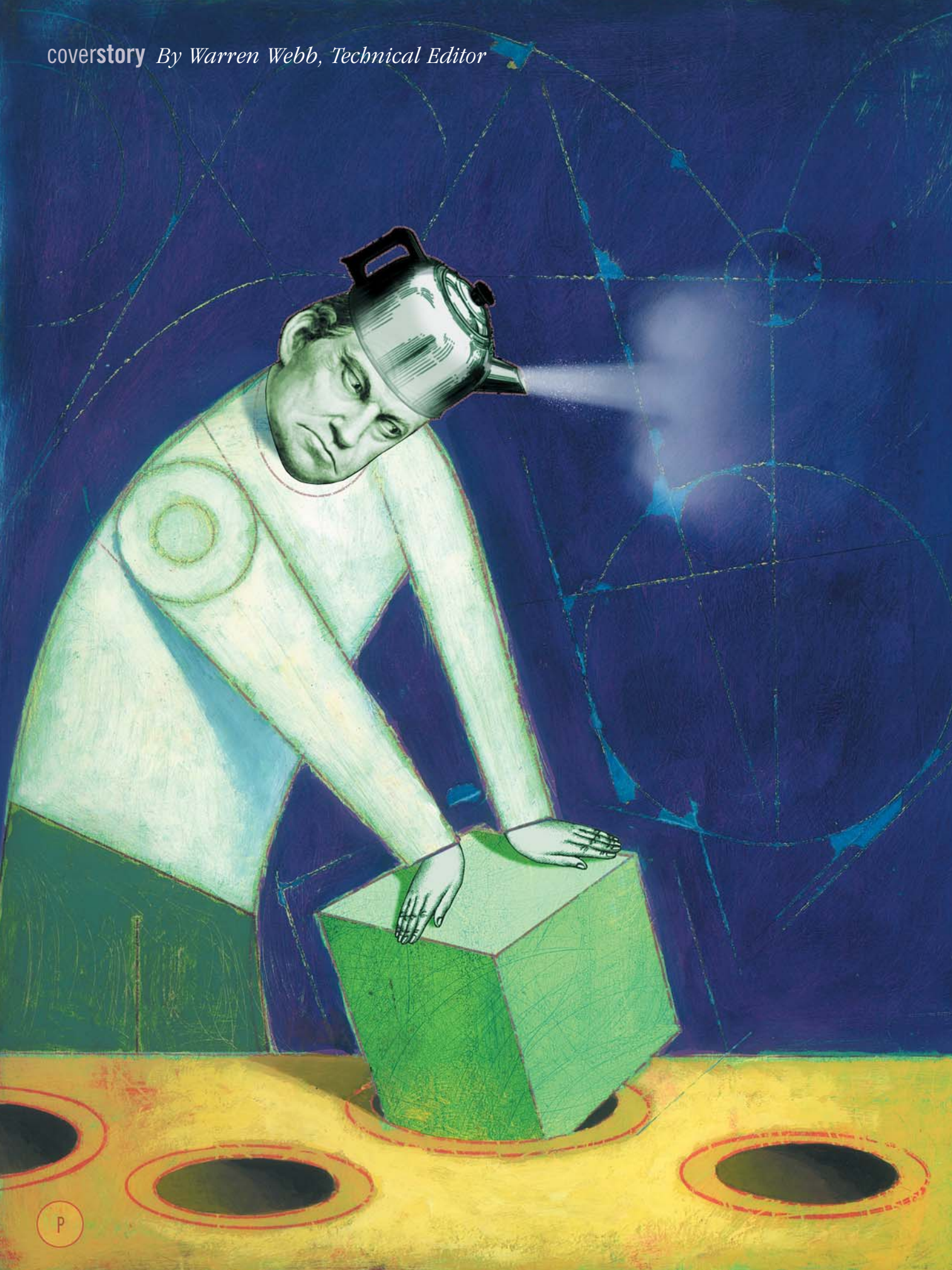
coverstory *By Warren Webb, Technical Editor*



BOARD MANUFACTURERS ARE UPDATING THEIR OFFERINGS TO PARTICIPATE IN THE EXPLODING HIGH-PERFORMANCE SEGMENT OF THE EMBEDDED-SYSTEM MARKET.

EMBEDDED-SYSTEMS STANDARDS:

AVOIDING HIGH-PERFORMANCE HEADACHES

Embedded-designers find themselves in a perpetual tug of war, with management demanding reduced budgets and schedules and customers insisting on more system functions. Designers traditionally deal with this struggle by incorporating into their products COTS (commercial off-the-shelf) processor and peripheral modules from the embedded-computing market. However, as high-performance embedded systems stretch the limits of technology, COTS manufacturers must update and refine their specifications and products to meet the needs of a growing list of advanced applications. Medical instrumentation, military systems, communications installations, and process automation are just a few areas in which soaring data rates, increased processing requirements, and application complexity have put a strain on off-the-shelf, board-level technology.

Small and midsized companies provide most mechanical enclosures, power supplies, backplanes, and plug-in boards that serve the COTS industry. According to Andrew Reddig, chief executive officer of Tek Microsystems, "There are about 70 suppliers competing for the COTS-board business. Of the 70, only about 10 have annual sales in excess of $25 million."

Although the embedded-system segment is small, financial analysts expect growth in the near future. Jeff Berson, senior analyst at CIBC, predicts, "The embedded-system sector continues to drive growth and investment opportunity. Although small, the sector is extremely attractive from a Wall Street perspective, and investors will benefit from early participation in the growth cycle."

A typical embedded-system project may incorporate an off-the-shelf chassis, processor, and user-interface section and reduce the custom-design effort to little or no hardware and the application-specific software. Standards-based

Illustration by Peter Bennett

designs also reduce the software-development effort by providing access to compatible operating systems, as well as vendor-supplied drivers and sample firmware. Board standards also eliminate the trial-and-error design iterations necessary to achieve optimal cooling performance and mechanical alignment.

To gain the maximum benefit from off-the-shelf technology, many manufacturers base their high-performance embedded systems on popular COTS-board architectures, such as PCI, VME, CompactPCI, and AdvancedTCA standards. These open standards outline a basic set of board and enclosure characteristics along with optional extensions to satisfy unique performance or reliability requirements for a range of industrial, medical, telecom, military, and consumer applications. Although, in their basic configurations, most of these specifications describe traditional shared-bus technology with its inherent bandwidth and scalability limitations, clever updates and extensions deliver advanced performance. For high-performance applications, each standard now offers some form of switched-fabric architecture that eliminates many of the problems associated with a multidrop-bus scheme. With this architecture, high-speed point-to-point paths between computing nodes may change dynamically to support multiple simultaneous data transfers. A sophisticated switched-fabric system can also increase system availability by routing signals around defective paths or nodes.

In addition to the data-handling enhancements of switched fabric, high-performance systems require specification extensions in other areas. Board size is a good example. Although silicon designers are packing more functions into less space, the demand for increased complexity and redundancy in some applications puts a premium on board area. The most popular board size for VME and CompactPCI has been 6U. However, the latest board standard, AdvancedTCA, sports an 8U form factor with more than double the component area. Increased density and larger boards also create cooling and power-distribution headaches. The 0.8-in. board pitch that VME and CompactPCI use restricts power dissipation to a practical upper limit of 50W per board with forced-air cooling. However, several conduction- and liquid-cooled schemes are now available to extend this range. AdvancedTCA boasts an air-cooled dissipation of 200W per slot. With chassis power dissipation on high-performance systems potentially approaching 3 kW, distributing traditional supply voltages, such as 5 or 3.3V at 600 to 1000A, is impractical. AdvancedTCA specifies dual −48V-dc feeds directly to each slot, where dc/dc converters provide local logic-level voltages.

AT A GLANCE

- With high-speed-fabric-technology add-ons, shared-bus architectures continue to support today's high-performance embedded systems.
- Most high-performance embedded systems are proprietary or based on PCI, VME, CompactPCI, or AdvancedTCA board standards.
- COTS (commercial off-the-shelf) products allow designers to trade a higher recurring cost for savings in both development costs and schedules.
- Optional updates to COTS board-level specifications foreshadow possible industry fragmentation and product-interoperability issues.

OLDIES BUT GOODIES

Legacy compatibility is one of the most sensitive issues when upgrading or extending the performance level of board standards. VME and PCI have undergone several upgrades to increase the shared-bus data-transfer rate and allow legacy products to communicate at their original speed. The more recent switched-fabric upgrades send high-speed data across backplane and edge-card connections that the shared-bus configuration does not use. Long-term availability is also a prime requirement for high-performance embedded products. Although the average life of a desktop component is about 18 months, users expect typical embedded products to remain in service for five years or more. Some military projects ask for a 15-year life cycle.

Since its introduction in the early 1990s, the PCI bus has become the bastion of the desktop-computer industry. The initial bus frequency was 33 MHz with a 32-bit-wide parallel datapath yielding a 133-Mbyte/sec data rate. A series of legacy-preserving updates has boosted clock frequencies to 1 Gbyte/sec with PCI-X. PCI is an important source of low-cost system components when environmental concerns are not an issue. The latest generation, PCI Express, offers scalable, high-bandwidth datapaths; packetized data protocols; and compatibility with PCI hardware and driver software. The basic PCI Express link comprises two signal paths that use LVDS (low-voltage differential signaling) and constant-current line drivers to communicate at 2.5 Gbps in each direction. An update is in the works to increase the base data rate to 5 Gbps. You can increase the bandwidth of an individual PCI Express link simply by adding signal pairs, or lanes, until you reach the desired performance level.

The new RadiSys Endura AB915GM is a 9×7.5-in. ATX motherboard for low-power, high-performance embedded-system applications (**Figure 1**). It supports PCI Express and Intel Pentium M processors with a 533-MHz front-side bus and a 2-Mbyte Layer 2 cache. With integrated, high-performance graphics, the AB-915GM supports dual independent displays. Both PCI and PCI Express slots, an MM/SD (multimedia/secure-digital) flash socket, and a PCI Express Mini Card

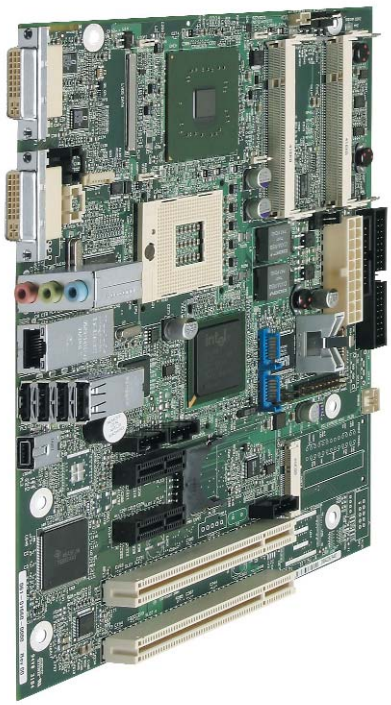


Figure 1 RadiSys' new Endura AB915GM motherboard provides both PCI and PCI Express slots and a PCI Express Mini Card slot.

slot provide peripheral expansion.

The PICMG (PCI Industrial Computer Manufacturers Group) introduced CompactPCI during the telecom boom with the goal of packaging low-cost, PCI-based desktop hardware in a rugged form factor. This scheme gave embedded-system developers access to off-the-shelf silicon and desktop-software applications. The PICMG controls and supports CompactPCI; it bases CompactPCI boards on the Eurocard industry standard, which defines both 3 and 6U board sizes. The rear of the more popular 6U version has as many as five connectors, allocating two for the CompactPCI bus and the remaining three for optional user-defined I/O connections.

The CompactPCI packet-switching backplane, PICMG 2.16, a recent update to the base specification for high-performance applications, adds dual switched 10/100/1000 Ethernet fabrics to the user-defined pins. SBS Technologies recently introduced a PICMG 2.16-compliant CompactPCI Gigabit Ethernet switch for high-speed network-connectivity applications (**Figure 2**). The 24-port CP6 switch targets Layer 2 switching and Layer 3 IP (Internet Protocol) network routing and requires no host intervention or software drivers. The CP6 comes in air- and conduction-cooled versions for commercial- and extended-temperature applications. Prices for a convection-cooled CP6 start at $4900, and the products are available now.

Figure 2

SBS Technologies' CP6 features a PICMG 2.16-compliant, 24-port CompactPCI gigabit-Ethernet switch for high-speed network applications.

BIG BOARDS RULE

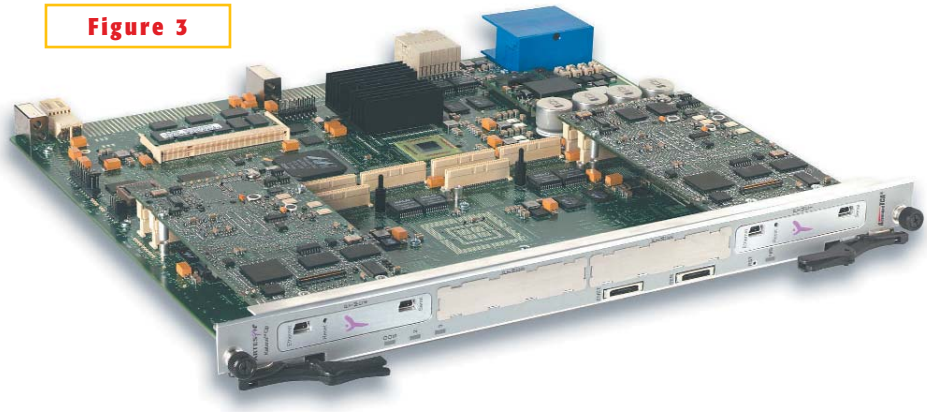
With a larger form factor, high-availability features, and high-speed fabric interconnections, AdvancedTCA promises to be a viable off-the-shelf alternative to the proprietary equipment prevalent in the telecom industry. The AdvancedTCA specification provides hot-swap capability for all boards and active modules, allowing systems to achieve and even exceed the elusive "five-nines" (99.999%) availability. The fabric interface provides a full mesh interconnection in which each slot has a direct connection to every other slot.

To appease divergent views in the industry, the base AdvancedTCA specification does not call out the specific fabric technology for data transport. Instead, a series of subsidiary specifications defines backplane details for the various fabrics, such as Ethernet, Fibre Channel, InfiniBand, StarFabric, PCI Express, and RapidIO. Although this approach allows manufacturers to build conforming boards with any fabric technology, it creates interoperability issues and promises to fragment the specifications.

Artesyn Technologies just announced an AdvancedTCA packet-processing blade for the telecom industry (**Figure 3**). The KatanaPPB features as many as six Freescale PowerPC 7447A processors, each with an Altivec vector processing unit, 32 kbytes of Level 1 instruction and data cache, 512 kbytes of Level 2 cache, and cache-coherency mechanisms for symmetric multiprocessing. Two MPC-7447A processors are mounted directly on the baseboard for use in distributed or symmetric multiprocessing. Users can mount as many as four additional processors on separate ProcessorPMC mezzanine cards. Todd Wynia, vice president at Artesyn Communication Products, explains, "Katana's six PowerPC processors and high-speed switched fabric provide control and packet-processing power to a wide range of telecom systems, including WAN access, SS7/signaling-transport, media gateways, traffic processing, wireless-base-station controllers, and soft switches." Software support for the KatanaPPB includes carrier-grade Linux with built-in support for symmetric multiprocessing. OEM prices for the KatanaPPB with a pair of MPC7447A processors start at $4407.

Dating to 1981, the VMEbus (VERSAmodule Eurocard bus) standard is the oldest embedded-system architecture. VMEbus employs a 3, 6, or 9U circuit board with a pin- and socket-con-

Figure 3



A new AdvancedTCA packet-processing blade from Artesyn Technologies features as many as six PowerPC CPUs for symmetric multiprocessing.

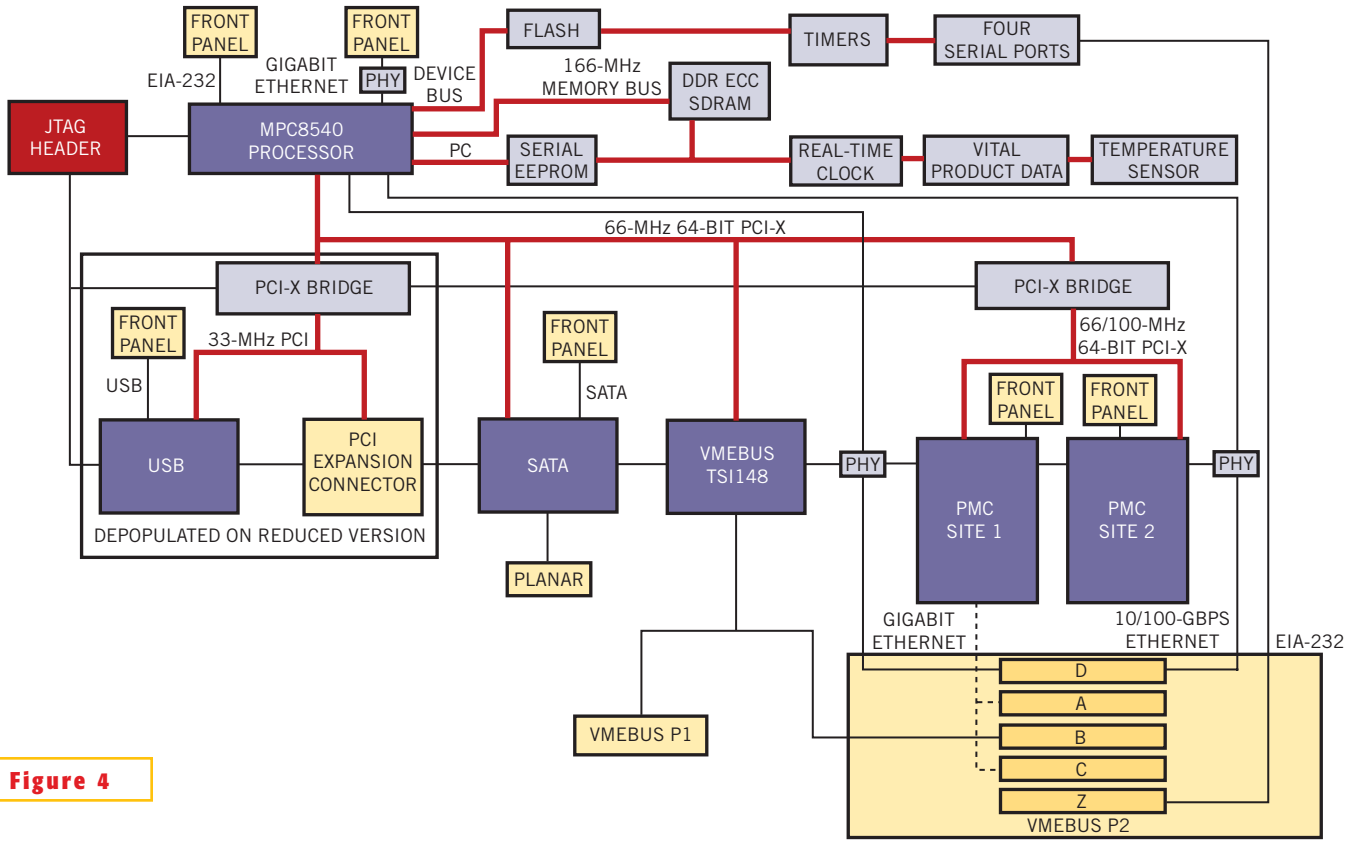


Figure 4

The MVME3100 single-board computer drives the VMEbus with a 320-Mbyte/sec 2eSST protocol and provides PMC-X sites for expansion.

nector interface to the backplane for harsh industrial applications. The basic standard defines a master-slave relationship between boards with asynchronous data transfers based on a variable-speed handshaking protocol. Data-transfer rates on the VMEbus have increased with each new VITA (VMEbus International Trade Association) standard. VME64, which VITA approved in 1996, increased data rates to 80 MHz by doubling the path width to 64 bits. Another doubling of the data rate to 160 Mbytes/sec reduced the transfer protocol from a four-edge to a two-edge handshake.

The latest 2eSST (two-edge-source-synchronous-transfer) interconnect can transfer data across the VMEbus at 320 Mbytes/sec. Motorola's MVME3100 single-board computer, a recent incarnation of the 2eSST protocol, employs a Freescale MPC-8540 PowerPC processor; as much as 512 Mbytes of SDRAM and 128 Mbytes of flash memory; dual 66-MHz, 64-bit PMC-X sites for expansion; gigabit Ethernet; and USB 2.0 interfaces (**Figure 4**). Versions of the MVME3100 will be available in the third quarter of 2005 for prices starting at $1895.

FABRIC EXTENSIONS

The recently approved VSX (VITA 41 switched serial extensions) add fabric functions to the VMEbus standard and maintain compatibility with legacy products. A new P0 connector routes high-speed serial signals to one or two in-chassis switch cards for distribution to the target destination. To prevent tying the specification to a single fabric technology, VITA 41 subspecifications define switch-slot and card definitions for InfiniBand, RapidIO, Gigabit Ethernet, and PCI Express.

As an example of a high-performance COTS board's using the VMEbus VXS extension, BittWare recently announced the T2-6U-VME for radar, sonar, communications, and imaging applications (**Figure 5**). The board features eight 600-MHz ADSP-TS201S TigerSHARC DSPs, two Xilinx Virtex-II Pro FPGAs, a PMC+ site, 512 Mbytes of SDRAM, and more than 9 Gbytes/sec of high-throughput I/O interfaces via the front panel, VXS switch fabric, and 2eSST VME. BittWare president Jeff Milrod says, "Our TigerSHARC family of PCI and CompactPCI boards has been well-received, and, now, with VXS, we can deliver a VMEbus form factor with the

Figure 5 **Available in both convection- and conduction-cooled versions, BittWare's T2-6U-VME features eight 600-MHz TigerSHARC DSPs and two Xilinx FPGAs.**

same continuous I/O and real-time signal processing performance." The commercial, air-cooled version is available now, and conduction-cooled versions will follow. Prices start at $18,995 (one).

A pending VITA 46 update replaces the VMEbus connectors with a seven-row connector rated for more than 6 Gbps and provides high-speed serial fabric for all board-to-board communications. Although dimensionally and electrically compatible with VMEbus modules, the device sacrifices backward compatibility for maximum performance. Clever backplane designers have proposed hybrid-VITA 46 configurations that allow each generation to coexist in the same chassis. Like previous fabric standards, VITA 46 defines specific fabric configurations in subspecifications.

Regardless of the standard you select, an ample catalog of readily available COTS boards is vital to the high-performance, embedded-development process. As designers stretch the technological envelope, board vendors and standards bodies must rush to update specifications and fill the pipeline with relevant products. A possible flaw in the continued success of COTS products could be the failure of the industry to settle on one or two switched-fabric technologies. With vendors manufacturing boards to support as many as six competing fabrics, expect a growing interoperability problem among modules from the same standard.□

You can reach Technical Editor Warren Webb at 1-858-513-3713, fax 1-858-486-3646, e-mail wwebb@edn.com.

FOR MORE INFORMATION...

For more information on products such as those discussed in this article, contact any of the following manufacturers directly, and please let them know you read about their products in *EDN*.

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