Get on the Bus: USB in Industrial Applications

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For industrial automation users, technology giveth and taketh away. On one hand advances in

semiconductors and software result in smarter and more capable computers and machines,

making the job of automating a process easier and more robust. On the other hand those same

advances can spell trouble. Automation products have long lifetimes that are measured in decades

and not years. So advances in technology – particularly PC technology – may mean that

automation products and applications have to change, sometimes painfully.

The question for industrial users then becomes what change should be made? And what can be

done to avoid a repeat of this problem in the future?

Consider the PC’s internal bus, the electrical pathway used, in part, for communication with the

outside world. At this time and for that case, Advantech believes the answer to both questions is

the aptly named Universal Serial Bus or USB.

This bus change in industrial PCs is a result of changes in the larger market. Currently, PCIExpress

is on its way to becoming a new backplane standard for PCs. So automation users are

faced with the prospect of changing how their devices interface with industrial computers.

As an added twist, embedded processor boards are increasingly popular and frequently these

boards come with no extendable bus, either PCI-Express based or one based on another standard.

For example, a study by Venture Development Corp. of Natick, Mass. predicted the share of

shipments of larger form factor embedded boards, those larger than 70 square inches, will decline

by 9.7 percent from 2004 to 2008 while the overall market grows by nearly 12 percent in dollar

volume shipments over the same time period. The growth will come from boards having only USB

ports and no extendable bus.

Any solution to this bus predicament must enable communication that is high speed, deterministic,

robust, and capable of covering the needed distance. The solution also must build upon a long

lived standard that is universally available.

USB meets these requirements. Virtually all industrial computers ship with multiple USB ports and

they’re on many other industrial devices as well. USB has the necessary speed and millisecond

determinism, more than enough for almost all industrial users. With some modifications,

particularly in the areas of securing connections and bridging long distances, USB can meet all of

the industrial application criteria.

**The Changing PC Landscape**

The consumer world long ago abandoned ISA, the Industry Standard Architecture bus created by

IBM in the early 1980s, in favor of PCI, the Peripheral Component Interconnect bus developed by

Intel and others in the mid-1990s. Consumer PCs are now in the process of moving to PCIExpress,

the standard debuted by Intel and others around 2004.

How soon PCI will disappear from consumer PCs is unknown. ISA hung on for years after the

introduction of PCI, with boards sporting a mix of ISA and PCI slots appearing during the

transitional period. It’s hard to pin down an exact date when ISA became extinct in the consumer

space but reports indicate that ISA was around for as long as decade or so after PCI was

introduced. It also should be noted that ISA is still available in industrial PCs and the embedded

industrial PC specification, PC/104, still calls for an ISA bus, although in a different form factor.

For technical reasons the switchover from PCI to PCI-Express may be faster than that from ISA to

PCI. For one thing, the replacement of PCI with PCI-Express is transparent to software, thus

developers don’t have to rewrite code to port an application from one to the other. That feature

makes the change much more painless than the transition from ISA to PCI.

Another benefit is that PCI-Express offers some significant advantages in enhanced performance,

particularly with regard to high speed applications like video cards, gigabit Ethernet, high speed

image capture, and others. Whereas PCI enables data transfers at 133 megabytes per second,

PCI-Express in its current form allows a maximum of eight gigabytes per second in each direction.

For that reason, major manufacturers of high end graphics cards like AMD subsidiary ATI and its

competitor NVIDIA are increasingly offering PCI-Express chipsets. Other applications, such as

high frame rate video capture, are also taking advantage of the speed offered by the new bus.

On the other hand, there are many different types and a great number of PCI devices, with both

type and number of devices much more numerous than were around when ISA reigned. Thus, this

legacy may act as a drag and slow the switch from PCI to PCI-Express. The date when PCI will

finally die in the consumer space probably won’t be known for sure until it’s already effectively

happened.

While the switchover is taking place, there will be a period when both PCI and PCI-Express slots is

found in the same motherboard. Industrial users need to take this transition into account because it

may impact them.

This change isn’t necessarily bad news. For one thing, the greater graphics performance enabled

by PCI-Express could prove beneficial in industrial applications. Today such applications

increasingly have a rich graphical user interface and being able to update a GUI at greater speeds

and with less drain on the CPU could be useful. In addition, machine vision applications could

benefit from the higher throughput, with the result that capturing more images per second would be

possible. Finally, it’s possible that a PCI-Express based solution could eventually be less

expensive than one based on PCI, once manufacturing volume increases.

In general, industrial users need to take advantage of the latest technology and being able to put

PCI-Express to work in particular could pay off in a number of areas. The problem becomes one of

I/O, communication with peripherals of all kinds. Industrial users still have some ISA boards,

although that number has been declining for years. There are presently many, many PCI boards in

use, providing connections to a wide variety of devices.

What’s more, such now obsolete internal busses, whether ISA or PCI, offer speed and

determinism. All provide access to a PC-derived clock, an eight megahertz one for ISA and 33

MHz for PCI. They also both can deliver megabits of data per second. Thus these internal busses

supply significant advantages in industrial applications, benefits any replacement also needs to

provide.

**Thinking outside the Box**

The solution, Advantech believes, literally involves out-of-the-box thinking. It’s long been standard

practice in industrial applications to have an internal PC bus and an external fieldbus, with the

fieldbus handling communications throughout the plant floor. The internal PC bus, for its part,

provides the connection between the processor and the outside world. This division worked but it

does mean the internal bus and its architecture play an important role in talking to the external

world. As a result, changes to the bus can have consequences far outside the PC.

If instead all I/O is moved out of the PC chassis, such problems vanish and advantages appear.

One consequence is that innovations and advances to the internal bus no longer disturb field

networks. So the internal architecture of the industrial PC can easily move to PCI-Express, with all

the performance and cost benefits. It’s even possible to run the latest version of the standard,

thereby ensuring that graphics cards and other applications benefit from the best possible

performance and fastest speed.

Clearly, such a move should be made to an established standard, one with a long lifetime ahead of

it. Otherwise, shifting the I/O outside of the PC will only lead to problems later, as the I/O method

becomes obsolete and is replaced. Given the length of time automation solutions exist once

implemented, the projected life has to be at least a decade and preferably longer.

Other necessary parameters of any out-of-the-box remedy are also rooted in the nature of

industrial applications. These include speed, determinism, distance, and robustness. For the first,

transmission rates have to be sufficient to meet data and control needs. In some cases, only a few

bits per second will suffice but in others data rates have to be substantially higher, megabits or

more. As for the second, most industrial applications can operate well with a time resolution of a

millisecond or more.

The distance requirements are in the tens of meters range for the most part, although there can be

cases in larger plant floors where longer runs are needed. Plant floors are frequently full of

vibration and dust, with high humidity and other harsh conditions a factor in some settings. Thus,

any solution has to be capable of handling the environmental conditions.

Finally, any attempt to move I/O out of the PC can’t be to some standard that isn’t readily available.

The interconnect has to be found not only on all PCs but also be present on most industrial

machinery as well. Meeting this criteria will ensure that implementation of the solution doesn’t

present an undue cost burden or require extensive upfront specialized specifications.

**The Contenders**

When surveying the ways in which this out-of-the-box move can be accomplished, there are a

number of possibilities. These include wired approaches, such as various forms of Ethernet,

Firewire (IEEE-1394), and USB. There are also wireless protocols, such as Bluetooth, different

implementations of 802.11, and the recently introduced wireless USB.

Of these the two most universal are Ethernet and USB. Both are found on nearly every computer

and an ever growing percentage of industrial machines. Both are expected to last for a long time

and hence should be available a decade or more from now. Both also benefit from decreasing cost

solutions due to increasing use in consumer goods. Finally, both have issues for industrial

applications, and in particular industrial I/O, that require some careful consideration before either is

selected.

Ethernet isn’t a single standard but is rather a host of communication protocols. Versions of it have

been around for over 30 years and it is today the standard for connecting all local area networks.

Even wireless connections eventually run through Ethernet to reach the wider world. Versions of it

also offer plenty of speed, which is one reason why market surveys show 100 megabit and gigabit

per second Ethernet each showing up in four out ten planned industrial data acquisition

applications over the next year or so. Other industrial uses should have similar penetration rates.

What Ethernet doesn’t offer, at least in a native or widely available form, is real-time performance.

As implemented in most applications, Ethernet doesn’t prevent data collisions between competing

nodes and doesn’t offer any Quality of Service (QoS) provisions. Thus in a deterministic setting,

such as is the case on the plant floor where a machine must service an interrupt without delay

when an internal clock ticks, Ethernet will fail. Given enough traffic, the micro-second level

response times of the network will balloon out to milliseconds and that can render Ethernet

unreliable for real-time industrial applications.

There are, to be sure, solutions to these problems. Real-time Ethernet protocols exist. The key

word here is protocols, indicating multiple and non-compatible methods. Thus, until a single

standard emerges there’s a chance of picking the wrong version.

One of the most promising ways to ensure performance is to build upon the IEEE 1588 Standard

Precision Time Protocol. This standard synchronizes clocks with sub-microsecond accuracy, and

this precision allows distant devices to talk via Ethernet in turn without stepping on any other

communication. On the other hand, this does mean that devices and network stack

implementations have to be constructed with IEEE 1588 in mind.

However, industrial users have another choice, one that doesn’t require waiting for a standard to

be finalized. USB, particularly since the advent of the 2.0 implementation with 480 megabit per

second data rates, offers the speed required and is found on virtually all motherboards and in

many industrial devices. That universality is evident in surveys of USB penetration among

industrial users of data acquisition modules. USB penetration will jump from 25 percent a few

years ago to nearly 50 percent in 2007.

It’s easy to see way. In addition to being on every device, USB is also deterministic, offering

millisecond response times. Those reaction times are more than enough for most industrial

applications. There are versions of USB for portable devices like PDAs and another for wireless

connections.

USB does have two shortcomings when being considered for the plant floor and both are physical

in nature. The first drawback is the limited run, which is only five meters for a standard USB cable.

However, that run can be stretched to 100 meters over CAT5 cabling and with the use of a

distance extender. Such an extension allows USB to be deployed over the entire plant floor. For an

example of the architecture using this solution, see the attached diagram. (Advantech USB DAQ

solution architecture slide image here).

The second issue has to do with the USB connector. Made for hot swapping, the connectors allow

for easy insertion and removal. There’s no active latch such as is found in other types of

connectors. Thus, it’s possible to unplug a cable with a simple tug, which could be inadvertent but

still bring down an entire plant floor network. Even without that problem, a vibration filled industrial

setting could cause the connector to work its way loose, leading to an eventual communication

failure.

Solutions exist for this problem as well. One is a screw lockable clamp developed by Advantech for

both USB type A and type B connectors. (See picture) The screw clamps on the type A connector

can be removed, allowing the cable to be used with a commercial PC. If present, the clamp

attaches to a kit mounted on I/O and hub modules, enabling the cable to be held securely against

accidental disconnect and ongoing vibration. This particular solution is low cost and is similar to the

type of connection technology used for years to lock printer, serial, and other cables in place.

**Recommendations and Conclusions**

For industrial users, the advent of a PC bus architecture change presents both a challenge and an

opportunity. The latter arises because the new architecture typically brings better performance and

enables new applications. The former is due to the central role the bus currently plays in essential

I/O.

By moving the I/O off of the bus and out of the PC, the problem can be averted and industrial users

will then be able to take advantage of the improved performance of the new bus. However, the

communication channel over which the I/O runs has to be carefully chosen, with such

characteristics as universality, data rate, determinism, robustness, and distance being important in

the selection.

While no bus today natively meets all of these criteria, simple and inexpensive modifications to

USB will allow it to satisfy all of the needs of automation and industrial applications. These

changes include the use of a distance extender and a lockable connection. With those

enhancements, none of which involve developing new standards or changes to drivers of other

software, USB can provide a pathway for data acquisition and transmission as well as for control

signals in industrial settings.

Done properly, this solution will provide a case where the best part of the old saying will repeat.

Technology will giveth – and then giveth some more.