By Herman Strass,
Technology Consulting.

IndustrialPCI Candidate for PLC Replacement

The PCI has been a great success in the home and office market. It is without any doubt the most widely used bus in the desktop PC market. Will it be accepted in an industrial environment as well? PCs with or without PCI cards have been used in industrial applications for some time now. Real industrial applications, however, require careful analysis of environmental and real-time conditions. These issues have been addressed by the developers and suppliers of IndustrialPCI (IPCI). They have been and still are supplying PLCs (Programmed Logic Control) and other control equipment to industrial customers. Their 'know-how' has gone into the design and development of IPCI.

PCI HISTORY

PCI was developed in the Intel Architecture Labs (IAL) in 1991. The PCI SIG (Special Interest Group) was formed in June 1992 to promote PCI as an open standard. Initially PCI was a local bus to interconnect chips on a board. It was then carried off-board by means of connectors making it a backplane or motherboard bus. This 'local' inheritance is a problem even today when trying to transfer data at high speed over distances more then a few centimetres. Connectors, who were not part of the original design, also cause problems. Once these limitations are carefully considered there appear to be many solutions to make the PCI do much more than it was originally designed to do.

Other local or not so local buses like VLB (VESA Local Bus), EISA (Extended ISA) or MCA (MicroChannel Architecture) fell by the wayside. Today we have the traditional ISA bus for lowest cost, low-performance applications and PCI for everything else. ISA will eventually be dropped from desktop systems since hardly any new designs are done for this bus. But ISA will survive much longer in the industrial world. Industrial systems do not change with the seasons. They may stay in service typically from 5 to 25 years. This means there is a long-term demand for upgrades and repair/replacements.

PCI Facts

The PCI features a 33 MHz, 32 bit bus with a transfer rate of 132 megabytes/s. It is limited to 5 slots on a backplane or motherboard because it was designed to drive a maximum of 10 standard CMOS loads. The chip on the board and the backplane connector count as one unit load each. Originally PCI was not meant to become a backplane bus which explains why there was no provision for bus termination. One of the inventors explained the design "you send energy out on the driver output pin and wait long enough for the reflections to build up a level high enough to switch". This might be OK for a trace of a few centimetres on a motherboard, but creates problems on a backplane with several connectors and boards.

Rev. 2.1 of the PCI standard has been unchanged for a long time now. It is maintained by the PCI SIG. Double bus width and clock rate have been specified already in Rev. 2.1 giving room for improvement for quite a while. There are still severe technical problems to be solved for the advanced versions to maintain reliable operation at these higher data rates and large bus widths. In a modern PLC with distributed processing using fieldbus communication speed is hardly ever a big concern. Deterministic behaviour in real-time is the real issue. High-speed data like graphics to display status information is local, demanding high speed only within the box or cabinet. This is where PCI is needed.

PLC AND INDUSTRIAL NEEDS

Extreme conditions of temperature, moisture, vibration or aggressive gases may be present all at the same time presenting a harsh environment to industrial computers. They should be built to withstand all of these adverse conditions up to a degree as set by the designers. It turns out the environment is not that hostile in the majority of applications. However, good industrial quality systems are an insurance against possible problems.

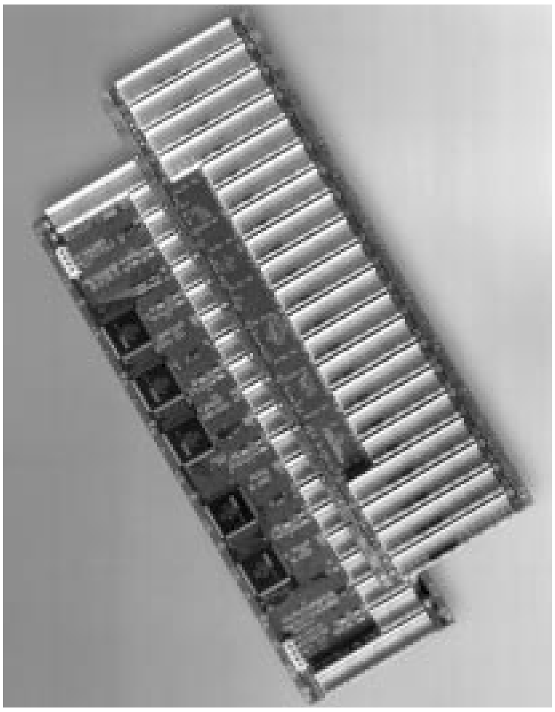

Figure 1.

Before buying a so-called industrial PCI-based computer define your environmental and functional requirements. Card-edge connectors cannot be used where moisture, dust and aggressive gases are present. Gas-tight pin-and-socket or leaf-style connectors are required. If there is the slightest possibility of shock or vibration then a card cage with guides, respectively locks on all four sides of a board is needed.

Dependable Operation

A PLC or industrial control and automation equipment has to work error-free and in time, all the time. This may also be called deterministic behaviour in real-time. As mentioned already, speed is typically not the most important parameter in real-time operation. Electromechanical devices and temperature sensors operate at very low speed compared to the high data rate of the PCI. Their data should be processed locally. Only results, control or configuration information should be transferred to or from a supervisory system. Most industrial computer systems have priority controlled interrupt functions to ensure real-time operation.

I/O

The PCI bus was made for burst transfers, not for the transmission of individual bits. However, industrial systems may have racks full of I/O boards and perhaps fieldbusses that connect to even more I/O points. The I/O points are typically independent, very often just single bit lines and they operate asynchronously. This is not exactly favourable for PCI-based I/O. This problem creates quite a challenge for the industrial board designer, at least if he wants to retain some of the original performance of the PCI bus. The IPCI design solves this problem by providing seamless integration of legacy busses to accommodate many low or medium speed I/O points from time-proven, debugged existing boards and software drivers.

Industrial I/O boards have their I/O signal lines connected through front panel connectors or through I/O pins on the backplane connector. Most professional boards use opto-isolation devices right behind the frontpanel or backplane I/O connector. This is a mandatory requirement for critical applications in Europe. Hazardous voltages shall not be carried alongside standard signal lines. Sometimes the I/O connections are moved over to a mezzanine board, like PMC (PCI Mezzanine Card) which allows for even more modularity. In the IPCI design there is also a USB (Universal Serial Bus) integrated into the backplane for more variety and capacity of signal transmissions.

PCI Issues

If a PCI-based system is used as a replacement for a PLC or in other industrial applications some or all of the items on the following list should be inspected for relevance to the intended use.

- deterministic behaviour
- hard real-time operation
- interrupts
- fan-out
- termination
- signal quality/reflections
- software reliability
- drivers for bridged devices

Other points may have to be added in specific cases.

INDUSTRIAL PCI-BASED SYSTEMS

Not all computers, which are used in industrial applications, are really industrial computers. Some are unchanged office/desktop PCs and maybe use metal cases with a few levers and screws to keep the boards in place. Others may have passive backplanes (big, flat motherboards blocking vertical airflow). IPCI industrial computers use EuroCards, which are mechanically secured on all four sides. They use gas-tight pin-and-socket connectors and utilise other features, which are necessary to make them real industrial as expected from a true PLC.

Since about the late eighties 19" rack-mount systems with PC architecture were used. They are primarily based on AT96, ECB, ISA96, SMP16 and VMEbus systems. Most of these systems have a common design; the computer and peripheral boards are plugged into a standardised passive backplane. In such an industrial PC all components, including the microprocessor can be configured by replacement or addition of individual boards.

INDUSTRIALPCI (IPCI)

IPCI uses EuroCard sized boards (both 3U and 6U) and a mechanical layout with a vertical passive backplane. EuroCards have been in use for more than 20 years in PLCs and other automation and control equipment. EuroCards as also used for VMEbus for over 15 years do have a well-established infrastructure.

IPCI developers have chosen a 2-mm connector because of its higher density than traditional DIN connectors at 2.54 mm (0.1 in.) pitch. High-density 2 mm connectors in multiples of 6 rows are used to provide enough pins for 32 bit and 64-bit operation and for I/O signals. Two pieces of 24 rows are 96 mm high on a 100 mm EuroCard this leaves exactly enough board space (top and bottom 2 mm each) for guide rails. A total of 240 pins are available from standardised connector modules on single height EuroCards (3U). The connector is a modular 3-piece standard design as used for many years in great numbers in telecom applications. The centre section (120 pins) carries the 32-bit PCI bus with all signals. The top section (60 pins)

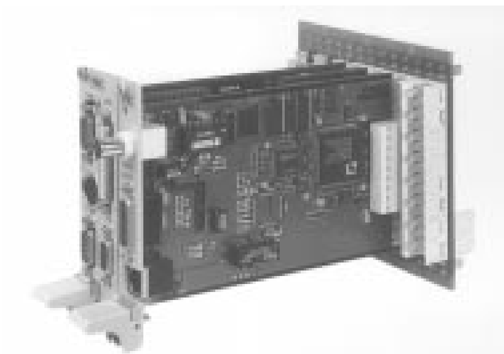

Figure 2. IPCI system with CPU & Ethernet cards

will carry the additional signals for a 64-bit version of the PCI, if implemented. The lower section (60 pins) is used for universal I/O or for a variety of already existing backplane busses. Pin-outs have been defined for several busses, including AT96/ISA96, ECB, SMP16 and VMEbus. The centre section of the connector is mandatory. The other sections are only installed when needed.

The main advantage of this 'dual' system (PCI plus legacy busses) is to provide the required continuity and long-term usability of an industrial system. Boards from traditional busses, which are available in great variety at low cost, can be used in a modern system together with a powerful CPU and a fast bus for graphics, mass storage and high-speed communications applications. Most systems would have a PCI section on one side of the backplane and a legacy bus section on the other side. Some may have legacy busses on both sides of the PCI section. The motherboard functions and circuits were moved onto the master or system CPU card. This is one of the maximum 5 available PCI slots in terms of the PCI specification. The USB (Universal Serial Bus) is specified on the basic connector (32 bit PCI). Most CPU boards have USB connectors at the front panel and out on the rear, off the backplane.

To prevent false placement of boards into slots a keying mechanism is used. Small plastic pegs are clipped onto the sides of the connector. The coding repeats along both sides of the connector shroud. This guarantees very good mechanical protection against false placement. This scheme does not take space from any pin connection on the connector, like coding on CompactCPI where 15 pins are lost for the coding mechanism.

The PCI specification limits clock skew to 2 ns between any two chips on the bus. The IPCI backplane has been defined to maintain this limit for all slots. The length of the signal paths is adjusted in the backplane to maintain uniform length for all slots. A maximum of 3 PCI devices is allowed on each IPCI adapter card. The IDSEL lines are decoded accordingly. Other PCI variants may only allow 1 device on a board.

The IPCI developers have chosen the classical 2 mm connector, which has been used in telecom applications for many years. IPCI connectors are available from Berg Electronics (METRAL), FCI (MILLIPACS), ITT Canon (TEMPUS CBC 20), Robinson Nugent (METPAK 2) and others.

The IndustrialPCI (IPCI) specification is owned by the SIPS (Standard Industrial PC Systems e.V.) consortium, an international organisation headquartered in Mannheim, Germany. A full range of products, including I/O boards, are available from several manufacturers. The web address is ‹http://www.sips.com›. The complete specification in English language is available for download.

OTHER PCI FORM FACTORS

CompactPCI (CPCI)

A similar standard, administered by the PCI Industrial Computer Manufacturers Group (PICMG), has also defined boards based on EuroCard standards using the electrical signals and protocol of the PCI bus. It is called CompactPCI (CPCI).

The 2 mm connector, which is used for CPCI, is different from the one used for IPCI and telecom applications. The CPCI connectors are available from AMP (Z-Pack), ERNI and others. These connectors normally come in multiples of 5 rows. Because of the size of a EuroCard two connectors, one connector with 25 rows (standard) and a special version with 22 rows are used for a total of 94 mm. On the standard connector 3 rows of contacts are lost because these are used for plastic pegs which provide mechanical keying for voltage and board options. A total of 22 rows are available for the PCI bus (32 and 64 bit) and some I/O. Both connectors together then provide 220 pins on a single height (3U) EuroCard.

The CompactPCI differs from standard PCI by defining 8 slots for one bus without using a bridge circuit. By PCI definition a connector and the PCI chip on a board are counted as 1 CMOS load each. The PCI drivers are designed for 10 loads. This would only allow for 5 boards max. (1 system and 4 adapter slots) as in desktop PCs and with IPCI. The PICMG has done simulations, which show that because of connector quality there should be enough signal power and quality to drive 8 slots. One requirement, however, is to add a 10 Ohm stub termination resistor on each signal line on every board. This is not defined in the original PCI standard. If only one system board and one adapter board are used on one end of the bus it needs special treatment. Diode termination is required on the far end of the backplane.

In a CPCI system only one PCI peripheral on each peripheral adapter board is addressable. There are not enough I/O pins to build bridge connections to other (legacy) busses on a standard 3U board. To do this a dual height EuroCard (6U size) is needed to accommodate the bridged bus.

CompactPCI is promoted by PICMG from Wakefield,

Figure 3. CPU card with Pentium chip

MA. Their web address is “http://www.picmg.com”.

PCI Mezzanine Card (PMC)

VITA (VMEbus International Trade Association), owner of the VMEbus and other specifications has defined a common mezzanine card (CMC) family (IEEE 1386). One of these card families is PMC (PCI Mezzanine Cards), IEEE 1386.1. The name describes the concept. Standardised modular boards with a full PCI bus interface are sandwiched onto a carrier board (VMEbus or other). Additional connectors for I/O are also defined. The mechanical design is specified in IEEE 1301 (IEC 917).

This layout adds PCI functionality to widely used industrial bus systems without the need for a separate backplane. The mezzanine boards fit onto a rasher of 75 x 150 mm (single size) or 150 x 150 mm (double size). On a VMEbus board these PMC mezzanines fit within the horizontal slot pitch (20.32 mm), so no extra space is needed. Up to 5 connectors (64 pins each) are defined for the PCI bus and many I/O signal lines.

PMC mezzanine boards are available in great variety from many vendors. The standard is promoted by the GRoupIPC consortium. Their web address is http://www.groupipc.com. Information on VMEbus and related bus standards is available at http://www.vita.com.

PCI and ISA (PISA)

The PISA (PCI and ISA) form factor uses the same connector as EISA (Extended ISA) used many years ago. The pins which used to carry the Extended ISA signals are now used for PCI. A big advantage of this concept is its small size and consequently the small size of the boards. This connector has the same dimensions as an ISA connector but because of its double story contact design it provides 2 times the number of pin connections in the space of an ISA connector. Functionally this is almost identical to another solution from the PICMG, which uses both ISA and PCI connectors inline. The PISA version is significantly smaller than the PICMG solution. Space is very often at a premium in industrial applications. An additional benefit is that all ISA boards can be used in any PISA slot. The user can start with a pure ISA system and upgrade or add PISA boards later.

Several manufacturers in Europe do already sell a variety of PISA boards. Companies in other countries, including the US, have plans for PISA boards. At this time PISA has no promotional consortium. Contact ‹hans.muehlbauer@jump.de› by email for more information.

SmallPCI (SPCI)

The PCI SIG who administers the original PCI specification also has defined a mechanically smaller version. SmallPCI uses the same mechanical form factor as PCMCIA (Personal Computer Memory Card International Association) but with a 108-pin connector replacing the 64-pin PCMCIA connector. With this number of pins an unrestricted PCI bus can be used directly. In the PCMCIA world a reduced version of the PCI bus, called CardBus, is used on the 68 pin connector. SmallPCI with enough signal lines for a full PCI bus therefore does not need a special driver or a chip, which converts PCI to CardBus, and vice-versa. This reduces cost, space, power consumption and possible conversion problems. SmallPCI is just a ’small PCI’ card.

SmallPCI cards are typically mounted parallel to the motherboard or carrier board, like a mezzanine. Small PCI boards are mounted inside the computer enclosure, not accessible to the user. Therefore they are not encapsulated like PCMCIA cards. This again saves cost and reduces heat conduction problems.

Incorporating too many functions on a traditional motherboard is impractical because of rapid increases in subsystem performance and technology changes. With the flexible SPCI design it is easy to upgrade only when needed but with up-to-date components. Motherboards can be manufactured cheaper (less layers, less complexity) in larger standardised quantities.

SmallPCI is administered by the PCI Steering Committee within the PCI SIG (Special Interest Group). SmallPCI products are available from Berg Electronics, IBM and others. Their Internet address is http://www.pcisig.com.

PC/104 Plus

The original PC/104 is an open standard for small square modules (3.6 x 3.8 in.) using the ISA bus. These modules are self-stacking like a sandwich made from boards. There are now at least two proposals to add a PCI connector in this small space. With today’s chip sizes there is not enough room left for a Pentium processor with supporting chips. There are efforts going on to overcome this limitation.

FUTURE DEVELOPMENTS

There will not be one uniform industrial PCI solution because applications have to cover such a broad range. Each of the described form factors is positioned in their respective application or geographical market section.

Full width backplanes for 19 inch rack mounting are needed where there are many I/O connections in a system. A 20-slot backplane has been shown at Hannover Industrial Fair (April 1997).

There are ongoing efforts to drastically lower the supply voltage of chips to run them cooler. In most cases it is not acceptable in real industrial environments to use a rotating fan mounted on a chip because of reliability problems and danger of explosion because of arcing.

True hot-plugging or live insertion may become available sometime not too soon. Having a few longer or shorter pins on the board connector is not enough. Some sophisticated low-level software and a reliable interrupt function is needed. The PCI world might benefit from the development in the VMEbus community.

IPCI has been developed by companies who have been in the PLC and automation business for many years. This makes IPCI a prime candidate for this market segment.

Hermann Strass is a consultant for new technologies, including bus architectures (industrial PCI,

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Systran

PMC, USB, VMEbus, Fibre Channel, SCSI, PCMCIA), mass storage technologies and industrial networking (AS-i, Fibre Channel, PROFIBUS, fieldbus USB). As a neutral expert he also organises seminars, conferences and training on these topics. He is an active or corresponding member of more than a dozen standardisation committees, including ANSI, DIN/DKE, ECMA, IEEE and VITA/VSO and Technical Co-ordinator for VITA Europe. Hermann Strass is the author of many technical articles and of books on SCSI, Mass Storage, PCMCIA and CD-ROM.