

AS NEW EMBEDDED DESIGNS COMBINE HIGHLY INTEGRATED SILICON, PORTABLE PLATFORMS, AND SOARING DATA RATES, THE INDUSTRY IS ADOPTING SMALLER FORM FACTORS THAT EMPHASIZE COOLING, RELIABILITY, AND PERFORMANCE.



Figure 1 The CC40x single-board computer from General Micro Systems packs the Atom processor, memory, and peripherals onto a conduction-cooled, 3U CompactPCIe module.

SHRINKING STANDARDS SQUEEZE EMBEDDED DESIGNS

BY WARREN WEBB • TECHNICAL EDITOR

Continued pressure to reduce the size of industrial, medical, consumer, and other space-critical applications has sparked a new wave of embedded computing platforms with extremely small form factors. Employing both open standards and proprietary designs, these new platforms give system designers a growing selection of off-the-shelf computing and peripheral modules to simplify size-constrained applications. Despite their compact size, these miniature system components take advantage of new computing elements, serial communications, and clever heat-dissipation techniques to deliver significant processing power and I/O performance.

Smaller form factors are possible because of fundamental changes in the architecture and design of embedded devices and systems. The latest silicon technology can integrate multiple processors, graphics elements, and networking interfaces onto a single-chip device, thereby saving enormous board area. High-speed data rates have also pushed

designers to change from parallel, multidrop-bus structures to serial-switched-fabric technology, with the added benefit of reduced real estate. Product developers have also found new techniques for power delivery, cooling, and packaging that minimize the overall system size.

With new, smaller size requirements, embedded-system designers are turning

to pre-engineered, off-the-shelf modules that integrate the latest CPU technology with standard peripherals. These standardized computer modules allow designers to trade substantial savings in nonrecurring-engineering costs for slightly higher recurring costs. A replaceable processor section provides several technical and economic advantages over traditional single-board designs. For example, designers can provide their embedded systems with a more sophisticated processor section to take advantage of advanced features, such as networking, graphical displays, complex software, and real-time operating systems, that would be difficult or impossible to implement on a limited design budget.

While increasing data bandwidth, switched-fabric technology also offers a major benefit to system size by reducing the number of pins and board area necessary for board-to-board communications. Switched-fabric architectures, such as Ethernet, PCIe (peripheral-component-interconnect express), Rapid I/O, and InfiniBand, are the latest board standards, and they eliminate many of the problems associated with parallel-bus schemes. Each connection is a direct point-to-point datapath yielding better electrical characteristics and higher bandwidth than bus architectures. Datapaths may also change dynamically to support multiple simultaneous data transfers and to route data around malfunctions. PCIe is one of the more popular fabric technologies because of its compatibility with driver and operating-system software. The basic PCIe

link comprises two signal paths that use small differential-voltage swings and constant-current line drivers to communicate at speeds as high as 4 Gbps in each direction. Designers can increase the bandwidth of an individual PCIe link by simply adding signal pairs, called lanes, until they achieve the desired performance level. The PCIe specification supports one-, two-, four-, eight-, 16-, and 32-lane widths.

EXPRESS LANES

Almost all of the major board standards have included PCIe along with other fabric extensions to boost data rates for high-performance applications. For example, PICMG (PCI Industrial Computer Manufacturers Group) followed the lead of desktop technology and incorporated PCIe into the CompactPCI specification. CompactPCIe offers scalable, high-bandwidth datapaths, packetized data protocols, and compatibility with PCI hardware and driver software. One of the latest incarnations of CompactPCIe in a small form factor comes from General Micro Systems. The company's conduction-cooled, 3U CC40x single-board computer has a typical operating power consumption of 3.5W (Figure 1). General Micro based the module on Intel's Atom processor operating at speeds as high as 1.6 GHz with 512 kbytes of L2 cache. The board

AT A GLANCE

▣ The latest fabric-based module computers package the processor, mass storage, and peripheral interfaces in a reduced-footprint, replaceable module.

▣ Standards organizations are constantly updating board specifications to provide embedded-system designers with off-the-shelf sources of pre-engineered products.

▣ Most small-form-factor board-level specifications have opted for PCIe (peripheral-component-interconnect-express) serial communications to retain software compatibility with PCI-based software.

▣ New module standards struggle to increase computing and communications performance and retain electrical and mechanical compatibility with legacy hardware.

delivers as much as 1 Gbyte of SDRAM and as much as 16 Gbytes of bootable flash memory, six USB-2.0 ports, two serial ports, and two SDIO (secure-digital-input/output) ports for custom I/O. In addition, the CC40x provides users with high-performance graphics with 3-D acceleration and supports video resolutions as great as 1280×1024 pixels at 85 Hz. Prices for the conduction-cooled version start at \$3110.

Continuing the small-form-factor

theme, MEN Micro recently introduced the XM1 computer module, which the company designed to comply with the proposed ANSI-VITA (American National Standards Institute VMEbus International Trade Association) 59 RSE (Rugged System-On-Module Express) mezzanine standard (Figure 2). The module couples the Intel Atom processor with 1 Gbyte of soldered DDR2 SDRAM for lower power dissipation and a reduced form factor. RSE combines the computer on a mezzanine model with advanced cooling technologies, the latest serial buses, and rugged components to ensure reliable operation in the harsh environments of railway, avionics, industrial-automation, medical-engineering, and mobile applications. The Intel-based XM1 offers a screened-temperature range of -40 to +85°C. MEN Micro distributed the electrical signals on two 120-pin connectors and defines the signals only for modern serial buses, thereby eliminating legacy compatibility. For PCIe, designers can configure four single-lane ports and one port as 16, eight, two×four, or two lanes. Other ports include three GbE (Gigabit Ethernet), eight USB, and several utility signals. Prices for the XM1 start at \$567.

Conceived in the late 1980s to use desktop architecture in embedded systems, PC/104 is one of the oldest and most popular small-form-factor open standards. With a connector arrangement meant for stacking boards without a card cage or a backplane, a PC/104 computer board can also serve as a mezzanine processor on an embedded baseboard. The developers of PC/104 derived its name from the PC and the number of interface pins on the 16-bit ISA (industry-standard-architecture) bus. Although the ISA bus is no longer available on the desktop, it still has advantages for embedded systems. Peripheral cards are simple, low-cost, and easy to design, all prime requirements of embedded products. The relatively low speed of the ISA bus also simplifies noise and EMI (electromagnetic-interference)-protection schemes. However, the main reason for its continued popularity is the large number of off-the-shelf products from which designers may choose. The PC/104-Plus specification emerged in 1997, and it gives board designers the choice of incorporating the



Figure 2 The XM1 computer module targets harsh-environment applications by integrating advanced cooling technologies, the latest serial buses, and rugged components.

ISA bus alone, the PCI and ISA buses together, or the PCI bus alone. PC/104-Plus requires a new connector to house the PCI-bus pins. This loss of board space is one of the few disadvantages of the PCI upgrade.

CONFLICTING STANDARDS

Efforts to further extend the PC/104 specification to take advantage of high-speed data transfers have run into differing opinions within the industry. In March 2008, the PC/104 Embedded Consortium adopted a new PCI/104-Express specification combining the PCI and PCIe buses. For additional room on a module, the PCIe/104 version removes the PCI bus altogether. Developers of the standard designed a new high-speed, surface-mount connector for this application. The connector handles the rugged environments of the embedded-system market, matches the 0.6-in. stack height of the PC/104 architecture, and transports the high-speed PCIe signals over large stack heights. You can download a free copy of the PCI/104-Express specification at the consortium's Web site, www.pc104.org.

Offering a different approach to incorporating PCIe into PC/104 architecture, the SFF-SIG (Small Form Factor Special Interest Group) announced details of the Express104 specification defining a new small, stackable module. Express104 specifies a 90×96-mm board with two 52-pin, high-speed SUMIT (stackable-unified-module-interconnect-technology) connectors that can support PCIe and USB as well as other popular moderate-speed interfaces for I/O expansion. Signal-integrity-test results demonstrate that a stack of Express104 modules support data rates of 5 GTbps, which is required for PCIe Generation 2. Designers can construct Express104 modules with only SUMIT connectors; however, its developers have defined a special configuration to support expansion with legacy PC/104 modules.

Offering a third approach to extending PC/104, Micro/sys Embedded Systems created a stackable architecture that the company based on the PC/104 form factor. Although it does not incorporate PCIe, the new architecture uses a modern communications protocol, USB, and retains the size and stacking advan-



Figure 3 With low-power- and portable-system applications in mind, Congatec recently announced the high-performance conga-CA processor module in a standard COM Express form factor.

tages of PC/104. StackableUSB supports as many as 16 peripheral boards, takes advantage of USB Plug and Play features, and eliminates the cable with a built-in stack-through connector. Further reducing the size, the Stackable-USB organization recently announced two new smaller module concepts that are one-half and one-quarter the size of a standard PC/104 board.

MICRO CHASSIS

PICMG members designed the AdvancedMC (Advanced Mezzanine Card), a relatively new small-form-factor standard, from scratch and based it on switched-fabric architecture. AdvancedMC modules include single-width, double-width, half-height, and full-height form factors. The basic single-width

module is approximately 74×183 mm. The basic specification defines a fabric interface with as many as 21 ports or 42 differential pairs, providing full-duplex, point-to-point connectivity between modules or to the baseboard. With a speed of 12.5 Gbps per port, AdvancedMC can handle multiple lanes of modern protocols, such as Ethernet, PCIe, Rapid I/O, and InfiniBand. With the high-performance, hot-swap, switched-fabric, and management features of AdvancedMC, designers suggested using these modules to plug directly into a backplane for small, stand-alone systems. As such, the recently adopted MicroTCA (telecom-computing-architecture) specification provides a stand-alone chassis with a backplane that directly accepts AdvancedMC cards. The smaller form factor makes the concept viable for lower-budget applications in telecom and a wide range of embedded projects.

COM (computers on modules) Express is another open PICMG industry standard for small-form-factor designs. COM Express includes PCIe to replace the PCI bus, PCIe Graphics as a replacement for AGP (Accelerated Graphics Port), and Serial ATA (advanced technology attachment) as a replacement for Parallel ATA. The processor-architecture-agnostic COM Express defines only industry-standard system-I/O interfaces. In support of COM Express, Congatec

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recently released the low-power conga-CA module, which is based on Intel's Atom processor and system-controller hub (**Figure 3**). The conga-CA is available with a 1.1- or 1.6-GHz processor, 512-kbyte L2 cache, and as much as 1 Gbyte of onboard DDR2 memory. Typical power requirements for this module are less than 5W. The conga-CA supports as many as two PCIe lanes, eight USB 2.0 ports, two Serial ATA ports, one IDE (integrated-drive-electronics) interface, and Intel high-definition audio. Additionally, the module features include two SDIO expansion sockets, a multimaster I²C (inter-integrated-circuit) bus, and GbE.

With a new wave of standards and updates that attack the data-transfer and cooling problems of small-form-factor systems, embedded-system designers can purchase many of the most complex portions of compact- or mobile-product development. High-performance, off-the-shelf processor modules with built-in graphics and networking interfaces leave the design team with the application-specific technology plus packaging. With a shortened design schedule and early access to a compatible software-development platform, standardized small-form-factor modules may be just the ticket for your next development assignment. **EDN**

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