VME & CompactPCI Backplane Standard

- The Best of Both Worlds -

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ABSTRACT

VME and PCI already coexist in the form of PMC expansion slots on many VME boards. Combining VME and PCI allows customers to leverage their existing investments in VME hardware and software while taking full advantage of the latest developments in desktop computing. New developments in silicon and software for PCI can be safely transplanted to the established, secure and rugged computing environment established by the VMEbus.

CompactPCI and the VME/CompactPCI bridge specification simply extend the coexistence of VME and PCI to another form factor.

CompactPCI merges the electrical and software standards of the PCI bus with the Eurocard format and high density 2-mm pin and socket connector. CompactPCI I/O can be extended to eight slots, while front panel and rear back-plane access are provided in a format similar to VME. The Eurocard mechanical structure of CompactPCI is the same format popularized by VME, which eases system integration and servicing of PCI I/O boards in the system.

This paper provides a technical overview of the coexistence and advantages of a 19-inch VME backplane system coupled with the robust connectivity of CompactPCI I/O boards in a common backplane environment.

I. INTRODUCTION

Every modern computer architecture uses an internal PCI system to connect the I/O functions to the processor subsystem, whether or not it supports PCI add-on slots. The new industrial CompactPCI bus architecture enables system designers to build any computer compliant to these standard reference platforms by adding a high performance industrial PCI subsystem bus. As a result, CompactPCI systems can be built using standard PCI components and can run practically any operating system and application without modification. (see figure1: Generic Computer Platform)

II. OPEN BACKPLANE TECHNOLOGIES

Although CompactPCI and VMEbus share some similarities, in most cases a comparison is unreasonable. Today, the intended uses of these two architectures are so unlike each other that ultimately the differences are much more important. PCI is optimized for a chip or small module interconnect environment, and is defined for its primary function as a bridge between the CPU Subsystem (CPU, ext. Cache and Main Memory) and peripherals. VME is more generalized, and is designed to connect multiple 6U boards in a loosely coupled multiprocessor environment. The differences between the two architectures are reflected in a variety of ways.

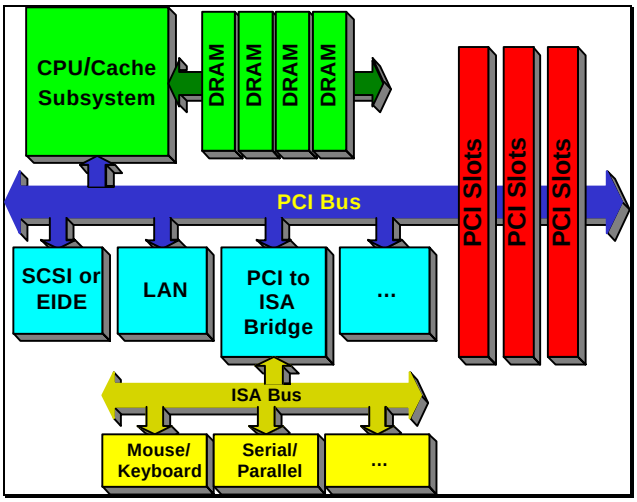


Figure 1: Generic PCI Computer Platform

III. VMEbus ARCHITECTURE

The VMEbus is designed as a global parallel interconnect supporting multiprocessor architectures. The majority of multiprocessor applications based on the VMEbus use loosely-coupled processors communicating through shared memory accessed via the VMEbus. During the last 10 years, VME has been adopted by the embedded market and has emerged as the open bus of choice in the telecommunication and industrial control markets. The VME market continues to expand, and the VME International Trade Association (VITA) has increased there activities to extend the standard. In the late 80's the VME specification was expanded for 64-bit data and address capability, which doubled the bus performance to 80Mbyte/s for as many as 21 slots. Additionally, Bus-locking, Retry-termination and some other features were also added. These additional features effectively migrated VME into the early 90's. This standard and related products are commonly referred to as VME64.

Over the last years the VITA Standards Organization (VSO) was working to add features to the current VME64 Specification. Most of the features are independent of each other and collected within the VME64 Extensions Draft Standard. New features are for example a new expanded 160-pin connector, which is backward-compatible to the current 96-pin J1/P1 and J2/P2 connector. The new connectors hold the additional defined signal and power lines, as well as provide extended user I/O pins for the additional backpanel I/O routing.

Also a new transceiver type was developed for the VME64 Extension Standard, called ETL (Enhanced Transceiver Logic). ETL-tranceivers became necessary to improve the bus driver and transceiver characteristic to achieve a higher transfer throughput on the VME backplane. A new transfer protocol is currently under work to double the 80Mbyte/sec VME64 performance again.

The combination of the new backward compatible VME64 Extension features with the well established VME IEEE1014 and VME64 ANSI/VITA 1-1994 standards guarantee a continuous growth of the VME architecture in its market.

IV. CompactPCI - WHY A NEW BUS?

CompactPCI is a new embedded and industrial Bus technology that combines the PCI electrical and software specification with the industrial Eurocard mechanical standard. CompactPCI supports up to 8 PCI slots on a passive backplane and offers a packaging scheme that is much better suited for use in industrial applications than a standard PC.

Standardization and future developments of the CompactPCI specification are being handled by the PICMG (PCI Industrial Computer Manufacturers Group), a consortium of embedded and industrial computer companies.

Desktop PCI cards are not feasible for embedded industrial systems, because of their form factor, the edge connectors and particularly the cooling restrictions. In addition, desktop PC's usually support only up to 4 PCI expansion slots compared to the 8 CompactPCI Expansion slots.

(see figure2: Desktop PCI Expansion Cards)

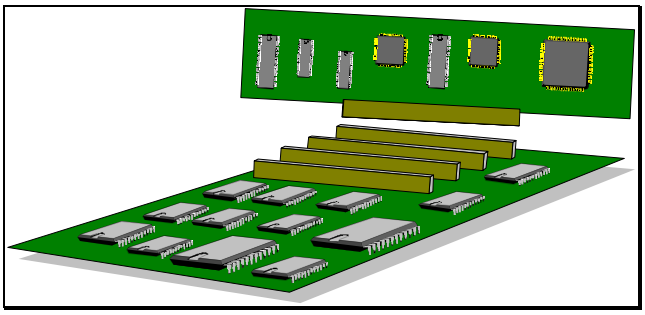


Figure 2: Desktop PCI Expansion Cards

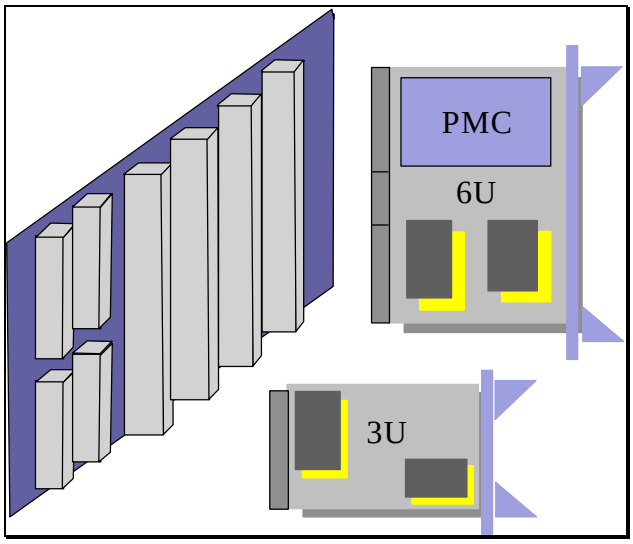


Figure 3: CompactPCI Expansion Cards

Unlike PCI desktop solutions, CompactPCI boards use a high-quality 2mm pin and socket connector that meets industrial and telecom standards (Bellcore, IEC,..). These connectors are significantly more reliable and provide better shock and vibration characteristics than the card edge connectors of standard PCI cards. Eurocard 3U and 6U CompactPCI boards are inserted from the front of the system, and I/O can be brought out either from the front or the rear. Like VME, the cards are mounted vertically allowing for convection or forced air cooling. (see figure3: CompactPCI Expansion Cards)

A typical CompactPCI system is built around eight CompactPCI slots and consists of one System Slot with up to seven Peripheral Slots. The System Slot provides mainly a central arbiter, clock distribution logic, interrupt processing and is responsible for the system initialization. An 8 slot CompactPCI system can be easily expanded with a PCI to PCI bridge chip which acts as a buffer for the second PCI subsystem. (see figure 4: CompactPCI Bus Architecture)

CompactPCI's electrical and software specification are fully compliant to the PCI local bus specification, allowing the use of low cost and high-performance 'off-the-shelf' PCI components. Therefore, CompactPCI and desktop PCI cards have identical schematics.

The CompactPCI bus is processor independent, enabling an efficient transition to future processor generations and defines already a 64-bit extension of the data and address bus. Processor independence allows to build CompactPCI cards, which can be used in various architectures and can work concurrent to the processor/memory subsystem.

CompactPCI bus standard offers additional benefits to the user, by specifying a standard configuration layout for each device on the bus. A system with embedded auto-configuration software automatically configures the whole I/O PCI subsystem at power-on. The configuration software running on the Host-CPU board in the System Slot, dynamically identifies all PCI I/O devices within the CompactPCI system and sets the system up according to the requirements of all PCI participants, e.g. address space, latencies, bandwidth, etc.

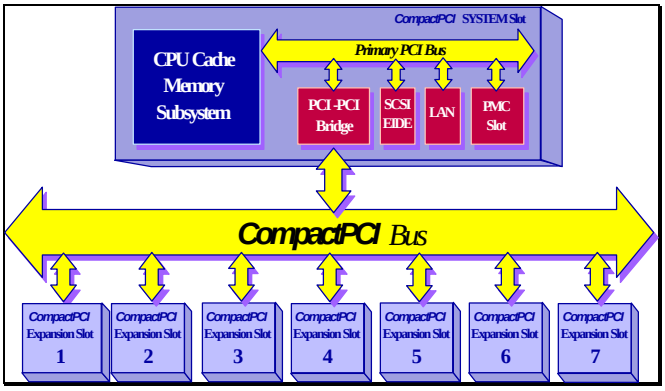


Figure 4: CompactPCI Bus Architecture

V. COMPARISON VMEbus - CompactPCI

A - Bus Technologies

One difference is the technologies used by the two buses.

VMEbus systems can contain up to 21 slots. The flexibility to install between 1 and 21 boards in a large VME backplane system introduces a disadvantage, a requirement for high-current drivers. As the technology is bipolar TTL-based, the signal loading can be quite high. Also the bus is a transmission line with a low impedance, and both ends of the bus are terminated. For this reason, VMEbus specifies high-current drivers for most of the signals.

The CompactPCI bus was designed around the electrical characteristics of CMOS circuitry. This means most ASIC technologies can drive the PCI signal lines directly. Like PCI, the CompactPCI bus design is based on reflected wave signaling instead of incident wave signaling. The direct PCI chip-level interconnect advantage, enables designers to build CompactPCI I/O peripheral cards at lower power, cost and complexity. This technology limits the total amount of available slot to eight.

B - I/O Interfaces

There are obvious differences in building I/O peripheral functions on the VMEbus compared to the CompactPCI bus.

The CompactPCI architecture is defined to connect PCI devices directly to the PCI bus. This is advantageous since it eliminates the need for separate bus drivers and receivers and simplifies the design.

Unlike CompactPCI, VMEbus solutions always require a VMEbus interface function, even for single functional units. The cost of adding a VMEbus interface to a simple I/O function, where the VME interface comprises more than half of the total board cost, migrating non-intelligent I/O functions has resulted in more and more towards local I/O bus implementations. The trend towards VME Single Board Computer (SBC) integration with the concept of mezzanine I/O expansion allows system designers to add a range of functionality for a lower price than VME I/O multiboard solutions.

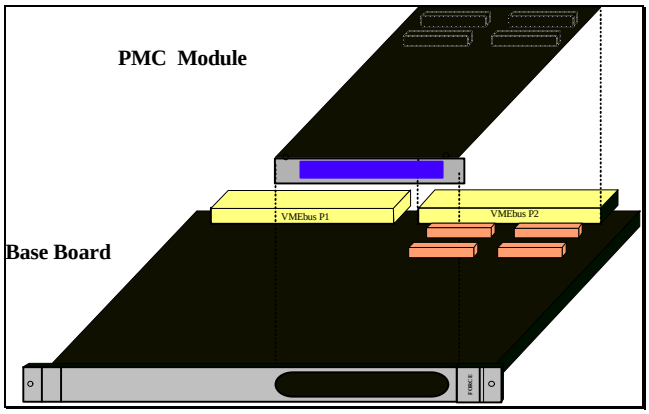


Figure 5: VME Board with PMC Expansion Card

C - Mezzanine Concepts

In the last year the PMC (PCI Mezzanine Card) concept has been introduced by many VME vendors and is intended to be the first common mezzanine open standard (IEEE1386.1). This mezzanine module interfaces directly to the local baseboard PCI bus and allows one to design PMC cards more easily and at lower cost. PMC is an excellent solution for VME-based high-performance standard system I/O requirements, such as graphics, LANs, etc. Mezzanine modules are provided in a small form factor and their flexibility is normally limited to two expansion modules. Furthermore, mezzanine concepts have some significant physical and electrical limitation to build telecommunication and industrial interfaces. Since PMC mezzanines are specially defined to fulfill a single- slot VME implementation, there are necessarily some height restrictions built into the mechanical specification. In some cases this prevents the use of standardized telecom connectors, galvanic isolators or other high components. In addition, it's very difficult to realize a proper shielding of an I/O connector mounted on a mezzanine module.

On the other hand, CompactPCI supports up to seven PCI expansion slots and offers a full 3U and 6U mechanical Eurocard specification that is much better suited for telecommunication and industrial control I/O implementations. For example, CompactPCI cards are designed for front panel and backpanel I/O access and provide the full real-estate for peripheral functionality.

Additionally, because the CompactPCI bus is fully compliant with the electrical and software PCI specification, all PCI performance and low cost benefits are still guaranteed.

D - Multi-Processor Applications

Many applications require a multi-processing capability from their architecture plus an way to run multiple and different operating systems within on system. One of VME's major strengths is its scalability in fitting into a very large number and types of computer applications. VME is a more general purpose backplane bus, which allows to couple different architectures and operating systems, since the VMEbus only describes a hardware protocol of communications. (see also the section: Software)

The CompactPCI backplane bus has physical and logical constraints which limit its ability to efficiently

support a large number of processors required for multiprocessor applications. However, PCI, and therefore CompactPCI, is optimized for a high performance and cost-effective I/O implementation.

E - Software

CompactPCI is based on standard PCI system architectures and uses standard PCI silicon firmware. Therefore, operating systems, drivers, and applications can be used "as-is" on a CompactPCI system. That is, software developed for a standard PCI-based desktop system can be instantly reused on a CompactPCI system. From the software's point of view there is no difference between a PCI system and a CompactPCI system.

This advantage is a disadvantage when one tries to build loosely-coupled, memory-mapped, multiprocessor networks. Since most off-the-shelf operating systems assume complete ownership of the PCI bus and its peripherals, it is difficult, from a software standpoint, to install more than one CPU board into a CompactPCI backplane. In this regard VMEbus is a more flexible solution. VMEbus easily supports many CPU board's running standard off-the-shelf operating systems and communicating via the VMEbus as though it were a network e.g. with the BusNet protocol.

F - Transfer Performance

CompactPCI's performance level provides the ability to support the bandwidth requirements of multiple PCI cards commonly installed in a host system. Because of its extremely high bandwidth, CompactPCI is particularly well suited for many high speed data communication applications, such as ATM, ISDN, etc.

CompactPCI provides a practical performance of up to 130Mbyte/sec in a 32-bit wide backplane and specifies already a 64-bit wide transfer mode. A CompactPCI migration to the 66MHz double-speed mode may not be practical. Anyway, the 264MByte/sec bandwidth of the bus should be powerful enough to adapt to the telecommunication and industrial standards of the future.

VME64 offers a theoretical bandwidth up to 80MByte/sec, today. The new 2eVME protocol will double this bandwidth close to 160MByte/sec. If the bandwidth can be increased beyond that will be speculation from today's point of view.However, many applications do not require such high data rates and the technology decision will be driven by other factors, like software support, etc.

G - Serviceability

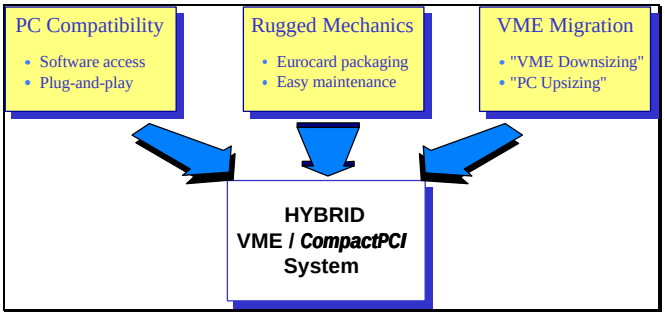
Both technologies, CompactPCI and VME, are based on the Eurocard standard and are vertically mounted within a standard 19" chassis. Both are well suited from the serviceability point of view.

H - Cost

It is not possible to make a direct cost comparison between pure VMEbus-based and CompactPCI solutions, since many factors have to be taken into account. The application, software and performance requirements can be so different that the system concepts are not comparable. However, in an industrial single-processor environment with less real-time and multiprocessor requirements a CompactPCI solution can be the most cost effective. If flexibility, in terms of loosely-coupled multiprocessor environments, is required a VMEbus-based solution should be selected.

I - Comparison Summary

Despite some similarities, VMEbus and CompactPCI are very different. This is a reflection of the different applications they are meant to solve. They do not compete, but in fact are compatible, and can be symbiotic. VME can be used as a global multiprocessor communication path and CompactPCI can be the path through which high-performance I/O options are customized easily, and at low cost. There are many benefits to such a symbiotic approach, and FORCE COMPUTERS has announced such a combined VME/CompactPCI solution.



VI. VME HYBRID SOLUTIONS

VME and CompactPCI solutions will be used in many different configurations. However, an interesting solution is the integration of CompactPCI technology with the VMEbus environment. The two standards in one environment can solve many of the limitations of each architecture. In addition, users can also take advantage of existing VME boards and combine this functionality with newer CompactPCI technology.

FORCE COMPUTERS has developed a specification that maps all VME64 signals to the CompactPCIP1/J1connector. This VME/2mm standard was provided by FORCE COMPUTERS to the PICMG committee fdardization. This will provide the capability to build VME64 to CompactPCI bridge boards in a single Eurocard slot. (see figure7: 2mm VME / CompactPCI connector)

Hybrid CompactPCI/VME systems are able to support multiprocessor and multi-operating systems, e.g. a real-time OS such as VxWorks or pSOS running on the VMEbus and Windows NT running on the CompactPCI subsystem.

A hybrid system might contain one VMEbus and one or more CompactPCI subsystem buses. The VME section contains standard VME boards compatible with VMEbus IEEE and ANSI standard. The CompactPCI host slot provides the VME bridge functionality into the VMEbus and supports the CompactPCI expansion bus. The number of CompactPCI I/O cards required and the application requirements for these cards will determine the number of 6U or 3U CompactPCI slots. Since the total number of CompactPCI expansion slots is limited to seven, a hybrid system can be defined to bridge into another CompactPCI subsystem either form the CompactPCI backplane bus or directly from the local PCI bus of the CompactPCI CPU board.

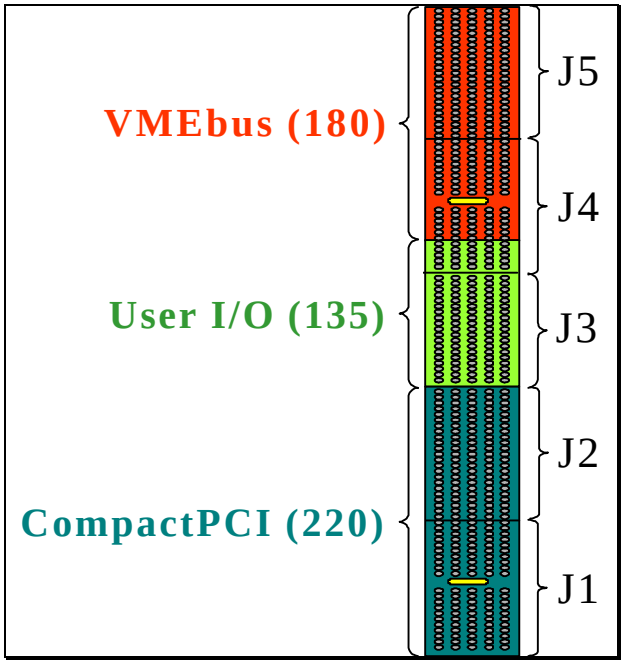


Figure 7 : 2mm VME / CompactPCI Connector

VII. CONCLUSION

Industrial systems based on a CompactPCI/VME combination with the unique advantages of the VME architecture and the high performance, cost-effective CompactPCI I /O expansion capabilities can be very successful in the future . Furthermore, special software integration problems between the PC-architecture and real-time VME boards can be solved by on open standard backplane communication protocol, called BusNet.