The Evolution of Single Board Computers

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Single Board Computers (SBCs) have changed dramatically over the years. Initially the selection factor was based primarily on the CPU and its associated peripheral chips. Twenty years ago that meant Intel, Zilog, or Motorola were the silicon vendors for microprocessor systems. As the density, complexity and capability of the silicon improved, so did the choice and selection methodology for SBCs. Today software, board size, and time-to-market are the key decision factors in addition to just the power and speed of the CPU.

Hardware Definitions and Standards

Because of expansion options, there still remains a misunderstanding and perhaps mislabeling of an SBC. Historically, an SBC-based system has not necessarily been a single board. An SBC may have served as an initial building block, but expanding system options often dictated a mezzanine or backplane bus. Regardless of the form factor of an SBC, they all provide expansion options. Support for expansion is needed because of risk and uncertainty factors faced both by customers and vendors. Customers are driven by their sales and marketing departments from their customer inputs for more features, capabilities or options. Vendors want expansion options since they want to be sure that they offer "universal" boards with many opportunities for design wins and sales revenue.

The first SBCs were proprietary designs needed to satisfy a specific application. There were no standard board sizes. Design, manufacturing, testing, and software coding were relatively easy such that companies routinely designed their own SBCs for projects needing 50 or more units. Time and money were available so that non-computer companies could spend their internal human and capital resources to design computers from the chip level components into their end products. CPU types, expansion options and software coding techniques varied greatly. No industry-wide standards had been developed or adopted and there were not a wide variety of off-the-shelf products from which to choose. The end result was a hodge-podge of hardware, software and system configurations typically based upon an engineer's preference of CPU.

As the SBC market moved from its infancy, system architecture standards began to develop. The initial SBC structure was a simple extension of the common bus architecture used by the microprocessor. It had an onboard local bus and off-board expansion bus. Early SBCs could only support a minimum number of functions on a single board. Therefore, initial SBC specification standards focused on memory and I/O expansion by means of multiple boards connected via a backplane bus or mezzanine. However, as the SBC market has evolved and matured, the backplane bus importance has diminished.

The first industrial microprocessor-based SBC standard was Intel's Multibus I introduced in the late 70's. It was optimized for Intel's 80xx processor family. It became quite popular with designers and became the IEEE standard 796. Its size was large, 6.75 x 12 inches, in order to accommodate the numerous chips necessary to build a system on a single board. The backplane bus was seen as an integral part of the design decision since it

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often required multiple boards beyond the SBC to satisfy a total systems I/O and memory requirements.

Other popular, non-proprietary architectures that were introduced in the late 70s and early 80s included the Pro-Log/Mostek STD Bus, Motorola Exorbus, and VME bus. Each had its own different size, processor preference and expansion options for additional I/O functions. And both the IEEE standard STD Bus and ANSI standard VME bus continue to be actively supported by multiple vendors.

Motorola, Mostek, and Signetics defined and championed the VME bus. This architecture is popular and has grown to over $1 billion in annual sales. Traditionally, choosing VME meant using 68K processor and UNIX; however, vendors do offer Intel x86 processors, SHARC, SPARC, and DSP as well. It also was the first to address worldwide standards for board and system packaging which is a keystone to its popularity.

The STD Bus is unique in the fact that it is an industrial I/O bus. Originally, the size of the board, 4.5" x 6.5", allowed only one function per board. Additional boards were added for memory and I/O expansion. However, as the integration increased with the newer, more powerful chipsets, it became possible to create single board computers as well.

Designers did not like the idea of only backplane expansion. Strong pressure was felt for smaller size, fewer boards, and no card cages. Yet they still needed a road map for growth if their customers or marketing departments demanded more features. This prompted the rise of various mezzanine bus structures that would mount on top of SBCs. The earliest example was Intel's iSBX bus which was designed

The STD Bus fits compact, industrial applications with service-friendly convenience.

to extend their Multibus SBC architecture with low-cost local I/O expansion. The concept was accepted immediately as multiple vendors began producing the modules. SBX became the IEEE standard 959.

The early 1980's saw the onslaught of large-scale integrated (LSI) and very large scale integrated (VLSI) components. The result of the semiconductor advances was that it was possible to increase the functional density on the boards while decreasing cost and increasing reliability. Instead of a system requiring multiple boards, a complete system could be realized on a single board.

Designers began to shift from in-house designs to SBCs. They started to look upon a SBC as a system component that could be economically purchased as a standard product to streamline the design-to-market cycle. However, this gain was largely realized as a hardware benefit. The software development phase was growing increasingly complex and time consuming since there were no clear standards. Designers were looking to leverage and reuse code from one machine or project to another. There had to be a better way.

Enter the PC

The PC has forever changed the face of the computing landscape and impacted single board computers as well. It has spawned a generation of trained, computer-literate engineers and technicians across many different disciplines. The result is that the initial design process evolves around the question, "Why don't we put a PC in this application?" The reason for this turn to PC technology is an attempt to leverage widely available hardware and the vast software infrastructure supporting personal computers.

With the hundred of millions of PCs installed worldwide, the PC-architecture has become a de facto standard. The PC architecture is neither the most efficient nor the most sophisticated, yet it has become a popular embedded standard. The reason is that it is the software, not the computer hardware that drives the selection process for a system. Although SBCs still come in a wide range of types, by far the most popular are those PC-based on the x86-compatible CPU. Single board computers, modules and single-chip processors have made and are continuing to make significant inroads in areas once dominated by microcontrollers, PLCs and custom designs.

The project design cycle has evolved into a software project focused on the specific application at hand. The reason for this design approach methodology is that it focuses on a company's core competency emphasizing areas where they can add value. Another reason is the lack of internal human resources within a company to com-

When to use an SBC.

- Reduces development time for faster Time-to-Market
- Proven design by vendor increases reliability and reduces risk
- Multiple vendors provide a variety of different size, functions, and price options
- Component-level design is too complex for in-house engineers
- Lack of internal company resources
- Lack of internal manufacturing expertise

When not to use an SBC.

- Not cost effective for very large volumes
- Application requires a special size or format
- A special CPU or configuration is needed for the application
- Non-commercial environ ment because of shock, vibration, heat, humidity, radiation, or power requirements
- Special I/O interface needs

plete a project in a timely manner. This means that off-the-shelf SBCs and "shrink wrap" software and application packages are used whenever possible.

The vast array of compilers, debuggers, operating systems, development tools, utilities, and application program interfaces had made the PC a very attractive host platform. Also, there is a base of knowledgeable and trained engineers and programmers familiar with working with PC-compatible hardware and software. Choosing to buy rather than make existing technologies increases reliability and gets the product to market quicker. (See **Build or Buy an Embedded PC? First Count the Costs** article.) The bottom line is that time, money and the lack of resources drive the system design methodology.

Emerging Trends

The single board computer market has matured in many ways. The result is that there are a number of current and emerging trends that will continue to both define and evolve as the technology progresses. These trends have emerged based upon economics and industry standards.

Make vs. Buy

A key factor that should not be overlooked is the economic barrier of entry both for companies doing their own custom design and vendors offering standard off-the-shelf products. With the increased density provided by new VLSI chip sets, there has been an increased complexity in design, manufacturing and test. Years ago processor speeds were slow (such as a 4MHz Z80) and the board could be built with simple through-hole technology. Current high performance SBCs routinely have clock speeds approaching 1GHz which require special EDA tools and layout techniques. Most VLSI parts are only available in surface mount PQFP or ball-grid packages that require significant capital investment in production equipment.

The manufacturing process has become increasingly complex requiring a thorough understanding even if boards are built at contract assembly houses. Finding parts, even simple resistors and capacitors without 30 to 60 weeks lead times, adds cost through purchasing, inventory, and inability to respond to customer's changing requirements. Finally, the rapid growth of the technology is accompanied by a rapid obsolescence of various components. Unavailability of parts causes a major upheaval and disruption to ongoing manufacturing operation of a board. Yet for lack of a part that costs less than a penny, a product can not be built and shipped.

The result is that a once simple task of designing and manufacturing a SBC in-house is now being purchased from an outside vendor. The traditional make vs. buy cross over-point has shifted dramatically to the point where it is now cost effective to buy 5 to 10 thousand or more boards per year rather than build them. The result is quicker faster time to market, with more sophisticated functions and a higher level of reliability.

Standards

Over the years, as processors got faster and memory more dense, the performance and functionality of single board computers have moved with it. Today's silicon routinely integrates multiple board functions easily onto a small single board computer or a mezzanine module. The increased capability and reduced cost of highly integrated silicon, has allowed the cost and size of a SBC to decrease while the power and capabilities increased.

The fastest growing standard SBCs are based upon three form factors: AT motherboards, EBX, and PC/104. All are embedded PCs with expansion capability through onboard serial I/O or with the PCI/ISA bus. AT motherboards are ubiquitous, but are designed primarily for the desktop environment with a backplane expansion. The PC/104 and EBX form factors are designed specifically to address the unique space, power, and reliability constraints of industrial and small embedded systems.

PC/104 is a worldwide, small form-factor standard. It can be used either as a SBC, mezzanine, or as an expansion bus. It is hardware and software compatible with the standard desktop-PC architecture in a compact (3.6 x 3.8 inches) module. It supports both the ISA and PCI expansion in self-stacking modules spaced 0.6 inches apart. The difference is that it is targeted for embedded PC systems where a small space is available without sacrificing full hardware and software compatibility.

Motorola and Ampro developed the Embedded Board eXpandable (EBX) specification to define a small, deeply embedded, SBC standard. EBX defines the physical size, hole pattern and power connector locations of an open-standard SBC that measures 5.75 x 8.0 inches. However, it does not define the processor type or electrical characteristics. This permits an EBX-compatible SBC to be architecturally neutral. There are additional recommendations for serial/parallel, graphics, networking connector placements as well as expansion options via PC Card (PCMCIA) and/or PC/104/PC/104-*Plus*.

SBC Technology Trends

Three technical developments will impact the use of single board computers in industrial automation in near term. They are flat panel display technology, network-based computing, and Linux

Display Support

Man-machine interface is a rapidly growing application segment. The availability of less expensive panels with better bright- ness, wider viewing angles and wider operating temperatures coupled with lower costs, are the key factors for its popularity. A SBC is needed to operate the display as well as link it to local operator input/control. Many SBCs are offered with flat panel/video support integrated directly on the board. The MMI demand will stimulate SBC use by customers buying either a complete integrated panel PC or building their own out of system components for their specific application.

Cost, quality, and the mobile and laptop markets drive technical improvements. However, panel manufacturers are realizing a large and growing market in the industrial area. Companies such as Planar are offering panels that will both survive and operate over a temperature range of -25°C to +85°C. These improvements open new applications previously not served by panel PCs.

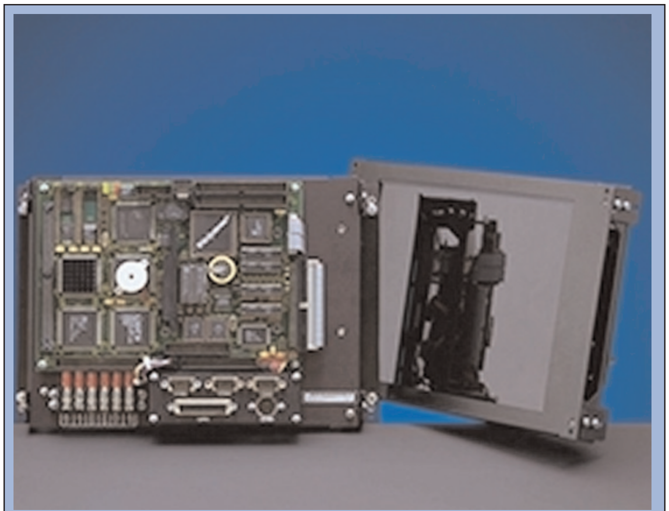
Connectivity

The internet and intranets are experiencing explosive growth. This growth is fueled by both the newly installed infrastructures necessary to carry the data as well as the ease of accessing data. The consumer/commercial market is the engine that is driving the rapid adoption of this technology.

Serial interfaces have been onboard SBCs since their inception yet they have evolved over time. RS-232/422, Bit-Bus or Arcnet were some of the original serial buses. Newer serial buses such as USB, Ethernet, and 1394 (Firewire) open up multi-media and peer-to-peer communications. Bandwidth has increased while most of overhead is handled in the silicon. It has facilitated the increased use of networking technology to augment processing, monitoring and data sharing.

Linux

The momentum of the Intel x86 architecture and Microsoft software is undeniable. Because of the software development environment, the x86 PC-compatible SBC makes sense for mid to high range computing power. However, Linux is quickly becoming the "other" operating system if a designer does not want to use a Microsoft Windows-based solution. Linux is open



WinSystems' Panel PC puts all the pieces together in a compact, rugged form for use as a display subsystem for factory automation or industrial instrumentation. including a flat panel VGA display, SBC with Ethernet and PC/104 expansion, plus optional touch screen.

source and known for its reliability and ease of networking which is appealing for embedded applications.

A standards movement is taking place to develop an embedded Linux initiative. The Embedded Linux Consortium has been formed with over 99 members so far to promote its use. It is gaining popularity because of its low cost, open source, and growing user base. One interesting consequence of Linux is that it may break the hold of the x86-compatible CPU as the building block of SBCs. Linux supports a wide variety of silicon which will result in new and different SBC platforms to potentially gain popularity.

Summary

Single board computers are still driven by the silicon vendors since it is the building block of any design. PC-compatible (and all that implies) has made the x86 family the silicon of choice for the SBCs. Therefore the most widely used off-the-shelf SBC has become an embedded PC with all the positive and negative attributes associated it. The reason is that trained and knowledgeable designers can take complex off-the-shelf SBCs and software and transform them quickly into useful computing platforms at a modest cost.

This does not mean that other CPU architectures are invalid or not used. Only that a design is based upon a total cost of ownership that must consider all aspects of the design, manufacturing and production cycle over the total life cycle of a product. Software, standards and application environment drive SBCs. The easier it is to use a product, the more successful the project will be.

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