

Spoiled for Choice: CompactPCI Serial or VPX?

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Nuremberg, August 2011

During the last years the parallel PCI bus technology has more and more been complemented by fast serial point-to-point connections. For this reason, the structure of a computer has slowly changed from a bus-based system to a system with a star topology connected by serial point-to-point connections. Of course, modular computers are still needed in industrial environments. Depending on the field of application, a considerable number of new standards with these serial interconnects has been created, which – unfortunately – have been optimized for special markets or applications at least at the beginning. Only two of the more recent standards have taken over the proven 19" technology and the single or double Eurocard format to create a migration path: CompactPCI Serial (PICMG CPCI-S.0) and VPX (ANSI-VITA 46.0).

Successful Beginnings – CompactPCI and VMEbus

As early as 1981, 30 years ago, the VMEbus (Versa Module Eurocard bus) was developed by a consortium around Motorola and Philips and standardized as ANSI/IEEE 1014-1987 by the IEC. Originally, it was supposed to be used on the basis of the 68000 Motorola processor family in control systems. Soon, the VMEbus supported both RISC (e.g., PowerPC) and CISC (e.g., x86) architectures and was able to establish itself in industrial automation, medical engineering, telecommunications, aerospace and especially in military engineering. As the PCI bus was not yet known then, communication on the backplane had to be developed from scratch. The original variant was equipped with a 16-bit data bus and a 24-bit address bus, the advanced version VME64 offered a bus width of 64 bits with 80 Mb/s while VME320 (2eSST) additionally provided a higher data rate of 320 Mb/s.



Fig. 1: VMEbus PC with Intel Core architecture and XMC/PMC slots (MEN A20)

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The VMEbus has long been the uncontested number one for robust and modular bus-based systems with a passive backplane.

Some 15 years later, in 1994/95, Ziatech and Pro-log presented a concept for modular computers based on PCI bus plug-in cards in Eurocard format, connected to a passive backplane. The concept was called CompactPCI and soon more companies like Motorola, Radisys (Intel) and Lucent showed their interest. They participated in the standardization – PICMG 2.0 was one of the first ever PICMG standards. The CompactPCI bus was successful and soon reached a high market penetration for industrial, reliable systems. It became the most important standard in the telecommunications industry. But it also soon conquered markets which had traditionally been occupied by the STD bus or the VMEbus. Beside wide areas in industrial environments, these were medical engineering, measurement and transportation. CompactPCI was cleverly based on the IEC 1101 mechanical standards for Eurocards and 19" systems known and proven from the VMEbus. Finally, the conductive cooling solutions were also taken over, so that even military applications opened up for the CompactPCI bus.



Fig.2: CompactPCI slave CPU with e300 PowerPC (MEN F218)

Hybrid Solutions – CompactPCI PlusIO and VXS

In the 2000s the parallel PCI bus technology has more and more been complemented by fast serial point-to-point connections. Depending on the types of peripherals and functions, different interface standards are taking root. For example, SATA or SAS is the interface for mass storage devices like hard disks. USB has established itself for WiFi components and loosely coupled peripheral devices like keyboards, touch screens, external hard disks etc. Beside the traditional network technology, Ethernet is also used as an interface for multiprocessing and as a fieldbus for decentralized I/O. PCI Express is used for connection of closely coupled computer peripherals. These interfaces coexist and each has got its own special range of applications. A modern computer needs all of them. Unlike in the past, however, they are not connected to separate controller chips which are interconnected by a bus, but in modern chipsets all these interfaces are directly available at the chipset. For this reason, the structure of a computer slowly changes from a bus-based system to a system with a star topology connected by serial point-to-point connections.

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But how are these technologies transferred to industrial systems and how can you keep their modularity? What is more, it has to be taken into account that for many applications only a smooth migration is possible because of the large inventory of systems in the field – in other words an evolution instead of a revolution to preserve the existing investments in the hardware and the software.

For VMEbus, VXS (VITA 41) ensures backward compatibility, i.e. VXS boards are mechanically (19" and Eurocard format with 0.8" board distance) and electrically (P1 and P2 connectors can be kept) compatible to VME and VME64 systems. Using a 7-row multigig RT2 connector, they offer fast serial communication via Infiniband, Serial Rapid I/O, Aurora, PCI Express and Gigabit Ethernet. The theoretical bandwidth is up to 3 Gb/s per slot. CompactPCI uses the same newly defined connector in its PICMG 2.16 extension – calling it J3 while VXS calls it P0. However, this extension is limited to 6U boards for VXS and CompactPCI 2.16. Small and compact solutions cannot be implemented. In addition, only Ethernet and PCI Express, being widely used serial interconnects in the PC world, are used, SATA and USB remain excluded. VXS systems also need a switch board or a corresponding slot at the backplane, and star and double star configuration also have to be differentiated.

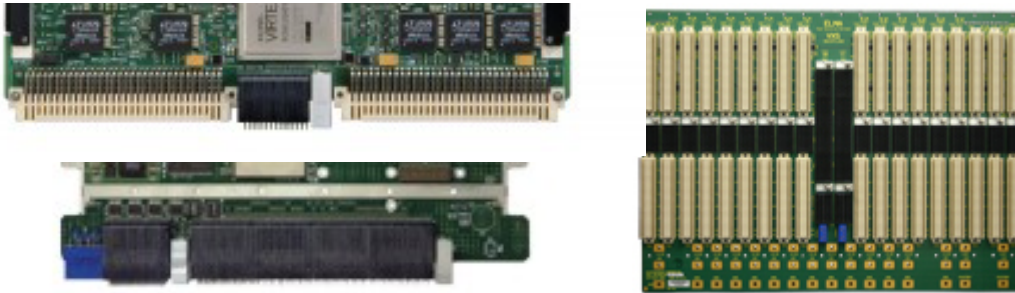


Fig. 3: VXS board, switch and hybrid backplane

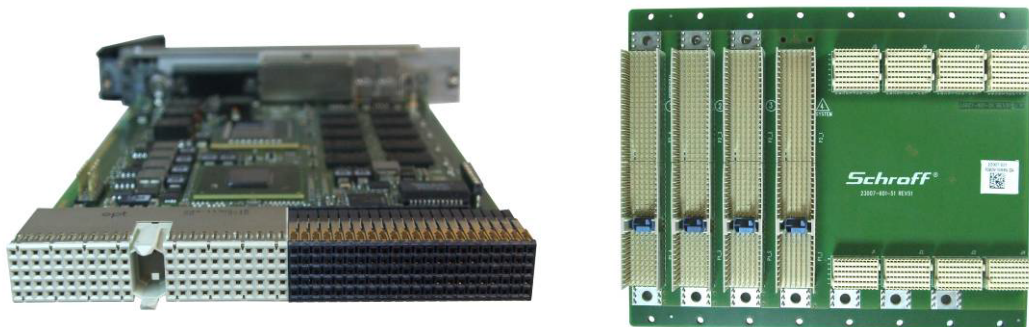


Fig.4: CompactPCI PlusIO board and hybrid backplane

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For 3U boards, PICMG is at least three steps ahead. After the rather unsuccessful introduction of CompactPCI Express (PICMG EXP.0) some years ago, the adoption of CompactPCI PlusIO (PICMG 2.30) followed in 2010. While CompactPCI Express was still limited to a single serial interface type – PCI Express – and is not compatible to CompactPCI due to new connectors, CompactPCI PlusIO has learned its lesson from the standards of the early 2000s. As the name suggests, PICMG 2.30 is an extension of PICMG 2.0 fixing the pin assignment of the J2 connector which had been free before and provides four PCI Express, USB, SATA and two Gb Ethernet. The new, perfectly shielded connector supports differential signals with over 2.5 Gb/s, while being 100% compatible with the previous 2-mm-connector. This way, CompactPCI PlusIO is backwards compatible to CompactPCI and supports all current serial interfaces and can be used both for 3U and 6U board formats. As the connector does not cause additional costs, CompactPCI PlusIO system slot boards make sense both in CompactPCI and in hybrid systems with CompactPCI Serial peripheral slot boards. This makes CompactPCI PlusIO an independent concept for applications with mixed parallel and serial communication requirements in contrast to VXS as a transition solution. As CompactPCI PlusIO needs no switch boards in the system it is also cost-effective.

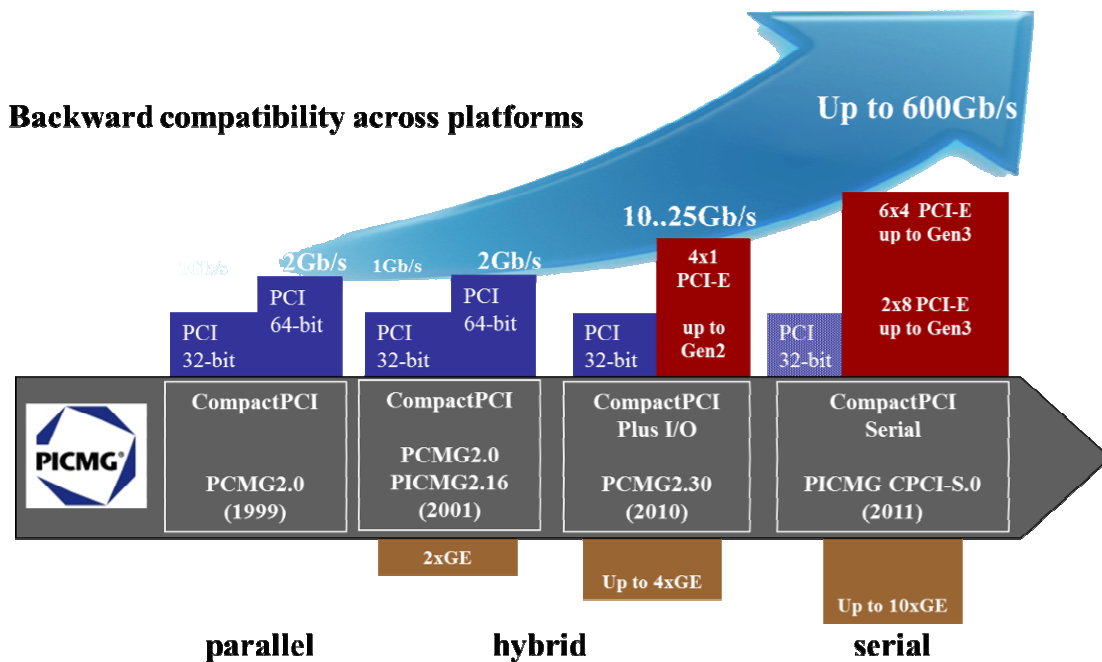


Fig.5: Migration from CompactPCI via CompactPCI PlusIO to CompactPCI Serial (www.compactpci.org)

Arrived at the Destination – CompactPCI Serial and VPX

But they already exist, the "pure" serial system standards for the industry, and they come exactly in time for data hungry applications with high requirements regarding visualization, image capture, memory or multiprocessing. However, only two of the new standards are modular and really robust for harsh environments without limits: VPX from 2007 and the recent CompactPCI Serial from 2011. Both rely on the proven IEEE 1101 mechanics (single and double Eurocards and 19" technology). Thanks to these features, important functions for

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safety and reliability such as hot-plug/hot-swap or a good heat dissipation including conductive cooling do not have to be reinvented. Modularity and robustness cannot be specified as an afterthought, as can be seen in standards such as ATCA and MTCA.

VPX was developed based on the VMEbus as a successor of VXS. The most striking innovation is the robust 7-row multigig RT2 connector. For 6U boards it provides 464 signal pins, 32 of which are differential pin pairs for serial interconnects and 128 pin pairs are for customer-specific I/O. The complex connector, built up in a 16-layer wafer technology supports transfer rates of up to 6.25 GHz with less than 3% crosstalk. Board detection and ground signals are also implemented. The dimensions allow plugging of XMC mezzanine boards and offer enough space for stiffener plates and CCA frames. The power supply per board is 115 W (+5V) or 384 W (+12V) and 768 W (+48V). Another specification describes how the corresponding high power dissipation in the system is handled – VITA 48 (VPX REDI, Ruggedized Enhanced Design Implementation). Apart from different cooling techniques including liquid and spray cooling, it also describes the deviation from the 0.8" board distance of the IEEE 1101 as well as thicker PCBs.

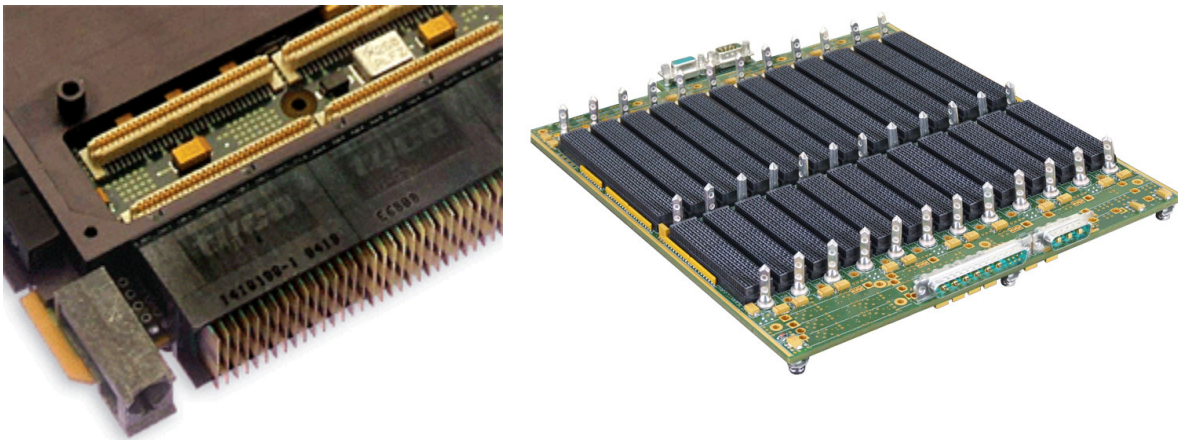


Fig.6: VPX multigig RT2 connector and military backplane

VPX supports a whole string of fast serial fabrics. However, these are described in extra specifications complementing the base specification which only defines the mechanics and the electrics of the standard. Besides PCI Express and (10) Gigabit Ethernet these are Serial RapidIO or Fibre Channel, but also the signal routing for rear transition modules and for PMCs or XMCs are described separately in this way. Many auxiliary specifications are not yet officially adopted by the VITA.

VPX does not only work with different interconnects but also with different communication architectures which require certain switches or bridges depending on the built-up of the overall system – except for some mesh configurations which can do without a central switch. OpenVPX (VITA 65, adopted in 2010) now tries to lift the separate parts of the VPX specifications from the board level to the system level, this way solving manifold problems of interoperability. OpenVPX defines a system architecture which manages and limits board and backplane designs, including the definition of pin assignments, physical addressing, line definitions for serial communication (corresponding to PCI Express links x1 to x16), structure

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and hierarchy profiles, levels for utility, management, control functions, data and extensions. Accordingly, there are backplanes with topologies which are branched, distributed or managed via a central switch. And there are different pin assignments for the system slot ("payload slot"), peripheral slot and switch slot.

The base and sub-specifications around VITA 66, 67 and 68 not adopted yet also deal with extensions and additions to the original VPX standard VITA 46. Even though VPX is not backwards compatible to the VMEbus, customer-specific hybrid backplanes allow connection with VME64 and VXS.

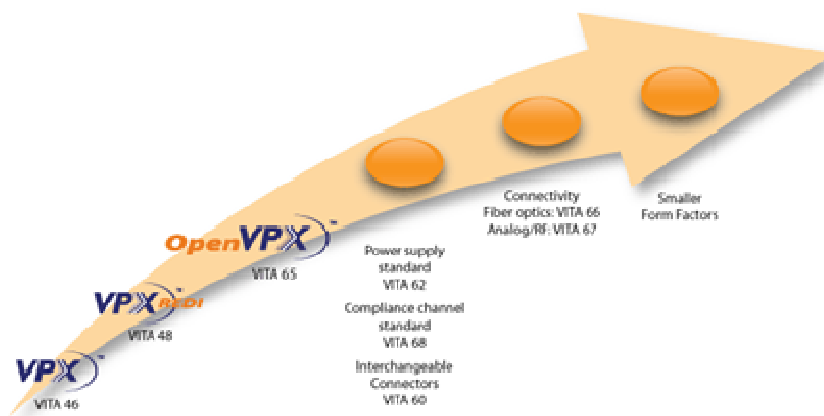


Fig. 7: VPX Technology Roadmap (www.vita.com)

CompactPCI Serial has been developed in parallel with CompactPCI PlusIO for hybrid systems based on CompactPCI. Here, too, a more dense connector with 184 pin pairs (368 pins) per 3U board (AirMax from FCI or Amphenol TCS) guarantees transfer rates of up to 12 Gb/s and more even with less than 3% crosstalk. The new codable connectors resemble the old 2-mm types, but as they are using up to six connectors per 3U board with their own connector walls, they are much more robust and protected against accidental wrong plugging. In addition, the headers are placed on the board, to avoid twisted pins on the backplane. The power dissipation of a board is 60 W with a voltage supply of +12V.

Mezzanine boards such as PMC and XMC can also be used with CompactPCI Serial. Special mezzanines can also be plugged directly into the backplane. For this, there are AirMax connectors which are turned by 180°. Rear connection and the built-up of transition modules as well as the mechanics for systems with conductive cooling are explained with the complete system architecture directly in the base specification CPCI-S.0.

Compared to VPX, this architecture is very simple for CompactPCI Serial and plug&playable in every sense of the word: a star for PCI Express 1 and 2 (optional SRIO), SATA/SAS and USB 2.0/3.0 combined with a full mesh for Ethernet based on the 100/1000/10GBase-T standard. CompactPCI Serial does not require any switches or bridges in systems with up to nine slots. Up to 21 slots can be implemented in a 19" housing with a bridge. The pin assignment of all peripheral slots is 100% identical.

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The system slot supports a total of six PCI Express links with up to four lanes each, two links with up to 8 lanes, eight SATA/SAS interfaces, eight USB, eight Ethernet interfaces and a number of signals for supporting these interfaces and for general system management (reset, IPMB, hot plug, geographical addressing, etc.). Accordingly, there is one PCI Express, SATA/SAS and USB on every peripheral slot. Each slot can support up to eight Ethernet interfaces. All interfaces are always available simultaneously. This is important, for example, for standards like Mini PCI Express cards, which expect USB as well as PCI Express support. What is more, system slot CPUs can be plugged into any peripheral slot and be used for building up multiprocessor systems without additional overhead. Communication is done via Ethernet (star or mesh).

Physical addressing – only defined by the separate OpenVPX specification for VPX – is simple and convenient for CompactPCI Serial. It uses automatical configuration mechanisms of SATA, PCI Express and Ethernet and is compatible with standards like SFF-8485 for hard disk RAID.

To ensure the compatibility of different manufacturers, the CompactPCI Serial specification prescribes the order in which interfaces must be implemented on the system slot, if not all 8 interfaces can be supported.

This way, CompactPCI Serial ideally corresponds to the chipset architecture in the mobile and server area in the coming years. The configuration of systems can always be done in an optimal and cost-effective way based on a wide range of COTS components. Correspondingly, there is a wide range of applications, reaching from a simple industrial PC via I/O-intensive data acquisition and processing up to highly complex computer clusters. Independent of single markets, CompactPCI Serial is at home where robust computers have to perform their tasks reliably and where safe equipment for the protection of life and the environment is required.



Fig. 8: Airmax connector at the CompactPCI Serial system slot and standard backplane

VPX or OpenVPX as well as VXS and VME before that have a long history in military applications and have implemented their specific requirements in several specifications in close cooperation with the strategists from this market. Even in the avionics and aerospace industry, where boundaries between military and civil are fluid, VPX is relatively well established. Geographically, VPX has a leading role in North America, followed by India, Japan, Korea and Australia, France and Italy dominating in Europe.

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CompactPCI Serial was long in the making. In the meantime, VPX has begun to leave the military niche and intensifies its efforts to supply civil applications. Both standards are the best that the market has to offer at the moment regarding robustness and reliability. However, potential customers should consider carefully in advance for which system features they want or have to spend their money. There might very well be some industrial or civil applications, where the higher costs of a VPX system are justified, especially when the NRE purchase costs are too high anyway. In that case, however, enough time should be scheduled to familiarize oneself with VITA 46, 48, 65-68 and all sub-specifications – while CompactPCI Serial only consists of a 128-page base specification.

On board level already, higher costs are incurred due to the complex VPX connector which has no advantages regarding speed, safety or robustness compared to the CompactPCI Serial connector and even provides fewer signals.

On the other hand, CompactPCI Serial offers no special interconnects such as Serial RapidIO or Aurora – but at least the whole range of serial interfaces just like any PC. Current x86 processors support the whole range of PCI Express, Ethernet, USB and SATA – but not SRIO, which is limited to some PowerPC and DSP types.

Management controller hubs, switches, bridges etc. cost money and make systems more complex, in other words more expensive. Whatever purpose they have (connecting a slot with the right interface) – CompactPCI Serial can do completely without, even in a complex multicomputer system. Additional overhead for software adaptations is not required either with CompactPCI Serial.

The high number of possibilities when configuring VPX systems eventually causes problems with interoperability which OpenVPX tries to reduce. Nonetheless, the multitude of options makes it almost impossible to exchange plug-in boards of different manufacturers one-to-one and application-specific backplanes are the rule rather than standard backplanes.

Thanks to the strictly standardized pin assignment of CompactPCI Serial on the other hand, most applications, simple or complex, can be built up of standard boards and backplanes at least for the most part; there are no or very small NRE costs.

As effective cooling is also required in civil applications such as planes, trains, buses and mobile machines from time to time, CompactPCI Serial also specifies a CCA frame for boards and the corresponding infrastructure for conductive cooling systems. In order to save costs, standard assemblies do not have to be layouted anew for a conductive-cooled environment, which would reduce available space on the PCB, but are equipped with a CCA frame.

The last cost factor: the PSU. For its 5V/12V/48V strategy, VPX also needs more complex PSUs. CompactPCI Serial defines a single 12V supply and can use COTS PSUs when there is cost pressure.

VPX and CompactPCI Serial – two solid standards, many things in common, but two worlds nonetheless: The costs are what separates them. What is suitable for military and defense

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applications, must not necessarily be right for cost-conscious markets. CompactPCI Serial is not cheap either, but the price/performance ratio as a driving factor for the standardization is good.

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