 By Warren Webb, Technical Editor

Profit with PLUG-IN PROCESSORS

OFF-THE-SHELF MODULE COMPUTERS LET DESIGNERS SKIP THE MOST COMPLEX PORTION OF EMBEDDED-PRODUCT DESIGN AND SIMPLIFY FUTURE UPGRADES.

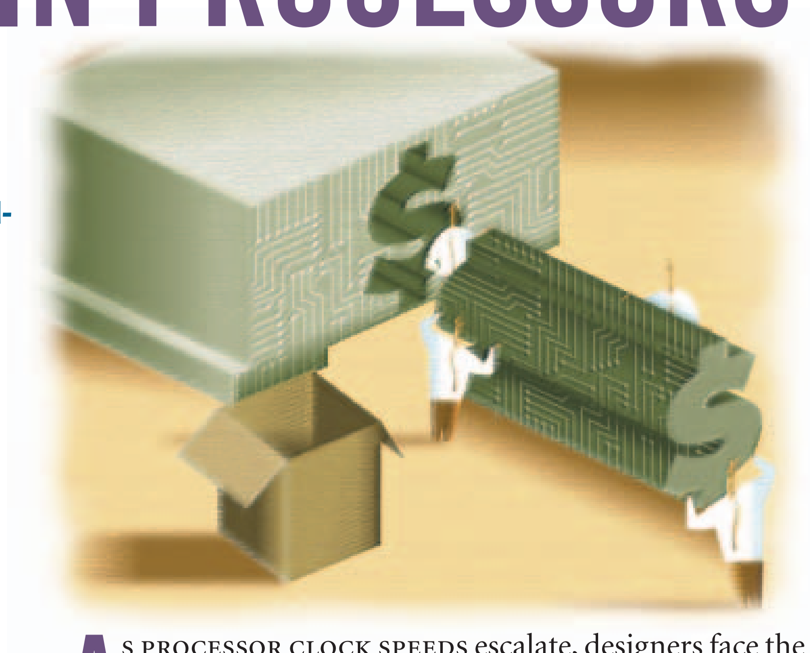


Illustration by Daniel Guidera

As processor clock speeds escalate, designers face the increasingly difficult task of developing a state-of-the-art processor section to drive their custom embedded circuitry. To bypass this complex design and beat the competition to market, many designers are turning to off-the-shelf plug-in modules that include the CPU and standard peripherals. These modules allow designers to treat the processor section of their designs as purchased components, thereby trading substantial savings in nonrecurring-engineering costs for slightly higher recurring costs.

Designers often use these plug-in processors, also known as module computers or core modules, in embedded designs in which a single pc board houses all electronics, including CPU, processor-peripheral interfaces, mass storage, and application-specific I/O. You typically find single-board electronics in smaller or portable embedded systems, such as instrumentation and medical systems, set-top boxes, kiosks, and game consoles. With a compatible baseboard design, you can purchase a large portion of the system's computer and general-purpose electronics on a replaceable plug-in module to save design and debugging costs.

Module computers are simply single-board computers with standardized provisions for easy attachment to a special-purpose, embedded baseboard. Modules range in size from tiny processor-only modules no bigger than a postage stamp to almost 20 square inches of board space, complete with desktop-compatible I/O. Although designers can use and have used bus-compatible boards, such as PCI, ISA, VME, and CompactPCI, to provide the computer section for embedded designs, designers usually run into mechanical problems trying to adapt card edge connectors to baseboards and retain a low profile.

A plug-in processor section provides

several technical and economic advantages over a traditional single-board design. For example, module computers allow designers to provide their embedded systems with a more sophisticated processor section to take advantage of advanced features—such as networking, graphical displays, complex software, and RTOSs—that would be difficult to implement on a restricted design budget. Instead of designing with an 8-bit processor with limited peripherals, module computers allow designers to easily step up to a 16- or 32-bit processor with a choice of predesigned I/O.

Module computers may also effectively extend the life of your embedded products when critical components are no longer available. Some embedded products have extended longevity requirements, sometimes as long as 20 years, yet many embedded devices are forced into redesign when a processor or support chip unexpectedly reaches its end of production. An upgradable, plug-in computer section is an ideal option for extended-life products, because module computers allow equipment manufacturers to upgrade the CPU without redesigning the system.

SHRINKING SCHEDULES

An obvious benefit of purchasing the processor section is the shortened development schedule and corresponding faster time to market and revenue. The design, debugging, and validation of a processor section may consume as much as 50% of a typical embedded product's schedule. Therefore, eliminating this effort may give you a huge competitive advantage. Including an off-the-shelf processor section no doubt affects the makeup of the embedded-design team. Without a CPU section to worry about, you do not need the high-speed hardware-design skills that complex-processor development normally requires. Depending on the complexity of the required processor section, you may also be able to reduce the number of designers the project needs.

Another reason for plug-in processors' popularity is that they provide design flexibility. Because module computers generally include a choice of standard peripherals, you can select custom I/O for special versions of your product with different features. This flexibility also allows you to upgrade the processor section as needed for more memory or higher clock speeds or to add features that customers demand.

The software-design team is also a major beneficiary of a purchased processor section. With module computers, a working CPU section is available long before the hardware debugging of application-specific devices. CPU availability permits software-development efforts to begin before the full system is ready. Because most embedded-hardware-debugging problems occur in the more complicated CPU section, a module computer also bypasses many of the headaches of system checkout. Most module computers also come with a preconfigured operating system that can eliminate custom software-driver development.

A plug-in processor can also enhance future development and add to serviceability after a product has been shipped to the customer. Module computers also allow you to easily test your embedded product with another processor or operating system without creating a test breadboard or redesigning the product. For example, you might want to evaluate the feasibility of Linux to reduce recurring software costs or investigate product performance with a faster processor. An easily changeable plug-in module also allows technicians to easily fault isolated problems in the computer section instead of replacing or troubleshooting a large-system embedded board.

You can realize many of the benefits of module computers if a compatible plug-in replacement or upgrade is available when technology changes. Widely accepted industry specifications are an attempt to ensure upgrade standardization. However, new features and incompatible pinouts in next-generation processors make exact replacements difficult. One of the biggest problems facing module-computer manufacturers is trying to anticipate the next-generation technology.

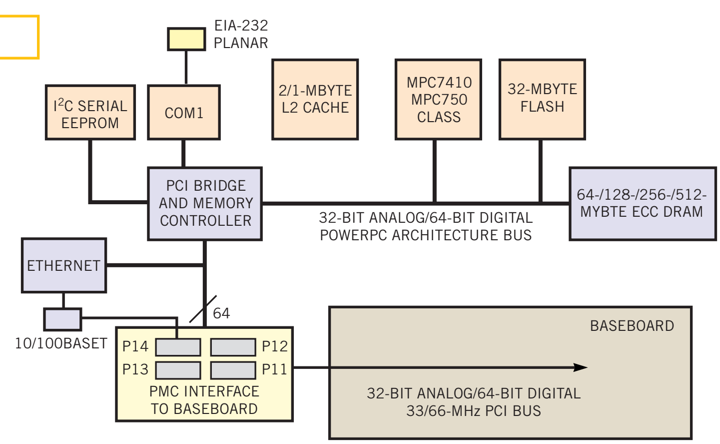
ON THE MEZZANINE

The developers of the PPMC (Processor PCI Mezzanine Card), a popular

AT A GLANCE

- ▷ Module computers package the CPU, mass storage, and processor-peripheral interfaces on a replaceable mezzanine card.
- ▷ Replacing the CPU and peripherals allows designers to update and retrofit embedded devices without product redesign.
- ▷ An off-the-shelf processor section trims man-hours from the development schedule and may also reduce the size of the design team.
- ▷ Plug-in module computers also allow the software team to begin development before the prototype hardware becomes available.

Figure 1



The PrPMC800 Processor PPMC (PCI Mezzanine Card) from Motorola Computer Group offers designers of embedded systems an MPC7410 PowerPC plug-in CPU section.

module-computer configuration, derived it from extensions to the PCI bus. An IEEE Computer Society committee developed the original PMC (PCI Mezzanine Card) draft standard, known as IEEE P1386.1, to satisfy the need for replaceable I/O modules in embedded systems. The PMC specification is electrically equivalent to the PCI bus but allows plug-in mezzanine modules that are parallel to the baseboard. A logical extension to the PMC concept was the development of CPU mezzanine modules so that developers of embedded systems could replace the entire processor section without redesigning the baseboard. The VMEBus International Trade Association maintains the draft PPMC specification, which is known as VITA32. The proposed standard maintains electrical and mechanical compatibility with PMC modules and includes provisions for interrupts, 66-MHz PCI operation, PCI-bus enumeration, and a module-present signal. The PPMC standard also defines two new terms, "Monarch" and "Nonmonarch," which specify a module's characteristics in multiprocessor operation.

The Motorola Computer Group PrPMC800 is a high-performance PPMC designed for digital-signal-processing applications in the medical-equipment, semiconductor-production and test-equipment, and telecommunications markets (**Figure 1**). The PrPMC800 includes a MPC7410 PowerPC microprocessor with AltiVec technology plus 2 Mbytes of L2 cache, as much as 256 Mbytes of SDRAM, 32 Mbytes of onboard flash memory, and a 10/100BaseTX Ethernet interface. The PrPMC800 with a 450-MHz MPC7410 costs approximately $1795 in single-unit quantities.

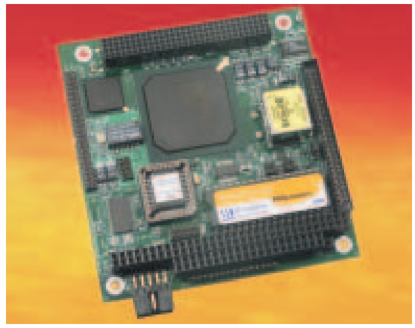


Figure 2 PC/104 computer modules, such as this Bobcat board from VersaLogic, make effective off-the-shelf, plug-in processors for embedded devices.

Although few bus-type boards make good module computers because of mechanical-interface problems, the PC/104 form factor is an exception. With a connector arrangement meant for stacking boards without a card cage or backplane, a PC/104 computer board can easily serve as a mezzanine processor on an embedded baseboard. These modules have the additional advantage of stacking another I/O module on top of the processor if you run out of board space. PC/104 modules are "compliant" if they measure 3.55×3.775 in. and conform to the PC/104 electrical specifications. PC/104-"compatible" modules can be any size but have bus connectors that mate with other PC/104 modules. You can purchase PC/104 modules that interface with the original ISA bus, the newer 32-bit PCI bus, or both from more than 80 manufacturers worldwide. You can also download complete specifications for both module types from the PC/104 Consortium at www.pc104.org.

Typical of PC/104 computers modules, the recently introduced Bobcat extended-temperature computer from VersaLogic interfaces to both the ISA and PCI buses (**Figure 2**). This new PC/104-*Plus* module features a 586 CPU running at 100 MHz and operates at −40 to +85°C. The Bobcat uses the Elan SC520 CPU, a low-power 586 processor, and features 10/100 Ethernet, 64 Mbytes of system RAM, and a DiskOnChip flash socket. Standard I/O includes floppy, IDE, and four COM ports. The board is software-compatible with Windows, QNX, Linux, RT-Linux, and other popular RTOSs. The Bobcat is appropriate for military, medical, transportation, automation, and other high-reliability or harsh-environment applications. Priced at $406 (OEM), the Bobcat is available from stock.

EXTENDED TECHNOLOGY

Several module-computer manufacturers have adopted the newer ETX (Embedded Technology eXtended) standard that Jumptec developed for high-volume applications. At 3.9×4.5 in., the ETX form factor is slightly larger than PC/104. However, it supports the same ISA- and PCI-bus structure. Unlike PC/104, ETX

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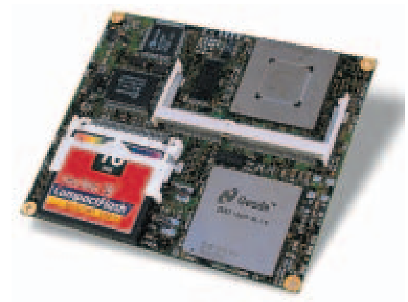

Figure 3 The ETX (Embedded Technology eXtended) form factor from Jumptec supports both the ISA and the PCI buses and all I/O signals through four 100-pin connectors.

routes all I/O along with bus signals to the baseboard through four low-profile, high-density, 100-pin connectors, thereby eliminating short-run cabling. The ETX-mgx from Jumptec is a low-power ETX module incorporating the National Semiconductor Geode GX1 CPU running at 266 MHz (**Figure 3**). An onboard DIMM socket supports 128 Mbytes of external SDRAM, and a CompactFlash socket enables a bootable flash hard disk. The low-power Geode processor permits board operation without active cooling in applications in which space limitations are major requirements. Despite the small board dimensions, the ETX-mgx offers all standard PC interfaces, such as sound, Ethernet, communications, and graphics. Most operating systems support the 16-bit stereo, full-duplex, AC97-compatible sound chip. Communication interfaces include two serial ports, a parallel port, two USB ports, and a 10/100 Ethernet controller. The integrated video controller drives CRT monitors as well as LCD panels. With as much as 4 Mbytes of video RAM, the ETX-mgx can display maximum resolutions of 1280×1024 pixels in 256 colors.

Although plug-in modules conforming to an open standard make the most sense, several manufacturers have been successful with proprietary designs. For example, Ampro Computers recently expanded its x86- and MIPS-based EnCore family of processor modules to include the PP1, which is based on a PowerPC-compliant microprocessor. The EnCore PP1 incorporates a 300-MHz MPC8245 processor with a built-in 66-MHz PCI-bus interface. It supports as much as 512 Mbytes of SO-DIMM SDRAM and provides 2 Mbytes of flash memory with a built-in universal bootloader and monitor software. The EnCore PP1 provides the functions of a complete embedded CPU subsystem in a 100×145-mm format. Onboard I/O includes a 10/100BaseT Ethernet controller, a JTAG interface, two serial ports, four USB ports, an enhanced Ultra 33/66 EIDE interface to two drives, a floppy-disk controller, a PS/2 keyboard and mouse ports, an IrDA port, an ECP/EPP (Enhanced Capabilities Port/Enhanced Parallel Port) bidirectional parallel port, and an AC97 audio interface. EnCore modules communicate with a baseboard via a PCI-bus interface and standard I/O signals. Because the EnCore-to-baseboard interface avoids processor dependencies, you can easily interchange EnCore modules with various processor architectures on a common baseboard. Ampro also provides boot-ready operating-system board-support packages for the EnCore PP1, supporting both Linux and the VxWorks RTOS from Wind River Systems. The EnCore PP1 is priced at less than $300 in volume.

Parallax in 1992 introduced one of the first module computers for the hobbyist market. Each module, called a Basic Stamp, comes with a Basic interpreter chip; internal RAM and ROM; a 5V regulator; a number of general-purpose, TTL-level I/O pins; and a set of built-in commands for math and I/O operations. Basic Stamps can run a few thousand instructions per second and are programmed with a customized form of the Basic programming language. Because of their simplicity, low cost, and ease of use, Basic Stamps have found wide applica-

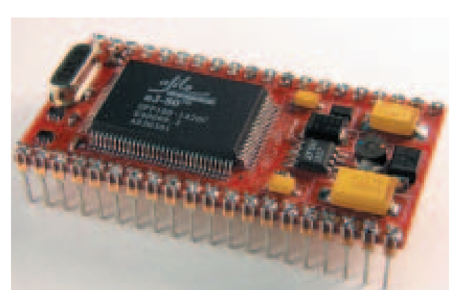

Figure 4 The 1×2-in. Jstamp processor module from Systronix directly executes Java language statements and costs approximately $100.

tion in embedded projects and products. One of the more recent modules, the Basic Stamp 2, includes a Microchip PIC16C57 microcontroller operating at 20 MHz, 2 kbytes of EEPROM, and 32 bytes of RAM in a 24-pin DIP module. The Basic Stamp 2 accommodates a 500-line Basic program and costs $49 in single-unit quantities.

MORE STAMPS

Systronix recently introduced another plug-in processor following the postage theme—the Jstamp, a 1×2-in. module that contains the first commercially available 32-bit, native-execution controller based on Sun Microsystems' Java language. The module's controller, developed by aJile Systems, directly executes Java-language statements. The JStamp is housed in a 40-pin DIP and includes 512 kbytes of SRAM and 512 kbytes of flash memory, a power converter, dual UARTs, and a JTAG programming/debugging port (**Figure 4**). Jstamps are reasonably priced at $99 (10) and are available from the Systronix Web site. Jstamp development kits are also available at prices starting at less than $300.

Another low-cost, proprietary plug-in design from Rabbit Semiconductor, the RCM3100 microprocessor core module, allows designers to rapidly develop and implement embedded systems (**Figure 5**). The module mounts directly on a user-designed baseboard and acts as the controlling microprocessor for the user's system. Measuring 1.85×1.65 in., the RCM3100 operates at 3.3V (with 5V-tolerant I/O) and features six serial ports. Rabbit based the RCM3100 module on the company's 3000 microprocessor, which has built-in low-EMI features, including a clock-spectrum spreader. Available in two models, the RCM3100 comes with as much as 512 kbytes each of flash memory and SRAM, quadrature encoder inputs, PWM outputs, and pulse-capture and -measurement capabilities. Two 34-pin connection headers provide 54 digital I/O lines shared with the six serial ports. A pin-compatible RCM3000 with Ethernet is available for parallel development and implementation of both Ethernet and non-Ethernet systems. RCM3100 models are available immediately, and prices start at $27 (1000).

Figure 5 The $27 RCM3100 core module from Rabbit Semiconductor measures 1.85×1.65 in. and features 54 digital I/O lines.

Advantech produces a series of plug-in computers, including several versions of its system on modules, for small, embedded Internet devices and ultralight, power-conscious mobile applications. For example, the Advantech SOM-2365 features the Transmeta Crusoe TM5400 processor for low-power, high-performance portable products. Based on a very-long-instruction-word core architecture, the Crusoe TM5400 provides x86 compatibility with code-morphing software. The SOM-2365 features a 3.4×3.9-in. board and includes a 500-MHz CPU, 64 Mbytes of onboard SDRAM, a flash BIOS, AC97 audio, and support for a plug-in CompactFlash card. Power consumption is typically 1A at 5V. Standard interfaces include keyboard, mouse, EIDE, floppy, serial, parallel, USB, IrDA, and 100BaseT Ethernet.

Module computers give designers the opportunity to divide their projects into two portions, one of which they can purchase. Off-the-shelf processor modules fit many embedded devices, leaving the design team with application-specific technology, including the electronics, the power supply, the operator interface, and the packaging. The one potential flaw in the module-computer concept is that no one knows what the next generation will look like, and, therefore, no one knows how to interface to it. For example, much speculation exists that, as CPU clock rates increase, switched fabrics will replace bus architectures. These changes could affect compatibility with next-generation processor modules. In the meantime, plug-in processors are saving untold man-hours of reinventing the common embedded-computer section.□

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