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Get Off the Bus:
Why Ethernet Is Your Best Connection

When UniWest of Pasco, Washington, wanted to network their motion control application, they connected their ETC-2000 three-axes scanner to a Compumotor 6K4 Controller via Ethernet. A leader in the non-destructive testing industry, UniWest began using the 6K4 and Ethernet connection last year, upgrading from a ISA-based controller. UniWest's ETC-2000 inspects jet engines, and it's now operating at full capacity.

So why have UniWest and hundreds of other motion control users chosen Ethernet over fieldbus and PCI? As far as industrial motion control is concerned, Ethernet, fieldbus and PCI are all capable of carrying the same information between a high-level machine controller and a motion controller. Ethernet is a networking protocol, PCI is a PC bus architecture and fieldbus is used in industrial control. These three technologies are now competing for the same users, and while the playing field may be level, the technologies offer their own highs and lows.

Ethernet: A Worldwide Standard
Developed more than twenty years ago as a high-speed serial data transfer network, Ethernet has become a worldwide standard and is now the most widely used Local Area Network (LAN) in existence. More than 85% of all installed network connections in the world are Ethernet. The most common Ethernet data transfer rate is 10 million bits per second (Mbps), although most installations are rapidly converting to Fast Ethernet or 100 Mbps. The next generation of Ethernet is Gigabit Ethernet capable of 1 Gbps (1000 Mbps). Ethernet is generally incorporated into a motion control system through a standalone controller connected to the PC or network via a standard Ethernet cable.

Fieldbus: A Popular Protocol
The term "fieldbus" covers many different industrial network protocols. Two of the most popular protocols are DeviceNet and Profibus. The majority of fieldbus protocols have been developed through and are currently supported by specific PLC manufacturers such as Allen Bradley and Siemens; however, a dominant fieldbus standard does not yet exist. Network performance and hardware interfaces differ depending on the fieldbus chosen, although data transfer rates from 500 Kbps to 12 Mbps are typical. A PLC usually serves as the fieldbus master, which then communicates to distributed follower devices such as industrial I/O or motion control systems. A motion controller is typically a standalone or bus-based follower device on the fieldbus.

PCI: High-Speed Date Transfer

Peripheral Component Interconnect (PCI) architecture is currently the industry standard for desktop PCs. It is the latest in a line of ever-improving bus architectures offering faster speeds and greater throughput. PCI was designed to accommodate the extreme amounts of data transferred by today's high-bandwidth applications such as audio and video peripherals. PCI is far superior to the bus architectures it replaces, such as ISA, EISA and VESA because it moves the peripherals closer to the CPU, thus eliminating processing latencies. It is a parallel interface, and the most common version today has 32 data lines capable of achieving 133 million bytes per second (MBps). Most new PCI chipsets are capable of 64 data lines and throughputs of 266 MBps. The next generation of PCI or PCI-X will be capable of 1 GBps. A PCI motion control solution comes in the form of a traditional bus-based card that fits into an expansion slot of the PC.

	Ethernet	Fieldbus	PCI
Data Transfer Rates	10/100 Mbps	0.5 to 12 Mbps	133/266 MBps
Type of Protocol	Serial	Various (mainly serial)	Parallel
Control Implementation	Standalone controller connected to PC or Network Interface.	Standalone or PC peripheral card follower device connected to PLC or PC master.	PC peripheral card

Figure 1: Technology Comparison

Since PCI data-transfer rates are about 20 times greater than that of Ethernet and fieldbus (see Figure 1), it is tempting to assume that PCI the most obvious choice for your control system. Well, not necessarily. Why? Speed, although important, is only one of the many criteria that must be considered to determine the proper control structure. Other important issues in control system specification are flexibility, package size, PLC compatibility, installation and maintenance and long-term viability. Let's examine each of these areas relative to Ethernet, fieldbus and PCI solutions.

Speed

While PCI may clearly win the data-transfer-rate race, the important issue is how that throughput is being utilized.

It is very unlikely that a motion control application will use the entire bandwidth of the PCI bus. Usually the computer is sharing the PCI bus with several other devices such as an Ethernet card, a sound card or a video application. In fact, being able to handle Fast Ethernet and other high-bandwidth functions is one of the main reasons that PCI has been upgraded from 32 bit to 64 bit. PCI is necessary as a backbone to carry all of the information a network and other devices on the PCI bus transmit. Even if the entire PCI bandwidth were available, most PC-based motion controllers are simply not fast enough to send and receive large amounts of data as quickly as the PCI bus allows. In other words, the bottleneck is not the data transfer protocol but the device sending and receiving the data itself.

Another speed-related concern is whether the majority of motion control applications require the throughput associated with a PCI bus. If we look at the type of information that is typically sent and received by a motion controller (i.e., position, velocity, acceleration or error), the actual

amount of data transferred every cycle is relatively small--perhaps 512 bytes. With an Ethernet motion controller, these 512 bytes equal only 4% of the overall bandwidth in a 10 Mbps network.

Flexibility
Motion control applications today are carried out by a variety of controllers. Depending on the application, a bus-based, standalone or network motion controller may be required.

Unfortunately, a PCI solution allows for only one of the form factors: bus-based. In applications where the motion controller must carry out functions independently of a PC or in situations where there is no PC control on the machine, a PCI-based solution is simply not feasible. On the other hand, most Ethernet or fieldbus controllers are also capable of operating as standalone devices.

As for networking, a PCI-based solution is not a viable option for remote access. Implementing a motion controller on a factory network requires a controller with a network interface; since most factory networks are Ethernet the choice is made even easier.

Package Size
Often, when deciding between a standalone or network-capable controller and a PC-based controller, an engineer mistakenly assumes that a PC-based controller saves space since it resides in the PC. While this is true of the controller itself, there is also an external box required to connect servomotors, step motors, encoders and I/O. In many cases this external box is as large or larger than a comparable standalone controller.

PLC Compatibility
In many applications today a PLC is used for the primary control and it tells a motion controller when to move, how far to move and how fast to move. The communication between the two devices can range from discrete I/O to a network connection. Discrete I/O is not a favored solution due to the time and effort required in wiring and installing the system. An Ethernet or a fieldbus solution is preferred in this case. Most PLCs on the market today offer Ethernet as a standard networking option in addition to their fieldbus of choice.

Installation and Maintenance
Most companies cannot afford to have a DeviceNet or Profibus specialist on staff who thoroughly understands the network protocol. Even if a company could afford such a person, it is unlikely fieldbus would be their specialty. However, almost every company has a network administrator who is well versed and specializes in Ethernet protocol, making Ethernet all the more attractive for industrial control.

Unlike connecting bus-based controller cards to a computer, connecting Ethernet to a PC is simple. The only connection between the PC and an external Ethernet motion controller is a category 5 Ethernet cable (see Figure 2). To add additional axes of control just use a readily available Ethernet hub or switch. Replacing a controller simply means configuring a new motion controller via software and making the same easy Ethernet connection. Bus-based controller card installations, on the other hand, require most computers must be shut down or taken offline.

Then you must remove the PC cover, an especially difficult task if the PC chassis is buried inside a machine. Finally, most bus-
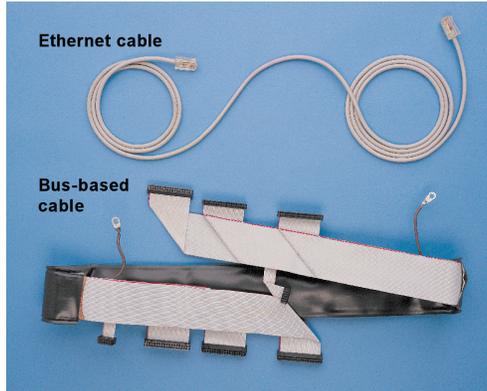

Figure 2: Ethernet Wiring Simplicity

based motion controllers require two or more PCI slots for installation. Additional axes of control require additional slots and unwieldy cables must be snaked through yet another open expansion slot. If the controller fails for any reason, the whole process must be repeated to replace the controller.

	Ethernet	Fieldbus	PCI
Speed	10 - 100 Mbps Fast enough for most motion control applications.	0.5 - 12 Mbps Fast enough for most motion control applications.	133 - 266 MBps Extremely fast to handle high bandwidth applications.
Flexibility	PC, PLC and network connectivity.	PC, PLC and network connectivity.	PC connectivity only.
Package Size	Smaller in stand-alone applications where no PC is required. Comparable when used with PC.	Comparable when used with PC or PLC.	Comparable when external connections are factored in.
PLC Compatibility	Compatible with PLC Ethernet modules and/or discrete I/O.	Compatible with PLC fieldbus modules and/or discrete I/O.	Typically discrete I/O only.
Installation and Maintenance	Simplified standard installation Highly maintainable Availability of trained resources	Requires specialized knowledge Lack of trained resources	Difficult installation and removal Complex wiring Lack of trained resources
Long Term Viability	Multi-industry support Widely developed infrastructure	Control industry only	Multi-industry support Subject to changes in PC technology

Figure 3: Ethernet Advantages

Long-Term Viability
When choosing control architecture, an important question to ask is, "Will this architecture be available and viable for the life of my machine?" Although it seems likely that PCI will be

available for many years to come, one must wonder if the same was true for ISA, which is now obsolete. How much longer before a faster and more efficient bus structure is developed for the PC? Additionally, how far can the fieldbus technologies be pushed and who will motivate such action? A good point to consider is, "Will companies like Oracle, IBM or Coca-Cola care if a particular fieldbus becomes obsolete?" Probably not, but you can bet that they are concerned about the future of Ethernet since their company infrastructure is most likely built upon it.

Ethernet has shown remarkable staying power. With over 85% of network connections in the world using Ethernet, there is widespread industry acceptance and thus little chance the technology is going to disappear anytime soon. Since the 1970s Ethernet has seen many PC bus architectures come and go and with every new bus there are companies that have developed Ethernet components for that particular bus.

Naturally, Ethernet offers the added benefit of remote networking. Texas Instruments in Attleboro, Massachusetts, for example, is using the 6K Controller's Ethernet capability to remotely troubleshoot one of their machines in the UK, eliminating the expense of sending a technician to Europe.

The dominant technology--whether it ends up being Ethernet, fieldbus or PCI--will need to be flexible, easy to maintain and will require industry support and confidence in its long-term viability. Ethernet clearly leads the group in these concerns, while the other two technologies provide only partial solutions. Ethernet-based motion controllers are flexible enough to operate in standalone applications as well as those requiring an easy and reliable interface to a PC or a PLC. Couple this with local or remote networking possibilities, and it is easy to see that Ethernet allows a manufacturer to standardize on one motion controller regardless of the application. Overwhelming industry acceptance of Ethernet technology ensures its speed and performance will continue to improve, as evidenced by the significant progress already made in Gigabit Ethernet and end-users like UniWest and Texas Instruments. Time and experience will tell which technology will dominate the factory automation industry. But networkable, remotely accessed industrial motion control is the key to the future, and Ethernet is most clearly the architecture of choice.