SBC stands for Single Board Computer. But where did this term originate? More importantly, what really qualifies as an SBC? In this article, Rick reviews the history and evolution of the SBC phenomenon, including the role it has played in the birth of PC/104 technology and the synergy between the two. He also gazes into his “crystal ball” and prognosticates the changes that are likely to affect single board computers in the first few years of the new millennium.

Strolling down memory lane
The term SBC was coined in the late ’70s when Intel, AMD, ProLog, and others managed to cram the three key computer functions (CPU, ROM, and RAM) into a single card slot of the backplane bus architectures popular at that time:

- Multibus
- STD bus
- S100

In the early ’80s, you were lucky to squeeze a 4 MHz Z80, 4K of ROM, and 16K of DRAM on one board. But you didn’t actually have a useful system without adding two or three more cards— not to mention the backplane and cardcage necessary to physically support all these cards.

In its genesis, an SBC wasn’t really a fully functional computer. Design engineers needed additional backplane plug-in cards for a number of important functions. Among these were:

- interfacing floppy and hard disks
- networks (remember ARCnet?)
- CRT displays
- serial/parallel I/O

In 1980, if you wanted to run a commercial disk operating system (remember CP/M?), it was necessary to fill up a six-slot backplane!

Fueled by the explosive popularity of the desktop-PC architecture, these functions were each implemented as single-chip solutions by the early 1990s. Today, they have been reduced to mere silicon macro-cells within highly integrated CPUs and core logic chipsets.

In our current development environment, an SBC is no longer “just a computer.” The term single board computer has expanded to encompass a fully functional system.

Where did SBCs come from?
One of the first attempts to integrate all the functions of a complete computer system on one board was featured in Byte magazine in 1982. Called the Big Board, this innovative SBC managed to include…

- CPU
- ROM
- RAM
- serial and parallel ports
- floppy controller
- built-in ASCII terminal logic

…all on a single, large PC board.

In 1983, Ampro created a small alternative to the Big Board, in a form factor that was identical to the footprint of the latest 5.25-inch floppy drives (5.25 x 7.75 inches). Behind Ampro’s new form factor was a simple but unique idea: If you want to run an operating system, you need a disk drive. So, why not make the SBC size the same as the disk drive?

Not surprisingly, Ampro’s Little Board was a Big Success! Figure 1 provides a photo of the Ampro Little Board/Z80, which integrates:

- 4 MHz Z80 CPU
- 64 Kbytes of DRAM
- floppy controller
- serial/parallel ports

In essence, the original Ampro Little Board SBC offered “all the awesome computing power of an Osborne on a single compact circuit board.” A great many companies quickly followed in Ampro’s footsteps, producing SBCs with the dimensions of the Little Board (which evolved to 5.25 x 8.00 inches).
Early competitors supported a wide range of CPUs:

- Z80  68000  64180
- 80186  8088  V40
- V20  80286  80386DX
- 80386SX  80486DX  80486SLC

As the Little Board form-factor frenzy grew, Byte magazine’s well-known columnist Steve Ciarcia even got into the act. Featured on the front cover of Byte’s 10th anniversary commemorative issue was Ciarcia’s 64180-based Little Board knockout.

At this point, the IBM PC entered the scene and changed everything!

PC mania
In 1985, the big questions asked by customers were:

- Will it run Flight Simulator?
- Will it run Lotus 1-2-3?
- Does it have an IBM-compatible BIOS?

Before the IBM PC, embedded system engineers were primarily worried about:

- wait states
- instruction set efficiency
- DMA and interrupt response efficiency
- chip count minimization

After the PC, the emphasis began to shift to software compatibility (and even register-level compatibility) with the chips used on the IBM PC.

The IBM PC thus created the first system-level microcomputer standard. The computer, no longer the proprietary invention of each project’s design team, began to be perceived as a mere record player for playing software – the records. (Today, oddly enough, both records and software share a common media: CDs.)

As a result of this major development shift, IBM PC compatibility became more critical than architectural integrity. In short, it was becoming more important to be an imitator than an innovator! So, how would the IBM PC standard change the future of SBCs?

The “little boards” meet PC/AT
Recognizing this new trend, Ampro in 1986 added IBM PC compatibility to its Little Board form factor. This goal was accomplished via a small (3.6 x 3.8-inch) expansion module with a 64-pin header connector adaptation of the PC’s 62-pin edgecard expansion bus.

Recognize this? That’s right: It was the original 8-bit version of PC/104. Soon afterward, an 80286-based PC/AT compatible version of this SBC sported a 16-bit expansion module with today’s full 104-pin PC/104 bus. PC/104, as we know it today, was born in this process. Furthermore, the PC/104-expandable embedded-PC SBC was well on its way to standardization.

As the PC architecture became increasingly popular in embedded applications, the market for PC compatible SBCs with modular expansion skyrocketed. A growing number of companies jumped on the Little Board form factor and PC-compatibility bandwagon. Among the early entrants were:

- American Industrial Micros
- Computer Dynamics
- Emerald Computer
- Innovative Technologies
- Megatel

Today, PC/104-expandable SBCs in the 5.25-inch form factor are available from many companies.

Motorola and the birth of EBX
In the summer of 1996, Motorola Computer Group was beginning to develop a new family of SBCs based on its PowerPC microprocessor. Motorola already made PowerPC-based desktop-PC style motherboards using the ATX and NLX form factors. However, Motorola’s salespeople had uncovered a number of embedded applications where something smaller (and at the same time more rugged) than ATX and NLX was required. So, Motorola embarked on a search for a standardized, embeddable, SBC form factor.

Although no IEEE or other formalized standard could meet Motorola’s needs, Ampro’s Little Board format closely matched the requirements. Motorola was definitely surprised to learn that Ampro was busy adding PCI to the Little Board form factor. The addition of PCI to PC/104 (which created PC/104-Plus) made the Little Board form factor even more enticing. Motorola had already chosen PCI as a key feature of its new PowerPC SBC product line.

SBC standards: An oxymoron?
Although numerous companies were making SBCs of a similar shape, Motorola felt that the Little Board form factor needed to be more formally documented. To achieve this goal, Motorola and Ampro collaborated in the Autumn of 1996 to convert Ampro’s third-generation Little Board form factor into an open, multi-vendor specification. The result of this effort was EBX, an acronym for Embedded Board eXpandable.

The name EBX was chosen to mimic the desktop ATX and NLX motherboard form factor names, however, beginning with E for embedded. The specification is jointly published by Ampro and Motorola, and is available at both company websites:

- www.ampro.com
- www.motorola.com

In the EBX Specification, the form factor is characterized as small enough for deeply embedded applications, yet large enough to contain the functions of a full embedded computer system.

A typical EBX SBC might contain:

- the CPU (up to 266 MHz Pentium)
- DRAM (up to 256 MBytes)
- Flash disk (up to 72 MBytes)
- interfaces to IDE and floppy drives
- CRT and flat panel displays
- serial and parallel ports
- Ethernet LAN

Bowls of porridge
By now, you might be thinking: If EBX (at 5.75 x 8.0 inches) is good, why wouldn’t something half as big be twice as nice? Well, that depends! Certainly, an SBC could be smaller; but SBCs could be bigger, too. Let’s call EBX a medium-sized SBC. Take a look at a typical EBX SBC, the Ampro Little Board/P5x, shown in Figure 2. This newest member of Ampro’s EBX compliant SBC family includes a full set of state-of-the-art, desktop/laptop features that include:

- 266 MHz Intel mobile Pentium processor
- up to 256 MBytes DRAM
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high-performance LCD interface
10/100BaseT Ethernet
USB
disk controllers
serial/parallel ports

You’ll notice quite a few key benefits that depend upon this medium size.

- Tough connectors. Rugged, shrouded pin-and-socket I/O connectors with provisions for connector locking clips
- Convenient memory expansion. Sockets for high-capacity, industry-standard SIMM or DIMM memory modules
- Reliable mounting. Eight standardized mounting hole locations for rigid system attachment
- Modular expansion. Onboard self-stacking PC/104-Plus module stack location, for flexible ISA/PCI bus expansion using off-the-shelf modules or custom circuitry
- PCMCIA option. An option (used by Motorola) of an onboard PC Card (PCMCIA) slot
- High performance. Room for the latest high-end CPU chips (namely, Pentium-class devices) with their associated heat sinks and optional cooling fans
- High integration. Space for a full system’s worth of features (including CPU, serial/parallel, mass storage, display, and networking on a single card) without dependence on proprietary, short-lifecycle integrated CPUs or exotic manufacturing processes

Is EBX too big? Is it too small? To borrow a phrase from the story of Goldilocks and the Three Bears – for a great many embedded applications, “this one’s just right!”

Of course, applications will come along that lack the space for a medium-sized SBC. For these requirements, currently more than 50 companies are claiming to offer SBCs on the very small PC/104 module form factor (3.6 x 3.8 inches).

What’s the best choice? Your decision is likely to be based on features and performance. When the application demands a full-featured, high-performance PC system on as few boards as possible, a PC/104-expandable SBC such as EBX probably makes the most sense.

On the other hand, if you need something that is more akin to a simple embedded controller (CPU, RAM, ROM, and serial/parallel I/O), an SBC built on a PC/104 compliant form-factor is hard to beat!

It’s true that PC/104 form-factor SBCs have begun to include floppy and IDE controllers, flash disks, and even LCD interfaces. However, as suppliers try to push the PC/104 CPU integration too far, the cautious designer will be watching out for such things as:

- unreliable or hard-to-use connectors
- marginal manufacturability
- questionable heat dissipation
- form-factor violations

How “real engineers” use PC/104-expandable SBCs
PC/104-expandable SBCs are often used as the base of a compact Lego-like stack, as shown in Figure 3. PC/104-expandable SBCs can be expanded in a modular and flexible manner. And with PC/104-Plus, expansion can be both PCI or ISA-based. These expansion modules can be either off-the-shelf, or they may be custom modules that you have designed and built specifically for your application.

A module stack like the one in Figure 3 takes up very little space, and can often be “bolted” directly inside the system’s enclosure in a convenient location. For example, a three-level stack composed of an EBX SBC and two PC/104 expansion modules requires approximately 92 inches³ (5.75 x 8.0 x 2 inches) of space – just 0.05 cubic foot! Using this approach, designers of systems that otherwise might require an external, “attached” PC for their operation can easily embed a rugged and reliable PC compatible subsystem directly within their products.

When it comes to module stacks, a common question would be: “How many PC/104 expansion modules are typically plugged into the expansion headers of PC/104-expandable SBCs?” Four, perhaps? As many as six or eight? The answer may surprise you: On the average, it’s more likely to be one. Why?

An appetite for sandwiches
Due to their unique nature, most embedded applications need at least some custom electronics. In an effort to simplify their systems and minimize cost, engineers often design a single custom application board containing all required functions and interfaces that aren’t provided by the SBC.

This application board plugs into the header connectors of the SBC’s PC/104 (or PC/104-Plus) expansion stack location, as shown in Figure 4. Many embedded systems incorporate a PC/104-expandable SBC and an application-specific expansion board in this compact sandwich. Standard PC/104 modules add further flexibility, which is evident in the photograph.

Figure 2

- high-performance LCD interface
- 10/100BaseT Ethernet
- USB
disk controllers
- serial/parallel ports

Figure 3

- PC/104 Expansion
- PC/104 Expansion
- Little Board SBC

Figure 4
The SBC contains all the required embedded-PC functions, and the custom application board provides all the rest of the electronics required for the embedded system. Depending on bandwidth and other requirements, the application board may interface with:

- the ISA bus only
- the PCI bus only
- both

In terms of size, the application board can be PC/104 form factor. However, it often doesn’t conform to any particular form-factor specification. Instead, it takes whatever shape will work best for the application. Among the functions that might be included on a custom application board are:

- Specialized analog and digital I/O
- Sensor or actuator interfaces
- Fieldbuses such as LON, CAN, or Profibus
- Power supply or power conditioning circuitry
- Filtering or signal conditioning for the SBC’s onboard I/O
- Keypad, display, or touchpad interfaces
- PC/104 expansion, for addition of current or future off-the-shelf PC/104 modules

Incidentally, many PC/104-expandable SBCs offer stackthrough PC/104 bus connectors, in the same manner as on PC/104 form-factor modules. This option lets you plug the SBC on top of an application board, instead of the other way around. This approach offers the advantage of leaving the shape and size of the custom application board completely unrestricted.

Lehrbaum’s embedded-PC crystal ball

What’s in store for PC/104-expandable SBCs in the future? Here are just a few intriguing trends and possibilities.

SCSI

Once a standard feature of embedded-PC SBCs, SCSI has been fading in importance as the Small Computer System Interface for all types of peripheral expansion. SCSI has lagged behind IDE in popularity among desktop PC users, and is increasingly reserved for niche applications. Today’s enhanced performance IDE offers:

- speed
- multi-drive and multi-device support
- DMA for reduced CPU overhead

Rick’s projection: SCSI will continue to fade in popularity and will have an increasingly difficult time competing for precious SBC real estate.

Ethernet

Contrary to its former role as purely a corporate LAN interface, Ethernet is rapidly becoming the high speed serial port of choice within all kinds of embedded applications. This is a natural consequence of two factors, both fueled by the huge volumes of the desktop-PC market:

- low-cost, single-IC Ethernet controllers
- readily available, easy-to-use Ethernet communications software (namely, TCP/IP stacks) for both Windows and real-time operating systems

Rick’s projection: Expect Ethernet ports to be included on all “integrated” embedded-PC SBCs, with 100BaseT becoming dominant over 10BaseT in two years or less.

LCD interfaces

With the rapid proliferation of laptop PCs, LCDs are becoming brighter, larger, and much more affordable. Embedded application display requirements are therefore rapidly migrating to PC-resolution color graphic LCDs, and away from:

- EL and plasma panels
- CRTs
- primitive character LCDs

Thankfully, excellent quality super VGA LCD/CRT controllers (readily available from companies such as C&T) ease the task of integrating state-of-the-art LCD display interfaces into embedded-PC SBCs. In the past, you had to settle for a slower, lower-resolution controller for LCDs versus what was available for CRTs. The choice was clear:

- CRT-only controllers for high performance and resolution
- LCD/CRT controllers when flat-panel support was required

As this gap continues to close, LCD controllers are becoming standard equipment on all “integrated” embedded-PC SBCs.

Rick’s projection: Watch for a new round of CRT-LCD differentiation confusion, as new 3D-video and AGP standards begin to reach the desktop.

IEEE-1284

Now included in just about all super-I/O chipsets, the EPP/ECP enhanced parallel port standard has arrived. But does anybody care?

Rick’s projection: 1284 is probably destined to be useful as a speed enhancement only; for the same devices used today with PC parallel ports (printers, zip drives, and the occasional specialty interface).

USB

Who among us hasn’t heard about the coming of USB? Like the hype surrounding all new desktop-PC interface standards, it’s always: “Next year will be the year of USB!” No, it wasn’t this year. Maybe next year? It’s coming…slowly but surely…it’s coming. Actually, USB is currently being integrated into all new CPU core logic (for example, Intel’s TX chipset), so you can expect USB to begin showing up on embedded-PC SBCs within the next 12 to 18 months. Yes, USB has few current uses; however, given its flexibility and the fact that it allows many devices to connect to a single port, you can be sure it will be a “must have” feature on embedded-PC SBCs.

Rick’s projection: Give USB a couple of years to catch on, but be sure your new designs are prepared to accommodate it.

FireWire

What about the much heralded IEEE-1394 high speed serial bus? Offering data rates in excess of 200 Mbits/sec, FireWire also eliminates bulky parallel cables for interfaces to things like disk drives and printers. While it looks promising for 1394 to eventually become a popular long-term interface for desktop-PCs, the jury is still out. The possibility remains that it could end up going the way of SCSI. In embedded systems, 1394 offers many exciting possibilities:

- higher serial communications speed than even 100 Mbit Ethernet, and with greater determinism
- plug-and-play connection to standard peripherals
- elimination of bulky cabling

But watch out: the standard keeps changing. In fact, Intel is now pushing a new version of 1394 that essentially obsoletes today’s silicon.
Rick’s projection: Give 1394 a couple of years to settle down, but keep your eyes open and your CAD systems ready!

The death of ISA?
Haven’t you heard? Both Intel and Microsoft are telling PC designers to stop using the ISA bus.

Rick’s projection: Don’t abandon ship prematurely. Although the desktop world is rapidly abandoning the ISA bus, many chipsets continue to support it (including long-lifecycle chipsets like the TX from Intel) and a vast number of PC/104 modules are based on it. ISA isn’t going to disappear overnight from the embedded world. Keep in mind, PC/104 doesn’t depend on ISA for its survival, so our industry isn’t threatened! When necessary, PC/104-Plus (with ISA and PCI) allows the eventual elimination of the old 104-pin ISA connector, making its 120-pin PCI connector the primary system expansion interface.

The death of PCI?
Yes, believe it or not: Intel has begun preparing us for a world without PCI! This is the story: ISA and PCI are going to be replaced by USB, FireWire, and something called AGP (a new video interface).

Rick’s projection: Don’t run for cover just yet! PCI is going to be around for a good many years.

SBC as a new-century bridge
With all the talk about what’s dying on the vine, are you looking for some really good news? The SBC form factor standards like PC/104 and EBX allow you migrate in an evolutionary manner from yesterday’s to tomorrow’s technologies, often without major redesign. Some SBC customers who started with Z80 SBCs in the early ‘80s (and moved to the PC/104-expandable SBCs in the late ‘80s) are now migrating to PC/104-Plus expandable Pentium-based EBX SBCs.

Funny thing—even though today’s SBCs offer a thousand times the performance of the earliest versions, they don’t necessarily accomplish real-world tasks any faster. Often, those power-SBCs run thousands of times as many lines of code per second (with thanks, I suppose, to Mr. Gates & Co.)

My proposal is simple: Let’s revisit this topic in five years, and assess what has really changed in PC/104-expandable SBCs. Mark your calendar, and I’ll see you then! Ω

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