Figure 1 Digital-Logic's MSM200 series single-board computers are compatible with the PC/104-Express standard that the PC/104 Embedded Consortium recently approved.

ALTHOUGH STANDARDS ORGANIZATIONS DIFFER ON UPDATES TO REPLACE THE OBSOLETE ISA-BUS TECHNOLOGY, CLASSIC PC/104 CONTINUES TO ATTRACT EMBEDDED-SYSTEM DESIGNERS.

BY WARREN WEBB • TECHNICAL EDITOR

STACKABLE ARCHITECTURES DIVERGE

With recent additions to the official specification plus multiple customized variations to extract more performance, PC/104-like architectures continue to be prime candidates for rugged and space-constrained embedded designs. These architectures could face troubled waters in the future, however. PC/104 has been a flexible and rugged favorite of the embedded-system industry since its introduction, allowing designers to choose from hundreds of off-the-shelf processor and expansion boards coupled with widely available desktop software to simplify system integration. Unfortunately, as users are increasingly demanding higher data rates for some applications, industry associations have not yet agreed on a strategy for the next generation of board-to-board communications. In addition, users content with the currently available data rates also face problems as the latest processor chip sets omit support for the legacy PC/104-bus architecture.

Ampro Computers in 1987 developed the original PC/104 concept to take advantage of low-cost desktop silicon and software for embedded systems. The company derived the name from the PC and the number of interface pins on the 16-bit ISA (industry-standard-architecture) bus. The company in 1992 published the first formal specification for PC/104, which the PC/104 Embedded Consortium currently maintains. PC/104 cards employ stack-through connectors that eliminate the need for a motherboard, a backplane, or a card cage. These pin- and socket-bus connectors provide a reliable signal path even in harsh environments. PC/104 cards have four corner mounting holes for board support to resist shock and vibration. Each card measures 3.6×3.8 in., and stacked-card spacing is 0.6 in.

Although the ISA bus has vanished from the desktop, it still has advantages for embedded systems. Many embedded-system designers are happy with prior-generation processors and the extinct ISA bus. 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 fact that a large number of off-the-shelf products employ the architecture, giving designers a wide selection. Dozens of manufacturers now produce hundreds of unique, low-cost, off-the-shelf

PC/104 products (see **sidebar** "A new look at PC/104").

CHANGE THE BUS?

Since PC/104's introduction, designers have incorporated several enhancements to extend performance. The PCI (peripheral-component-interconnect) bus has effectively replaced ISA on the desktop, and it was only natural for system architects to add it to PC/104. The PCI bus brings a much higher data rate for high-performance peripherals and application-specific hardware. The PC/104 Embedded Consortium in 1997 released the specification for the PCI extension, formally known as PC/104-Plus. The specification gives board designers the choice of incorporating the ISA bus alone, the PCI and ISA buses together, or the PCI bus alone. PC/104-Plus requires a new connector, J3/P3, to house the PCI-bus pins. Because loss of board space is one of the disadvantages of the PCI upgrade, the PC/104 Embedded Consortium created the PCI-104 variation, which eliminates the ISA bus. The original PC/104 version continues to outsell both the PC/104-Plus and the PCI-104 updates.

To keep up with advances in technology and remain in tune with evolving desktop software, industry groups have put forth no fewer than three standards for the next generation of PC/104 development. These updates take advantage of the latest PCIe (PCI Express) specification, which the PCI SIG (special-interest group) defines, and USB (Universal Serial Bus) 2.0 technologies for higher data rates and improved board-to-board communications (see **sidebar** "PCI Express: the ideal fabric for stackable systems"). Although each of the new standards delivers substantial performance improvements in stackable architectures, the resulting products do not interoperate, and each provides varying degrees of compatibility with legacy PC/104 products.

The PC/104 Embedded Consortium agreed on the PCI/104-Express specification in early 2008 to define a standard method for using the high-speed PCIe

AT A GLANCE

- The size, rugged configuration, low power, low cost, and availability of PC/104 modules make them effective embedded-system-development platforms.
- Even though developers based the 20-year-old PC/104 architecture on the fading ISA (industry-standard-architecture) bus, it continues to outsell higher-speed extensions, including PC/104-Plus and PCI-104.
- Recent specification proposals for PC/104 updates have included PCIe (Peripheral Component Interconnect Express) or USB (Universal Serial Bus) communications to maintain compatibility with PCI-based software.
- New PC/104-form-factor updates sacrifice direct legacy compatibility to boost computing and communications performance and retain board real estate.

A NEW LOOK AT PC/104

By Christine Van de Graaf, Kontron

Design budgets address more than cost. When they consider development time, enclosure space, and performance factors, PC/104 or PC/104-compatible systems can be effective choices. Ideal for designs that require little–if any–hardware customization, PC/104 and PC/104-compatible systems are stable platforms that have evolved to deliver increased performance within small form factors.

A stable platform allows designers to interchange PC/104 products from vendors, perhaps to capture a performance jump they couldn't achieve with a product they implemented in years past. The fact that manufacturers keep components in the same place on a board is probably one of the most important advantages of working with an industry-standard product and one that makes it simple for designs to evolve from older PC/104 to newer PC/104 architectures. Further, some manufacturers keep features consistent from module to module, which avoids complicating the interior of the enclosure due to the added cabling that PC/104 designs require. PC/104 signals use pin-through rather than plug-in connectors; cabling then brings the signal through to the outside. Alternatively, the designer incorporates a carrier board with its own plug-in connectors.

A PC/104 stack typically has a maximum of six boards. So, a designer places the CPU board atop the baseboard with all the connectors. If the CPU board lacks a feature, a common issue in some vendors' boards, the designer must use another block of boards on top. The next block could include graphics, another could include sound, and another could employ Ethernet or Firewire. More advanced boards can reduce the size of the stack. Some have built-in I/O capabilities so designers don't need a separate PC/104 board with graphics, Ethernet, or sound, for example. Using more functional and properly selected boards can quickly reduce your stack from six small-form-factor single-board computers to just two.

PC/104 has other advantages in, for example, designs that require moderate performance with a small budget. And, if a design uses a PC/104 board, the designer's tendency would be to stay within the same technology area. Tight budgets and small enclosures could mean some trade-offs to stay with the same platform, but advances in PC/104 have improved the potential in this area. Not all PC/104 boards are created equal, and some are just more advanced than others.

AUTHOR'S BIOGRAPHY

Christine Van de Graaf is a product-marketing manager at the embedded-modules division of Kontron America. You can reach her at christine.vandegraaf@us.kontron.com.

bus in embedded-system applications. The basic PCIe link consists of two signal paths that use LVDS (low-voltage-differential-signaling) swings and constant-current line drivers to communicate at a rate of 5G transfers/sec in each direction. You can increase the bandwidth of an individual PCIe link by adding signal pairs, or lanes, until you reach the desired performance level. Although the PCIe specification defines one-, two-, four-, eight-, 16-, and 32-lane widths, the PCI/104-Express specification supports only four one-lane links and one 16-lane link.

Digital-Logic offers several PCI/104-Express cards, including the MicroSpace MSM200 series single-board computers (**Figure 1**). The modules come with the Intel Atom processor operating as fast as 1.6 GHz plus several options for onboard RAM. The modules target applications in battery-powered mobile computers, information terminals with video displays, game systems with music output, measuring instruments, and telecommunication devices. Besides the fast CPU, the MSM200 provides all standard PC interfaces for such demanding applications, including Ethernet, an audio controller, four RS-232 interfaces, and two serial- and one parallel-disk interface. Prices for the MSM200 start at 364 euros (approximately $520) per unit (100).

EXPRESS104

Taking a different approach, a recently formed industry trade group, the SFF SIG (Small Form Factor special-interest group) in early 2008 defined the Express104 PC/104 extension. These boards incorporate one or two newly developed 52-pin SUMIT (stackable-unified-module-interconnect-technology) connectors. One of the connectors provides two one-lane links and one four-lane link, plus three USB 2.0 interfaces, a low-pin-count bus, dual SPI (serial-peripheral-interface) channels, an SMBus (system-management bus), and a set of ExpressCard interface signals. The optional second connector provides another set of one- and four-lane links. Express104 also supports an optional

⊞ For more on the appeal of PC/104, go to www.edn.com/article/CA47270.

⊞ For another article on how shrinking standards are squeezing embedded designs, go to www.edn.com/article/CA6570999.

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PCI EXPRESS: THE IDEAL FABRIC FOR STACKABLE SYSTEMS

By Steve Moore, PLX Technology

Many types of SFF (small-form-factor) embedded-system applications use stackable architectures to enable system and I/O expansion without the need for backplanes or card cages. The interconnect element for stackable systems has over the past 16 years migrated from ISA (industry-standard architecture) to PCI (peripheral-component interconnect). Now that the PCI/104-Express standard is available, embedded-system designers can take advantage of PCIe (PCI Express) technology to deliver lower cost and power consumption, smaller boards, less cabling, fewer connectors, higher data throughput, lower latency, and legacy-PCI-software compatibility that greatly simplify the transition to PCI/104-Express.

Thanks to broad silicon availability resulting from PCs, servers, and workstations adopting PCIe, the sheer volume of PCIe devices has surged, dramatically reducing their costs. The reduced power consumption comes from the fact that a 250-Mbyte/sec PCIe link uses only four wires–one transmitter pair and one receiver pair. Contrast this number with the cost and link requirements of the 32-bit PCI bus, which requires more than 100 I/Os and which delivers a maximum of 125 Mbytes/sec. This substantially lower I/O count also accounts for the reduced pin count on the PCIe chips, meaning reduced board space, smaller connectors, and improved PCIe cabling.

Designers are already using widely available PCIe Generation 1, which operates at 2.5G transfers/sec, and Generation 2, which operates at 5G transfers/sec, switches from vendors such as PLX Technology to build higher-performance interconnect fabrics within PCI/104-Express-based stackable/SFF systems. PCI/104-Express calls for four one-lane PCIe Generation 1 links, each capable of 250-Mbyte/sec transfers–twice the bandwidth of 32-bit, 33-MHz PCI that PCI/104 uses. You can also use Generation 2 switches because they automatically downlink to Generation 1. This speed gives stackable/SFF systems a significant I/O bandwidth boost, yielding a much faster fabric. Additionally, it provides as many as four high-speed I/O channels that need not share bandwidth across a single bus, as with PCI/104. PCI/104-Express also specifies a 16-lane PCIe link, providing a throughput boost of more than 32 times that of the PCI 32/33 standard.

Designers have applied other I/O interconnects, such as USB and GbE (gigabit Ethernet), but neither approaches the throughput capabilities and low latency of PCIe. A high-speed USB 2.0 connection, for example, can support only 40 Mbytes/sec, compared with the slowest, one-lane Generation 1 PCIe link, which delivers 250 Mbytes/sec. GbE supports only 125 Mbytes/sec with a high-latency overhead, whereas the fastest, 16-lane Generation 2 PCIe link provides throughput as fast as 10 Gbytes/sec.

AUTHOR'S BIOGRAPHY

Steve Moore is a senior product-marketing manager at PLX Technology (Sunnyvale, CA). You can reach him at smoore@plxtech.com.

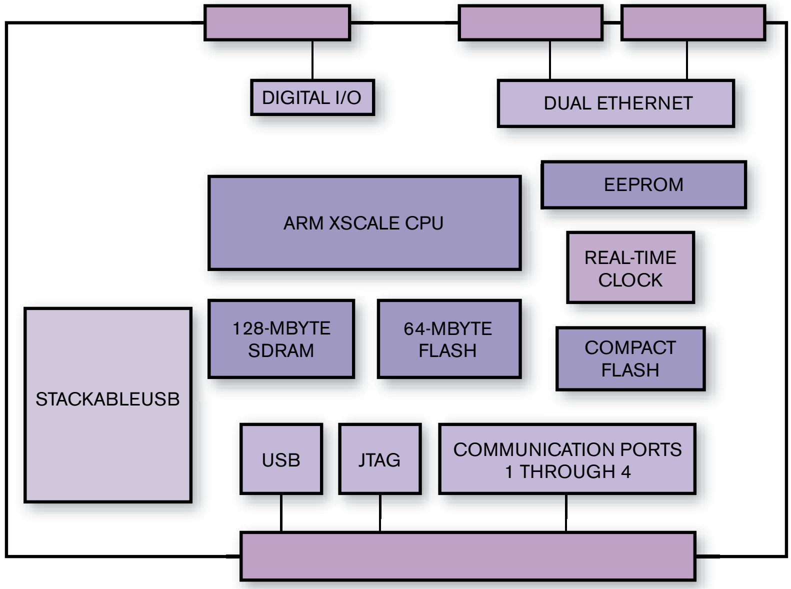

Figure 2 The SBC1626 single-board computer from Micro/sys combines a fast Intel XScale processor, memory, and StackableUSB I/O on a PC/104-form-factor board.

configuration that includes a PCI-to-ISA-bridge chip to retain compatibility with legacy PC/104 boards. Although several manufacturers have shown interest, none had publicly announced Express104 modules as of late 2008.

Offering yet another approach to enhancing the communications protocol, Micro/sys Embedded Systems created a new stackable architecture that it based on the PC/104 form factor. StackableUSB employs USB and retains the size and stacking advantages of PC/104. StackableUSB supports as many as 16 peripheral boards, takes advantage of USB plug-and-play features, and eliminates the need for a cable with a built-in stack-through connector. Micro/sys recently introduced the SBC1626 network-ready controller, which it based on the 104 form factor with seven USB ports, including five host ports through the StackableUSB connector and two client USB ports (**Figure 2**). In addition to its networking functions, the ARM-based SBC1626 also features 24 digital I/O lines, eight readable DIP switches, eight LEDs for application use, and four RS-232 ports; 64 Mbytes of onboard linear flash and 128 Mbytes SDRAM accommodate high-level operating systems, such as Linux or Windows CE. Prices for the basic SBC1626 start at $450 (one).

For standard performance, embedded-system designers will continue to specify and integrate classic PC/104 as long as legacy products are available. In addition, manufacturers will continue to produce these products as long as their board designers can find ways to link newer silicon to the obsolete ISA bus. For higher-performance applications, an update is necessary. Unless the industry chooses a successor to PC/104, the architecture will most likely enter a fragmentation phase, with manufacturers producing incompatible products. In the meantime, classic PC/104 lives on. EDN

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www.stackableusb.org

You can reach Technical Editor Warren Webb at 1-858-513-3713 and wwebb@edn.com.