooling mechanisms. Moreover, vendors have wanted to hold prices down on small devices, which required using inexpensive processors.

In the past, therefore, mobile processors have run at no more than 30 MHz for PalmOS PDAs, 80 MHz for cellular phones, and 200 MHz for devices that run Microsoft's Pocket PC OS.

However, many mobile-device users now want and will pay for advanced features like wireless Web access and location-oriented services, such as finding a nearby restaurant. This requires more processor power than basic cell phones or simple information-management PDAs have.

Higher chip performance is thus becoming increasingly desirable, said John Cornish, ARM's director of CPU programs. With this in mind, vendors have been developing faster mobile processors. For example, Intel recently demonstrated a 1-GHz processor.

Designers will achieve faster clock speeds the same way they do in PC processors: with smaller feature sizes and optimized designs. The optimized designs include the integration of memory and other functions on a single chip.

The challenges

The key challenge that designers face is providing consumption, high integration, and low cost in a package small enough to fit in a handheld device, said Laurie Pegrum, platform architect for Intel's Handheld Computing Division. To keep mobile processors small, vendors have adopted smaller feature sizes and system-on-chip (SoC) approaches.

Lowering power consumption is the most significant challenge because it has the biggest impact on chip size, cost, and performance, according to Cornish.

Designers reduce power consumption (and, in the process, heat generation) by lowering the voltage at which chips run, minimizing capacitance, and using a technique called *clock gating*. With clock gating, a chip can execute an instruction without switching transistors or involving gates that aren't needed for the operation.

Other techniques involve power management schemes implemented in hardware and software, said Markus Levy, senior analyst at MicroDesign Resources, a processor-industry analysis company. For example, most mobile processors have multiple or variable power-use modes. Also, Levy said, recent chip designs include more sophisticated power-scaling techniques that adjust to the application in use.

Thus, Motorola's Valdez said, even though mobile-processor speeds will increase, power consumption and heat generation should decrease.

System on chip

Companies such as ARM, IBM, Intel, National Semiconductor, and

Texas Instruments (TI) have established an important mobile processor trend: integrating many system functions on a single chip. According to Levy, SoC designs can lower prices, increase reliability by reducing the number of system components, lower power consumption, and increase performance by reducing the distance over which data must travel.

According to Heikki Liimatta, a senior research manager at Nokia, SoC platforms would include microprocessor cores and such additional functionality as digital signal processing, memory, and application program interfaces for software developers.

VENDORS TAKE NEW APPROACHES

In response to user demand and technological developments, several mobile-processor vendors have taken new approaches to their products.

ARM

ARM doesn't make chips itself but instead develops instruction sets and processor core architectures that have begun to dominate the market.

Many companies—such as IBM, NEC, and 3Com—have licensed the ARM core. Their products provide similar functionality, although they may differ in a few ways. For example, TI's ARM cores typically provide digital signal processing, while Motorola's new ARM products include wireless communication capabilities.

According to Cornish, ARM focuses on maximizing performance while creating cores and a development environment that make it easy for chip vendors to implement the technology. The optimized instructions, as well as clock gating and other techniques, also make ARM's chips energy efficient.

ARM offers instruction-set extensions that add functionality to its core architectures. For example, Thumb is a popular extension of ARM's 32-bit RISC architecture designed to optimize code density so that applications will run better on systems with small memories. Thumb works with a subset of ARM's most common 32-bit instructions compressed into 16-bit operation codes. On execution, Thumb translates the code to expand the 16-bit instructions to a 32-bit format in real time.

Most of the company's current designs, including various manufacturers' ARM7-core-based processors and Intel's StrongARM chips, use ARM's v5 instruction set. However, high-end devices use chips with the more expensive and more functional ARM9 core, which also works with the v5 instruction set.

ARM is taking a dominant position in the mobile chip market.

The company has announced the ARM10 core, but it has not appeared in products yet.

ARM also recently announced version six of its instruction set, whose primary improvement over v5 is the addition of multimedia functions.

Other v6 enhancements include improved memory management, better support for dividing tasks among multiple processors, and single-instruction multiple-data technology. The SIMD approach increases performance by letting one microinstruction operate at the same time on multiple data items.

ARM's first v6-based core, named Jaguar, is due by the middle of this year. Jaguar chips, which will use a 32-bit architecture, will run up to 1.6 billion operations per second at 400 MHz and 3.2 billion operations per second at 800 MHz.

ARM has designed the core for use in high-end PDAs, smart phones, and entertainment devices. Cornish said Jaguar-based products could be on the market by the end of 2004.

Intel's StrongARM and XScale

Intel acquired StrongARM processor technology from DEC in 1997 and has used it to carve out a strong position in the mobile chip market. StrongARM chips are used in several smart cellular phones, including NTT DoCoMo's popular iMode, as well as the Compaq iPaq and Hewlett-Packard Jornada PDAs. Other handheld vendors have announced plans to use StrongARM chips in the near future.

Unlike most chip makers that use ARM technology, Intel has an ARM architectural license. Instead of licensing predesigned processor cores, Intel licenses the ARM instruction set and builds its own cores.

StrongARM chips are based on ARM's v4 instruction set and currently run at up to 200 MHz on about 0.5 W of power. However, Intel said it expects next-generation StrongARM processors to have smaller feature sizes and deliver up to 600 MHz and 750 MIPS while using 40 to 450 mW.

Intel has also released a new mobile-processor platform called XScale, which uses ARM's v5 instruction set, as well as digital signal processor, Thumb, and Java extensions. XScale is faster than StrongARM. It also has more signal processing capabilities and thus runs multimedia better.

In addition, XScale will be highly scalable. Intel uses a new dynamic voltage management technique that adjusts processing power and power usage to application and operation demands.

Intel has demonstrated speeds of up to 1 GHz and very low power consumption. Therefore, a single chip could be used in various devices or in devices that experience a range of user and application demands. Some smaller devices could even run on a standard AA battery.

In practice, initial XScale-based products will probably clock at 600 MHz and consume no more than 0.5 W.

Intel has designed XScale for use in high-end PDAs and cellular phones, devices such as wireless routers, and applications such as embedded microcontrollers, explained Intel's Pegrum.

Motorola

Motorola traditionally has been the leading mobile processor manufacturer.

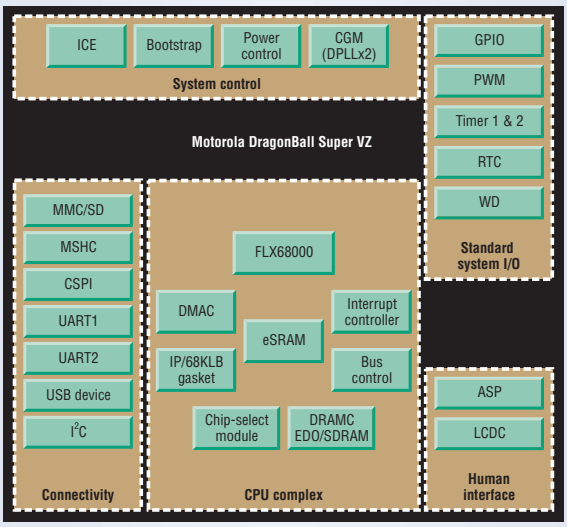


Figure 1. Motorola's DragonBall Super VZ mobile processor, based on the company's own 68000 architecture, was the only chip that Palm PDAs used until Palm's recent decision to transition its OS to ARM-based chips.

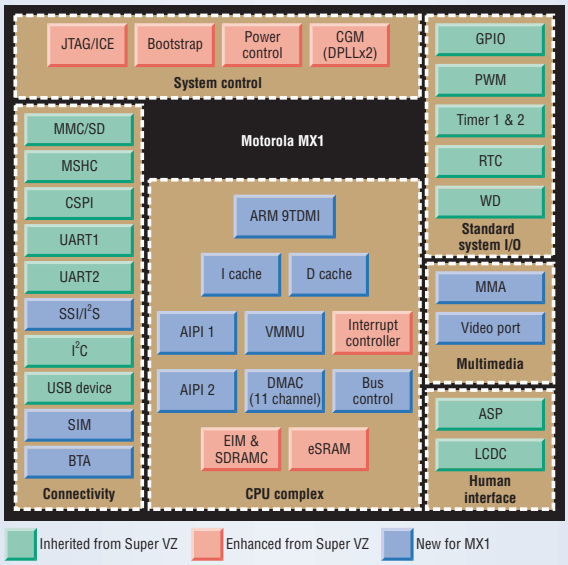


Figure 2. Motorola's new ARM-based MX1 mobile chip offers improvements over the company's older DragonBall Super VZ, shown in Figure 1. For example, the MX1 uses the ARM 9TDMI processor, instead of the Super VZ's FLX68000 CPU. The MX1 enhances memory with separate information and data caches (I cache and D cache), as well as enhanced static RAM (eSRAM), and an upgraded direct memory access controller (DMAC). The MX1 also improves data transfer with ARM-high-performance-bus-to-IP-bus interfaces (AIPIs). The processor upgrades connectivity with a Bluetooth accelerator (BTA) and supports multimedia with a video port and multimedia accelerator (MMA).

As MicroDesign Resources' Levy noted, the company has been able to use its chips in its own popular mobile phones, and until now, market-leading Palm's PDAs have used only Motorola chips. In addition, Motorola has been building mobile microprocessors longer than most vendors.

However, Palm has announced plans to transition its PalmOS from Motorola's DragonBall processor, shown in Figure 1, to faster ARM-based chips. This would help Palm and device makers that license the PalmOS, such as Handspring and Sony, develop PDAs that could compete with more functional Pocket-PC-based devices, such as iPaq and Jornada.

This also means that Intel and TI, and perhaps other companies eventually, will compete with Motorola to provide chips for PalmOS-based devices. In response, Motorola has begun designing cores based on ARM technology.

Like Intel, Motorola has an ARM architectural license. Its first ARM-based product, the MX1, shown in Figure 2, will be based on the ARM9 core and will run at up to 200 MHz.

The MX1 will include universal serial bus and liquid crystal display controllers, permitting connections to peripherals and display screens, respectively. The chip will also include a Bluetooth device-connectivity interface, an MPEG-4 codec that will accelerate multimedia capabilities, and Thumb extensions, said Motorola's Valdez.

Qualcomm

In contrast to the increasingly complex ARM-based designs, Qualcomm has announced a stripped-down mobile chipset for low-cost handsets that need only voice and text messaging capabilities.

The company anticipates demand for inexpensive, minimalist cellular phones even after next-generation wireless-networking technology becomes widely available. Therefore, Qualcomm has designed its MSM-5010 chips to be relatively inexpensive

but with no support for most of the new wireless technology's features, such as packet-based data transfer and multimedia.

Java chips

Java is an increasingly important part of mobile devices. In fact, Nokia expects to ship 50 million Java-enabled mobile phones by the end of 2002.

Java's portability is especially valuable in the mobile market, which features numerous platforms and device types. In addition, said Nokia's Liimatta, Java can increase programmer productivity and give vendors access to the many programmers working with the technology.

Also, many Java applications run with minimal microprocessor overhead. And Java permits a richer user experience and thus could attract new mobile technology users and new revenue streams, said Eric Chu, group manager of industry marketing at Sun Microsystems, which developed and manages Java technology.

Numerous chip manufacturers—such as aJile Systems, ARM, Aurora VLSI, inSilicon, Nazomi Communications, Parthus, and Zucotto Wireless—have licensed Java from Sun to implement in their mobile processors. These companies will implement in hardware at least part of the Java 2 Platform, Micro Edition's (J2ME's) virtual machine, which translates Java instructions into commands the chip can understand. According to Cornish, ARM has developed its Jazelle extension, which executes the most frequently used J2ME bytecodes in hardware. Interpreting Java in hardware reduces memory access and switching, which saves power and makes applications run faster, he explained.

FUTURE

"A lot of the hot new technology announced in the microprocessor field is making its way into mobile chips," noted Linley Gwennap, founder of the Linley Group, a processor-market research firm.

IBM's strained silicon

IBM has developed a chip-making technique that should be useful in the mobile market, said Philip Wong, the company's senior manager of exploratory devices and technology.

Java is becoming an important part of mobile chip design.

The *strained-silicon* technique places silicon over a substrate made of a silicon-germanium alloy. The alloy's atoms are larger and thus spaced farther apart than the silicon atoms. When the silicon layer is put on top, its atoms expand to align with those of the alloy. This strains the upper layer's atom spacing.

Electrons in the silicon layer experience less resistance and thus move up to 70 percent faster, which would both increase chip performance by up to 35 percent and use less power. IBM plans to release the initial strained-silicon chips for servers by next year.

Motorola technologies

Motorola has also announced new processor technology for wireless devices. The company's next-generation technology will have 0.18-micron feature sizes. This is smaller than current mobile chip feature sizes and will thus permit more transistors and more power per processor. The chips will use a silicon-germanium alloy and carbon, which will enhance radio-frequency power gain and reduce noise for advanced wireless and optical communications applications.

Motorola expects to begin designing products using the new technology later this year.

According to market-research firm IDC, revenue generated worldwide by chips for PDAs and handheld computing/communications devices will increase from $969 million this year to $3.046 billion in 2005.

Meanwhile, stiff competition among ARM-based chip manufacturers will drive better designs and lower prices, predicted Allen Nogee, senior wireless technology analyst at Cahners In-Stat Group, a market research firm.

In the process, Motorola's Valdez said, mobile chip makers will adopt new process technologies quickly. For example, he said, feature sizes will drop from today's 0.35 and 0.25 microns to 0.18, 0.13, and even 0.10 microns. Also, he added, the industry will soon make chips from 300-mm silicon wafers instead of 200-mm wafers, to save money by producing more chips per wafer.

According to MicroDesign Resources' Levy, ARM technology has an advantage in becoming the standard platform in this market, particularly as mobile devices require higher performance. He said ARM's advantage is based on its getting into the market at the right time and consistently delivering a good product and development environment.

On the other hand, said the Linley Group's Gwennap, a single platform probably won't dominate the market. "The needs of various devices are quite diverse," he said, "and in many cases, there is no need to standardize. However, ARM certainly is doing well in this space and will continue to do so in the future."

Meanwhile, said ARM's Cornish, as users move to next-generation wireless-networking technologies, much greater data bandwidth will become available for advanced applications, and vendors will develop more functional devices. "This will drive microprocessor makers to design chips that are smaller, faster, and more integrated." ■

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