Changing the shape of embedded computing

By Don Dingee

EBX is a multivendor initiative developed to unify embedded computing on a small footprint (5.75" x 8") embedded single-board computer standard. EBX combines the advantages of standard packaging with expandability including PC/104, PC/104-Plus, and PCMCIA. The EBX form factor is already a defacto standard and is widely deployed in several embedded products. Its acceptance is broadening as exciting new OEM applications that leverage the benefits of EBX continue to appear.

EBX has changed the shape of embedded computing in several ways. With the joint support of Ampro Computers and Motorola, the EBX Specification was launched in June of 1997 as a true multivendor standard for non-backplane products in embedded computing. This article explores the details behind the standard and the reasons for its creation. A discussion of the overall market for EBX is followed by examination of the key features of the EBX Specification. An actual implementation of EBX – the Motorola MBX series – is discussed, along with application ideas for EBX platforms.

EBX and non-backplane market overview

Embedded computing applications are segmented along a range of performance levels and form factors. The three main performance tiers include:

- ❏ Low-end implementations based on 8- and 16-bit microcontrollers.
- ❏ Mid-range implementations designed around 32-bit microcontrollers or embedded microprocessors – many with a 16-bit system bus.
- ❏ High-end platforms based on high performance 32- or 64-bit system microprocessors, perhaps with multiple processors on a single board, and a 32- or 64-bit system bus.

Refer to the vertical axes of Figure 1 for a depiction of these performance ranges.

In regard to form factors, two main choices exist:

- ❏ Backplane
- ❏ Non-backplane

Backplane implementations rely on a card-based form factor that plugs into a main system bus and provides power, intercard communication, and mechanical support. Examples of backplane implementations include:

- ❏ VMEbus
- ❏ CompactPCI
- ❏ PCI and ISA slot cards (dubbed "passive backplane")
- ❏ Traditional desktop PC motherboards

These solutions are positioned within the triangle of Figure 1. Note that the horizontal axis represents the unit volume of applications each type of solution is able to cover. The OEM volume opportunity increases as solutions become more cost effective.

VMEbus dominates the high-end performance tier of embedded computing. It offers a high-performance, 64-bit system bus with multimastering, distributed interrupt handling, and superior scaleability with up to 20 slots in a single bus system. VME also offers a very robust mechanical form factor suitable for industrial and high reliability applications. VME has a reputation for constantly pushing down the price/performance curve, especially with the introduction of PCI infrastructures for VME CPU boards in the last several years. In many cases, however, VME may not represent the most cost-effective solution – particularly when scaled down in size to address lower performance needs. This application gap opens the door for other solutions in the OEM's design portfolio to address lower performance designs.

CompactPCI capitalizes on the emerging use of 32-bit PCI as a systems bus (in spite of its design as a peripheral bus)

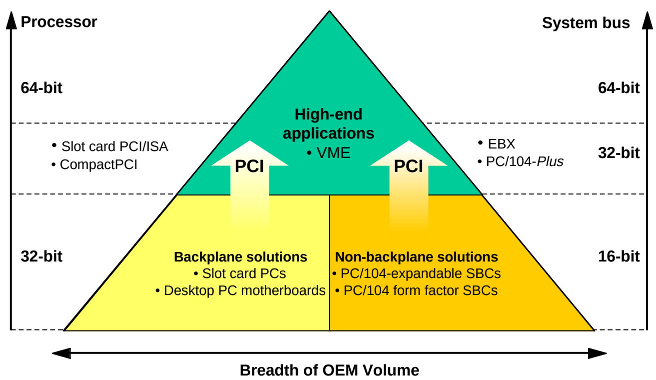
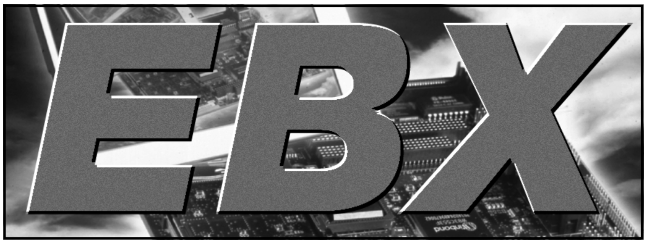


Figure 1. Embedded board-level architecture alternatives



for mid-range performance needs. A CompactPCI system – while mechanically similar to VME using the same Eurocard form factor – can have up to 8 slots on a single PCI bus (many implementations have multiple PCI buses), and provides master/slave capability to distribute I/O tasks. While not as upwardly scaleable as VME, CompactPCI can fill many applications that require only a single CPU board and multiple I/O cards.

PCI and ISA slot cards combine the 32-bit PCI bus with the venerable 16-bit ISA bus to create a highly expandable backplane system. Slot card systems are very flexible and relatively inexpensive to implement, but are less mechanically robust than VME or CompactPCI. Traditional desktop PC motherboards can also be grouped into the backplane solution, since most implement PCI and/or ISA buses and many require some add-on functionality to form a complete solution. Desktop motherboard products generally lack key attributes that are necessary for embedded applications, including longevity and integrated features such as Ethernet.

In their simplest form, non-backplane implementations consist of:

- ❏ a standalone single board computer (SBC)
- ❏ daughterboard I/O options installed as expansion

SBCs integrate most features required for an embedded application, but usually offer some open expansion option that provides flexibility and investment protection. Through integration, a non-backplane solution reduces size, cost, and complexity, allowing it to address a class of smaller, more cost sensitive applications than backplane solutions.

Examples of non-backplane implementations include...

- ❏ embedded motherboard form factors such as ATX and the new NLX, and
- ❏ expansion form factors such as PC/104 and PC/104-*Plus*, utilized in standalone mode or as expansion options to larger SBCs.

EBX, which informally stands for "Embedded Board, eXpandable," was created as a non-backplane solution to fit the mid-range of performance needs. EBX offers enough board space to implement a 32-bit microcontroller or microprocessor with integrated SBC functions, yet still offers a small form factor. EBX capitalizes on the trend of using PCI in embedded applications by offering a PC/104-*Plus* expansion interface. This also takes advantage of the wide range of I/O functions available on PC/104 today. EBX also innovates by defining standard areas for presentation of I/O, allowing OEMs and package developers to plan around EBX for future versions of boards with enhanced performance or features.

As can be seen in Figure 1, EBX spans the area between the mid-range and the high-end performance space. As a small board, an EBX form factor can be scaled down in performance to be a very cost-effective solution. However, by adding a higher-performance processor and the I/O bandwidth provided by PCI, EBX platforms can move up into the higher-performance area – once the exclusive domain of larger motherboard form factors and backplane solutions.

EBX physical outline

EBX defines a board outline of 5.75" x 8" (146mm x 203mm) as pictured in Figure 2. This provides a small form factor capable of fitting into many embedded applications, yet still allows enough space to deliver a sophisticated SBC with features such as Ethernet, graphics, and mass storage connections. The EBX form factor outline was, in fact, originally derived from the 5.25" disk drive. Boards were designed to mount directly to a floppy drive, allowing users to boot an operating system such as CPM or DOS. Years later, the outline has proven to be a winner in the marketplace as it has emerged as the defacto standard for the industry.

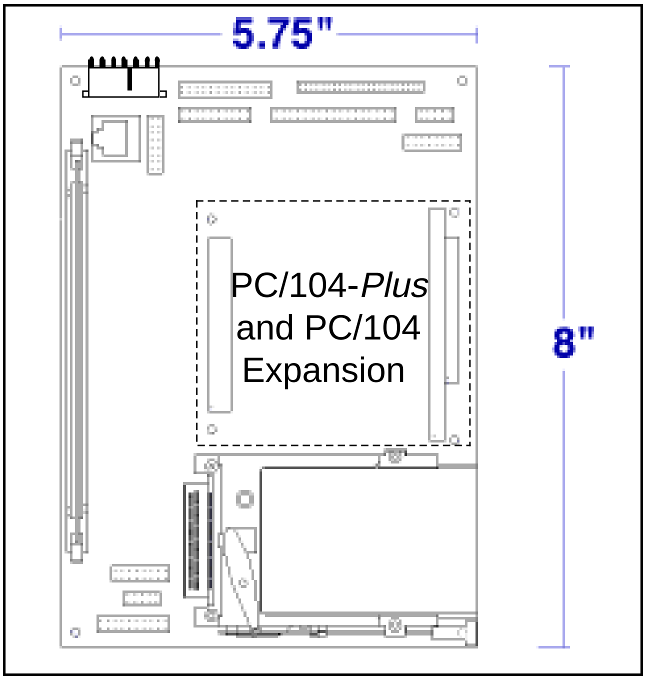


Figure 2. EBX form-factor outline

EBX defines eight mounting holes, each measuring 0.125" in diameter with a surrounding 0.25" grounding pad for EMI management.

- ❏ Four holes are located in the corners of the board (0.20" from each edge), providing a secure mounting mechanism.
- ❏ Four additional holes are located on the periphery of the PC/104-*Plus* card location.

The additional holes on the periphery of the card serve a dual purpose. They obviously provide secure mounting for any installed PC/104 or PC/104-*Plus* cards (or a similar custom form factor). PC/104 cards are 3.6" x 3.8". Secondly, these four holes allow an EBX board to be secured to a chassis or baseboard assembly, providing additional mounting points to supplement the four corner holes. Mechanical stability was a prime concern in defining hole locations for EBX, and the eight mandatory hole locations create a very stable mechanical environment.

Other general features of the EBX layout include a disk-drive style power connector, and use of headers to provide I/O such that the OEM may decide on cabling. Also, sections of the layout are dedicated to the mandatory PC/104-*Plus* expansion site and the optional PC Card slot.

PC/104-*Plus* expansion site

An open expansion strategy for EBX has been deemed crucial for embedded computing needs. EBX defines a PC/104-*Plus* module stack location. PC/104-*Plus* represents the evolution of the widely popular PC/104 standard – which uses an ISA bus – into the realm of PCI. This expands the bandwidth available to the embedded designer from around 5 Mbytes/sec available in ISA to a theoretical peak of 133 Mbytes/sec with PCI.

Either PC/104 or PC/104-*Plus* cards or a combination of both in a stack may be mounted on this expansion site. The PC/104-*Plus* location is precisely defined in the specification, and is based on the location of the bus connectors and the four mounting holes (described previously). "Keep out" areas defined in the PC/104-*Plus* Specification are observed.

The connectors for the PC/104-*Plus* site are stable, reliable pin-and-socket versions.

❑ The 104-pin ISA connector pair consists of the same 64-pin and 40-pin 0.1" headers popularized by PC/104.
❑ The new 120-pin PCI connector is a 2mm high-density connector designed to place the high-performance PCI bus into the PC/104-*Plus* form factor.

Example part numbers for these devices are referenced in the EBX Specification.

Over 200 PC/104 and PC/104-*Plus* adapters are available from many vendors in a wide variety of functions that include:

❑ graphics
❑ networking
❑ analog and digital I/O
❑ mass storage adapters
❑ FLASH devices
❑ Global Positioning System (GPS) modules and others

Up to five modules may be stacked on an EBX board. PC/104-*Plus* modules are recommended for placement at the bottom of the stack – closest to the EBX board – to optimize the PCI bus routing length. Since PC/104 boards mount horizontally using pin-and-socket connectors, they form a very stable stack as a non-backplane assembly – thus the term "self-stacking."

A key feature of the EBX PC/104-*Plus* expansion location is the ability to feed the buses through the bottom of the EBX board (referenced as the "stackthrough bus option" in the specification). Optionally populated with stackthrough connectors, an EBX board can be easily and securely mounted onto another baseboard assembly. In this way, the OEM can purchase an EBX processing module and the standard operating systems available for it, and design a baseboard with I/O specific to the application. The OEM leverages the off-the-shelf advantages of the EBX products, while gaining access to the industry standard PCI and ISA buses for proprietary, value-added design.

In addition to PC/104 and PC/104-*Plus* cards, OEMs can adapt the PCI and ISA buses using a custom module into several options:

❑ standard PCI and ISA adapters
❑ PCI Mezzanine Card (PMC) modules
❑ proprietary form factors to meet special mechanical needs of the applications

An OEM is not required to observe the PC/104-*Plus* outline as a restriction in mechanical design. Should the need arise to build an oversized or uniquely shaped board, the OEM is free to do just that. EBX compliant boards supplied by computing vendors must observe the guidelines in the EBX Specification, protecting the OEM design and allowing true choice in mechanical designs to use standard or custom equipment.

I/O areas and vertical clearance zones

EBX was designed to fulfill two of the key principles of embedded computing: architecture independence and open interfacing. With this overriding theme, one of the primary objectives of EBX was to maintain an environment where board vendors can design with a variety of processor architectures without any obligation to implement a strict profile of SBC features. In this way, EBX could provide flexibility and scaleability from simple embedded control platforms up to sophisticated SBCs with all features available.

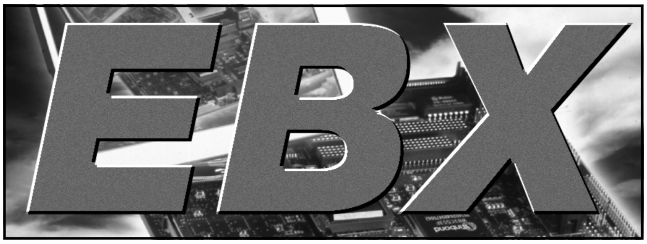
At the same time, OEMs need to be able to design packaging around EBX platforms with assurance that boards from various vendors will fit. Interoperability builds critical mass around a standard, and is one of the key reasons for the powerful success and longevity of embedded computing standards such as VME. To be successful, it was essential for EBX to capture this attribute as well.

The easiest way to accomplish these objectives was to define the areas in which I/O is presented. EBX is subdivided into zones intended for various interfaces and components, and those zones are controlled dimensionally.

Each zone defined in the EBX Specification has both a placement area within the horizontal dimensions of the board outline, and a vertical dimension in which all components of that area should fit. The goal is two-fold:

❑ By defining horizontal placement areas, OEM cabling is consistent between various EBX platforms. If a feature is implemented, its I/O should be within the same general area of the board.
❑ By defining vertical height constraints, OEMs are assured that EBX boards from various vendors will fit within the envelope of their package.

Again, board vendors are required to comply with these guidelines to sell EBX board products, while OEMs may adapt these guidelines to fit their needs.



The following I/O zones are defined in the EBX Specification with both horizontal dimensions and vertical clearance dimensions (including mating items where appropriate):

- ❑ Memory expansion. EBX defines a region where SIMMs or DIMMs may be installed using widely available vertical mount sockets.
- ❑ Power connector. A 7-pin locking power connector standard is defined, with +5V, +3.3V, and +12VDC input voltages available for use by the board or any installed expansion modules. EBX boards are not obligated to use all these voltages. The current capacity is 7 amps per pin.
- ❑ Video I/O (option). Many EBX boards will provide onboard interfaces to CRT or flat-panel displays. This area is defined so boards with video have their outputs in the same general area.
- ❑ General purpose I/O. A zone for various I/O – including IDE, SCSI, floppy, keyboard, mouse, serial, parallel, and other miscellaneous ports – is defined. Again, this does not imply that all boards have these features. However, when an EBX board does have this feature, the OEM may rely on its I/O to appear in this given area. The height of typical mating connectors is included.
- ❑ PC/104-*Plus* stack location. This is an important feature: it defines not only the mandatory horizontal location for PC/104-*Plus*, but it also incorporates the stack up of PC/104 and PC/104-*Plus* modules to their recommended height of five boards. Most applications will be satisfied with only the EBX baseboard and perhaps one or two PC/104 or PC/104-*Plus* modules. Also taken into account is the height beneath the first installed PC/104 module such that onboard components do not interfere.
- ❑ Tall CPU (option). The EBX Specification is processor independent, which means it has no requirements for a specific CPU or microcontroller. Some of today's high performance CPUs require more cooling to implement reliably, and EBX allows a "tall" CPU option to allow for a sizable passive or active heat sink. Use of the "tall" CPU option requires a PC Card to be implemented via a PC/104 or PC/104-*Plus* adapter.
- ❑ PC Card Slot (option). Although EBX does not mandate a PCMCIA interface that supports a PC Card, the wide availability of PCMCIA modules makes this feature attractive. PCMCIA allows installation of common features such as modems and FLASH storage cards, representing very popular functions for embedded environments. In the specification, this area overlaps the area allowed for the "tall" CPU option. When installed, a PC Card has its external edge flush to the edge of the EBX board.
- ❑ Secondary side components (excluding the stackthrough connector option) and board thickness are also controlled. EBX boards are intended to have all I/O on the primary side of the board.

By defining general regions instead of specific dimensions on a per-function basis, EBX retains flexibility for board vendors to design creative new products. At the same time, it provides enough constraint to allow OEMs to choose between EBX products without wrestling with issues of compatibility.

Motorola MBX Series

The key elements of EBX are its multivendor status and its support within the industry as a defacto form factor standard. In 1997, Motorola introduced support for the EBX Specification and our first EBX products, the MBX860 and MBX821.

The MBX series leverages the high level of integrated communications and performance characteristics of the MPC860 PowerQUICC or the MPC821 processors. Both are based on an embedded PowerPC processor core and the same Communications Processor Module (CPM) found in the widely popular 68360 family. The MPC860 and MPC821 uniquely offer industry leading value in processing price performance combined with integrated communications, integrated PCMCIA, and low power consumption (with full power approximately 1.25 watts at 25 MHz, and lower power modes available).

This high level of integrated features delivered in a small 357-pin BGA package achieves several objectives.

- ❑ First, it allows a fully functional SBC to be delivered in an EBX form factor, including Ethernet and the integral onchip PCMCIA interface.
- ❑ Secondly, it reduces the cost of power supplies and cooling devices, providing the OEM with a cost savings and allowing deployment in more cost-effective applications.
- ❑ Finally, it offers enhanced reliability with a lower part count to achieve the total functionality possible with an EBX SBC.

The MBX860 is pictured in Figure 3, and a block diagram appears in Figure 4. The entry level version includes:

- ❑ MPC860 or MPC821 processor
- ❑ DRAM, FLASH, and NVRAM
- ❑ Ethernet
- ❑ Several high-speed serial communication channels
- ❑ Several low-speed serial channels
- ❑ Parallel port
- ❑ PCMCIA port

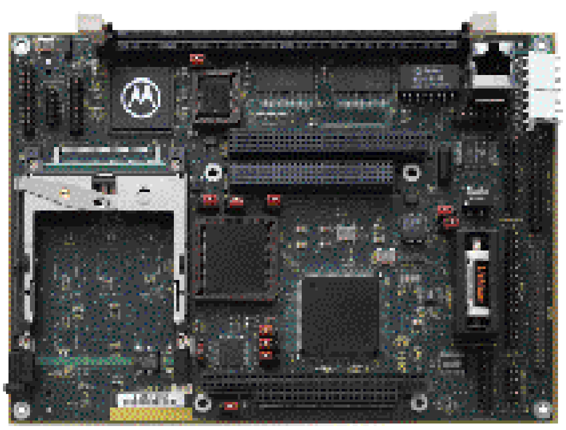


Figure 3. MBX860 EBX module

The MBX821 offers an LCD interface in place of two of the high speed serial channels on the MBX860. Standard version features include the PC/104-*Plus* interface with PCI and ISA infrastructure, EIDE and floppy interfaces, and keyboard and mouse ports.

As can be seen from the photo of the MBX, the highly integrated MPC860 or MPC821 processor results in a rather sparsely populated yet fully featured board, translating into lower costs and increased reliability.

The MBX860 and MBX821 form the backbone of an exciting new class of embedded platforms taking shape around MBX, and are finding homes in various applications as outlined in the following section.

Applications for EBX boards

EBX boards can be applied to a wide range of OEM applications. The best applications key on the combination of small form factor, communications with integrated networking, and flexibility with PC/104-*Plus* and PCMCIA expansion. Here are some ideas:

- ❏ Distributed control platforms. Today's high performance process control applications call for a network of interconnected computers. On the "back" end exists a Windows or UNIX workstation product, performing the tasks of operator display and data management and processing. On the "front" end, EBX form factor boards (connected in a network such as Ethernet or Fieldbus) perform the actual control and manipulation functions. An EBX board combines a potent package of a small form factor with powerful integrated processing capability. The integral open features of EBX – primarily the PC/104-*Plus* interface – allow a standard platform to be configured for a number of different missions within an application, saving on hardware and software development costs.
- ❏ Point of sale. EBX is small enough to be placed into a console at a point of sale terminal. It allows typical functions – operator interface, serial communications and printing – to be constructed with a compact, cost-effective package. Several platforms can easily be networked together to form a comprehensive solution for information delivery and management.
- ❏ Medical and analytical equipment. EBX is perfect for laboratory instrumentation, with its compact size and open interfaces. PC/104 boards such as motor control, analog and digital I/O, and proprietary designs are particularly useful in these applications. Open instrument architectures, leveraging modularity and scaleability, can be developed around EBX boards which place computing and control power exactly where needed.
- ❏ Network access points. Handheld devices for inventory control typically operate with a wireless network. A gateway is needed to interface the wireless network to the main wired network in the facility – usually Ethernet or Token Ring. An EBX platform with integrated communications and control can serve very effectively as the base platform for the wireless access point. With the right processor architecture choice, it might even be able to share an operating system architecture with the handheld units, further reducing development time and effort. The wireless interface can be implemented with PCMCIA (for instance, using the emerging IEEE 802.11 modems) or PC/104 designs, depending on the application.
- ❏ Operator interfaces. Large, fixed equipment such as machine tools, medical imaging equipment (ultrasound, X-ray), high end printer/scanner/copier platforms, and semiconductor process control equipment have often utilized a PC or workstation product. An EBX platform, with video and networking interfaces, can serve as a very cost-effective way to distribute the interfaces to the platform effectively over a network. This is the real power of "network computing" in the embedded world – to function as an information appliance, placing just enough compute power exactly where it is needed to provide control and interface functions. EBX allows truly modular and creative designs.

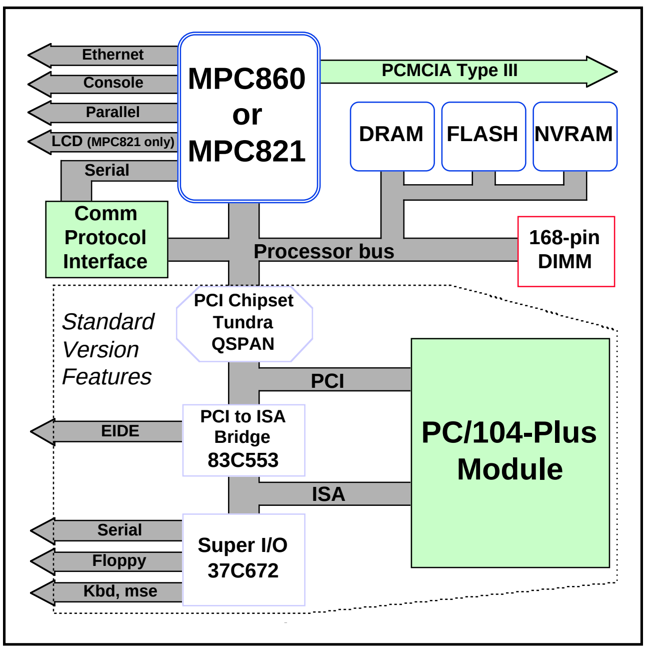


Figure 4. MBX860 EBX module block diagram

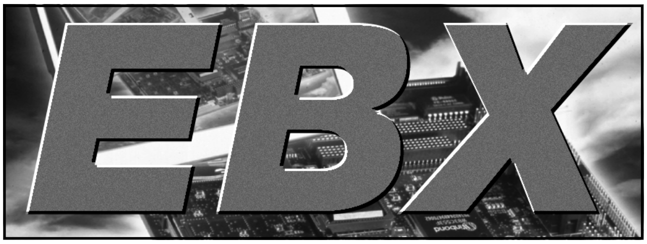
A final thought

EBX allows OEMs to control their embedded designs more precisely than ever before. Many stories have been told about the designer who was compelled to add a PC to his application simply because it was expedient, realizing full well that it was overkill in both size and price. With a truly embedded form factor available, designers can choose the EBX products and expansion options that fit their exact needs. They will no longer be forced into adapting to the available technology from the PC industry.

EBX compliant boards have a form factor large enough to implement a powerful SBC capable of hosting today's advanced operating systems, yet small enough to fit in the tight spaces of deeply embedded applications. This creates an exciting new opportunity for embedded system OEMs to standardize their designs and begin taking advantage of off-the-shelf modules.

The future outlook for EBX

EBX is already a defacto standard, and more vendors are expected to announce support for EBX products in 1997. A robust choice of board products in several processor architectures exists, and several vendors of chassis, including Interay (Burgum, The Netherlands), are developing EBX-compliant packaging. The backing of embedded



computing partners including Motorola assures "critical mass" behind EBX. OEMs will find new and creative ways to use EBX as they gain experience with the products, and can make the choice to deploy EBX today with full confidence.

Want to find out more about the EBX Specification?

A brief, two-page white paper entitled "Introduction to EBX" and the full EBX Specification are both available for further review.

Ampro Computers and Motorola jointly maintain the EBX Specification. It is available freely to all interested companies, and may be used without licenses or royalties. Electronic copies of the specification in Adobe Acrobat PDF format are available on Motorola's website at *www.mot.com/computer/*.

The EBX Specification also incorporates heavy references to the PC/104 and PC/104-*Plus* Specifications. For further information on the PC/104 and PC/104-*Plus* Specifications – including a list of hardware vendors and functions available – the website *www.controlled.com/pc104/* is an excellent starting point. Ω

Don Dingee serves as Motorola Computer Group's OEM Programs Marketing Manger in the Embedded Technologies team. His primary activities are with embedded architectures serving customers in electronic imaging, communications, and industrial automation markets. He joined Motorola in 1990 and began in applications engineering and sales. His prior experience includes eight years with General Dynamics in new business acquisition and engineering. He received an MSEE from the University of Southern California in 1989 and a BSEE from Cal Poly Pomona in 1985.

