
Photo courtesy Versalogic

# PC/104: AN AGING BEAUTY

**EVEN THOUGH INTEL AND MICROSOFT HAVE JOINTLY BANNED THE BUS FROM FUTURE DESKTOP COMPUTERS, ISA-BASED PC/104 EMBEDDED PRODUCTS SHOW STEADY GROWTH.**

PC/104 modules simplify embedded-system development by leeching resources from the high-volume desktop-computing world (see **sidebar** "A PC/104 primer"). Designers of embedded systems have benefited from the low-cost silicon, extensive software, and off-the-shelf development tools by simply copying desktop architecture into the more rugged PC/104 form factor. So far, this approach has worked perfectly because each new advance in desktop technology has retained compatibility with the previous generation.

But PC/104 faces an uncertain future as desktop planners strip the ISA (Industry Standard Architecture) bus from new PC hardware and software.

Unlike the desktop, which is a general-purpose computing platform and must track the leading edge of technology, embedded systems, such as those built from PC/104 building blocks, are designed to perform a specific task. Typical PC/104 embedded applications include medical instruments, avionics, vending machines, test equipment, communications devices, vehicular systems, data logging, and industrial control. Once it goes into service, an embedded design may remain static for years without the need for more memory or a faster processor. Many designers of embedded systems are completely happy with previous-generation 386 and 486 processors and the lowly ISA bus.

## HERE TODAY, HERE TOMORROW

In fact, a prime requirement for products in embedded applications is long-term availability. This requirement means that manufacturers must select components and architecture that will be available for a sustained period. Silicon suppliers such as Intel (www.intel.com) identify a portion of their product lines

as extended-life devices to support the market for embedded designs. Although the average life of desktop components 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.

Although the ISA bus is fading on the desktop, it still has advantages for embedded systems. Peripheral cards are simple, low-cost, and easy-to-design—all primary requirements of embedded products. The relatively low speed of the ISA bus also simplifies noise- and EMI-protection schemes. However, the main reason for its continued popularity is the large number of off-the-shelf products from which designers may choose. Currently, more than 150 manufacturers are producing hundreds of unique PC/104 products. The PC/104 Consortium (www.pc104.org) lists more than 100 members and lets the visitor search for PC/104 components by manufacturer or type.

Desktop architects have effectively issued a death sentence for the ISA bus. Intel and Microsoft co-author the annual PC-system design guide with their recommendations and requirements for bus and device design (**Reference 1**). They claim that ISA-bus conflicts are the most frequent cause of PC problems and that a significant performance hit occurs when a fast processor accesses the low-speed ISA bus. Their solution is to eliminate the use of the ISA bus on all new PCs. Microsoft enforces design-guide requirements by withholding its "Designed for Microsoft Windows" logo on nonconforming hardware. Intel simply removes the ISA bus from interface silicon.

The main design goal of PC/104 was to combat the high cost of custom software. PC-compatible processors give embedded developers access to the same software that they use on the desktop, where reusable application routines are plentiful and inexpensive. Experienced programmers with desktop expertise are also more abundant than are embedded-software specialists. Desktop tools such as integrated development environments,

### AT A GLANCE

- PC/104 gives developers of embedded designs access to low-cost desktop software and development tools.
- Like the original PC, PC/104 is based on the fading ISA bus; however, PC/104-Plus extensions integrate the higher speed PCI bus.
- PC/104's popularity stems from the hundreds of off-the-shelf peripheral cards that are available from multiple vendors.
- The ruggedized configuration, compact size, light weight, low power, and low cost of PC/104 modules make it an effective embedded-development platform.
- Highly integrated and multifunction silicon now yields complete embedded systems on a single 3.6×3.8-in. form-factor board.

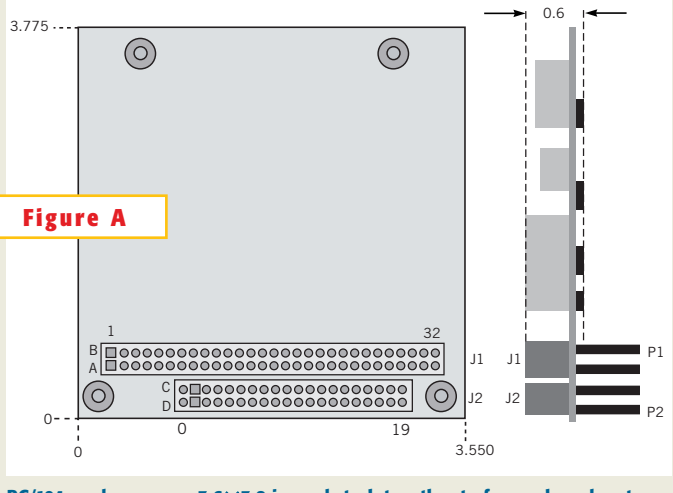
**The $2995 DDR-bitsi digital drop receiver from BittWare Inc contains four independent down-conversion channels for high-accuracy software-radio applications.**

## A PC/104 PRIMER

Ampro Computers conceived PC/104 in the late 1980s as a way of using desktop architecture in embedded systems. Ampro derived the name from the PC and the number of interface pins on the 16-bit ISA bus. PC/104's developers published a formal specification in 1992, and the PC/104 Consortium Web site (www.pc104.org) maintains the specification. Unfortunately, PC/104 signal descriptions are based on the P996 (PC and PC/AT bus) specification project, which the IEEE subsequently dropped. A Consortium FAQ points to commercial books available from Annabooks to document the original P996 contents.

A PC/104 system comprises a CPU board and optional peripheral boards stacked together. PC/104 cards are fitted with stack-through connectors, which eliminate the need for a motherboard, backplane, or card cage (**Figure A**). 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, when stacked, the card spacing is 0.6 in. Connector J1/P1 contains 64 pins to support the 8-bit ISA bus, and J2/P2 houses 40 more pins for the 16-bit version. Unlike boards for the desktop, 8- and 16-bit PC/104 ISA boards are the same size.

The bus specifications for PC/104 are identical to those of ISA except that PC/104 reduces the drive requirement for most signals to 4 mA of sink current. This decrease reduces overall power requirements and allows ASIC devices to directly drive most bus signals without the need for separate driver components.




**PC/104 cards measure 3.6×3.8 in. and stack together to form a board system with no motherboard, backplane, or chassis.**

compilers, and debuggers can save considerable project funds over their embedded counterparts.

PC/104 also works with a variety of desktop and embedded operating systems. Originally, DOS was the primary choice, and it still finds use in many applications. Today, you can select from almost any desktop operating system, including Windows 98 and Windows NT. You can also choose Linux, which works as a desktop or embedded operating system and has the added benefits of being an open source and having no recurring royalties. PC/104 processors also work with embedded operating systems, such as Windows CE and Windows NT embedded. If you have real-time requirements, you can select from the more traditional RTOSs, such as VxWorks from WindRiver Systems or QNX from QNX Software Systems.

Figure 1

Inside Technology's MM/104 Video and Sound multimedia adapter is typical of the off-the-shelf PC/104 peripheral boards available from several vendors.

Some pitfalls may cause problems when you apply a desktop operating system to an embedded project. You should be aware of the possible hardware differences between the desktop and an embedded system. A desktop configuration is fairly standard, so you can be assured of a display, a hard disk, a keyboard, a pointing device, and plenty of memory. However, an embedded system may have a multitude of configurations, including no display, no keyboard, and a specialized peripheral device that must be integrated into the operating system. You usually need to implement some customization whenever you port any operating system to embedded hardware.

### STACK 'EM UP

In addition to software selection, PC/104 requires mechanical-configuration choices. PC/104 usually is available as a board stack or as a custom baseboard. Either approach fits the basic PC/104 assumption of off-the-shelf building blocks that simplify design and reduce risk. A stack packs PC/104-sized boards into a dense cube and yields the minimum system volume. Custom hardware fits onto one or more standard PC/104 cards. If you have a significant amount of special hardware, you can create a custom baseboard and use standard PC/104 boards as plug-in mezzanine boards for the CPU and standard peripherals. If your design has sufficient height, you can stack expansion boards on top of the mezzanine boards as needed to upgrade the system.

Figure 2

The $264 Sensoray model 322 CRT/LCD delivers high-power desktop graphics to embedded applications.

Numerous peripherals and I/O boards are at the heart of PC/104's appeal. Users have a large selection of low-cost, off-the-shelf boards from more than 100 vendors. To illustrate with an example, the MM/104 Video and Sound multimedia adapter from Inside Technology provides the hardware to integrate live video and sound into your applications (**Figure 1**). The MM/104 has an onboard NTSC/PAL/SECAM video-input decoder with YUV output, is SoundBlaster-compatible, and includes an optional dual-PCMCIA controller.

Since its introduction, designers have incorporated several enhancements into PC/104 to extend performance. The PCI 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 specification for the PCI extension, formally known as PC/104-Plus, was released in 1997. The new 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, designated

## FINDING PC/104 INFORMATION ON THE WEB

Prospective users can find more PC/104 and PC/104-Plus technical information at several locations on the Internet. The PC/104 Consortium Web site at www.pc104.org lists specifications and manufacturers. You can also search for products from member companies. Ampro Computers, the originator of PC/104, maintains an engineering-university Web site with several technical articles at www.ampro.com/forum.enguniv.html.

The On-Line Journal of Computer Controlled Systems at www.controlled.com/pc104 is devoted to PC/104 and contains technical information, vendor listings, and additional links. You can also click www.pc104-embedded-solns.com for the *PC/104 Embedded Solutions Magazine*. And finally, a search for PC/104 products returns thousands of pages with vendor specifications and application information.

J3/P3, to house the PCI-bus pins. This loss of board space is one of the few disadvantages of the PCI upgrade.

The model 322 CRT/LCD adapter from Sensoray is a good example of a PC/104 peripheral board that takes advantage of the PCI-bus throughput (**Figure 2**). The card includes a 128-bit video accelerator for fast 2- and 3-D graphics, along with 1600×1280-pixel SVGA, PAL, NTSC-composite, and S-video outputs. Although the Model 322 is PCI-based, a 104-pin ISA-bus pass-through connector allows subsequent cards to use either bus.

PC/104 got another boost in efficiency in 1997 when Ampro and Motorola Computer Group jointly developed the specification for the larger EBX (embedded-board-expandable)-form-factor computer board. EBX boards measure 5.75×8 in. (the same size as a 5.25-in. floppy drive) and are large enough to implement a full 32-bit system with CPU, memory, display interface, and basic I/O on a single board. EBX also has an integral PC/104-Plus expansion interface so users can stack off-the-shelf peripheral boards to complete a system. The EBX specification at www.ampro.com/university does little more than state the board's mechanical dimensions, leaving designers free to implement almost any computer configuration (see **sidebar** "Finding PC/104 information on the Web"). The higher integration of EBX boards eliminates bus-interface chips and allows the hardware to exchange data at local-bus rates instead of having to meet the constraints of ISA- or PCI-bus speeds.

**Figure 3**

**The SOB-104 from Diamond Systems includes a 486 CPU, Ethernet, and data-acquisition hardware on a single 3.6×3.8-in. board.**

### A REAL SOB

Although PC/104 originally required multiple boards for an effective computer system, technology has caught up, and you can now get a complete computer and data-acquisition system on a single board. The integrated SOB-104 features a 100-MHz AMD 486 processor, 32 Mbytes of RAM, 10BaseT Ethernet, two serial ports, a parallel port, 16 16-bit analog inputs, four 12-bit analog outputs, and 24 programmable digital-I/O lines (**Figure 3**). This onboard capability is substantially more than was possible when the PC/104 specification was writ-

## FOR MORE INFORMATION...

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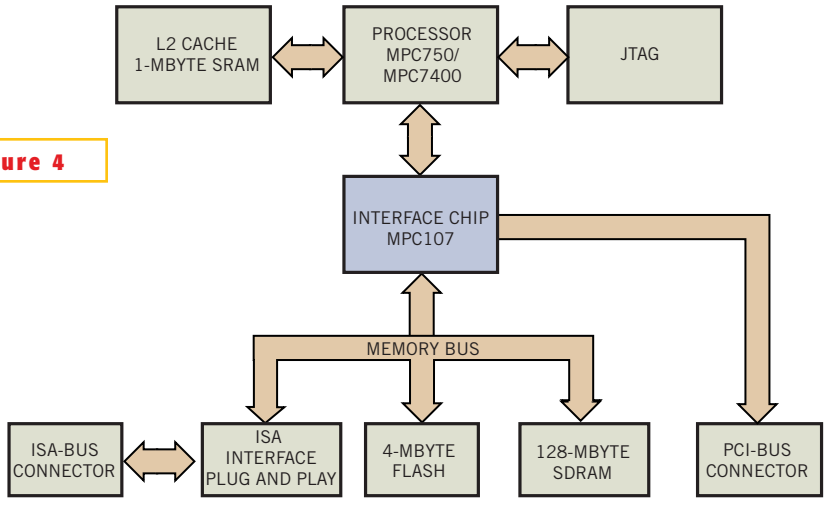
ten in the early 1990s. Prices for the SOB-104 start at $700 for single units and drops to $400 in OEM quantities.

PC/104 designers have also extended the architecture to include non-PC processors. CowBoy Industries recently introduced a standard-form-factor PC/104 board based on the low-power, 100-MHz PowerPC 750 RISC processor. The single-board computer, dubbed the Morgan, includes 128 Mbytes of SDRAM and 4 Mbytes of on-board RAM (**Figure 4**). Morgan also implements both the 16-bit ISA bus and the 32-bit PCI bus for flexible add-on expansion.

Figure 4

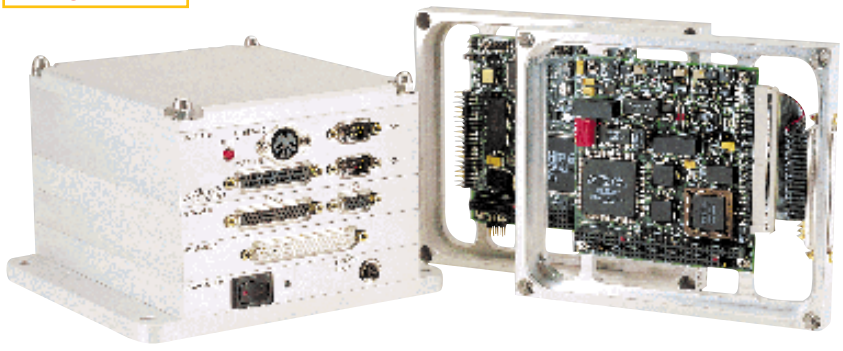



**The Morgan microprocessor board from CowBoy Industries replaces the PC-compatible processor with the popular and lower power PowerPC 750.**

Environmental capability is one of the primary reasons for selecting PC/104 over standard desktop enclosures. With several boards stacked and bolted together, the system is extremely rugged and has no backplane plug-in boards to jiggle loose. As a testament to its toughness, designers use PC/104 on many military and avionics projects. Some board manufacturers publish shock, vibration, temperature, and MTBF (mean-time-between-failures) specifications to appeal to the environmentally sensitive markets. Vendors have also developed ruggedized mechanical hardware to further enhance PC/104. For example, Real Time Devices USA offers a machined aluminum enclosure that acts as a heat sink and delivers performance of −40 to +85°C without a fan (**Figure 5**). An optional shock-mount baseplate isolates the PC/104 system under sustained loads as high as 5g. An internal 75W power-supply module with an 8 to 30V-dc input handles power requirements.

Stack-through connectors are one of the positive features of PC/104, but they create other problems. The densely packed PC/104 configuration makes it difficult to change boards, especially in the center of a stack. You must remove all of the connectors and unbolt the stack. Another potential problem with stack-through connectors is the increased board-assembly time. Because gold-plated wiping connectors appear on both sides of the board, you cannot use high-speed flow-solder techniques. Several approaches to solving the connector problem, including press-fit connectors and integral solder, have appeared. For example, Comm Con Connectors (www.commcon.com) offers PC/104 connectors with an integral solder system. A user inserts the connector and applies heat with a standard hot-air solder-reflow tool. Solder wicks through the board to provide a full solder joint on both sides of the board.

Figure 5



**This machined aluminum enclosure from Real Time Devices USA acts as a heat sink and extends the PC/104 operating-temperature range to −40 to +85°C without a fan.**

## NEW DIRECTIONS

It is only natural that developers of embedded designs prefer working with the most recent desktop software to take advantage of fixes and improvements. When this software no longer supports the ISA bus, expect a sudden decrease in new designs based on the original PC/104 specification. However, PC/104-Plus will remain an effective embedded-development architecture as long as PCI is popular on the desktop. Microsoft and Intel recommend that desktop-peripheral designers look at USB and IEEE 1394 for new designs. One of these serial interfaces may become the next step in PC/104 evolution.□

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REFERENCE

1. *The PC99 System Design Guide*, Version 1.0, Intel Corp, developer.intel.com/design/desguide/ or Microsoft Corp, www.microsoft.com/hwdev.

ACKNOWLEDGMENT

*Thanks to Tom Barnum, general manager at Versalogic, for his expert assistance and PC/104 product knowledge.*