

CompactPCI Serial – Compendium

Both CompactPCI PlusIO and CompactPCI Serial is based on CompactPCI, an established standard for building cost-effective, industrial and reliable computers. Users appreciate the modularity, robustness and economic efficiency of CompactPCI. With the new standards they get all these advantages plus fast serial data transfer – including the migration path.

Content

CompactPCI Serial – Compendium.....	1
History of a New Standard.....	4
CompactPCI Serial.....	7
Architecture Overview.....	7
Key Characteristics.....	10
Wiring and Connectors.....	11
Look Back on CompactPCI: Keep What is Tried and Tested.....	13
Computer Set-Up as a Star and Mesh.....	13
Modern Computer Architecture.....	13
Star Architecture with Ethernet, PCI Express, SATA and USB.....	15
The Special Role of Ethernet.....	15
Identical Peripheral Slots.....	17
Typical Tasks of the Serial Interfaces.....	17
Ethernet for Complex Systems.....	17

The Ethernet Mesh.....	17
PCI Express for High Bandwidth.....	24
SATA/SAS for RAID Systems	27
USB for Mobile Functions	29
Hot-Plug Functionality.....	30
Requirements for Hot Plugging	30
Typical Applications.....	31
Conduction Cooling.....	32
Convection Cooling	32
Conduction Cooling.....	32
Physical Addressing.....	34
Benefits and Pitfalls.....	34
Physical Addressing with CompactPCI Serial.....	34
Mechanics	36
The Guide Element	36
Connector Usage and Coding.....	37
Two Card Formats: 3U and 6U	39
Extension using Mezzanine Cards.....	43
Individual Rear I/O for 3U and 6U	44
Application-Specific Backplane Architectures.....	46
Use in Harsh Environments: EN 50155 as an Example	48
Spoiled for Choice: CompactPCI Serial or VPX?	49
Migration using CompactPCI PlusIO	51
Architecture Overview.....	51
Standardized Interfaces with CompactPCI PlusIO	52
Hybrid Systems as a Bridge between the Standards.....	53
PCI Express	54

Ethernet.....	55
Why BASE-T?	55
Possibilities through Ethernet on the Backplane.....	55
Electrical Specification	56
Interoperability	57
Defined Interface Order	57
Implementation in Real Life.....	58
Hybrid Systems	60
Using CompactPCI PlusIO.....	60
The Important Role of CompactPCI PlusIO	60
Hybrid Possibilities using CompactPCI PlusIO	61
Direct Connection between CompactPCI and CompactPCI Serial	63
Perspective.....	65
Abbreviations	67

History of a New Standard

In 1994/95, Jim Medeiros of Ziatech and Joe Pavlat of Pro-Log, among others, presented a concept for modular computers based on PCI bus plug-in cards in Eurocard format, connected to a passive backplane. They called their concept CompactPCI. Soon, other companies such as Motorola, Radisys (Intel) and Lucent showed interest in this concept and participated in its standardization. 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 that 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 IEEE 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.

During the last years 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 Wi-Fi 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 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. In modern chip architectures 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.

The Next Generation of Modular Computers: First Attempts

Naturally, modular computers are still needed. As there are many different serial interfaces new standards were created depending on the industrial range – optimized for the market and the application. For example, AdvancedTCA has been created especially for telecommunication applications, whereas standards such as VPX (ANSI/VITA 46.0) are focused on military applications.

Retroactively it was tried to make specialized standards universally usable again. One of these was MicroTCA. For MicroTCA a computer system was defined based on the mezzanines standardized with AdvancedTCA, the AMC. Due to the fact that originally this concept did not consider passive backplanes

for the mezzanines, there were high infrastructure costs for emulating the AMC carrier board. What is more, the mechanics are completely incompatible to IEEE 1101 (Eurocards and 19" technology). The amendments which were necessary later to make MicroTCA suitable for harsh environmental conditions also present certain problems.

Another standard exclusively based on PCI Express – CompactPCI Express – was not able to penetrate the market. This standard uses the IEEE 1101 but the limitation to PCI Express as the only interface type is not sufficient.

The aforementioned system concepts all work with so-called switched fabrics, i.e. additional switches and bridges which are required to connect each slot with the right interface. This causes higher costs for the infrastructure, requires special software for the configuration and does not prevent that customer-specific backplanes are needed. As there are a multitude of different options it is rarely possible to exchange plug-in boards of different manufacturers 1:1.

For this reason, most modular computers are based on the CompactPCI standard which has proven itself the world over. The serial point-to-point connections are realized as needed proprietarily via user-defined pins. Unfortunately, this leads to a growing incompatibility of assemblies from different manufacturers. Customized backplanes are needed to connect the serial buses. Is there a way that sustainably leads out of this dilemma?

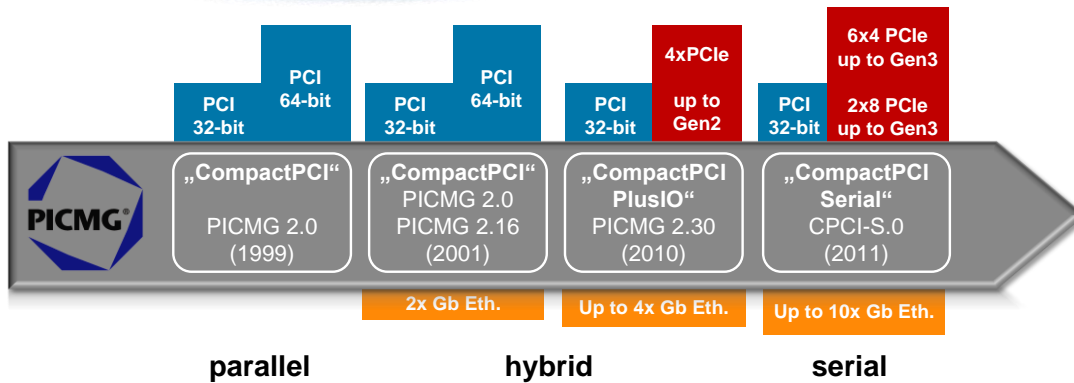
The Way into the Future: A Contemporary Concept

The aim is to develop a new concept that is future-proof but is based on the existing CompactPCI standard and the proven and no doubt robust 19-inch technology:

- It is supposed to allow for a smooth migration from the current standard to the modern point-to-point connections.
- It is also supposed to support all important serial interfaces on an equal footing, i.e. PCI Express, SATA/SAS, USB and Ethernet.
- The costs for the infrastructure have to remain low, which means that bridges and switches may only be used as an exception.
- It has to be possible to offer off-the-shelf backplanes, i.e. each slot has to be usable universally without special routing.

PICMG (PCI Industrial Computer Manufacturers Group) has defined two standards for this – PICMG 2.30 CompactPCI PlusIO, ratified in November 2009, and PICMG CPCI-S.0 CompactPCI Serial, ratified in March 2011.

Backward compatibility across platforms



Overview of CompactPCI and the new serial standards

A New Base Specification

The structure of PICMG's specifications always follows the same principle: A base specification is extended by follow-on standards. The base specification of the well-known, widely used CompactPCI standard is designated PICMG 2.0. The zero after the point indicates that this is a base specification. Standards building on it and extending it have higher numbers with the same prefix. PICMG 2.16, for instance, describes Ethernet over the backplane for 6U CompactPCI. PICMG 2.30 – CompactPCI PlusIO – defines the usage of the user I/O signals of backplane connector J2 for 3U and 6U boards, in order to make modern serial buses usable together with the parallel PCI bus. In this way, PICMG 2.30 details PICMG 2.0 CompactPCI.

CPCI-S.0 is the base specification of the new CompactPCI Serial standard. On the one hand a base specification defines as little as possible to stay open for later technological change, but on the other hand this specification needs to be complete enough to guarantee smooth interoperability of the products of different manufacturers – which in the end is, or at least should be, the basic idea of a standard.

Being a base specification, CPCI-S.0 must not refer to other base specifications. The mechanics of parallel CompactPCI is basically identical with CompactPCI Serial. Still, CPCI-S.0 must again describe all the technical details. On the one hand CompactPCI Serial is widely redundant to CompactPCI, but on the

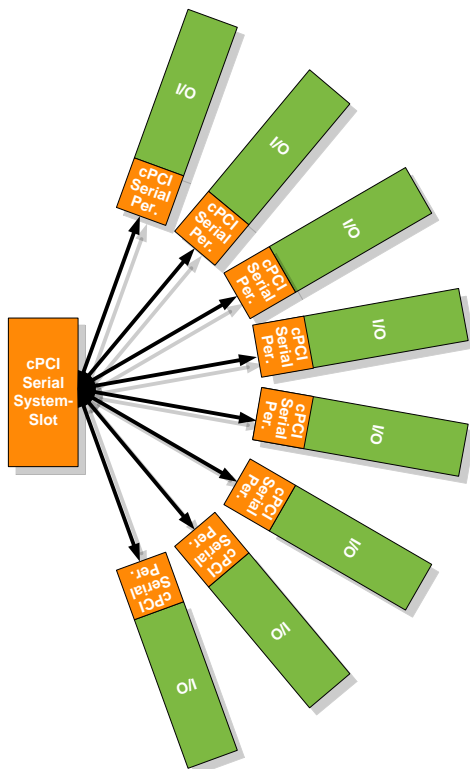
other hand a standard like this is easy to read, because this way one document contains all the technically relevant details.

CompactPCI Serial

Architecture Overview

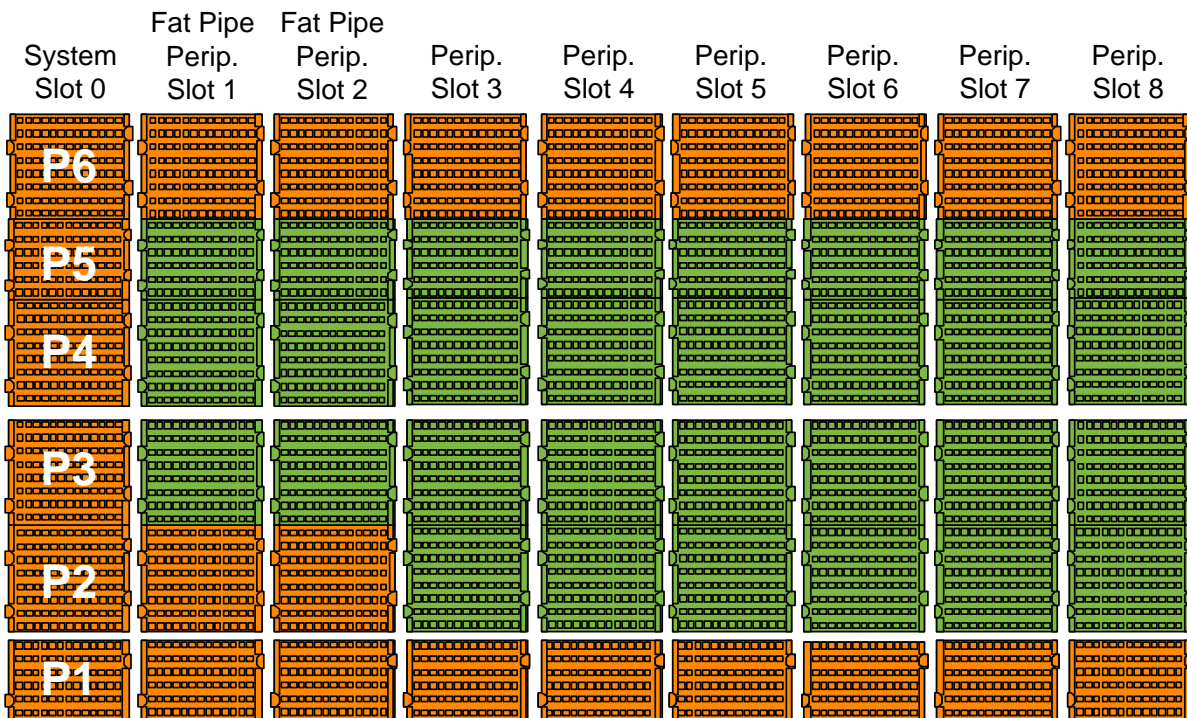
CompactPCI Serial is a design update for the proven CompactPCI. The new base standard of PICMG named CPCI-S.0 completely replaces the parallel signals by fast serial data transfer and introduces a new connector type. This way, CompactPCI Serial supports all modern point-to-point connections while keeping mechanical compatibility with IEEE 1101 and with the Eurocard format.

CompactPCI Serial is based on a simple, complete star topology equally for PCI Express (optionally also Serial Rapid IO, SRIO), SATA/SAS and USB. The system slot supports up to eight of these peripheral lots. No bridges or switches are needed for a system with up to nine slots.



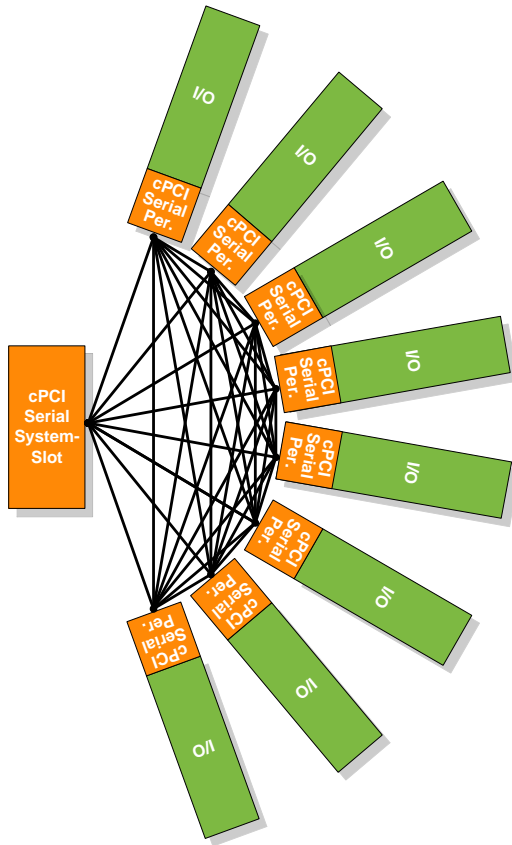
Star architecture with CompactPCI Serial

In principle all peripheral slots are identical. Only two are connected to the system slot using an extra wide PCI Express link called a Fat Pipe. These slots can be used for a high-end graphics extension, for example.



Slots in a CompactPCI Serial system

Ethernet is not wired as a star but as a full mesh network. In full mesh architectures each of the nine slots is connected to each of the other eight slots via a dedicated point-to-point connection. The wiring pattern has been chosen in such a way that – if a CPU board only supports two Ethernet interfaces – three slots are completely wired – even without switches, routing etc.



Full Mesh using Ethernet

Contrary to other concepts, the Ethernet transmission on the backplane is based on the proven standards for copper connections – 100BASE-T, 1000BASE-T and 10GBASE-T. This offers the advantage of unlimited interoperability even for different data rates. Electrical isolation is possible at least optionally, which ensures the absence of feedback from the boards. This is important for redundant, safety-critical systems. Besides, several systems can easily be connected to each other.

Key Characteristics

<i>Interface Type</i>	<i>System Slot</i>	<i>Peripheral Slot</i>
<i>PCI Express</i>	6 x4 links 2 x8 links (fat pipes)	1 link, maximum x8
<i>SATA/SAS</i>	8 channels	1 channel
<i>USB 2.0</i>	8 channels	1 channel
<i>USB 3.0</i>	8 channels	1 channel
<i>Ethernet 10GBASE-T</i>	8 channels	Up to 8 channels

CompactPCI Serial: Interfaces for system slot and peripheral slot

In addition, there are a number of signals to support these interfaces and for general system management, such as reset, IPMB, hot plug, geographical addressing, etc.

12 V are available for power supply, allowing a maximum power consumption of 60 W for one 3U slot. This includes the peripheral slots. The interfaces are all accessible at the same time. This is important, for example, for PCI Express Mini Cards, which expect USB as well as PCI Express support.

Wiring and Connectors

Star Topology using an Ethernet Mesh

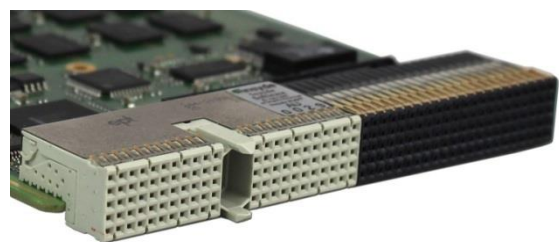
The architecture of CompactPCI Serial is a simple star of one system slot and up to eight peripheral slots, combined with a full mesh for Ethernet. The pin assignment for Ethernet is the same for the system slot and peripheral slots. One pin signals to the plugged-in board whether it is located in a system slot or peripheral slot.

This allows to plug a system-slot board (normally a CPU card) also into any peripheral slot. In this case some interfaces are not supported, of course – usually SATA. The Ethernet interfaces are always supported, however. Despite its star topology CompactPCI Serial supports symmetrical multiprocessing with up to nine CPUs in one system – without bridges and without a special backplane. With bridges even more are supported.

The New Connector Type

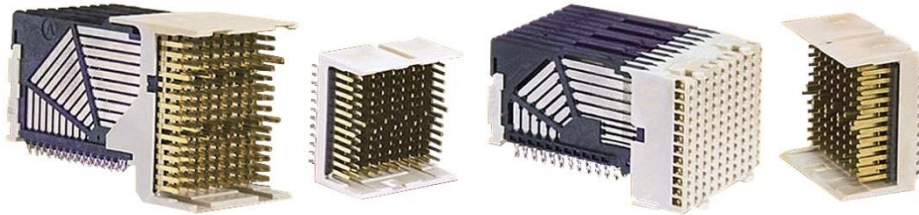
The usage of a new connector type allows for the necessary high signal density and high transmission frequencies of 12 Gbit/s and more. The AirMax connector (FCI, Amphenol TCS) offers space for up to 184 pin pairs on a 3U board. The high pin number is especially important for the system slot because of the above-mentioned star architecture of modern computers. It also allows using a multitude of free pins for customized rear I/O on peripheral assemblies. The mechanics of the connector meet the requirements of the IEEE 1101 and the look-and-feel is very much like that of the proven 2-mm-connector of the CompactPCI standard.

Compared to CompactPCI, the placement of the plug and receptacle connectors is swapped. The plug connector is placed on the plug-in card, while the receptacle connector is located on the backplane – just as in VMEbus systems. This makes twisted pins on the backplane a thing of the past.



CompactPCI Serial: Compared to CompactPCI the plug and receptacle are swapped

The AirMax connector was specially developed for use in harsh environments. For the plug connector, i.e. the connector on the plug-in card, there are versions that can be mounted side by side. They only have two walls. In other varieties the pins are enclosed by three or four walls.



CompactPCI Serial: Different versions of the AirMax connector

On a 3U board, there is always one connector with four walls and six pin rows. It is supplemented by several types mounted side by side and having two walls and eight rows. The final connector has three walls and eight rows.



CompactPCI Serial: Row of connectors on a plug-in board

On the whole this makes a plug connector that is protected on all sides and has a crossing wall at the center. This crossing wall supports the stability of the plug-in board, while preventing a CompactPCI Serial board from being plugged into a conventional CompactPCI slot and from twisting the pins there.

Look Back on CompactPCI: Keep What is Tried and Tested

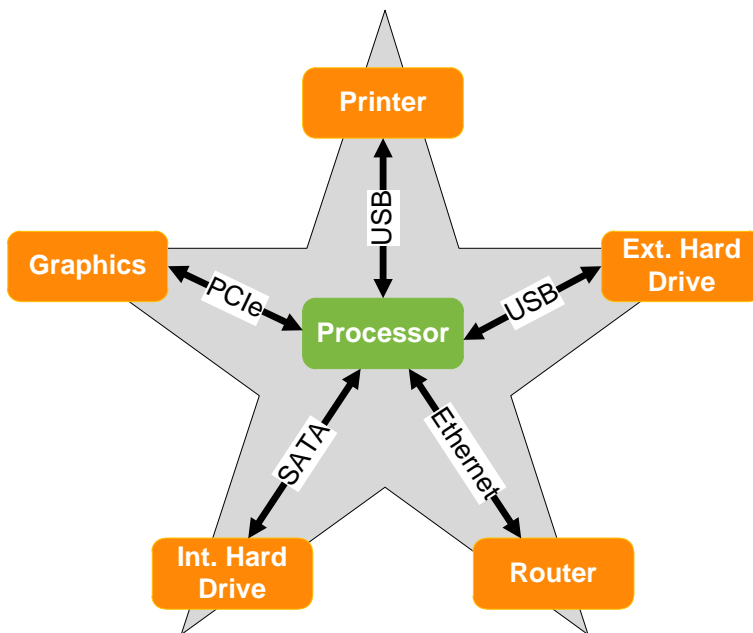
CompactPCI Serial is a design update to the proven CompactPCI. Together, they provide a future-safe platform for industrial computers. The architecture adapts to modern chipsets. As the mechanics are 100% compatible with IEEE 1101, you can use all standard 19" system solutions without limitations. The dimensions of the backplanes are identical to those of the CompactPCI backplanes and are fixed in the same way. Front panels and handles have not been changed either. The well-proven hot plug mechanics – the switch in the handle – remains the same and acquires a new meaning for hard disk RAIDs. Only the connector is replaced by a modern type which is able to support the high frequencies.

Computer Set-Up as a Star and Mesh

Modern Computer Architecture

Today's computer architectures no longer use parallel buses but point-to-point connections. With the parallel PCI bus disappearing, they now use a simple star topology. At the "center" there is the CPU chipset that is surrounded by peripherals like the points of a star. It centrally addresses the peripheral devices and components via PCI Express, USB, Ethernet or SATA – all of them serial point-to-point connections.

The electrical characteristics of these serial connections are easier to manage and they permit higher data transmission rates with fewer pins. With just one link (i.e. one differential receive and one transmit line), PCI Express already achieves 250 MB/s. Other bus participants do not limit the bandwidth of this connection. There is no direct influence. A higher number of links for a connection or a higher clock frequency further increase the data rate (up to 16 GB/s with PCIe 3.0) – and all this with full-duplex operation.



Traditional set-up of a computer system in star shape

This structure was used 100% for CompactPCI Serial. The system slot is the center of the star. Each peripheral board is a symmetrical point. This is inexpensive and simple. Suitable connectors are available – now also in rugged designs.

A Challenge: Modular and Inexpensive, Without Switched Fabrics

The star architecture is a technical challenge for the system slot and the backplane with modular computers like CompactPCI. The system slot must now provide a large number of connections. The backplane must spread all of these connections to the peripheral slots without needing too many layers. Standards like MicroTCA have defined switched fabric slots for this reason. These route the data over special backplanes as desired.

CompactPCI Serial intentionally does without such mechanisms, and without bridges and switches. A high reusability of standard components is essential for a cost-effective, modular computer system – in the end, the costs of a modular computer must stay competitive compared to non-modular computers.

This does not mean that you could not integrate any switched fabrics into a CompactPCI Serial system, if you wanted to build up complex structures, but you simply don't have to. Simple systems do have a market share of around 90% of all CompactPCI systems.

Star Architecture with Ethernet, PCI Express, SATA and USB

The star is supposed to be flexible and universal. This is why it must be able to control as many different devices as possible – but which? PCI Express as a replacement for PCI is especially used in a computer to communicate with further controller chips. It is the computer's classic "bus" extension and is software-compatible with its predecessor PCI.

But even serial connections need many connection lines. For **PCI Express**, there is at least one line pair for clock, one pair to receive data, and one pair to transmit data. To increase the bandwidth, you use several lanes, so that one connection can easily count nine line pairs or more. Because of the high data rate you also need to assure sufficient signal integrity, resulting in additional ground lines – at least one per signal pair.

Mass storage devices today are controlled using **SATA**, especially hard disks that are directly built into a computer. A RAID system where the hard disks are included as individual plug-in cards is a typical example of this. USB is another feature that you can hardly imagine not to find in a state-of-the-art computer.

There are three main fields of application for **USB**: removable storage (USB Flash drives, hard disks for data back-up etc.), wireless interfaces (GSM, UMTS, GPS, Wi-Fi) and the replacement of the classic serial interface. FTDI has set standards here. Devices that were formerly controlled directly via an RS232/RS485 interface are now serviced through a USB-to-serial converter. USB 2.0 is an established standard. USB 3.0 will be integrated in the latest chipsets of Intel, AMD and so on. Computers are interconnected using **Ethernet**, so that Ethernet needs to be another point of the star.

The Special Role of Ethernet

For Ethernet, CompactPCI Serial supports a full mesh network. This backplane wiring creates a dedicated connection of every slot with any other slot. Each of the nine slots in a CompactPCI Serial system is connected with each of the other eight slots via the backplane. (You can find more on the Ethernet mesh in Chapter [The Ethernet Mesh](#).)

Ethernet has taken hold as **the** interface for multicomputer systems. Since CompactPCI Serial allows using a system-slot CPU also as a peripheral card without any problems, it could hardly be simpler to build up modular systems. All CPU boards communicate via Ethernet. As these are point-to-point connections, no switch board is needed. Also, no special infrastructure or configuration is required.

Copper-Based Standards

CompactPCI Serial supports copper-based standards for Ethernet (10/100/1000BASE-T and 10GBASE-T). These standards offer important advantages compared to special Ethernet backplane standards:

- interoperability through autonegotiation even for different data rates
- support of standard Ethernet chips
- partly Ethernet controllers already included in the chipset
- extremely robust and fault tolerant
- no retroaction of the boards in case of a failure due to inductive or capacitive coupling
- easy expandability with more than nine plug-in boards even between board enclosures
- optional extension by standard Ethernet switches

One drawback is the higher number of lines: four line pairs per connection compared to two in the Ethernet backplane standard 1000BASE-BX. This standard only supports 1 Gbit/s, though. As many as eight line pairs are needed for 10GBASE-BX4 – with autonegotiation posing problems here. BASE-T is the future technology here, as it is simpler.

Simple but Flexible Set-Up

Does this mean that each CompactPCI Serial board has to be equipped with eight Ethernet channels? Not at all! Ethernet on the backplane is an option. Even with only one channel, communication with a second, identical card is possible. If there are two channels, a full mesh network with three CPU cards is possible, with three channels four boards can be interconnected etc. The backplane wiring was chosen in such a way that even with fewer interfaces all CPU boards are still completely wired if they are plugged next to each other.

CompactPCI Serial enables easy and cost-efficient multiprocessing based on Ethernet communication. Let us sum up the fundamental benefits:

- no switch boards are required in systems with up to nine slots
- full mesh network even with fewer Ethernet channels
- interoperability and future-safety by using BASE-T standards

Identical Peripheral Slots

For a modular computer to be simple and transparent in use, every peripheral slot must have the same features, i.e. must support all interfaces. Then the user does not need to be concerned about which slot supports which board.

With CompactPCI Serial all eight peripheral slots are identical, each supporting 1 PCIe x4, 1 SATA, 1 USB 2.0, 1 USB 3.0 and 1 Ethernet directed to the system slot. Every board can be plugged into every slot. There is only one exception: two slots support an additional PCIe x8 each. There are three main high-bandwidth applications for this addition: graphics, high-end telecommunications and CompactPCI Serial systems with more than eight peripheral slots. (You can find more on this in Chapter [PCI Express for High Bandwidth](#).)

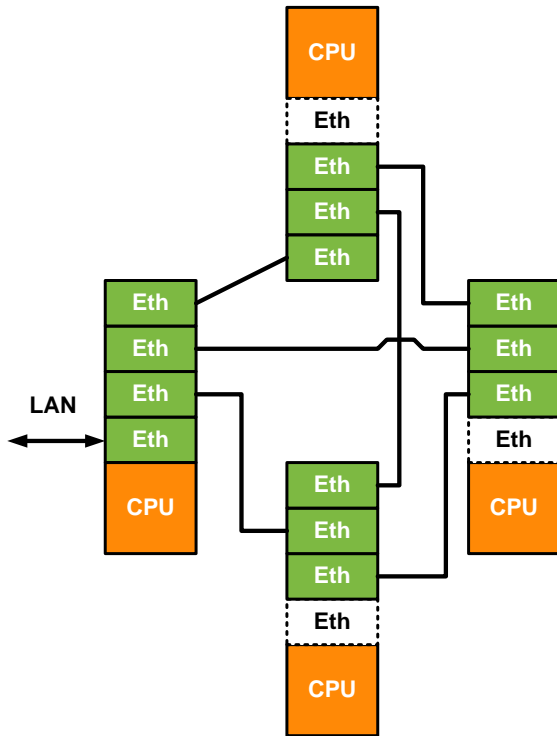
Typical Tasks of the Serial Interfaces

Ethernet for Complex Systems

CompactPCI Serial supports both star architecture and a full mesh network for Ethernet. While star architecture is fully sufficient for standard computers, a full mesh architecture is better suited for complex multicomputer systems.

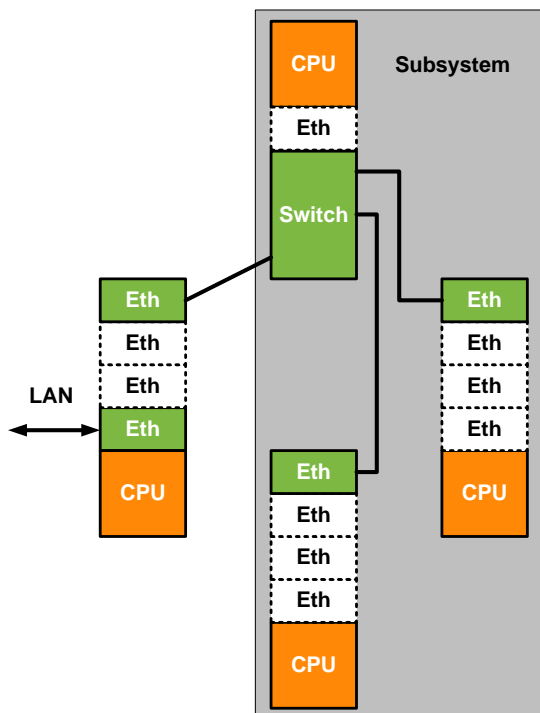
The Ethernet Mesh

In a full mesh, one Ethernet interface of every board is connected to exactly one Ethernet interface of another board. With a standard, nine-slot backplane you need eight Ethernet channels on every board, so that every board can communicate independently with any other board. As mentioned before, you do not have to fully use this option.



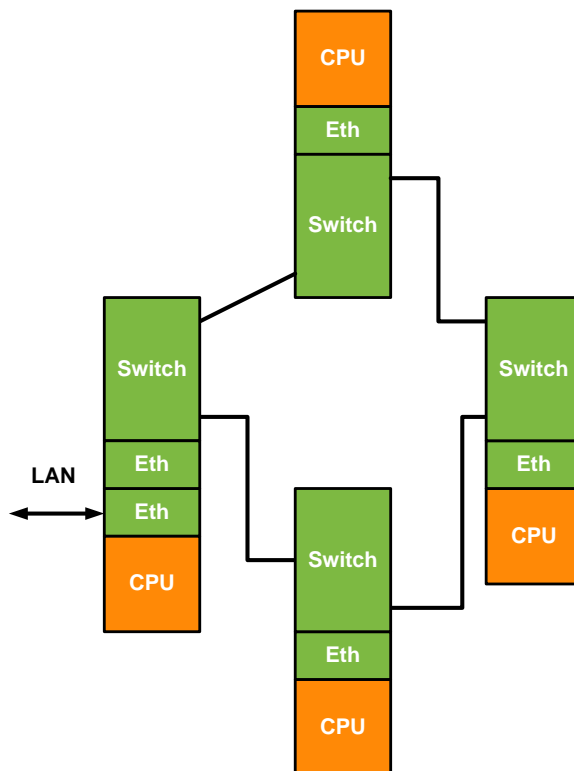
Full mesh with four boards, each based on three Ethernet channels

The above example shows how you can implement symmetrical multiprocessing in a CompactPCI Serial system. This way, you can also realize an architecture of intelligent subsystems:



Ethernet mesh for an intelligent subsystem

You can also connect the mesh network in the shape of a ring. This allows you to create redundant structures in an elegant and inexpensive way, where the failure of one plug-in board does not cause the failure of the entire system:



Ethernet mesh in ring structure

These are only some examples of architectures which can be realized using CompactPCI Serial. And all this can be done with standard backplanes and standard boards. All of the four boards shown in the above examples can be of the same type. Ethernet usage is determined by software.

As CompactPCI Serial is physically based on the BASE-T standards (10/100/1000BASE-T and 10GBASE-T), you can equip the boards with "common" Ethernet controllers. You can normally do without electrical or optical isolation between the boards. This allows capacitive coupling, saving space and costs.

Ethernet Mesh for Computer Clusters

If some years ago supercomputers were still built up of systems with a special technology, today mostly standard computer technologies are used. For this, a large number of single comparatively cost-effective servers are combined to form computer clusters.

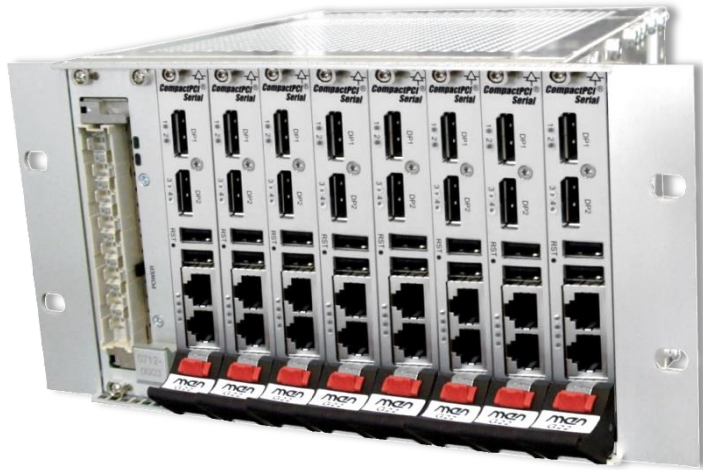
A computer cluster in most cases consists of a large number of single interconnected computers which are used to process parts of a total task in parallel. Seen from the outside a computer cluster acts as a single computer. The nodes are interconnected using a fast network. Building such server farms considerably increases the computing capacity and availability. In particular, the failure safety of a cluster compared to that of a single computer is a decisive advantage. If a system within a cluster fails, this has no direct influence on all other systems which are part of the cluster. This way redundancy is achieved.

Mainly two kinds of computer clusters are distinguished:

- **High-availability clusters** are supposed to increase availability and ensure better failure safety. In case of an error, the tasks of the defective host of the cluster are automatically transferred to another host. Areas of usage are applications in which down-times of only some minutes per year maximum are allowed.
- **High-performance computing clusters** are used to carry out calculations that are distributed over several hosts. From the user's point of view the cluster is a central unit, but which, from a logic point of view, consists of several networked systems. Fields of application are mostly found in the areas of science and military, but server farms for rendering 3D computer graphics and computer animations are also built up of this kind of cluster.

The CompactPCI Serial architecture is predestined for building high-availability clusters. But also for compact systems with high computing performance, solutions based on CPCI-S.0 are hard to beat.

The distribution computer responsible for this part of the cluster is plugged into the system slot, for example. It is connected to the eight cluster nodes via a 1 Gbit/s (optionally 10 Gbit/s) full-mesh Ethernet network. Such a 9-slot unit is a typical sub-cluster in a cluster network. Based on modern Intel technology it provides $9 \times 4 = 36$ cores with 4 GB memory each, for instance. For availability reasons, the sub-cluster, which has a typical power consumption of 400 W, is equipped with its own PSU, which can also be redundant if required.



Computer cluster with CompactPCI Serial

Eight of the sub-clusters are connected via Ethernet to form one cluster. A CompactPCI Serial computer is used for central management tasks as an NAS (Network Attached Storage). In total, the system has 288 cores plus management units. This cluster computer consisting of CompactPCI Serial components has a power consumption of only 3500 W and needs 20 U in a 19" cabinet. The total volume of the CompactPCI Serial cluster is only 50% of that of a solution with 1U servers. If required, it is also suited for operation in extreme temperature ranges and in mobile applications.

Ethernet in Safety-Relevant Systems

Safety-relevant computers often use the principle of redundancy to detect errors. If two computers are combined, this is called a 2-out-of-2 system. These two computers are often diverse, i.e. they differ, to avoid the occurrence of what are called common cause errors. Besides safety, availability is also of special importance for applications in critical areas.

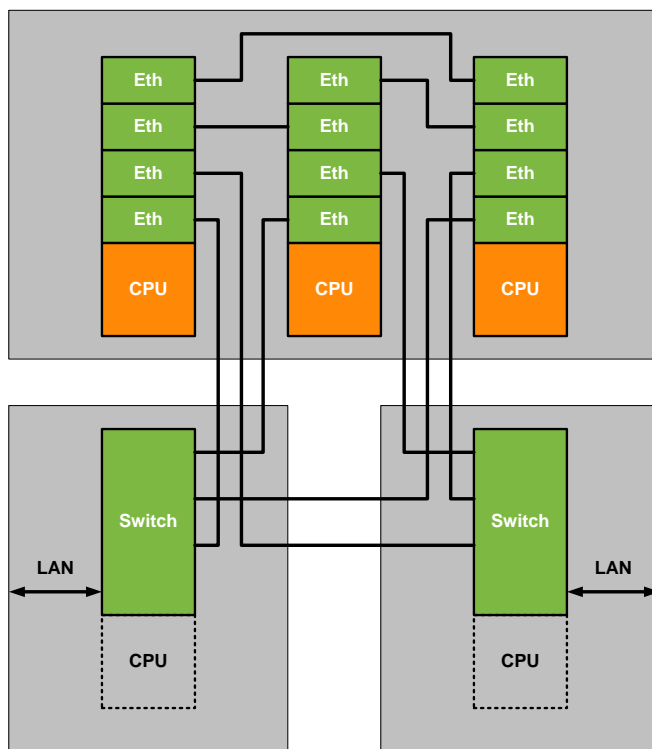
Availability is also achieved through redundancy. If non-diversitary subsystems are extended by another subsystem, you get a 2-out-of-3 system. For diversitary 2-out-of-2 systems, the desired availability is achieved by doubling the whole 2-out-of-2 system.

The computers have to compare and align their results. To do this, they need an interface which on the one hand offers a high enough data transfer rate and on the other hand guarantees absence of feedback. After all, the defect of one computer is not supposed to paralyze the whole system. Ethernet, especially the electrically isolated communication standards (10/100/1000BASE-T and 10GBASE-T) are particularly well-suited.

CompactPCI Serial particularly focuses on safety-relevant systems. For this reason, additional features such as hot plugging are included beside Ethernet as the communication interface. A board can be removed from the system without interrupting the function of the other computers. As the communication between the boards is based on Ethernet which implicitly supports hot plugging already, not even a special hot plug controller is needed for this function. A single 12V power rail is used as the main power supply. Building up redundant PSUs is especially simple if they only have to supply one output voltage.

A 2-out-of-3 system might for example consist of three CompactPCI Serial subsystems. Each subsystem would have its own independent standard backplane with possibly independent PSUs. The connection of the subsystems can be done via Ethernet and rear I/O (another advantage of BASE-T).

For wiring 2-out-of-3 systems, a full-mesh-architecture is well suited. A standard backplane accommodates three identical CPU boards. Switches, which are also redundant, can also be realized as independent CompactPCI Serial components on standard backplanes. The wiring of the subsystems among each other is possible with rear I/O. A customer-specific backplane will be helpful for optimizing this system function.



2-out-of-3 system with Ethernet full mesh architecture

Modular Set-Up using Mezzanines

Ethernet mezzanine boards are plugged directly onto the system slot CPU and lead up to eight Ethernet ports to the backplane via the dedicated P6 connector. They are used for the communication with (intelligent) peripheral slot boards in a star or mesh architecture.

A special feature of these Ethernet mezzanines is that the CompactPCI Serial system connector P6, where the Ethernet signals are routed to, is not located on the CPU board but directly on the mezzanine. In contrast to previously known mezzanine standards, the signals are led directly to the backplane and do not have to be routed over the carrier board.



Mezzanine with backplane connector P6 for Ethernet configuration of the system slot CPU

Another advantage of mezzanines is the flexible number of channels. The requirements can vary greatly, depending on the application. Nevertheless, you can always use a standard CPU card.

For building up a full mesh network for all nine plug-in boards, you would need one mezzanine each with the maximum of eight channels, in order to independently communicate with any other board. In simpler multiprocessing systems where a star architecture is sufficient, the same mezzanine module is used – in this case only once plugged onto the system slot CPU.

Ethernet at the Front using Peripheral Boards

A possibility for using Ethernet at the front are CompactPCI Serial peripheral boards. These cannot only be operated in pure CompactPCI Serial systems, but also ensure fast connection in hybrid systems with a system slot according to CompactPCI PlusIO. (You can find more on hybrid systems in Chapter [Hybrid Systems](#).)

Using specialized peripheral cards has many benefits for particular requirements:

- high data rates
- special configuration options, e.g., simultaneous operation of all channels, or optionally two redundant channel pairs
- usage of fiber-optics connections (e.g., 1000BASE-SX)
- design for harsh environments, e.g., for an operating temperature of -40 to +85°C
- configuration for market requirements, e.g., with M12 instead of RJ45 connectors for railway applications

Ethernet interface cards are peripheral boards that extend the number of the available ports of the system slot CPU on a separate slot. The connection is done via PCI Express on the P1 connector. Switch boards offer additional possibilities. Using an Ethernet switch in the system slot, multicomputers with CPU boards in the peripheral slots can be built up, for instance – via the P6 connector. A switch in the peripheral slot on the other hand offers the typical characteristics needed for connecting external devices – without software overhead.

PCI Express for High Bandwidth

Contrary to other serial interconnects such as SATA and USB 3.0, PCI Express is not limited to a single lane (a differential receive and transmit signal line pair) but combines up to eight of these lanes in parallel (PCI Express x8).

This makes PCI Express perfect for high bandwidths. CompactPCI Serial systems, too, use it wherever a lot of data are transmitted, especially for backplane communication between the CPU board and high-performance peripheral boards. Based on PCI Express 3.0, theoretical data rates of 8 GT/s per lane and direction between boards and a total of more than 80 GB/s (bidirectional) inside the system are possible.

Graphics

Similar to a classic PC, a modular computer is supposed to be able to control displays, too. Many chipsets have a built-in graphics controller today. As a rule, the CPU and graphics controller share the main memory in this architecture. This way, cost-effective and well-fitting solutions can be achieved for low to medium requirements especially in the 2D area.

If displays with a very high resolution are to be controlled, the bandwidth of this shared memory reduces both the performance of the CPU and of the graphics unit. If you want to operate several high-resolution displays at the same time or if you have higher requirements regarding the graphics itself (e.g., 3D rendering), it is advisable to use an external, independent graphics controller with its own video memory.

If you choose an external graphics controller, the data transfer rate of the connection between the chipset and the graphics controller is the critical factor for the performance. For this reason, this connection has significantly promoted the development of PCI Express.

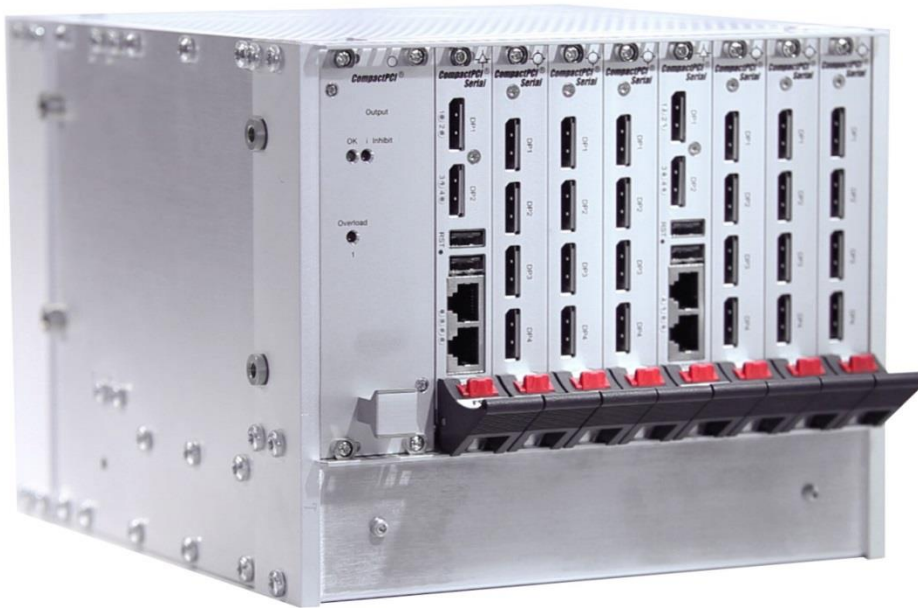
Especially for controlling the graphics card, you often use the complete bandwidth, i.e. PCI Express x16. As it is relatively frequent that more than one graphics card has to be controlled, all common chipsets and graphics controllers support a mode which splits the PCI Express x16 link into two x8 links. This splitting halves the maximum burst data rate. This is compensated for, however, by the constant advancement of the transmission frequency at the PCI Express interface (PCIe 1.0, PCIe 2.0, PCIe 3.0 etc).

Special Architecture for Graphics Extensions

Graphics extensions are one reason for the special CompactPCI Serial architecture. Two slots are connected to the system slot via two PCIe x8 interfaces. This way, two peripheral slots of a CompactPCI Serial system that uses a standard backplane can be equipped with high-performance graphics cards.

As all other peripheral slots are driven using PCIe x4, you can generally plug graphics cards into any peripheral slot. The performance is not quite as high there, but still sufficient for many applications.

Modern graphics chips are able to control up to four high-resolution displays simultaneously via DisplayPort. A CompactPCI Serial system can accommodate up to eight graphics cards without using bridges, making it possible to control 32 displays with the corresponding software.



19" system with eight graphics cards for control of 32 displays

This extensibility shows that the CompactPCI Serial architecture is very well suited for applications which far extend the possibilities of the parallel CompactPCI. You can now even equip control rooms of power stations, railway control centers, or even video walls with CompactPCI Serial systems.

Networking

The second classic application for PCI Express is in networking. Ethernet controllers and switches in high-end telecommunications also need high bandwidth. In many cases, it is DSP or FPGA based boards that benefit from PCIe x8. For these applications, it makes sense to use 6U boards, which also benefit from the rear I/O functionality of CompactPCI Serial. 6U boards can communicate with their I/O via any type of connector – even optical – in the rear area of the system. You can find more on this in [Chapter Individual Rear I/O for 3U and 6U](#).

Extending Peripheral Slots using Switched Fabrics

Another application is CompactPCI Serial systems with more than eight peripheral slots. For high-end systems, you can plug a switched fabric board into the system slot instead of a classic CPU. The CPU is located in a peripheral slot and communicates with the switched fabric via PCIe x8. The latter forms the interface to several CompactPCI Serial subsystems, in order to implement complex systems with 9+8 or with 9+16 slots.

SATA/SAS for RAID Systems

An important reason for extending CompactPCI to CompactPCI Serial was the possibility to realize RAID systems. For this reason SATA/SAS signals are available on the backplane beside the other interfaces. This way, you can use every peripheral slot as a hard disk slot. The system slot can then control up to eight hard disks – again in a star layout.

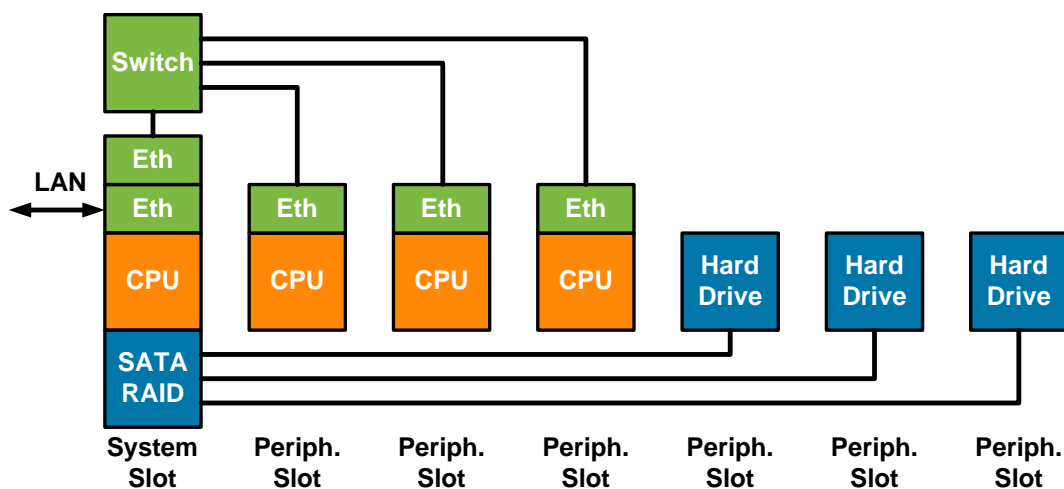
In a hybrid system, where the backplane brings together CompactPCI Serial peripheral boards with a conventional CompactPCI CPU or a CompactPCI PlusIO CPU in the system slot, you can at least control up to four hard disks. You can find more on CompactPCI PlusIO and hybrid systems in Chapter [Hybrid Systems](#).

The CompactPCI mechanics, which has been taken over unchanged for CompactPCI Serial, offers all characteristics that a RAID shuttle needs:

- Robust plug-in mechanics
- switch in the handle to signal removal of the hard drive
- (blue) LED to signal that the board may be removed

RAID System as a Multiprocessor NAS

With a centralized Ethernet connection the system can also act as an NAS (Network Attached Storage). A RAID system like that might look as follows:



RAID system with NAS connection

In this system with several CPUs, all CPU boards are identical, but only the CPU in the system slot uses its RAID controller and also has a plug-on switch to communicate with the other three CPUs over the backplane. These are plugged in the peripheral slots and have neither a switch nor a RAID function in the system.

Usage of SGPIO

CompactPCI Serial includes even more mechanisms that are required for a RAID system. For example it is possible to determine the disk to be changed through the physical addressing. A management bus which is compliant to the SFF-8485 specification provides the necessary communication between the RAID controller and the shuttle. SFF stands for Small Form Factor Committee, www.sffcommittee.org, where companies like Seagate, Sun, LSI, IBM and Intel push new standards.

The SFF-8485 standard defines a serial GPIO bus (SGPIO) especially in connection with Serial Attached SCSI (SAS) and Serial ATA (SATA). It serves for exchanging data between the RAID controller and the hard disk shuttle. It can transmit simple status information (e.g., "switch closed", "hard-drive powered") and control LEDs or monitor the power supply of the hard drive. The SGPIO bus is dedicated to the SATA/SAS functionality and independent of the system management bus of the CompactPCI standard.

The SGPIO bus uses four signals for data transmission:

- **SClock:** a clock cycle signal driven by the RAID controller
- **SLoad:** a synchronization signal to determine the start and the end of a transmission frame – also driven by the RAID controller
- **SDataOut:** the data output signal of the RAID controller
- **SDataIn:** the data input signal of the RAID controller. Here the shuttles transmit the status information while the time slot in the data frame corresponds to the physical address.

Extensions over the Backplane

Using SATA port multipliers even more than eight drives can be controlled in a CompactPCI Serial system. For this, a custom backplane is needed which can have more than eight SATA/SAS slots. A customer-specific solution could be to only specify part of the slots for SATA/SAS. Such a system could for example consist of eight slots for PCI Express, USB and Ethernet as well as of eight additional slots for SATA/SAS hard drives.

You can find more on specific backplanes in Chapter

[Application-Specific Backplane Architectures](#).

USB for Mobile Functions

While PCI Express is a relatively common backplane interface, USB seems to be rather unusual. USB is in fact a widely used standard for the connection of peripheral devices like keyboard and mouse, USB Flash drives and external hard disks especially to mobile computers.

Nearly all modern laptops also provide what are called Express card slots. These allow to retrofit the computer externally, for instance by GSM/UMTS modems. Express cards are based on USB and alternatively on PCI Express. Internally, laptop computers also use both interfaces to connect so-called PCI Express Mini Cards.

In order to be able to use all PCI Express Cards and PCI Express Mini Cards even in a modular 19" computer, you must also support these electrical interfaces – both USB and PCI Express in one slot. This way you can equip CompactPCI systems with wireless technology.

To keep things most simple for the users, they should be able to put any board into any slot. This is the case with CompactPCI Serial. The CPU centrally controls USB and PCI Express, and distributes the signals to each of the eight peripheral slots via the backplane.

Modules with a higher bandwidth usually use a PCI Express interface (e.g., WLAN), while USB is sufficient for modules with a lower bandwidth such as GSM/UMTS. With just one link (i.e. one differential receive and one transmit line), PCI Express v1.x already achieves a bandwidth of 250 MB/s. USB 2.0 falls far behind with its 480 Mbit/s. However, USB 3.0 reaches bandwidths similar to PCI Express.

CompactPCI Serial defines both USB 2.0 and USB 3.0, making it future-proof.



CompactPCI Serial peripheral card for PCI Express Mini Cards with antenna connectors at the front for wireless communication

Hot-Plug Functionality

The possibility to change individual assemblies during operation without damaging them and without disturbing the function of the computer is called hot plugging. This is a very useful feature particularly for modular computers. At the same time it has originally caused great efforts. This is different with CompactPCI Serial.

As the CPCI-S.0 specification consequently works with serial interconnects, many technical problems are solved implicitly. Ethernet, USB, PCI Express and SATA already support hot plugging. Naturally, some (simple) measures are required in order to be able to use this in a 19" system according to IEEE 1101.

Requirements for Hot Plugging

Power Supply

Minimum requirements concern the power supply, for example: In the instant of a load reversal due to plugging in or out a board it has to be ensured that the voltage remains in the allowed range. However, as the main voltage is 12 V, the tolerance is very high here. In addition, the module may not cause too high a surge current – with modern voltage regulators, the so-called soft start is state-of-the-art, however.

Slots and Hot-Plug Controllers

If you remove a board, you want to know which slot is concerned. Physical addressing enables this using four pins on the backplane. To access this information an interface to the hot-plug controller is needed. When is a hot-plug controller required?

If a peripheral board is based on Ethernet, for example, no controller is needed at all. This only works, however, because CompactPCI Serial is based on Ethernet standards for copper cables (100/1000BASE-T and 10GBASE-T). The situation is similar for assemblies based on USB – but here software interactions are often required ("You can now remove the device"...). In this case, it might help to support this action using a hot-plug controller: a switch announces the action and an LED signals the state. This switch is already specified for CompactPCI in the handle and does not have to be invented anew.

Using another well-established standard – SGPIO or SFF-8485 for RAID controllers – this information is sent to the hot-plug controller. SGPIO is a very simple interface, which transfers binary signals in real time using four lines. (Cf. Chapter [Usage of SGPIO](#)) It is already integrated in many chipsets, meaning the hot-plug controller does not cause any additional costs. PCI Express per se also supports hot plugging. The software overhead for supporting the non-transparent PCI Express bridges may not be underestimated, though.

Typical Applications

There are a number of quite different applications for which CompactPCI Serial and hot plugging are perfect. This is why hot plugging is an integral part of CompactPCI Serial. Applications range from a pluggable hard disk to RAID systems to complex multiple systems.

Hard Disk Drives

For example, imagine a hard disk that has to be quickly exchanged when there is an error. Or a quick way is required to access data recorded on the hard disk of a data logger. Then there are hard disk RAID systems, of course, which make it possible to exchange defect disks during operation without impairing the computer's functionality. All these examples are based on SATA (see also Chapter [SATA/SAS for RAID Systems](#)). A hot-plug controller is needed under certain circumstances, which in most cases is already integrated in the chipset.

Wireless Systems

Other applications are wireless solutions using Express Cards. These can be integrated on a CompactPCI Serial peripheral board with Express Card slots and are based on USB and/or PCI Express. As known from notebooks, you can plug in such cards during operation and can also remove them with software control. This comes in very handy when servicing is required. A separate hot-plug controller is not needed.

Multiprocessing

Complex multi-processing is also possible based on PCI Express. CompactPCI Serial allows the integration of up to nine CPU boards in one system without bridges (with bridges even more, of course). Communication is controlled centrally via the system slot. This way, very high data rates can be reached in clustered systems. No special hot-plug controller in the system slot is required, either.

It is much easier to build multiprocessing systems based on Ethernet. In a full mesh network, every card can directly communicate with every other card without using a switch, so the system slot is not a Single Point of Failure anymore, i.e. no central point that disrupts the entire system when failing. Special software is not required either.

Conduction Cooling

Good thermal management is a decisive factor for the reliability of computers. By a simplified formula, a computer's life is halved by every temperature step of 10 K (Kelvin). In CompactPCI systems, two basic types of cooling are common today.

Convection Cooling

The simplest technique is of course natural convection. Since warm air is lighter than cold air, warm air rises. The flow speed, however, is relatively low. For this reason, you require sufficiently large ventilation slots and large heat sinks. If you want to operate a CPU board with a power

dissipation of 25 watts at 85 °C, for example, you need a heat sink that covers the space of several slots in the system.

A smaller heat sink is possible if you accelerate the air using fans (forced air cooling). CPU fans directly attached to the boards need a lot of maintenance and are not an option because of their lack of reliability. Instead, the card cages are ventilated as a whole. This works well as long as the heat dissipated per slot does not exceed a certain extent, and as long as sufficient air flow, which must also be cool enough, can be guaranteed. The fan tray level below the card cage in turn needs maintenance.

Conduction Cooling

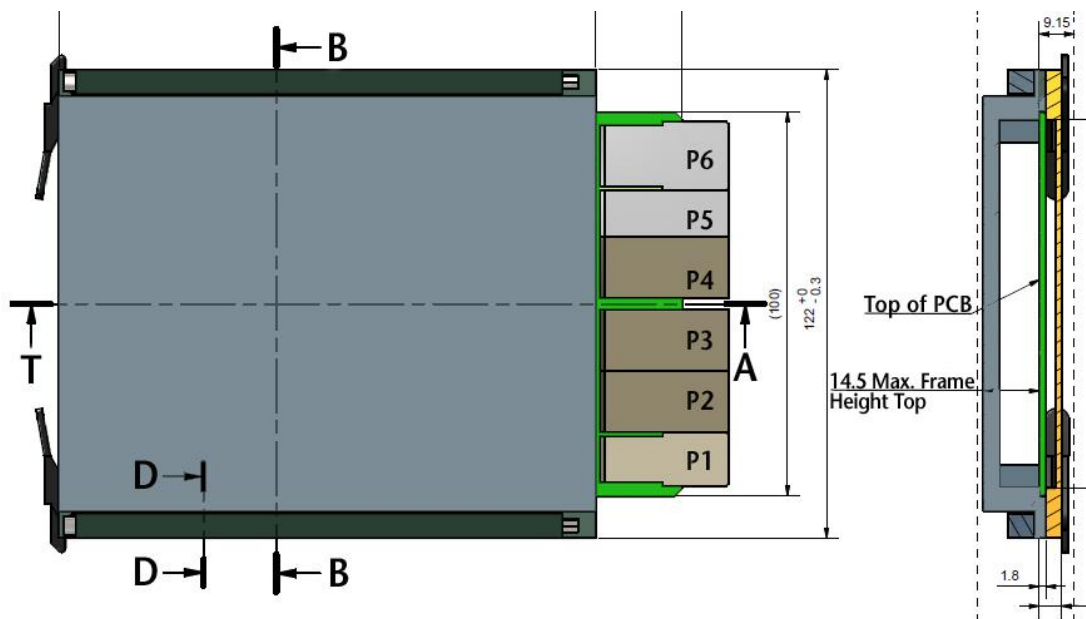
For even more demanding applications, for instance on board an airplane, the so-called conduction cooling technique is common. Strictly speaking, the term does not even mean the cooling of the boards but only the transfer of the boards' heat out of the enclosure. To do this, the conductive material is directly connected to the heat source.

Usually the board is framed by a tailor-made aluminum block, which takes off the heat and directly transfers it on to the massive enclosure wall over special tensioning wedges called "wedge locks", which also consist of thermally conductive material. This allows to make the enclosure hermetically tight, and to give it particular mechanical stability. Of course, the heat must then be transferred away from the outside of the housing through further measures (e.g., by a fan). Liquid coolers are also suited to do this.

The Approach of CompactPCI Serial

The IEEE standard on which the CompactPCI specification is based defines a special geometry for boards with conduction cooling, which does not allow cooling a board both by convection and by conduction cooling without further efforts. As quantities of conduction-cooled boards are rather low, such boards are especially expensive.

This is why the CompactPCI Serial specification takes another path. Any convection-cooled card can be converted into a conduction-cooled card using an individual aluminum block. Saving development costs for special conduction-cooled boards allows CompactPCI Serial to employ a technology that used to be expensive on a broad basis.



CCA aluminum frame for CompactPCI Serial assemblies



Standard board inside a CCA frame (left) and conduction-cooled housing (right)

Physical Addressing

Most modular computers support what is called physical addressing. For CompactPCI Serial this addressing is particularly important.

Benefits and Pitfalls

Modern serial buses such as SATA, PCI Express or Ethernet support all mechanisms for automatic configuration to simplify installation of new hardware. For instance, if you connect a hard disk to a computer using SATA, this drive will be automatically recognized and can be used without any further configuration.

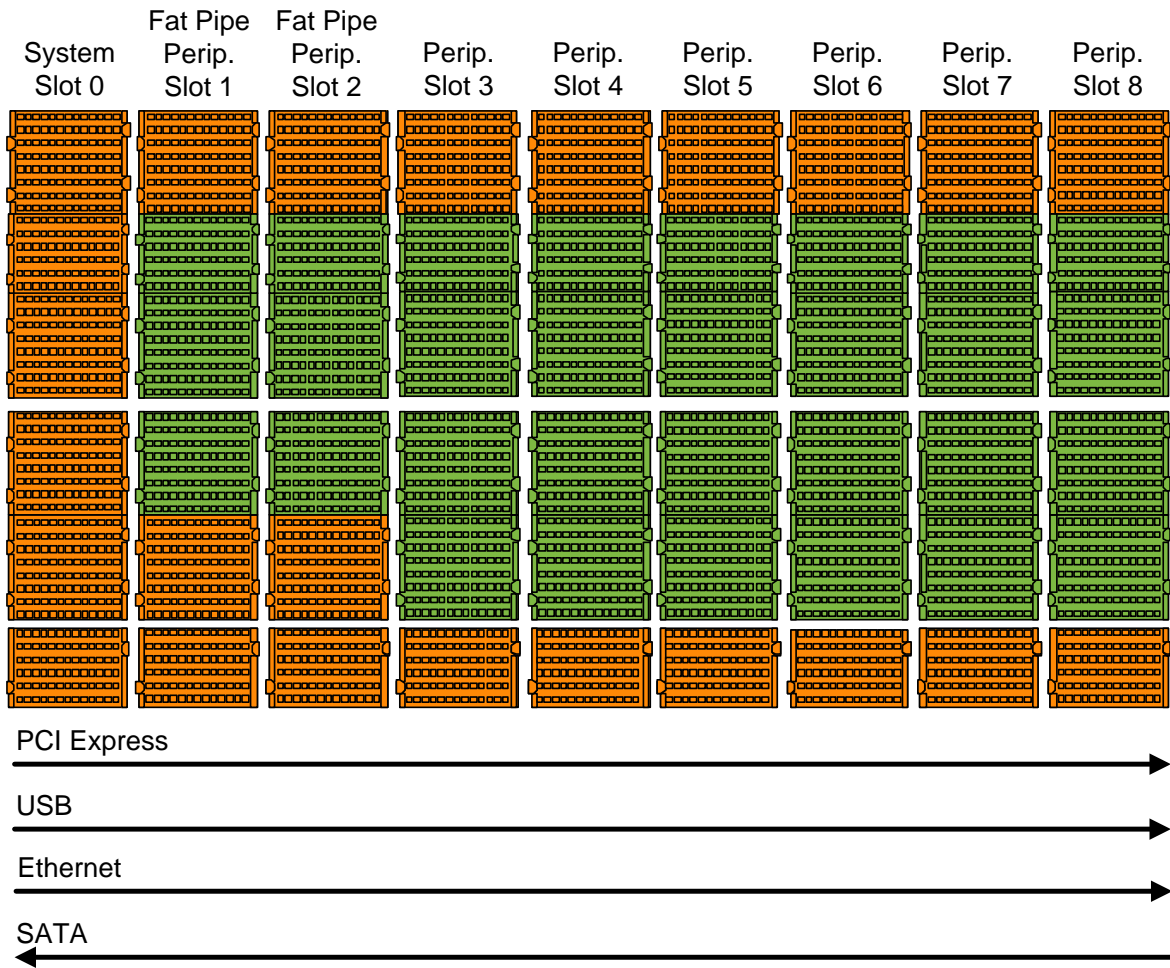
This advantage can at the same time be a pitfall – just think about a hard disk RAID configuration. In the case of a failure, you have to find and replace the right drive. This problem is also known with USB devices. If you connect two USB Flash drives to a computer, you don't know which drive is accessed where.

Physical Addressing with CompactPCI Serial

This is why physical addressing is a necessity for modular computer periphery. CompactPCI Serial considers this as well. The system slot is recognized by a special signal (*SYSEN*), not needing any additional address information. Even if the base standard does not explicitly describe this, you can of course expand the eight peripheral slots using suitable bridges. Since a 19-inch card cage accommodates a maximum of 21 slots, four lines *GA[3:0]* are provided for geographical addressing to distinguish these slots. Depending on the backplane position, these lines will be either left open on the backplane, permanently connected to ground (GND), or connected to ground with a 1-kOhm resistor. This results in 24 different combinations.

To assure the compatibility of different manufacturers, the CompactPCI Serial specification prescribes the order in which interfaces like SATA must be implemented on the system slot, if not all eight interfaces can be supported. If a CPU board is able to support only two SATA channels, for example, these need to be SATA 7 and 8 (SATA 1 to 6 remaining unsupported).

The base specification defines slots 7 and 8 to be implemented at the very right of the system, if only two SATA channels are used. (See implementation order in the figure below.) RAID controllers expect the first drive at address 0. For this reason, the slot at the very right of the system has ID 0 (i.e. all four address lines *GA[3:0]* are connected to GND). Accordingly, the neighboring slot to the left has ID 1, and so on.



Implementation order of interfaces with CompactPCI Serial

The physical addressing of CompactPCI Serial is compatible with standards like SFF-8485 (SGPIO) for hard disk RAIDs.

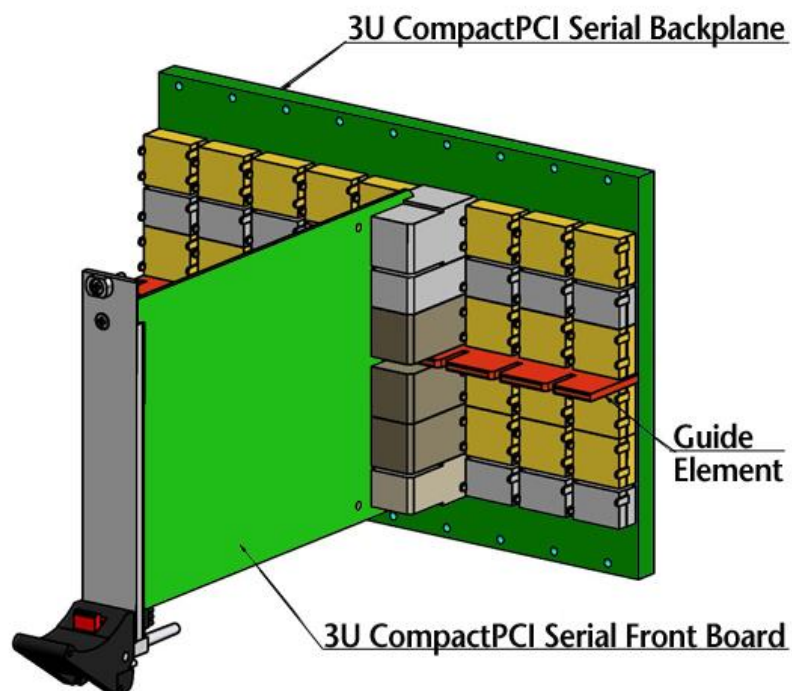
Mechanics

The Guide Element

In total, the CompactPCI Serial standard defines up to six individual connectors for single Eurocards and seven individual connectors for double Eurocards.

Depending on the function of the board, a different number of these connectors are assembled. A peripheral board in 3U format is usually only equipped with one connector at the backplane. This saves costs. There is a drawback to this, however.

A bigger connector helps to stabilize the board mechanically. Several modular connectors positioned next to each other are not capable of this. As the main focus of CompactPCI Serial has been usage in harsh environments from the start, an additional element has been introduced – the so-called guide element – for guiding, holding and stabilizing the plug-in card on the backplane.



The guide element at the center of the backplane

This way, a 3U assembly is also guided in the middle of the backplane, when only one (the lowest) connector is assembled. Due to this, the PCB cannot bend. The shock and vibration resistance is higher.

Connector Usage and Coding

CompactPCI Serial uses so-called AirMax connectors instead of the metric 2-mm connectors of CompactPCI to link the plug-in card to the backplane. These connectors were chosen for their high pin density, their excellent transmission behavior with high signal frequencies, and for their mechanical robustness. They are completely compatible with the IEEE 1101 standard, the common mechanical basis of CompactPCI and CompactPCI Serial.

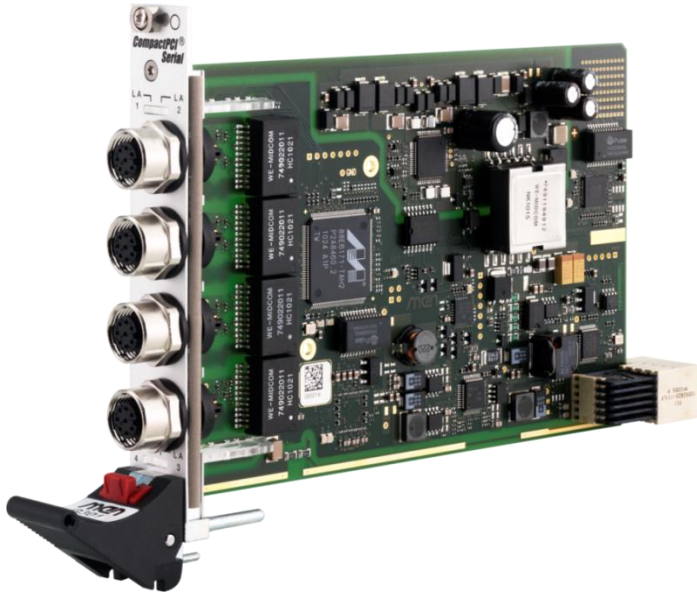
Mechanical Fitting of the AirMax Connectors

The pins of the connectors do not protrude through the backplane anymore. With the 2-mm connectors, the pins of the connectors that were press-fit from the front protruded to the rear side, and a plastic shroud was put over them from the rear. With the AirMax connectors, this is solved by pressing in connectors on the backplane from the front and in the rear I/O area from the back. The only prerequisite to do this is a specific thickness of the backplane.

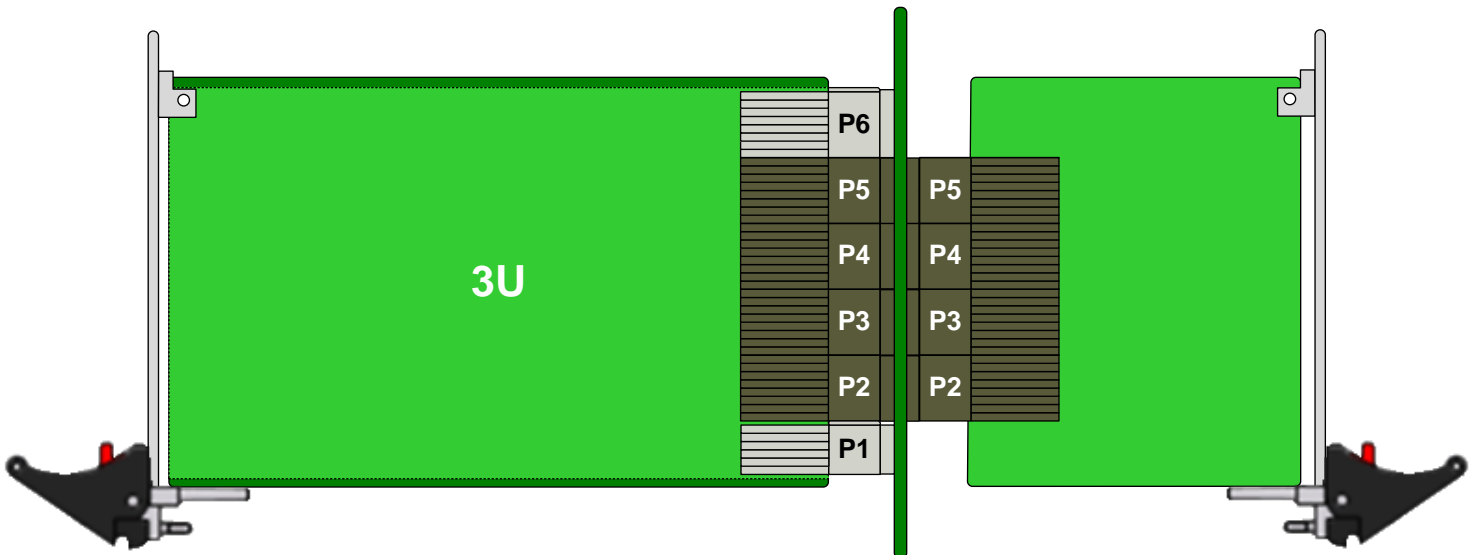
CPCI-S.0 now defines ground pins between the signal pins following a dedicated pattern. If you look at the backplane from the rear, this pattern is mirrored. It is an advantage of the AirMax connectors that there are no special ground pins in the connector. No problems occur when connectors are press-fit from two sides. Contrary to the common CompactPCI standard, CPCI-S.0 uses receptacle connectors instead of plug connectors on the backplane, so that twisted pins are a thing of the past.

Segmented Connector Block

The connector has segments. This means that depending on the board's function, not all connector segments are assembled. Especially connectors P2, P3, P4 and P5 are specified for user-defined I/O on peripheral cards and offer a total of 360 pins, 120 pins of which are normally defined as GND. If a rear I/O board is connected at the rear of the backplane, and the I/O functions are customized, the pin-out must correspond 100% with the front board. If you plug a card with a customized signal assignment into a wrong slot, the card could be damaged.



Connector P1 on a standard peripheral card (Ethernet switch) in CompactPCI Serial



Connectors P2 to P5 for user-defined I/O

The layout of the boards and backplane summarizes P2 and P3 as well as P4 and P5 as one hole-pattern block. As long as the block is completely assembled, you can populate it with any desired AirMax connectors. There are AirMax connectors with 6, 8 and 10 rows. The connectors are mechanically coded. A plug connector with 8 rows, for instance, cannot be plugged into a receptacle with only 6 rows.

The standard prescribes that block P2-P3 may be populated by two 8-row connectors, but also with one 6- and one 10-row connector. This makes for three possible P2-P3 configurations: 6-10, 8-8, 10-6. Block P4-P5 can be populated by 8-6 or 6-8. This makes a total of six different connector arrangements for customized I/O boards. The corresponding backplane must be populated by the receptacles matching the I/O board but uses the standard layout.

<i>Designation</i>	<i>Type</i>	<i>Number of Rows</i>	<i>Number of Walls</i>	<i>Implementation</i>
<i>P0</i>	<i>A</i>	<i>6</i>	<i>4</i>	<i>Optional</i>
<i>P1</i>	<i>A</i>	<i>6</i>	<i>4</i>	<i>Mandatory</i>
<i>P2</i>	<i>B</i>	<i>8</i>	<i>2</i>	<i>Optional</i>
<i>P3</i>	<i>B</i>	<i>8</i>	<i>2</i>	<i>Optional</i>
<i>P4</i>	<i>B</i>	<i>8</i>	<i>2</i>	<i>Optional</i>
<i>P5</i>	<i>C</i>	<i>6</i>	<i>2</i>	<i>Optional</i>
<i>P6</i>	<i>D</i>	<i>8</i>	<i>4</i>	<i>Optional</i>

Standard configuration of the connectors according to CompactPCI Serial specification

This coding option is another alternative to those already provided by IEEE 1101. The connectors are assembled correspondingly when the board and backplane are manufactured, so that the user cannot make any mistakes.

Two Card Formats: 3U and 6U

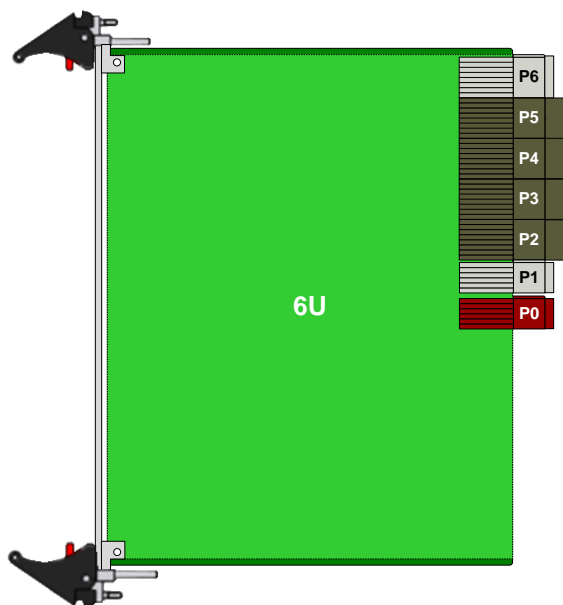
Just like parallel CompactPCI, CompactPCI Serial defines two standard board sizes: single and double Eurocards. The smaller single Eurocard format (100 x 160 mm, 3U) is particularly suited for compact and mobile applications. In the fields of servers, telecommunications and measurement, larger card formats (233 x 160 mm, 6U) may even be an advantage, since the electronic components need more space and can draw more power.

Compatibility of Formats

The two formats are electrically and mechanically compatible. This means that you can insert 3U boards also into 6U systems without restrictions. The connector types and even the pin assignment are identical. The only difference is that for 6U boards an optional connector (P0) was added to amplify power supply and to provide additional Ethernet channels as an infrastructure bus for server applications.

However, 3U boards with CompactPCI Serial are not inserted at the bottom, as for CompactPCI, but at the top, as was the case for the older VMEbus standard. This has two reasons. On the one hand, it is necessary to amplify the power supply for 6U boards. 3U boards are supplied via the P1 connector. For 6U, this connector needs to be extended.

For EMC reasons and in order not to influence data transfer on the serial interconnects, the power supply connections have as large a distance as possible to the critical signal paths. It is only logical to place the additional P0 connector directly next to P1, i.e. below P1. This makes the board grow towards the bottom.



CompactPCI Serial in 6U, extended by connector P0

It is important to note that P0 is the only electrical extension of 6U boards compared to 3U boards. All features of CompactPCI Serial such as eight PCI Express links, eight full-mesh Ethernet, eight SATA and eight USB interfaces are available in 3U systems just as in 6U systems.

The second reason for the arrangement from top to bottom is the simple build-up of hybrid boards. CompactPCI Serial also describes this kind of board. The upper area of a 6U board accommodates the new AirMax connectors, while the lower area uses the common 2-mm connectors of CompactPCI in their standard positions.

Power Dissipation and Power Supply

Power dissipation from 12 V is limited to 60 W for 3U boards. 150 W are permitted for 6U. This is sufficient even to supply power-hungry server chipsets. 150 W is at the same time the physical limit for air cooling of boards that fill up a 19" rack by 4 HP each. Consequently, a 19" enclosure with 20 6U slots could generate a theoretical thermal output of 3000 W.

The new AirMax connectors of CompactPCI Serial do not have special power supply pins. Voltage is supplied using standard connectors suited for signal transmission. The connectors withstand a current load of 1 A per pin at 85 °C. The mechanical design of the connectors has the contacts placed individually, without thermal coupling. If one contact connection heats up more than another, the internal resistance increases, and the current finds its way over cooler contacts. This guarantees that the load is spread equally over all contacts.

The connector type chosen for P0 is identical with P1. By result, it has 72 contacts and could connect up to 24 differential signals. Its pins amplify the 12-V supply, but also the 5-V standby supply. A 6U board may draw a total power of 25 W from the 5 V standby – which is also a concession for server chipsets.

6U only	6U only		6U only		6U only	
0 - 06	GND	+12V	+12V	GND	+12V	+12V
0 - 05	STNDBY	GND	GND	STNDBY	GND	GND
0 - 04	GND	2_UP_A+	2_UP_A-	GND	2_UP_B+	2_UP_B-
0 - 03	1_UP_A+	1_UP_A-	GND	1_UP_B+	1_UP_B-	GND
0 - 02	nc	nc	nc	nc	nc	nc
0 - 01	-48V_A	-48V_A	nc	-48V RTN_A	-48V RTN_A	nc
Pin	A	B	C	D	E	F
6U only	6U only		6U only		6U only	

Power supply pins for 6U boards on connector P0

A total novelty lies in two redundant, isolated 48-V power supplies. They are supposed to support different telecom standards, and especially solutions such as Power-over-Ethernet (PoE). A 6U board can provide almost 100 W over the backplane. This hardly has an impact on the thermal balance, because PoE supplies power for external devices and the 48 V are only controlled.

Ethernet Extension for 6U Cards

Two rows of P0 are reserved for two additional Ethernet channels. These add to the eight channels that are defined to form a full-mesh network. While these eight channels build up the multiprocessing network of CompactPCI Serial, the two additional channels can be used for integration into existing CompactPCI systems based on the PICMG 2.16 standard, but also for system administration.

Parallel CompactPCI systems still use the IPMB, an I²C bus, to do this. However, Ethernet more and more becomes the standard of choice, here, too. Intel calls this technology AMT (Active Management Technology). For instance, it can update software even when a system is switched off.

Backwards Compatibility and Sustainability

Especially the different formats and options for signal routing show that modular, industrial computer systems need flexible concepts. High demands have accompanied the development of CompactPCI Serial from the start, regarding both existing and future technologies, but also with respect to more special requirements. The main features in this context are:

- compatibility with parallel CompactPCI – PICMG 2.0
- compatibility between 3U boards and 6U boards
- 6U hybrid boards as a bridge between existing systems and the modern serial interfaces
- different connector arrangements for customized I/O boards
- backplane extensions, e.g., by additional Ethernet channels and Power over Ethernet for newer technologies

See also Chapters [Individual Rear I/O for 3U and 6U](#) and

[Application-Specific Backplane](#) Architectures for more on special backplane solutions.

Extension using Mezzanine Cards

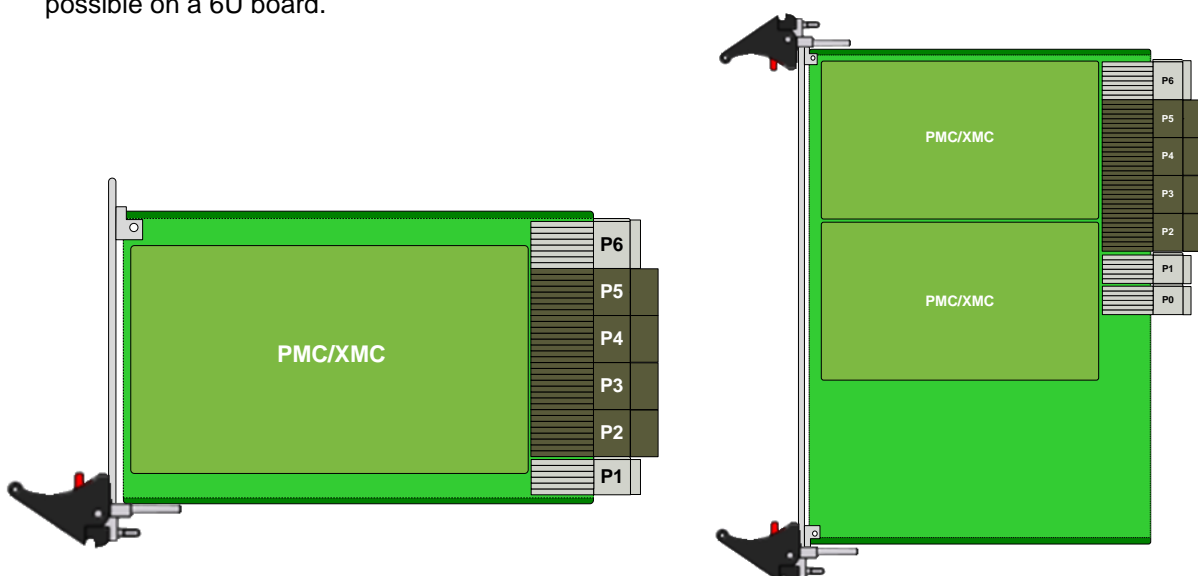
With CompactPCI Serial being mechanically based on the IEEE 1101 standard, the standard for 19-inch systems and Eurocards, mezzanine modules that were developed for these types of boards are also compatible with CompactPCI Serial. This is particularly important for backwards compatibility to existing solutions.

The most important types of such mezzanines are PMCs, XMCs and M-Modules. All of these modules fit on Eurocards. In general, a single Eurocard can accommodate one PMC/XMC or one M-Module, while a double Eurocard can carry two PMCs or XMCs, or four M-Modules.

Space Requirements

Because of the connector types used for CompactPCI Serial, the space usable for components is a little bit smaller than with parallel CompactPCI and VMEbus boards. This is why for CPCI-S.0 the P1 connector, being the only connector necessary for peripheral boards, was placed at the lower edge of the 3U board. As this connector is only 13 mm wide and a margin of 2.5 mm each is reserved for support rails, this leaves a width of 82 mm that is usable for components. A PMC/XMC module with a width of 74.5 mm comfortably fits on the board. Of course, this also goes for an M-Module with 53 mm width.

The same is true for double Eurocards – basically. Since 6U boards expand 3U boards at the lower edge, connector P1 is located quite at the center of the 6U board. This has no importance for PMC/XMC modules. Two of these modules find space on a double Eurocard. A maximum of three M-Modules are possible on a 6U board.



Different types of mezzanines for 3U and 6U boards with CompactPCI Serial

Signal Wiring

The electrical control of mezzanine modules that are based on modern serial interfaces is especially easy. For XMC modules, you only have to connect the right lines and generate the power supply locally. Of course, hot-plug support is possible, too.

For modules that are based on older, parallel buses, you need a bridge. PCIe-to-PCI bridges for PMC modules are available as standard components. For M-Modules you will rather choose FPGA-based solutions.

Individual Rear I/O for 3U and 6U

The parallel CompactPCI standard already provides the possibility to connect I/O for peripheral slots also using the backplane. The number of free pins, however, is very limited, especially with 3U solutions.

CompactPCI Serial offers the option of using around 100 pin pairs or 200 single pins even for 3U boards on connectors P2 to P5. These pins are all embedded into ground pins and are therefore shielded. For 6U boards more than 300 pin pairs or more than 600 single connections are available. Of course, the I/O signals benefit from the excellent transmission behavior and from high signal frequencies. This allows achieving data rates of 12 Gbit/s and more for differential signals.

Applications for Rear I/O

Rear I/O on 3U

In the 3U area rear I/O is needed for systems in harsh environments combined with conduction cooling. I/O signals are normally connected exclusively via rear I/O. Conduction cooling is an effective way for systems to meet both the thermal and the mechanical requirements, for instance for application onboard aircraft, trains, or agricultural machines.

Rear I/O on 6U

Rear I/O in the 6U area is very important for many applications. Telecom applications, for example, only allow front I/O for service purposes. The reason for the use of modular systems based on plug-in cards is actually the extremely short time that is needed to exchange boards in the case of service. Thanks to the hot-plug capability of CompactPCI Serial, you do not even have to switch off the power to exchange a board. Many connections at the front, which would have to be removed before exchange, could completely undo this advantage. The solution is rear I/O.

Rear I/O in Instrumentation

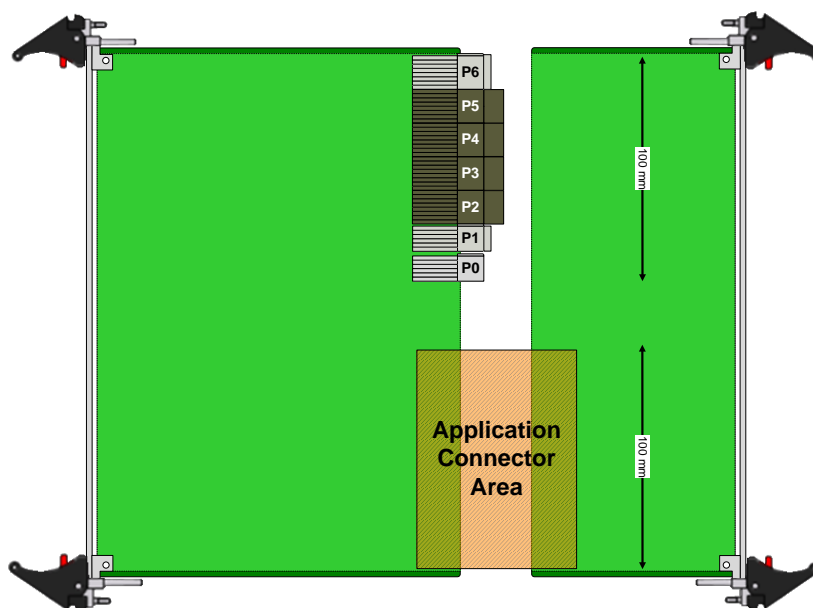
In measuring and instrumentation there is yet another motivation for rear I/O. A board with an analog front end often needs an adaptation for measuring values that is different for every application. You can very well accommodate line drivers on a tailor-made rear I/O adapter. This leaves the front for convenient status displays.

High Individualization

Rear I/O technology also incorporates two major difficulties. In common CompactPCI systems, all signals must be led from the front to the backplane. The backplane's connectors route the signals on to the rear I/O adapter. With parallel CompactPCI the rear I/O and also the PCI bus signals are fixed to 2-mm connectors. These are not well suited to support the high bandwidths of digital communication or to handle highly sensitive signals in the field of measurement engineering.

This is why CompactPCI Serial completely does without a definition of the rear I/O connector and even leaves out the backplane in this area. The individual connector of the front board directly meets the corresponding connector of the rear I/O board.

This approach has only benefits: Having nothing to do with rear I/O, the backplane becomes smaller and less expensive. As not all the slots may use rear I/O, because they do not need it, no connectors are reserved for rear I/O at all.



Free rear I/O layout using 6U CompactPCI Serial

While there is still a discussion in the VPX area on how to support optical interfaces, CPCI-S.0 offers a trouble-free way to make this possible. The front board can directly meet any desired optical connector of the rear I/O card. The same goes for sensitive signals in the area of measurement engineering. Special connectors with a high signal-to-noise ratio of the front board can directly contact the rear I/O board.

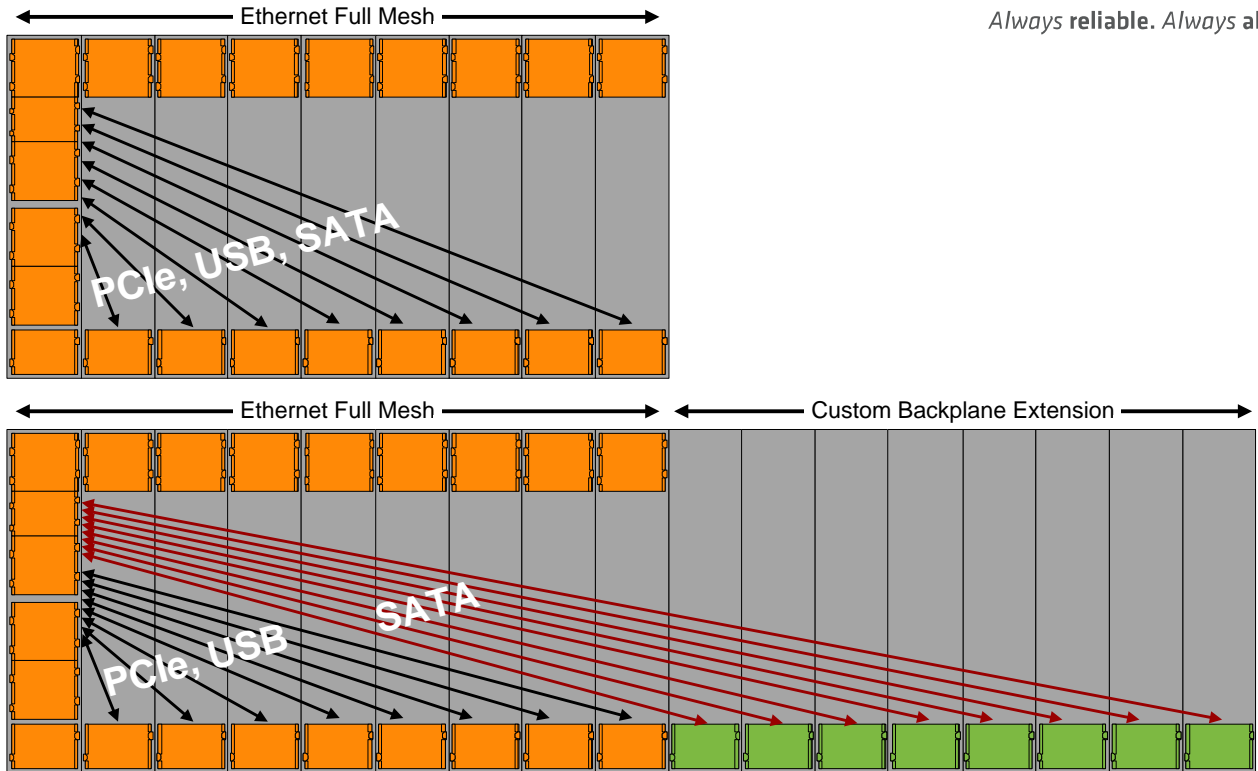
Again, the CompactPCI Serial concept for 6U rear I/O tries to stay as flexible as possible here. For applications like optical data transmission or the transmission of highly sensitive signals it offers the highest possible individualization. At the same time it achieves a very high degree of interoperability. You might as well employ common 2-mm connectors, for instance for backward compatible hybrid boards. The rear I/O connector then leads the signals of the parallel PCI bus to the rear I/O adapter. In this special case, the rear I/O adapter is simply a common CompactPCI backplane.

Application-Specific Backplane Architectures

CompactPCI Serial supports every interface defined in the specification on every backplane slot, i.e. Ethernet, PCI Express, SATA and USB. This is very convenient, easy to understand and easy to handle.

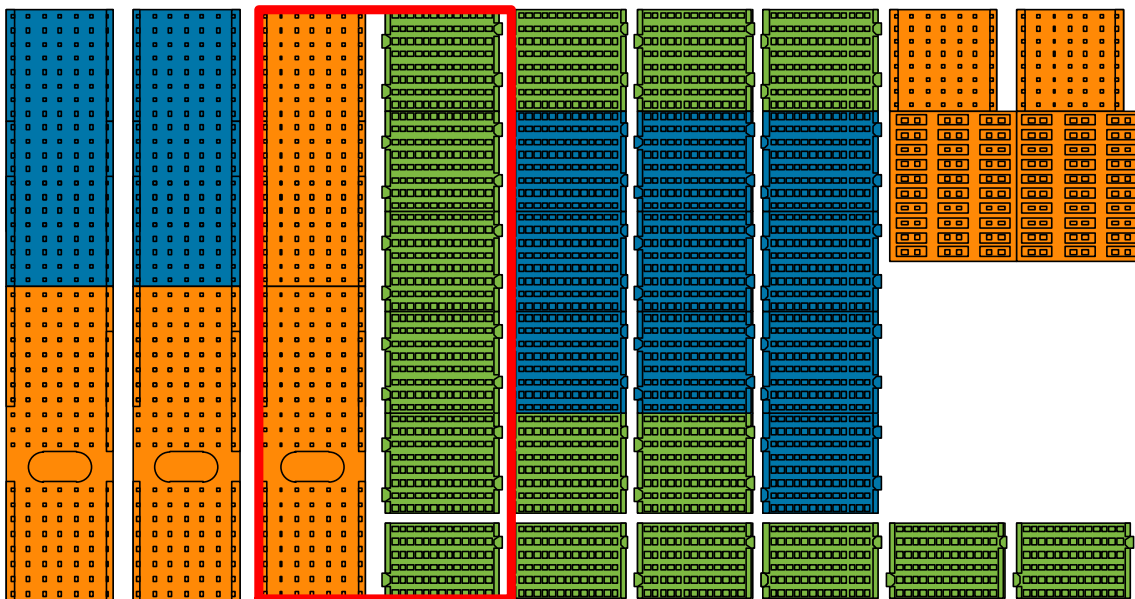
For certain applications with quantities of more than 50 systems, a customized backplane might be recommendable. On this backplane, specified interfaces can be wired to specified slots. Theoretically, such a backplane might have eight slots only for Ethernet, eight slots only for PCI Express, eight slots only for USB and eight slots only for SATA beside the system slot (i.e. a total of 33 slots). No switches or bridges are needed for this either, but now the peripheral boards can only be plugged into predefined slots.

A good example of such a backplane would be one where at least the SATA slots are separated from the other interfaces. This would result in eight peripheral slots which support Ethernet, PCI Express and USB, and eight additional slots which can only accommodate SATA boards (hard disks). Such a modular computer would have eight slots for typical peripheral functions and eight slots for a RAID system, i.e. a total of 17 slots including the system slot.



Standard backplane (top) and application-specific backplane with separated SATA slots (bottom)

PICMG 2.0	PICMG 2.0	PICMG 2.0	PICMG CPCI-S.0	PICMG CPCI-S.0	PICMG CPCI-S.0	PICMG CPCI-S.0	EXP.0 PICMG CPCI-S.0	EXP.0 PICMG CPCI-S.0
Periph. Rear IO	Periph. Rear IO	System Slot	System Slot	Perip. Slot	Perip. Slot	Perip. Slot		



Application-specific backplane with two system slots for CompactPCI and CompactPCI Serial

Use in Harsh Environments: EN 50155 as an Example

Just as CompactPCI, CompactPCI Serial is able to meet even the harsh requirements in a train, which we want to show here with the related standard as an example.

The EN 50155 for the electronic equipment in a train aims at a functionality of 24 hours a day for 20 years, i.e. about 175 000 hours. This is achieved by defining requirements which have to be met in all imaginable environmental conditions, including the shock and vibration, fog and salt, etc. The standard also prescribes how to meet fluctuations of the supply voltage and its transients:

- **Ambient temperature:** The EN 50155 requires up to -40 to +85 °C. In addition it defines a thermal shock of 3 °C/s as a requirement when passing through a tunnel. Because of the extreme temperatures, the thermal increase rates and the humidity the components and the PCBs have to resist condensation, which occurs if the temperature rises from values below zero degrees.
- **Humidity:** The EN 50155 prescribes general rules: Relative humidity of an average 75 %, followed by 30 consecutive days with a humidity of an average 95 %. This means that in most cases the electronic equipment requires waterproof housings or coated assemblies.
- **Pollution:** Depending on the accommodation of the equipment it can be subject to pollution: conductive dust, oil mist, spray salt and/or sulfur dioxide. Conformal coating and housings with IP protection class prevent the negative consequences.
- **Cooling:** Forced air cooling should be avoided because it requires increased maintenance work. Pure convection cooling requires a suitable board and housing design.
- **EMC:** Moving trains are subjected to a multitude of electromagnetic disturbances. The transient/burst resistance has to be proven according to EN 50121-3-2 and EN 61000-4-4. Resistance against radio disturbances has to conform to EN 50121-3-2 and electromagnetic radiation to EN 50121-3-2.
- **Shock and vibration:** The EN 50155 describes test methods and limit values which are defined in EN 61373. Even though the applications listed there stipulate DIN rail mounting, more stable mounting techniques, which CompactPCI offers, have to be used for high-vibration environments.

For the power supply in railway equipment additional requirements apply such as:

- **Input voltage:** In a system with 110 VDC the input voltage can fluctuate between 77 and 137.5 VDC without any temporal limit. In addition, the input voltage may vary extremely in a range from 66 to 154 VDC for a period of 0.1 s. In order to meet these extraordinary requirements for the input voltage range, only power supplies can be used which have been especially designed for use in trains. These power supplies are available for CompactPCI and thus also for CompactPCI Serial as COTS products.

- **Ripple of the input voltage:** The direct input voltage from a one-phase or three-phase-generator is more or less unsmoothed. It can contain significant ripples which may amount to 15 % of the average voltage and are not kept away from the input filters. In addition the control circuits of the power supply have to be quick enough to smooth the fluctuations of the input voltage so that they do not occur at the output.
- **Input voltage surges:** The EN 50155 defines the relation between surge voltage, duration and source impedance, and higher voltages, which occur for a shorter time and with higher source impedance. For 110 V, for example, a test with a 1.4-fold overvoltage (154 VDC) for 1 s with a source impedance of 1 Ohm is prescribed.

Reliability and long availability of the electronics is decisive for railway applications. CompactPCI Serial is based on CompactPCI and its proven mechanics. The IEEE 1011 standard includes all required shielding technologies. 3U systems are especially suited for applications in the railway market as they are extremely space-saving and cost-effective.

Spoiled for Choice: CompactPCI Serial or VPX?

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 (SRIO) or Aurora. While SRIO is limited to specific PowerPC and DSP types, however, current x86 processors support the whole range of PCI Express, Ethernet, USB and SATA – the serial interfaces that CompactPCI Serial is based on.

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

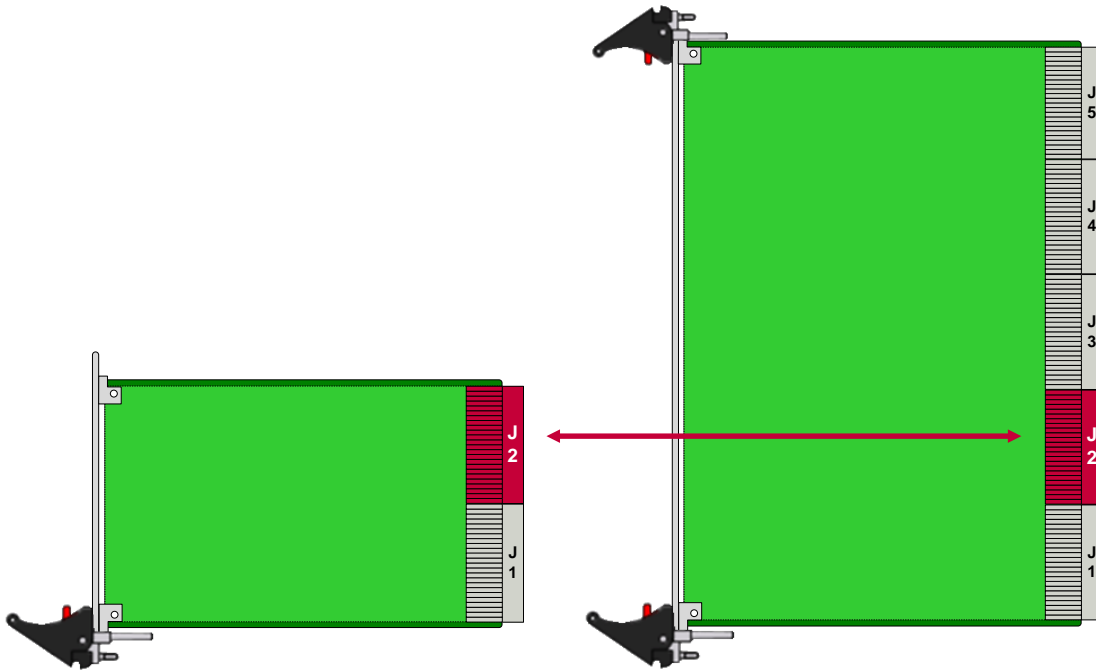
The last cost factor: the PSU. For its 5V/12V/48V strategy, VPX also needs more complex PSUs. CompactPCI Serial defines a single 12V supply and can use COTS PSUs when there is cost pressure.

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

Migration using CompactPCI PlusIO

Architecture Overview

The CompactPCI specification PICMG 2.0 permits to lead user I/O signals to the backplane beside the parallel PCI bus. The manufacturers use these user I/O pins to lead these peripheral signals – the modern serial interconnects – to the backplane. Unfortunately the pin assignment has not yet been standardized, so that the intercompatibility of the assemblies is lost. Often even boards by one and the same manufacturer cannot be exchanged among each other. What is more, the 2-mm connector was originally not developed for transmitting differential signals with a speed of up to 5 Gbit/s.



Backplane connector J2 with CompactPCI

Standardized Interfaces with CompactPCI PlusIO

An extension to the CompactPCI standard, PICMG 2.30 CompactPCI PlusIO, remedies this. The extension defines the J2 pin assignment and at the same time introduces a new, 100% compatible connector, which is also suited for transmission of high frequencies. For this, only a few additional ground signals are required, so that a high number of interfaces can be led to the backplane:

- 4 x PCI Express (one lane each)
- 2 x Ethernet 1000BASE-T
- 4 x USB 2.0
- 4 x SATA/SAS

The parallel PCI bus is not changed but is limited to a data bus width of 32 bit. PICMG 2.30 can be used for both single and double Eurocards. A board that supports CompactPCI PlusIO remains 100% compatible to the current standard. It can also be used without limitations in existing systems.

Pin Assignment J2							
Pin	Z	A	B	C	D	E	F
22	GND	GA4	GA3	GA2	GA1	GA0	GND
21	GND	CLK6	GND	2_ETH_B+	1_ETH_D+	1_ETH_B+	GND
20	GND	CLK5	GND	2_ETH_B-	1_ETH_D-	1_ETH_B-	GND
19	GND	GND	GND	2_ETH_A+	1_ETH_C+	1_ETH_A+	GND
18	GND	2_ETH_D+	2_ETH_C+	2_ETH_A-	1_ETH_C-	1_ETH_A-	GND
17	GND	2_ETH_D-	2_ETH_C-	PRST#	REQ6#	GNT6#	GND
16	GND	4_PE_CLK-	2_PE_CLK+	DEG#	GND	reserved	GND
15	GND	4_PE_CLK+	2_PE_CLK-	FAL#	REQ5#	GNT5#	GND
14	GND	3_PE_CLK-	1_PE_CLK+	4_PE_CLKE#	SATA_SCL	reserved	GND
13	GND	3_PE_CLK+	1_PE_CLK-	3_PE_CLKE#	SATA_SDO	SATA_SL	GND
12	GND	4_PE_Rx00+	1_PE_CLKE#	2_PE_CLKE#	SATA_SDI	4_SATA_Rx+	GND
11	GND	4_PE_Rx00-	4_PE_Tx00+	4_USB2+	4_SATA_Tx+	4_SATA_Rx-	GND
10	GND	3_PE_Rx00+	4_PE_Tx00-	4_USB2-	4_SATA_Tx-	3_SATA_Rx+	GND
9	GND	3_PE_Rx00-	3_PE_Tx00+	3_USB2+	3_SATA_Tx+	3_SATA_Rx-	GND
8	GND	2_PE_Rx00+	3_PE_Tx00-	3_USB2-	3_SATA_Tx-	2_SATA_Rx+	GND
7	GND	2_PE_Rx00-	2_PE_Tx00+	2_USB2+	2_SATA_Tx+	2_SATA_Rx-	GND
6	GND	1_PE_Rx00+	2_PE_Tx00-	2_USB2-	2_SATA_Tx-	1_SATA_Rx+	GND
5	GND	1_PE_Rx00-	1_PE_Tx00+	1_USB2+	1_SATA_Tx+	1_SATA_Rx-	GND
4	GND	VIO	1_PE_Tx00-	1_USB2-	1_SATA_Tx-	reserved	GND
3	GND	CLK4	GND	GNT3#	REQ4#	GNT4#	GND
2	GND	CLK2	CLK3	SYSEN#	GNT2#	REQ3#	GND
1	GND	CLK1	GND	REQ1#	GNT1#	REQ2#	GND
Pin Assignment J1							
Pin 1-25	Standard Assignment						

Fixed pin assignment of connector J2 with CompactPCI PlusIO



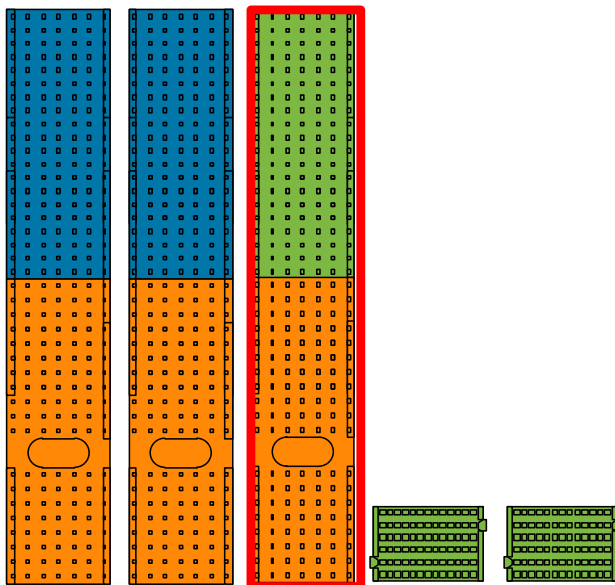
CompactPCI PlusIO CPU card with new J2 connector (shown individually at the right)

Hybrid Systems as a Bridge between the Standards

A CPU assembly that supports PICMG 2.30 can also be used as a system slot in a hybrid system. A hybrid system like this provides CompactPCI Express or CompactPCI Serial slots in addition to legacy CompactPCI slots.

So a small CompactPCI system can consist of a CompactPCI system slot (the CPU board), two CompactPCI peripheral slots for I/O and fieldbus and two CompactPCI Serial peripheral slots for a hard disk RAID with hot plug support.

PICMG 2.0 Periph. Rear IO	PICMG 2.0 Periph. Rear IO	PICMG 2.0 PICMG 2.30 System Slot	PICMG CPCI-S.0 Periph.	PICMG CPCI-S.0 Periph.
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Hybrid backplane with CompactPCI PlusIO and CompactPCI Serial (simplified)

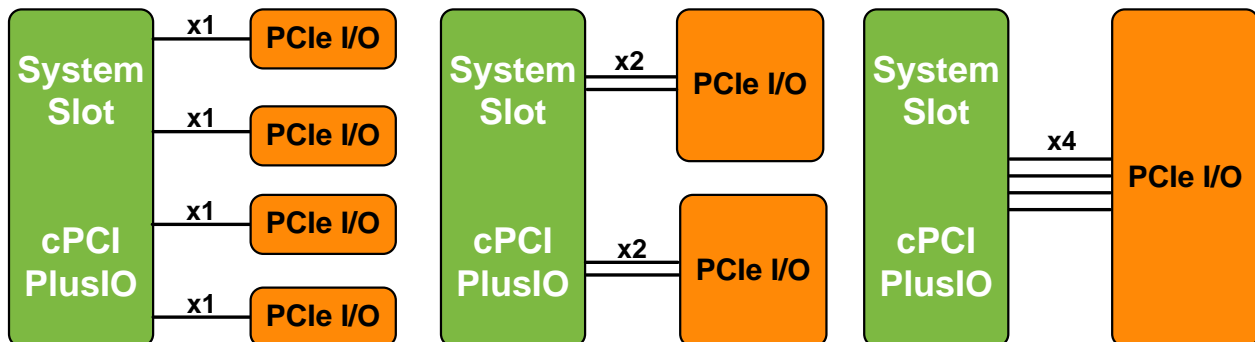
You can find more on hybrid systems in Chapter [Hybrid Systems](#).

PCI Express

CompactPCI PlusIO permits to lead a total of four PCI Express interfaces to the backplane. The "Ultra-Hard-Metric" connectors on the plug-in board permit data rates of up to 5 Gbit/s, traditional 2-mm-connectors being usable on the backplane.

These four interfaces can control four PCI Express based peripheral boards. Every interface is equipped with one differential receive pair and one differential transmit pair – one lane, with each forming one x1 link. The four PCI Express lines can be a connection to CompactPCI Express or to CompactPCI Serial, for instance.

Each interface reaches data rates of 250 MB/s with PCIe v1.x or 500 MB/s with PCIe v2.x per direction. For some applications, however, for example for image processing, these data rates are still not sufficient. For this reason, the PICMG CompactPCI PlusIO standard allows to "cluster" the four PCI Express links. This way, the four links with one lane each defined for PICMG 2.30 can also be configured as two links with two lanes each (x2) or as one link with four lanes (x4). In the last-mentioned case, theoretical data rates of 1000 MB/s with PCIe v1.x or 2000 MB/s for PCIe v2.x can be reached, but only with a connected device.



PCI Express connection with CompactPCI PlusIO: 4 x1 links, 2 x2 links or 1 x4 link

The PlusIO CPU board imports the configuration via four control lines which are also used to activate the respective 100-MHz clock that is allocated to a PCI Express interface. No additional lines are necessary.

Ethernet

CompactPCI PlusIO defines a total of two Ethernet interfaces at the backplane. As for PICMG 2.16, the Ethernet interfaces are based on the IEEE 802 standards for copper cables.

Why BASE-T?

The working group has intentionally decided against special standards for backplanes as were used for AdvancedTCA or MicroTCA. These special Ethernet standards – 1000BASE-BX (1 Gbit/s) and 10GBASEBX4 (10 Gbit/s) – use two or eight differential pairs, respectively, for transmission and need special PHYs for this. The PHY is the physical interface, i.e. the interface component between the actual Ethernet controller and the transmission medium.

As a rule Ethernet connections are implemented redundantly in the AdvancedTCA or MicroTCA standards. CompactPCI PlusIO, however, uses the common "BASE-T" standards, i.e. 10/100/1000BASE-T and 10GBASE-T. These are based on four differential connection pairs. Inductive coupling as well as the simple capacitive coupling is possible. The standards are interoperable without additional software overhead (autonegotiation). As a rule, from 1000BASE-T on, there is a fault tolerance within the connection. Modern 1000BASE-T PHYs for example build up at least one 100BASE-T connection if a wire pair is disturbed. The diagnosis capability of BASE-T PHYs leaves almost nothing to wish for.

BASE-T standards are the most future-safe Ethernet standards. Millions of nodes installed worldwide are based on them. Research has already begun on an extension to 100GBASE-T – still compatible to existing installations. The wide-spread use of the BASE-T standards has further consequences: The PHYs are produced in a very high quantity, so that they are cheap and often already integrated in the Ethernet controller itself. By now, the power dissipation of the PHYs has become impressingly low (think about green computing) and the reliability accordingly high.

Possibilities through Ethernet on the Backplane

CompactPCI PlusIO permits building up 3U and 6U multicomputer systems based on Ethernet on the backplane. As the BASE-T standards also allow line lengths of up to 100 meters, loosely coupled computers can also be interconnected. Using low-priced standard Ethernet switches complex networks can also be realized.

Electrical Specification

CompactPCI PlusIO is a standard for CompactPCI system slots, i.e. for CPU boards. Being no backplane standard, it does not set up rules for backplanes. The standard is limited to the necessary definitions for the CPU board and how the serial interfaces are led to the backplane.

If you use CompactPCI PlusIO to access the signals via a rear I/O adapter, this is sufficient. If you set up a hybrid backplane, for example based on CompactPCI Express, to control National Instruments cards at low cost, it is the responsibility of the backplane manufacturer to bridge the different standards and to guarantee interoperability.

When defining the rules for the system-slot board in the CompactPCI Serial standard, the approach taken was to split the electrical tolerances permitted by an interface standard (e.g., PCI Express) between the CPU board, a possible backplane, and a peripheral board in a "fair" manner. Fair means that the specified values were divided by three.

In order to make implementation simple, to avoid mistakes and to achieve maximum interoperability, the electrical specifications of every single standard were turned into clear PCB layout rules. These rules differ depending on the interface (PCI Express, SATA, USB, Ethernet). For PCI Express the following rules apply, for instance:

- Differential impedance 100 Ohms
- The distance between differential pairs and other signals shall be more than 0.4 mm
- The pair-to-pair pitch shall be 0.2 mm minimum
- Intra pair skew shall be less than 0.1 mm on the system slot board
- Trace length shall be less than 125 mm on the system slot board. There shall be a maximum of 2 vias per line on the system slot board

These clear implementation rules guarantee that the modern high-speed interconnects are really usable, and that boards of different manufacturers work together under all circumstances.

Interoperability

CompactPCI PlusIO supports four PCI Express, SATA and USB 2.0 interfaces as well as two Ethernet interfaces on the backplane. The pins used for this have been left free in the basic PICMG 2.0 standard for the user I/O of 32-bit systems. PICMG 2.30 can be used for both 3U and 6U systems, if no 64-bit PCI bus implementation is required.

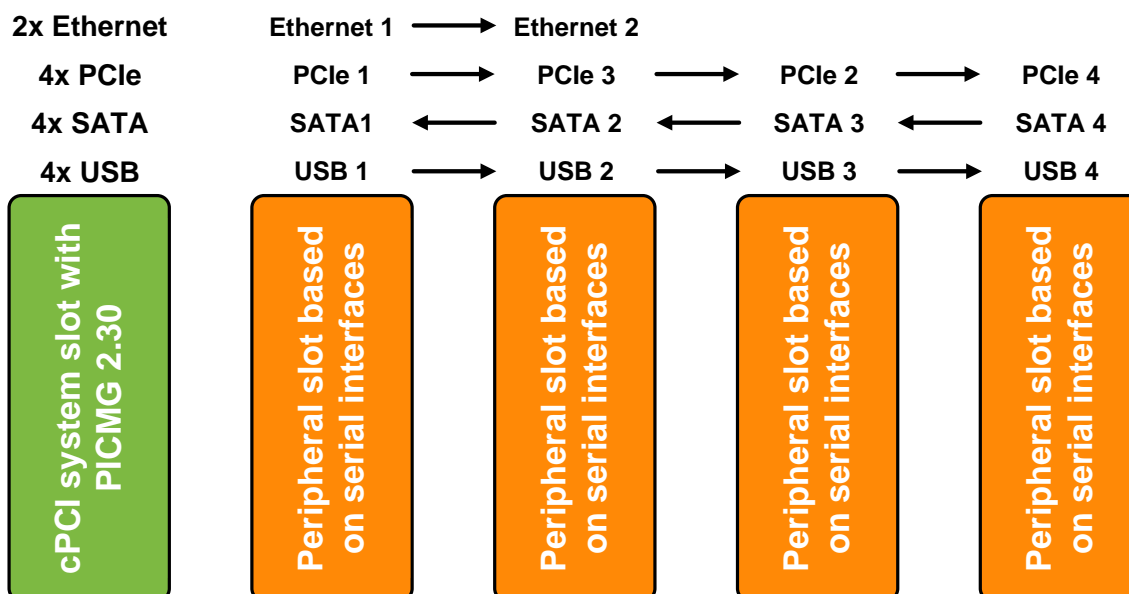
The signal definition aims at the highest possible interoperability between boards of different manufacturers. At the same time the standard tries to allow as much flexibility as possible.

Not every CPU board will use all of the new interfaces – also because of the costs. A typical Intel Atom platform might perhaps only support one Ethernet and one PCI Express. It depends on the implementation whether SATA can be used. Four USB interfaces are possible if required.

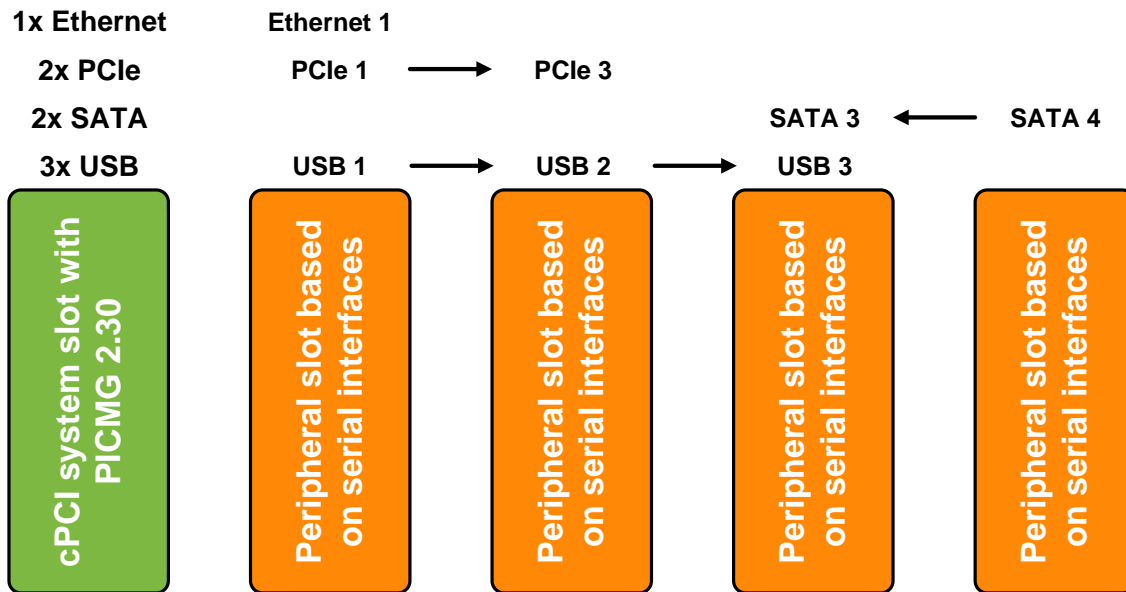
Defined Interface Order

To guarantee maximum interoperability between CPU boards of different manufacturers, CompactPCI PlusIO defines clearly the sequence in which the interfaces have to be "filled". This makes sure, for example, that the only PCIe channel of one manufacturer does not collide with a differing assignment of another manufacturer.

The prescribed order for Ethernet and USB is ascending: 1, 2 and 1, 2, 3, 4; for SATA it is descending: 4, 3, 2, 1; for PCI Express it alternates: 1, 3, 2, 4.



Maximum implementation of serial interfaces with CompactPCI PlusIO for four CompactPCI Serial peripheral boards



Partial implementation of serial interfaces with CompactPCI PlusIO

Except for SATA the interfaces are filled incrementing – why not the SATA interfaces?

A CompactPCI system using CompactPCI PlusIO can be equipped with up to four of the new serial CompactPCI Serial slots on the hybrid backplane. These four slots shall even be usable to the maximum if not all interfaces can be supported by a CPU board. When there are four slots it would be unhandy if all interfaces were led to the first slot and none to the last. PCI Express and USB are implemented concurrently in order to enable the use of PCI Express Mini Cards, for example. One slot will often be needed for a hard disk or an SSD. As only one interface per slot is needed in this case, the interfaces are filled descending.

Implementation in Real Life

A system based on an Intel Atom SBC might look like this: Ethernet on the backplane controls an additional computer, a video input card controlled via PCI Express is plugged into the first peripheral slot, the second slot is equipped with a USB-based RS485 extension, slot 3 supports a Wi-Fi interface – also USB – and slot 4 accommodates a SATA hard disk.

This shows that the implementation rules have got two advantages:

- maximum compatibility between the cards of different manufacturers
- optimum exploitation of the resources.

The standard also permits to assign other functions to pins, if necessary. So, if you do not need the defined four PCI Express, four SATA, four USB and two Ethernet interfaces, you can also lead other signals to the backplane and still be compatible with the standard. You only need to consider two things:

- **You must keep the implementation order of the interfaces.** This means that you cannot simply assign a different function to any PCI Express interface. Instead, you need to begin with channel 4 and continue in forward direction. With SATA the implementation order is the other way around – here you begin with the first pin that you can then assign differently.
- **Connected interfaces which comply with the specification must not be destroyed by user I/O signals.** The standard does not permit, for instance, that the pins are assigned +12 V instead of a SATA interface, because this could destroy a connected hard disk drive.

For example: Doing without one PCI Express interface and one Ethernet interface, we would like to bring LVDS graphics to the backplane. According to the implementation rules, we need to reassign Ethernet 2 and PCI Express 4 in this case. The output signals of the LVDS interface are differential, with a relatively low voltage level. These signals cannot destroy a connected Ethernet device. In the case of PCI Express, it is better not to drive against a connected device. Consequently, we should avoid using the PCI Express input pins. The following table shows a possible pin assignment.

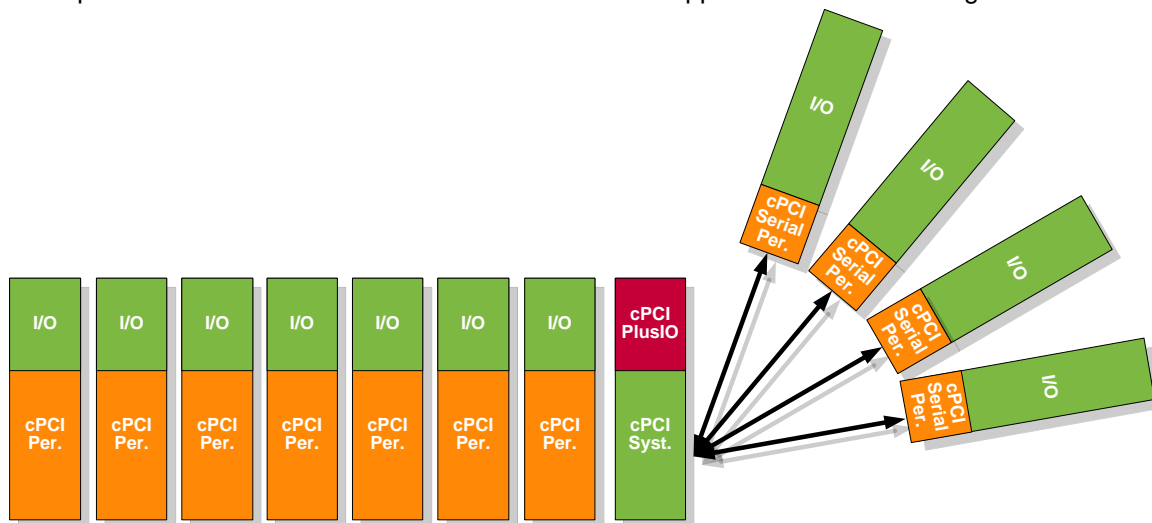
Pin Assignment J2							
Pin	Z	A	B	C	D	E	F
22	GND	GA4	GA3	GA2	GA1	GA0	GND
21	GND	CLK6	GND	LVDS_B+	1_ETH_D+	1_ETH_B+	GND
20	GND	CLK5	GND	LVDS_B-	1_ETH_D-	1_ETH_B-	GND
19	GND	GND	GND	LVDS_A+	1_ETH_C+	1_ETH_A+	GND
18	GND	LVDS_D+	LVDS_C+	LVDS_A-	1_ETH_C-	1_ETH_A-	GND
17	GND	LVDS_D-	LVDS_C-	PRST#	REQ6#	GNT6#	GND
16	GND	LVDS_CLK-	2_PE_CLK+	DEG#	GND	reserved	GND
15	GND	LVDS_CLK+	2_PE_CLK-	FAL#	REQ5#	GNT5#	GND
14	GND	3_PE_CLK-	1_PE_CLK+	4_PE_CLKE#	SATA_SCL	reserved	GND
13	GND	3_PE_CLK+	1_PE_CLK-	3_PE_CLKE#	SATA_SDO	SATA_SL	GND
12	GND	free	1_PE_CLKE#	2_PE_CLKE#	SATA_SDI	4_SATA_Rx+	GND
11	GND	free	free	4_USB2+	4_SATA_Tx+	4_SATA_Rx-	GND
10	GND	3_PE_Rx00+	free	4_USB2-	4_SATA_Tx-	3_SATA_Rx+	GND
9	GND	3_PE_Rx00-	3_PE_Tx00+	3_USB2+	3_SATA_Tx+	3_SATA_Rx-	GND
8	GND	2_PE_Rx00+	3_PE_Tx00-	3_USB2-	3_SATA_Tx-	2_SATA_Rx+	GND
7	GND	2_PE_Rx00-	2_PE_Tx00+	2_USB2+	2_SATA_Tx+	2_SATA_Rx-	GND
6	GND	1_PE_Rx00+	2_PE_Tx00-	2_USB2-	2_SATA_Tx-	1_SATA_Rx+	GND
5	GND	1_PE_Rx00-	1_PE_Tx00+	1_USB2+	1_SATA_Tx+	1_SATA_Rx-	GND
4	GND	VIO	1_PE_Tx00-	1_USB2-	1_SATA_Tx-	reserved	GND
3	GND	CLK4	GND	GNT3#	REQ4#	GNT4#	GND
2	GND	CLK2	CLK3	SYSEN#	GNT2#	REQ3#	GND
1	GND	CLK1	GND	REQ1#	GNT1#	REQ2#	GND

Possible pin assignment compatible with CompactPCI PlusIO with LVDS on connector J2

Hybrid Systems

Using CompactPCI PlusIO

The first that comes to mind when thinking of building up hybrid systems is CompactPCI PlusIO (PICMG 2.30). Here, the system slot CPU supports both the parallel CompactPCI standard (PICMG 2.0) and the new CompactPCI Serial standard (PICMG CPCI-S.0). Hybrid backplanes from different manufacturers enable configuration with peripheral slot boards on the left and on the right of the system slot board. Up to seven parallel and a maximum of four serial boards are supported – without a bridge.



Hybrid system with CompactPCI PlusIO CPU, and CompactPCI and CompactPCI Serial peripheral boards – schematic

This way, a cost-effective migration is possible, because the usage of future-oriented and standardized data transfer based on CompactPCI Serial is guaranteed even when already integrated CompactPCI components are used.

The Important Role of CompactPCI PlusIO

CompactPCI PlusIO's importance lies in a simple fact: because it has been so successful, CompactPCI has a large installed base, and to abandon this structure in favor of a completely new system is of no benefit to anyone – manufacturer, developer or end user.

The CompactPCI PlusIO standard provides for the addition of high-speed serial communication, while preserving PCI bus connectivity and maintaining the mechanical parameters of the original CompactPCI standard. The result is a practical migration path for users who require the added capabilities, without

disrupting continuity for those aspects of their applications where original CompactPCI hardware components still perform acceptably.

CompactPCI: an Evolving Standard

The development path of CompactPCI affirms that the standard is able to continually evolve, while maintaining the original mechanics. This attribute has enabled updated versions to remain compatible with legacy systems, and ensures that the extensive installed base of CompactPCI systems remain viable, relevant and cost-effective within the many industries using CompactPCI as well as those that can now benefit from the high-speed serial interfaces.

Areas with the most evolution are primarily seen where the systems' performance and ease-of-use, such as multi-computing networking, increased reliability and hot-swap functionality count.

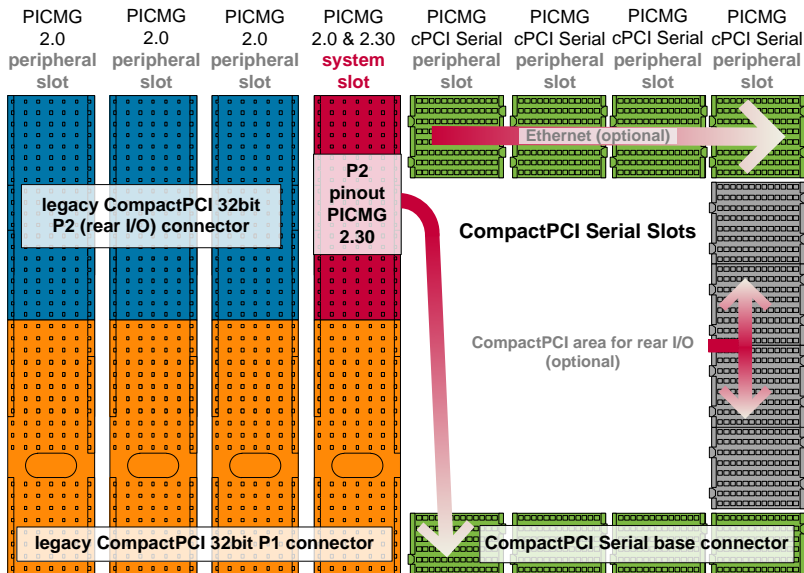
CompactPCI is one industry standard that will not easily fall victim to the fate that "all good things must come to an end," which has proven true time and time again in computing technology. The ratification of PICMG 2.30 and PICMG CPCI-S.0 (CompactPCI Serial) has in all probability delayed any possible obsolescence of CompactPCI for another 15 years or more.

Hybrid Possibilities using CompactPCI PlusIO

The CompactPCI PlusIO hybrid system offers the perfect connection between parallel and serial architectures, and a gradual transition from old to new. This type of solution offers the ability to incorporate existing CompactPCI I/O cards within an installation accommodating serial I/O connections that help maximize the value of the user's investment in CompactPCI hardware while providing the flexibility to satisfy increased operational demands.

It is not necessary to completely replace an existing system in order to upgrade it to the latest technological standard – nor is it necessary to scrap successfully proven components. Even implementation is surprisingly easy and cost-efficient due to compatibility with much of the existing hardware.

In its simplest application, the installation of a new CompactPCI PlusIO SBC into an existing system slot can integrate up to seven parallel I/O boards and four serial I/O boards (CompactPCI Serial) in the same configuration.



Hybrid system with a CompactPCI PlusIO CPU – example backplane

But whatever the eventual configuration, CompactPCI PlusIO remains true to the mechanical requirements of the original CompactPCI standard – including identical board and backplane dimensions, identical front panels and identical hot-plug mechanics. Also, since CompactPCI PlusIO needs no switch boards in the system, and the high-speed connector is low cost, it is an exceptionally money-saving option.

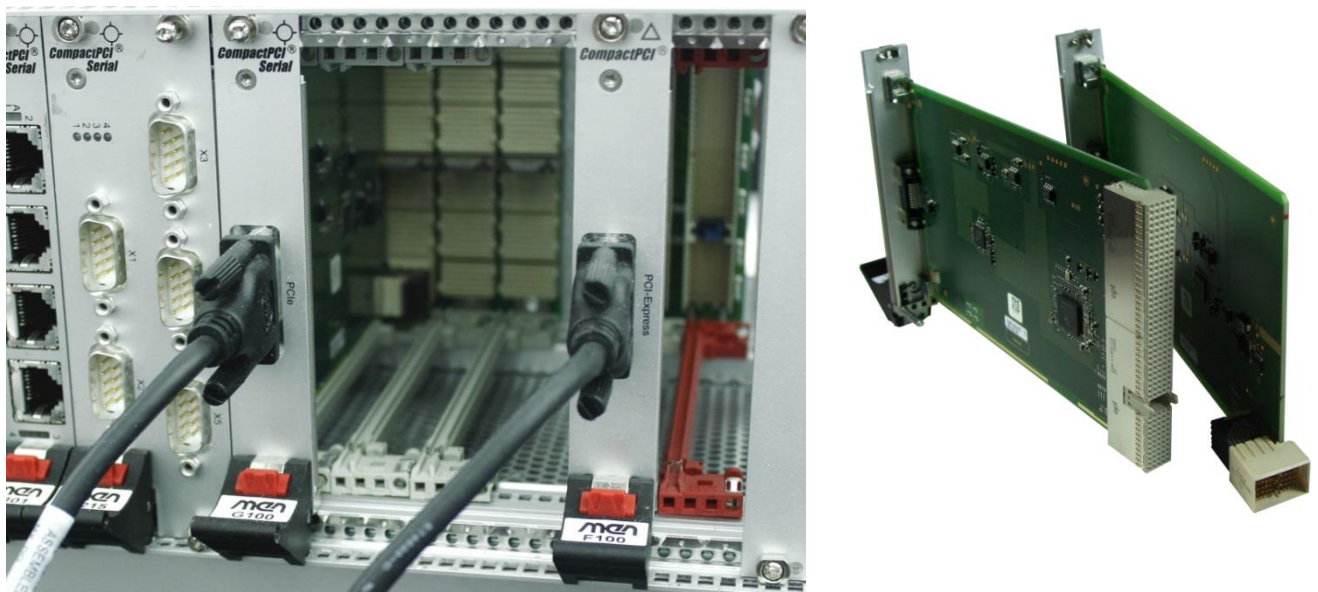


Hybrid backplane in a 19" system

Direct Connection between CompactPCI and CompactPCI Serial

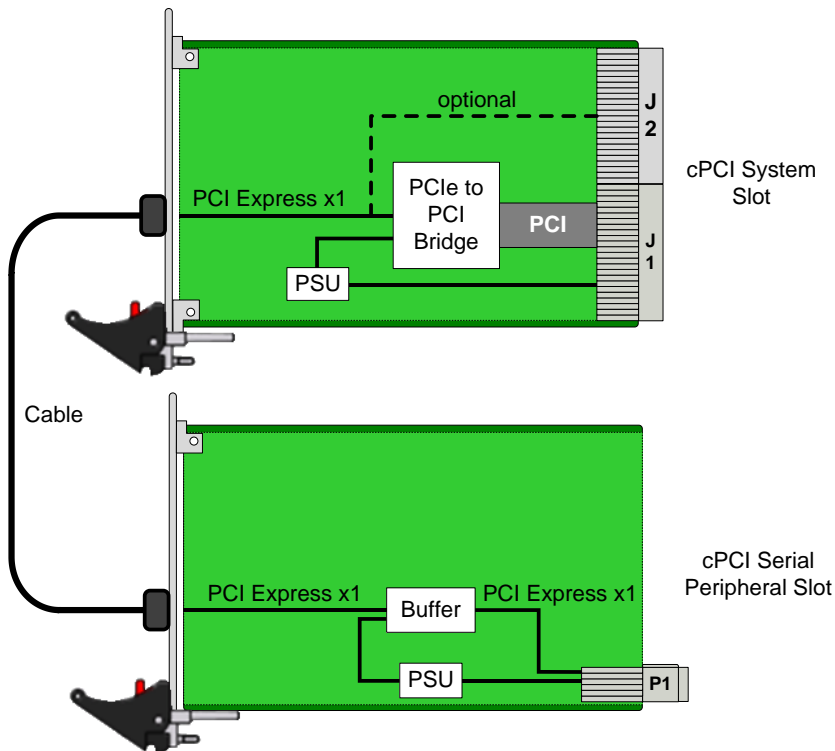
But what if none of the standard hybrid backplanes is suitable for the new application and/or more than four serial peripheral boards are needed and the (first) quantities are too small for the development of a customized backplane?

In this case, the two worlds – CompactPCI Serial und CompactPCI – have to be connected in a different way. For this, one board pair is used. One board is the interface from CompactPCI Serial to CompactPCI and is plugged into a peripheral slot of the CompactPCI Serial backplane. The second interface board replaces the system slot CPU on the CompactPCI backplane and is connected to the first interface board in the CompactPCI Serial system via a cable at the front panel.



Interface cards for CompactPCI and CompactPCI Serial connect the two systems

The new system slot board in the CompactPCI system is equipped with a PCI Express to PCI bridge, the communication over the cable is based on a PCI Express x1 link. As both standards are compatible to the 19" mechanics, the solution can be accommodated in one rack. On the other hand PCI Express enables cable lengths of up to 7 m so that two racks can also be coupled loosely.



Direct connection between CompactPCI and CompactPCI Serial and separated backplanes

If – for larger volumes – the development of a customized backplane is profitable, the PCI Express based connection of CompactPCI Serial to CompactPCI can be done via rear I/O. This means that you only need the second interface board, which is plugged into the system slot of the CompactPCI side.

Perspective

There are good reasons for using CompactPCI Serial:

- It is the logical extension of the existing CompactPCI technology.
- Many suppliers have already included CompactPCI Serial into their product range.
- Thanks to the higher data throughput and the fast serial connections CompactPCI Serial offers additional application possibilities.

So much for the levelheaded arguments. There's actually more to CompactPCI Serial than bringing a new technology to the market, because what's behind it is the impressive success story of one industry standard: CompactPCI.

CompactPCI has already proven itself in the field for the last 15 years. The 19" system technology with its typical design and interface assignment is to a large extent known in the industrial market. The design and structure of the boards, as well as front and rear I/O options are widely accepted by users.

This is why CompactPCI Serial consequently follows up on its parallel predecessor. Its high demand is to make modular systems simple, robust, flexible and inexpensive – while the mechanics remain 100% compatible with CompactPCI 2.0. Industrial computers do not follow fashion trends but hard facts, data and requirements. A technology that simplifies the building up of embedded computer systems, that allows the integrator to concentrate on his technical requirements while granting continuity and future-safety hits the nail on the head in the industrial arena.

Wide Support by Suppliers

In order to establish a new technology on the market, the potential users also need choices – both when choosing a suitable supplier and through a large product range. The support of CompactPCI Serial by a large number of suppliers on the one hand results in a high degree of innovation and a wide product range. On the other hand, it creates price competition.

This way, the user can choose between different products and the technical support of the respective suppliers. Thanks to this network it is possible to combine products of different manufacturers to build up a system or a special application.

Extended Fields of Application

By embedding serial interfaces into a system, new application possibilities open up, which could not be implemented anymore using the traditional parallel CompactPCI architecture. CompactPCI Serial supports serial communication, a high data transfer rate and high-performance graphics and can even be operated in combination with parallel CompactPCI in hybrid systems. This means that existing systems and applications do not have to be replaced completely, but can be extended by the new technology with high data throughput.

Everything Falls into Place

CompactPCI Serial is not a technology caprice. Several vendors together and with attention to detail have created a standard for the future and pay highest tribute to its predecessor CompactPCI. The concept was made not for the next three or five years, but for a minimum of ten years. After the initial introductory years, both the products and the first projects in real-world applications give proof that this technology can and will take hold.

CompactPCI Serial as a stand-alone architecture and as an extension of existing technologies offers the best prerequisites for an efficient implementation of your requirements. A whole network of suppliers with a wide variety of products is there to support you.

Abbreviations

AMC	Advanced Mezzanine Card, also: AdvancedMC
AMT	Active Management Technology
ANSI	American National Standards Institute
ATCA	Advanced Telecommunications Computing Architecture, auch: AdvancedTCA
CCA	Conduction-Cooled Assembly
IEEE	Institute of Electrical and Electronics Engineers
IPMB	Intelligent Platform Management Bus
IPMI	Intelligent Platform Management Interface
MicroTCA	Micro Telecommunications Computing Architecture, also: μ TCA
NAS	Network Attached Storage
NRE	Non-Recurring Engineering
PCI	Peripheral Component Interconnect
PCIe	PCI Express
PHY	Physical Layer
PICMG	PCI Industrial Computers Manufacturers Group
RAID	Redundant Array of Independent Disks
SATA	Serial Advanced Technology Attachment, also: Serial ATA
SAS	Serial Attached SCSI
SBC	Single-Board Computer
SGPIO	Serial General Purpose Input/Output
SRIO	Serial RapidIO
SSD	Solid-State Drive

STD Bus "Simple to Design" Bus

VITA VMEbus International Trade Association

VMEbus Versa Module European Bus

VPX Versatile Performance Switching

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October 2015

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