PC/104:
The Embedded PC Mezzanine

No one like to be backed into a corner without an escape route.
Yet users of x86-based SBCs faced that problem prior to PC/104.

by: Robert A. Burckle, VP
WinSystems, Inc.

The rapid growth of embedded PCs used for industrial applications demanded a way to expand SBC features without a large cost or space penalty. Sometimes the changing demands of an application, the end customer, or a designer's own marketing department dictated that another serial channel, instrument interface, display panel, switch closure, network interface, etc. be added to the system. Often this happens at the most inopportune moment with strict guidelines on limiting cost, space and time to implement the change.

The solution to the problem is a mezzanine board, which -- as its name suggest -- mounts directly on top of another board. Using a mezzanine module is the most cost-effective solution to mix and add a variety of I/O to a host motherboard or single board computer (SBC). It does not require the bulk and expense of a backplane expansion option and can maximize the space efficiency of off-the-shelf systems.

A mezzanine board can either be a customer's proprietary design or an off-the-shelf board purchased from a vendor. The decision to make vs. buy depends upon a number of issues including the functionality of the specialty I/O, availability of commercial products, in-house design and manufacturing expertise and cost per unit. The critical mezzanine issues are to select boards based upon industry standards, supported by many manufacturers worldwide, and with the functionality that you need. When a commercial board is not available or does not meet your needs, then a mezzanine board is easier and cheaper to design than a full-size backplane board.

PC/104 is an ideal mezzanine for industrial applications. The modules are small, rugged, and based upon proven industry hardware and software standards. It is easy to complete an in-house design or find hundred of vendors with thousand of products worldwide. PC/104 is unique in that it can serve either as a mezzanine bus expansion module, SBC or both. The result is that PC104 bus is well known and quite popular for a variety of applications.

Historical perspective

The first industry-standard mezzanine bus was pioneered in the early 1980s by Intel. It was called the iSBX and was designed to be small and low cost. Its purpose was to offer additional I/O without the need of an additional 6.75" x 12" Multibus I board and card cage. Two board sizes were defined: the single wide measures 2.5 x 3.7 in., and the doublewide measures 2.5 x 7.5 inches. Intel allowed the iSBX to be an open architecture standard and encouraged their customers and competitors to design specialty I/O boards. A board design was simple and easy and the concept was quickly accepted and eventually became IEEE standard 959. A variety of standard products were offered

> The solution to the problem is a mezzanine board,
> which, as its name suggests, mounts directly
> on top of another board.

including IEEE-488, SCSI, video, serial/parallel I/O, analog I/O, motion control, networking, modem, and prototyping modules.

The downside to the iSBX mezzanine was that it was an I/O only expansion board with the capability of adding only a single board per connector. Also, its popularity was directly tied to the Multibus I and Multibus II architecture rather than gaining acceptance across a wide spectrum of single board computers and other bus architectures. It did however gain limited acceptance with the STD Bus vendors such as WinSystems, Ziatech, Pro-Log, and others putting SBX connectors on their CPUs. The iSBX modules are at the end of their product life cycle as newer technologies have displaced them.

Paradigm Shift

The x86-based PC has made an enormous impact in the computing world that has spilled into the industrial and non-desktop market as well. The PC architecture has become the dominant standard that has worked its way into applications never dreamed of by its designers. The reason is that an embedded PC can reduce development costs and accelerate their time to market. The standard it brings is more than just bus timing or packaging. PC-compatibility means a definition of the internals of a system including the CPU family, DMA, interrupts, timing, serial ports, LAN interfaces, video, disk storage, etc. The bottom line is that the PC has become firmly embedded as a standard design element in a wide variety of applications.

A number of PC form factors have evolved either as standard single board computers or as bus expandable systems including ISA, PCI, CompactPCI, AT motherboards,

PC/104, and EBX. Yet all have a need for reliable expansion flexibility. System designers saw the benefits of low cost, simple upgradeability, small size and flexibility using mezzanine modules. Other vendor-driven cards were introduced, but open-standard expansion buses lead the way to mezzanines becoming mainstream. The best known and most widely used today are PC/104, PMC, and Industry Pack.

improve the technical standards plus promote worldwide industry visibility.

PC/104 is simply a repackaged, modular version of the PC architecture intended for embedded applications where space, power consumption and reliability are critical. These modules can serve as a mezzanine bus for an embedded SBC or it can become the entire computer and I/O system.
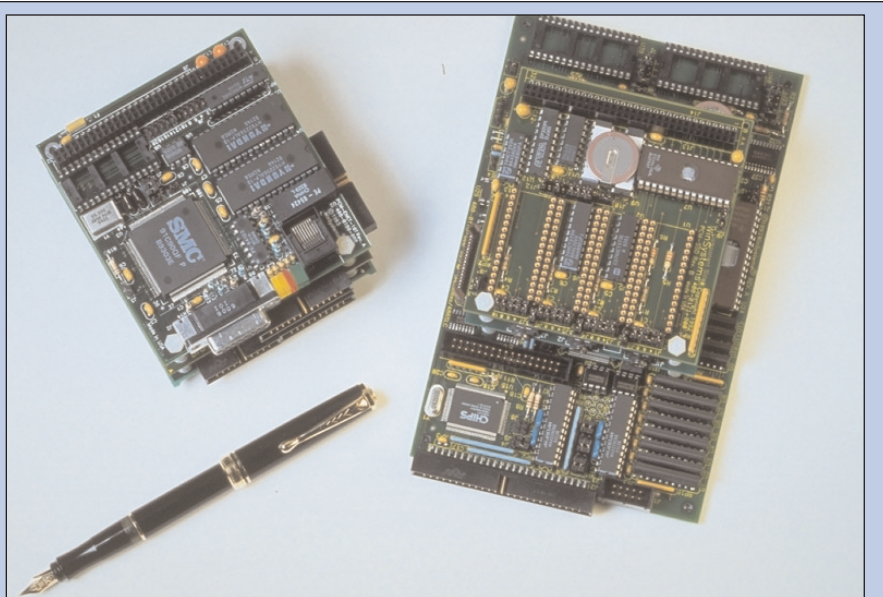
Two Ways to Use PC/104 Modules
1. **One or more PC/104 modules stacked together. The modules form an ultra-compact computer that does not require a backplane or card cage.**
2. **PC/104 modules as a mezzanine expansion bus. The modules can be plugged on a base SBC for easy system expansion.**

Introduction of PC/104

Embedded designers have reaped a bonanza from the PC. One of the finest examples is the PC/104 architecture whose first specification was published in 1992. Key features/benefits are that the modules are compact, modular, self-stacking, and PC-compatible offered in a variety of functions with multi-vendor support. Also, there is an active Consortium to maintain and

A PC/104 module is an Industry Standard Architecture (ISA) bus board reduced to 3.6 x 3.8-inch (90 x 96-mm) that is approximately the size of a 3.5-in diskette. The bus signal definitions and timing are the same. PC/104's P1 bus has 64 pins just like the PC-XT and is combined with 40-pins on P2 for full AT-compatibility. The sum of the pins (64 +40 = 104) is the origin of the name PC/104.

One of the cleverest features of

Don't underestimate the importance of an Industry Consortium. There are over 100 members worldwide of the PC/104 Consortium. Its purpose is to maintain and freely distribute the PC/104 Specification as well as direct its technical expansion as new technology evolves. The PC/104 Consortium provides a liaison to standards bodies and also maintains a source guide of manufacturers and products at its web site http://www.pc104.org.

Venture Development Corporation (VDC) forecasts that the worldwide market for PC/104 will increase from about $52 million in 1998 to around $149 million in 2002, at a Compound Growth Rate (CAGR) of 30%. PC/104 has grown so popular that there is an independent magazine that is published bimonthly titled PC/104 Embedded Solutions as well as well as dedicated, independent, commercial web sites at http://www.pc104.com and http://pc104-embedded-solns.com.

PC/104 is its reliable pin-and-socket connector. Each connector is designed in such a way as to allow more than a single module to be stacked. This is unique among mezzanine architectures. Multiple modules permit more flexibility in a design as well as further expansion capability. This allows more functions to be off-loaded from the host single board computer which gives a designer greater selection options.

The logical conclusion of this scheme would be to start with a PC/104 as the host SBC. The mezzanine bus then becomes the entire computer and I/O system forming a rugged, embedded PC. In addition to the self-stacking nature of the bus, four corner-mounting holes are included to attach metal or plastic threaded standoffs. They form a sturdy mechanical construction that adds resistance to shock and vibration.

Regardless of whether a PC/104, STD Bus, CompactPCI, VME Bus, ISA Bus, PCI Bus or other board is the host SBC, up 4 to modules can be stacked together. The total number of modules is a function of the drive current on the bus that is specified at 4 mA. From a repair and maintenance standpoint, a large stack of boards is somewhat more difficult to trouble shoot and replace compared to a backplane bus system. Also the retention force of the connectors makes it difficult to separate modules after a total unit is assembled. To make disassembly easier and quicker, parvus Corporation has a PC/104 extraction tool to speed up the job.

PC/104 specifies two module versions: 8-bit and 16-bit which correspond to the PC and PC/AT implementations. In today's market all current designs are 16-bit. However, customers want more performance.

PC/104-*Plus*

The original PC/104 bus has done a

great job of supporting the 16-bit ISA standard. However, certain applications require greater throughput. Therefore, PC/104-Plus was defined and standardized. It is the 32-bit standard migrated from the desktop to the embedded world while still offering the same

PC/104-*Plus* is a PCI implementation on a stackable board while maintaining the 3.6" x 3.8" form factor. PC/104-*Plus* modules can also include original PC/104 connectors to allow the most system configuration flexibility. PCI was chosen for a number of reasons. First it is the de facto standard for desktop 32-bit transfers that significantly improves throughput between cards. Next
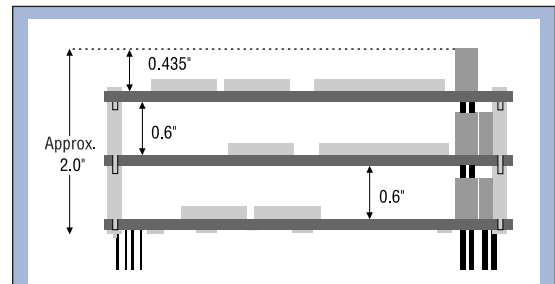
**Typical PC/104 and PC/104-*Plus*
Module Stack**

PCI is a known and proven standard. It is an open architecture that is well documented with no licensing requirements. Finally, PCI is supported by current and next generation integrated circuits. Even FPGAs have the PCI interface available to license as Intellectual property for custom designs.

The key to success of the PC/104-*Plus* again lies in the connector scheme. A third connector is added opposite the PC/104 P1 and P2 connectors. It is a 4 x 30 (120-pin) 2-mm pitch stackthrough connector (as opposed to the 124-pin card edge connector on a standard 32-bit PCI card). A shroud covers the male pins of the connector and guides it to the next connector in the stack. The PC/104-*Plus* connector fits between the mounting holes. Spacing of the stacked modules is maintained at 0.6 inches.

For mezzanine cards, the PCI bus usually connects to the circuitry on the module while the PC/104 P1 and P2 connectors pass the ISA bus though to the next module. Actual data throughput for the PCI bus is at least an order of magnitude greater than the ISA bus.

As with PC/104, a number of vendors have included PC/104-*Plus* connectors on their SBCs and bus expandable boards. There are mezzanine boards available for video, audio, networking, disk controllers, DSP, and motion control.

Adoption of PC/104-*Plus* has not been as swift as with the original PC/104. The reasons are market and application driven. The largest market for PC/104 is Industrial Automation Equipment and Instrumentation. Many industrial applications simply don't need the additional cost, complexity and performance of PCI to sense a switch closure, control a relay or perform some other simple task. However as more complex tasks such as machine vision, complex graphics, full-motion video, high-speed LANs, or very high-end data acquisition are needed, then PC/104-*Plus* is the solution. Why add another board for only a small amount of I/O when a mezzanine will do the job? Though there is no single technology that fits all the needs of the embedded industry, PC/104 fills most requirements from medium- to high-performance applications. Its popularity stems mainly from two features: PC compatibility and mechanical flexibility.

PC/104 is a miniaturized version of the desktop PC for embedded applications. The only major change is in its dimensions. It's a world-wide standard that is small, modular, expandable and low-cost and allows a designer to leverage his resources to get to market fast. Product upgrades and options abound with either commercial or custom-designed modules. Thanks to the PC architecture, it's possible to gain the advantages of using the PC standard while not sacrificing the flexibility, reliability, ruggedness and quality required for embedded applications.

WinSystems, Inc.

Telephone: 817-274-7553
WebSite: www.winsystems.com