

The Convergence of Processor Architectures for Embedded Computers

A remarkable trend in the evolution of computer board architectures in the embedded market, is the way they are today quickly merging into similar architectures, based on a common set of widely approved standards and technologies, such as PCI. Comparing today a modern Pentium VME board and a modern PowerPC VME board would bring out tremendous likenesses, not only at the overall architecture level, but also at the chip scale.

While this trend could imply uniformity, and tend to impoverish the marketplace, it actually opens new choices to the embedded system designer, based on best software suitability, best performance, scalability, or lifetime. This paper will describe how popular modern processors, Pentium, PowerPC and SPARC, are converging to new standards and what advantages this will ultimately bring to the industry.

ARCHITECTURE

The diagram in Figure 1 describes the overall architecture of a modern SBC (Single Board Computer).

Processor Bus

The processor bus is a high-speed 64-bit or 128-bit bus dedicated to inter-processor, processor-to-memory or processor-to-cache communications.

While most processor buses are proprietary, some are open and intended for high-speed expansion. Sun's UPA (UltraSPARC Port Architecture) offers the most advanced technology, with full support for multiprocessing, packet-switched messages and a 1.6 MB/s maximum throughput. Some processor buses incorporate high-speed graphics capabilities like Creator Graphics (UPA) and Intel's new AGP (Accelerated Graphic Port).

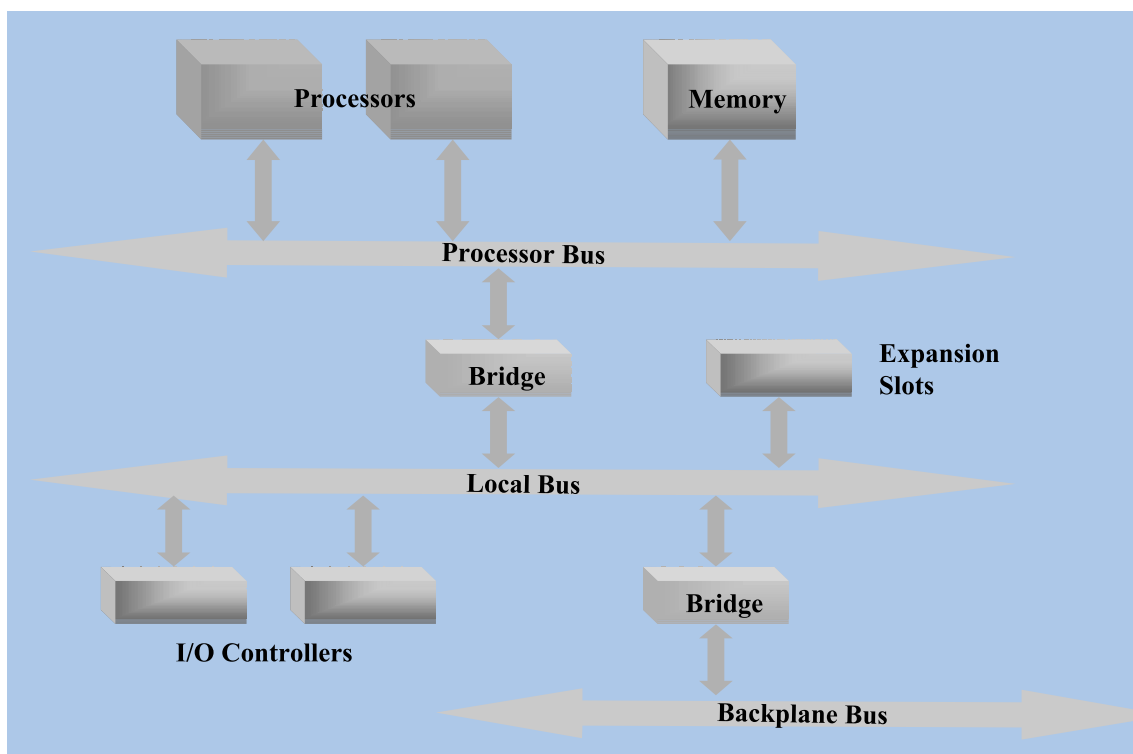


Figure 1. A modern Single-Board Computer

Local Bus

The main role of a local bus is to buffer traffic from intelligent I/O controllers and prevent the processor bus from being bogged down, and still provide a high bandwidth for fast peripherals like graphics. The concept really started to generalize itself in the early 90's with the availability of very high-clocked processors. Beforehand, I/O's and mezzanines were often simply directly sitting on the processor bus or a subset of it (in most cases a 68k processor).

While processor buses generally remain tied up to proprietary architectures, local buses tend to standardize around the PCI (Peripheral Component Interconnect) standard.

In the SPARC world, PCI succeeds the popular SBus. In fact, there is no evidence of a technological advantage in PCI, and there are actually many areas where the specification is known to be deficient. The real difference is on the commercial side. The tight linking of PCI with the PC world brings an incredible wealth of extensions, complex high-density controller chips, and human design skills. Embedded applications can also leverage from chips mass-produced for desktop products, with readily available reference schematics.

PCI is now used in many different processor architectures including UltraSPARC, Pentium, Mips, Alpha and PowerPC.

Mezzanine Bus

Mezzanines add functionality or increase the functional density of a standard board. The logical continuation of PCI on the mezzanine bus is PMC (PCI Mezzanine Card), whose form-factor and mechanics perfectly fit most industrial environments, and seamlessly extend the local PCI bus by using the same protocol.

In particular, mechanical configurations allow two PMC cards to fit on a single-slot 6U VME or CompactPCI card.

Backplane Bus

The notion of a backplane bus is specific to the industrial world, for which form-factor, maintainability and I/O resources are essential. Popular backplane buses include the venerable VMEbus, and the recent CompactPCI.

For VMEbus, attaching a processor board to the backplane comes down to bridging two buses with a fundamental difference, one synchronous (PCI) and the other asynchronous (VMEbus).

The industry is now seeing the second generation of PCI/VME interface chips. Universe, from Tundra Semiconductor, is today used in many different architectures, including V-I Computer's PowerPC boards, Themis Computer UltraSPARC-IIi boards, and the new Themis Computer quad-PentiumPro boards.

Designing around standards like Universe offers better quality and support, lower costs, and helps users preserve their software investment. Thanks to this convergence, third generation PCI/VME interfaces, such as the one Themis Computer will release in 1998, will bring an immediate benefit for different architectures.

While one could consider CompactPCI to be a simple

and direct variant of the onboard PCI bus, it requires operation on a separate bus, not only to extend the number of possible targets, but also to adapt electrical bus drivers. Specialized chips, called "PCI-PCI bridges" provide interfacing between the "master bus" (onboard PCI) and the "slave bus" (backplane CompactPCI). With CompactPCI still in its infancy, very few bridges are actually available to the designer, but the near future should bring second-generation chips, with lower latency and increased flexibility.

Monitor Software

Emerging out of proprietary monitors, OpenFirmware is today the only standardized board-level firmware. Specified by the IEEE (IEEE 1275), OpenFirmware offers similar functionality on architectures like SPARC and PowerPC, and an extremely high degree of portability. Based on Sun's OpenBoot, OpenFirmware is built around three major concepts:

- A processor independent programming language: Forth. Not only a command interpreter for debugging, testing, or configuring a system, Forth is also as a programming language for add-on devices.
- An abstraction layer between hardware and operating system. This was one of the fundamental concepts of the PReP (PowerPC Reference Platform) specification: to give the operating system a way to determine the hardware configuration it is booting from, and a set of callbacks to the underlying monitor. The abstraction layer also deals with byte ordering issues, for example: powering up in big-endian mode and then allowing a little-endian O/S to boot on top of it. The best illustration of this abstraction layer is provided by Solaris.

One of the immediate and historical advantages of OpenFirmware is to allow similar add-on devices to work on different processor architectures. Concretely, one can use the same PMC graphics card as a system console on a SPARC system and on a PowerPC system, without installing specific software drivers.

While Intel processors are likely condemned to stick with the old BIOS in order to maintain compatibility with DOS and Windows, the rest of the industry seems to be standardizing around OpenFirmware, with SPARC and PowerPC at the forefront.

SELECTION CRITERIA

Having defined a common architecture, common extensions, and a common firmware, what are the differences today between processor architectures and what are the factors determining the embedded system designer's choice?

Concordant surveys show that the embedded market is dominated by four processor architectures, 680x0, SPARC, PowerPC and Intel. Still showing the largest sales volumes but with no follow-on technology, 680x0 processors are quickly losing momentum and are rarely selected for new projects. Therefore, we will limit our discussion to SPARC, PowerPC and Pentium processors.

These three computer architectures remain different, not only in their intrinsic construction, but also in many

	SPARC	POWERPC	PENTIUM
Performance	****	****	***
SMP Multiprocessing	****	**	***
Real-time performance	**	***	*
Unix Software	****	*	**
Real-time Software	**	***	**
Windows Software	-	-	****
Price	**	***	***
Harsh environments	**	***	**
Low power dissipation	***	****	**
Roadmap	****	****	****

Figure 2. A comparison of the main processor architectures

factors like vendor endorsement and software support. The comparison in Figure 2 pretends to be nothing more than a quick general guideline. A simple go/nogo selection chart cannot deal in fairness with the many factors involved. An exhaustive comparative analysis is beyond the scope of this article.

SPARC

- Industry widely recognizes Solaris as the best Unix OS at present. Supported by Sun, the leading Workstation Company, Solaris works best on SPARC.
- SPARC probably offers the best SMP (Symmetrical Multi-Processor) architectures, with UPA of course (Themis USP-2), and also with MBus (Themis SPARC10MP and 20MP).
- Unmatched graphics performance: with Creator Graphics, a graphics accelerator directly attached to the UPA processor bus and capable of running the VIS Visual Instruction Set.

SPARC targets → Computer Telephony, simulators, and high-end military applications.

PowerPC

- Recognized as the natural successor to the 68k-processor family, PowerPC allows running most real-time kernels at an excellent price/performance ratio. For example, support for Vol Computer boards includes VxWorks, LynxOS, pSOS and OS-9.
- The range of implementations available to the embedded system designer is extremely large, with low power chips like the MPE603, micro-controllers (4xx, 5xx and 8xx series) and high-performance processors (G3 series).

PowerPC targets → most industrial and military applications, from deeply embedded to number crunchers

Intel

- The wealth of development tools, software of any kind available in the "Wintel" world, is obviously a plus, as well as a possible drawback (see part IV below)
- Windows NT is the first serious competitor to Unix for back-end server applications. In a similar manner, its underlying windowing system can sustain the comparison with Unix environments like X-Windows and CDE (Common Desktop Environment).
- With the availability of multi-processor VME solutions, such as Themis' new quad-PentiumPro board, Pentium processors are now able to provide server-class performance.

Pentium targets → MMI (Man-Machine Interfaces), NT servers

CONCLUSION: THE CHALLENGE

This convergence of processor architectures in the embedded computer market raises a number of issues. The very reason that make PCI, and thus PMC and CompactPCI, attractive - readily available low-priced complex chipsets - comes at the expense of major disadvantages: the short lifetime of most PCI chips and chipsets, and the lack of readily available software support for non-PC environments. Perhaps I2O will solve the problem, but there is no guarantee that it will.

It is a challenge for the manufacturer of industrial computer boards to combine the high expectations of the industrial customer in terms of product quality, lifetime, and support with the realities of a PC-driven chip market. To the end-user, the challenge is to select a product that fits his requirements, with a reasonably long lifetime and support at a good price/performance ratio. Thanks to special agreements with chip vendors and a rigorous selection in the design phase, vendors can commit to product lifetime while still using COTS chipsets.

At the bottom line, end customers and system integrators will leverage cost reduction, and still retain quality, diversity and open choice for their embedded processor requirements. ■

REFERENCES

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