Test-System Development Guide

Computer I/O Considerations

Application Note 1465-2

This application note is part of the Test-System Development Guide series, which is designed to help you quickly design a test system that produces reliable results, meets your throughput requirements, and does so within your budget.

The first application note in the series, *Introduction to Test-System Design*, covers test-system philosophy and planning and discusses how test is used in three sectors: R&D, design validation and manufacturing.

This application note, *Computer I/O Considerations*, is the second in the series. It describes the advantages of using computer-industry standard I/O and explores the advantages and disadvantages of GPIB, USB and LAN interfaces for rack-and-stack test systems.

See the list of additional application notes in the series on page 9.

Table of contents

Agilent Technologies

Introduction

Whether you plan to use your rack-and-stack test system for R&D, design validation or manufacturing, you are likely to program and control your system with a PC. For decades, the IEEE-488 bus, commonly known as the general-purpose instrumentation bus (GPIB), has been the standard interface for connecting test instruments to computers and for providing programmable instrument control. GPIB is still a common and useful technology, but now other I/O options are available. This application note explores the various I/O options and helps you decide which interfaces make the most sense for your test system.

Proprietary I/O versus industry-standard I/O

Most of today's PCs offer built-in Universal Serial Bus (USB) and Ethernet-based local area network (LAN) connections. These industry-standard PC I/O technologies are much faster than previous PC I/O technologies such as RS-232, and therefore are much more suitable for automating and controlling test-and-measurement instruments. IEEE-1394, or FireWire interfaces, while not as ubiquitous as USB and LAN ports on today's computers, also are readily available.

Using these industry-standard interfaces for communicating with your test instruments can save you time and money and reduce headaches as you build your test system. Some benefits of using industry-standard I/O are immediate and obvious. For example, with USB, you don't have the additional expense of purchasing an I/O card, and you don't have to dismantle your PC to install the card. There are other less obvious advantages to industry-standard I/O as well. Because the computer industry employs thousands of engineers who work on improving the throughput rate and data integrity of these interfaces, they are likely to continue to improve more rapidly than proprietary interfaces. Using industry-standard I/O also makes it easy to interchange instruments in your system with instruments from a variety of manufacturers.

Proprietary interface cards, such as MXI-2 and MXI-3 from National Instruments are expensive, with typical price tags of about US$1,500. You have to open up your PC housing to install them. And if you don't have an open expansion slot, you need to consider replacing your computer.

Because of the inherent advantages of industry-standard I/O and customer demand for it, instrument manufacturers have begun adding LAN and USB interfaces to their test equipment. For example, the Agilent 33220A arbitrary waveform/function generator, introduced in early 2003, includes LAN, USB and GPIB interfaces.

If you want to use your existing GPIB instruments in a rack-and-stack test system, you don't necessarily need to use GPIB as your interface. Agilent also offers converters–USB/GPIB and LAN/GPIB–that allow you to use your GPIB-equipped test instruments with USB- or LAN-equipped PCs, eliminating the need to install a GPIB card in your PC. National Instruments also offers a FireWire/GPIB converter. In the next section, we will look at GPIB and the two main industry-standard interfaces, LAN and USB, and explore the applications where each is most appropriate. (FireWire interfaces are used primarily for VXI test systems. You will find more information about VXI in Application Note 1465-4, Test-System Development Guide: Choosing your Test-System Architecture and Instrumentation.)

GPIB interfaces

GPIB is the most common interface for programmable test-and-measurement equipment, and it is still one of the best choices if you want to maximize throughput for a variety of block sizes. GPIB is a parallel bus that includes control lines, handshake lines, and 8 bi-directional data lines–specifically designed for instrument communications and control. GPIB supports up to 14 devices that can be connected to your PC. You can use either a star or a daisy-chain configuration for connecting multiple instruments (see Figure 1), but cable length is limited to 2 meters (times the number of devices) up to a maximum length of 20 meters.

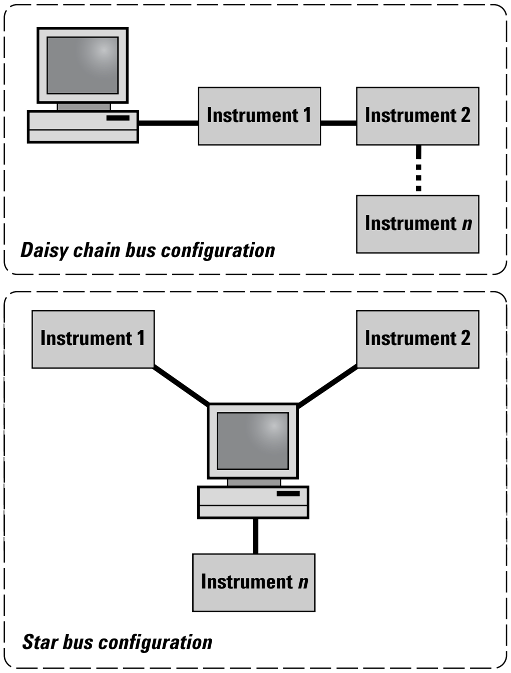


Figure 1. You can configure a GPIB bus in either a daisy-chain or star topology, or you can intermix these two configurations.

You can achieve data transfer rates of more than 500 KB/s on a GPIB bus if you limit bus cable length to 1 meter (times the total number of devices), up to a maximum length of 15 meters. Longer cable lengths reduce the maximum data transfer rate to less than 500 KB/s.

When you use GPIB, configuring the instrument I/O bus is a relatively easy task. However, each instrument on the bus needs to have a unique address. This requirement means you may have to manually change an instrument's address when you configure your system.

GPIB has other drawbacks, too. GPIB cables and connectors are rather large and bulky and they are relatively expensive. And because GPIB isn't a standard built-in PC interface, you have to open your PC housing and install an interface card in one of your PC's expansion slots.

To communicate with instruments over GPIB, you need to install an I/O software package. Plug and Play drivers, IVI-COM drivers, and VISA/SICL (Virtual Instrument Software Architecture and Standard Instrument Control Library) are examples. These packages support popular languages such as C and C++, Microsoft ® Visual Basic 6.0, Visual Basic .NET, National Instruments' LabView, and others.

USB interfaces

USB was originally intended as an alternative to the RS-232 serial interface and the Centronics parallel interface, an older and still widely used standard I/O interface for connecting printers and certain other devices to computers. USB is suitable for a range of computer peripherals, from slow devices, such as mice and keyboards, to high-performance devices such as scanners, printers, and cameras. Now, USB is finding its way into test-and-measurement instrumentation, too.

USB is a serial interface bus that includes two power wires and a twisted pair to carry data. USB is capable of data transfer rates of about 12 Mb/s for v1.1, and up to 480 Mb/s for v2.0. In addition, v2.0 is fully backward-compatible with v1.1. The only difference is the data transfer rate. If you decide to use USB v2.0 to obtain faster throughput, you need to be aware that the USB bus cannot transfer data faster than the specified throughput rate of the test instrument to which it is connected. For most GPIB-based instruments, the throughput rate will not exceed the USB v1.1 rate. In other words, using USB v2.0 will not increase the throughput speed if the instrument is not able to provide throughput at the faster rate. Also see the "Gating factors on data rates" sidebar on page 6.

USB is capable of supporting up to 127 devices on a given interface. If you use a GPIB-based system, you must ensure that instrument addresses are unique, but USB provides this function automatically. When USB devices are manufactured, they are given unique identifiers based on the manufacturer, the instrument serial number, and the product number. When the device is powered up and connected to a controller, the controller detects its presence automatically, and if the host-side software drivers are loaded, the instrument will be ready to communicate on the bus. USB devices also are "hot swappable," which means you don't have to shut down your PC to plug in or unplug an instrument.

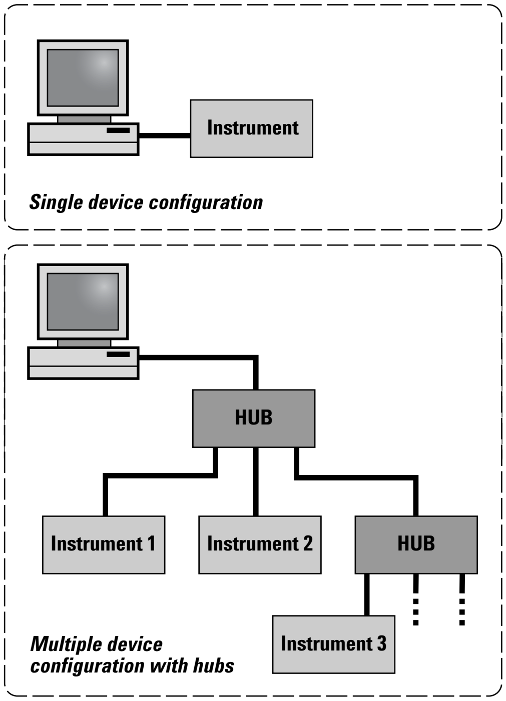
With USB, the computer schedules and initiates all transactions. If you are using a Windows NT® operating system, you will find that it does not support USB connections.

Configuring USB systems

USB cables and connectors are considerably smaller than their GPIB counterparts. However, device-interconnect configurations for USB are somewhat different from those usually seen in GPIB-based systems. Many USB instruments are equipped with a single USB connector, so you cannot daisy-chain multiple devices together. Instead, you need to use a hub to connect the devices to your computer, as shown in Figure 2. Not all test-and-measurement USB drivers are designed to work with hubs, so it is a good idea to check with the manufacturer.

Hubs provide expansion capability for USB, permitting multiple devices to be connected to a single USB port. These hubs are transparent to a controller, and you can cascade them

Figure 2. USB configurations with a single device and with multiple devices connected through a hub


Instrument
Single device configuration
HUB
Instrument 1
Instrument 2
HUB
Instrument 3
Multiple device configuration with hubs

up to five deep. Using hubs in your system offers several advantages. For example, many USB hubs include LED status lights that indicate which port is connected. Also, a hardware failure at the interface to one instrument, such as a shorted line, is unlikely to cause an entire bus to fail. This makes troubleshooting an I/O interface fault in a large system with many instruments a much easier task than having to disconnect each device in turn, as required in a GPIB-based system.

Simple connections

Connecting USB instruments to a PC controller is also a simple task. USB is especially useful with laptops, since typically they do not have the PCI slots required to install GPIB PCI cards. Most of the PCs produced within the last few years have several USB ports already built in (these will probably be USB v1.1-compliant). PCs that support USB 2.0 are beginning to appear in the marketplace; some even have ports on both the rear and the front of the PC as a convenience. For those PCs that don't have built-in USB ports, PC interface cards for both USB v1.1 and USB v2.0 are available from several manufacturers. If you use USB v2.0, you will want to use either the Windows 2000 or Windows XP operating system, since both provide support for USB v2.0.

As with GPIB, communications with instruments via USB requires the installation of an I/O software package. Plug and Play drivers, IVI-COM drivers, VISA/SICL, and IntuiLink software—supporting C/C++, Visual Basic 6.0 and Visual Basic .NET—are available with USB support.

LAN interfaces

You also can connect your test-and-measurement instruments to a PC via a LAN interface. Ethernet LANs are almost universally available at industrial and commercial sites, and most PCs found in these facilities are already connected to a LAN. As a result, Ethernet-based LAN interfaces for test equipment are likely to become even more common than USB connections. Ethernet-based LANs commonly support data rates of 10 Mb/s to 100 Mb/s, and some even operate at up to 1000 Mb/s.

USB and LAN interfaces share a number of features. They both operate in serial mode, and both use relatively small and inexpensive cables and connectors (especially when you compare the connector costs to those of GPIB).

You will probably need an Ethernet hub to interconnect multiple LAN instruments in a test system. But, Ethernet hubs are readily available today—and are relatively inexpensive. Many provide network status, or activity indication with a series of LEDs.

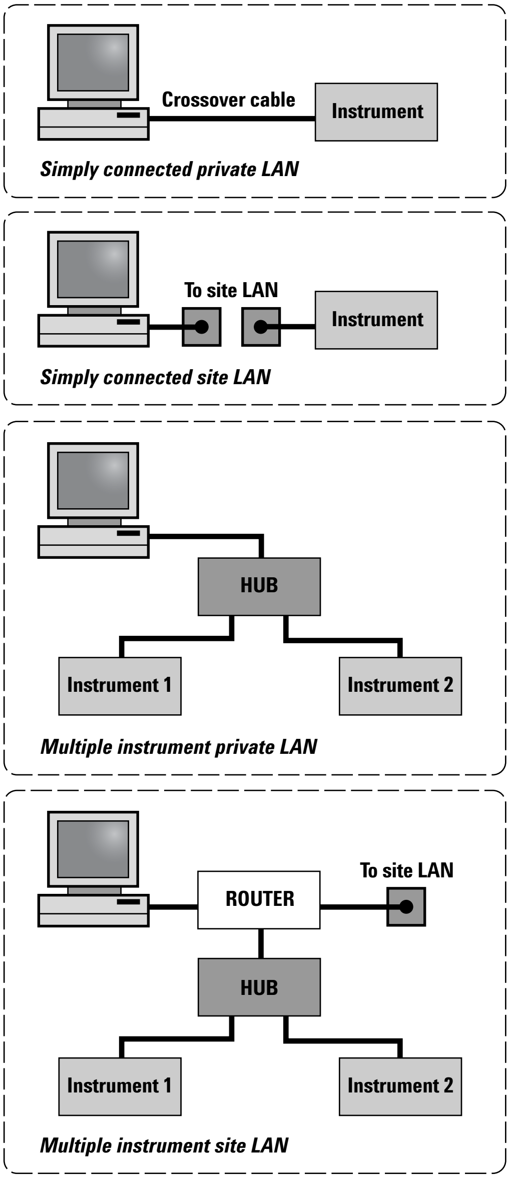
Ethernet-based LAN devices typically need to be configured to operate properly on a network. However, instruments that support Dynamic Host Configuration Protocol (DHCP) provide the capability for test instruments to configure themselves automatically to operate on a network—if these services are available on the network. Unlike other interconnection methods, using LAN interfaces requires knowledge of computers and the Local Area Network connections. You may need help from your local IT group to set up your LAN connection.

Connection methods

You can connect LAN-enabled instruments several different ways. They may be connected directly to a site LAN (a workgroup LAN, intranet, or enterprise LAN), or they may be connected to a private LAN.

In private-LAN configurations, your PC and your test instruments are connected to each other via a LAN, but they are not connected to a site LAN. The simplest private-LAN configuration consists of a controller and only one instrument. See the first illustration in Figure 3. You also can connect multiple instruments in a private LAN, as shown in the second illustration in Figure 3.

Figure 3. Single and multiple instrument configurations can be connected to private LANs and site LANs.



Simply connected private LAN

Simply connected site LAN

Multiple instrument private LAN

Multiple instrument site LAN

If you plan to use your site LAN, rather than a private LAN, you need to be aware of two potential drawbacks:

1. Traffic on your site LAN can slow down your measurements.
2. If you are using a LAN interface for controlling your test system, it is possible that a faulty instrument could damage or disrupt the network, particularly when the instrument is turned on and tested for the first time. Controlling your test instruments via a private LAN is the safest approach, since it limits the range of potential disruption and access.

For all setups, you can connect instruments to the LAN either with a conventional LAN cable or through a wireless adapter. Wireless routers and hubs also are available, as are wireless USB-to-LAN interfaces. See Application Note 1909-3, *Creating a Wireless LAN Connection to a Measurement System.*

Remote access

A site LAN has the potential for permitting any controller on the LAN to access instrumentation—either intentionally or unintentionally. If the site LAN can be accessed from physical locations outside of your facility, then others can access your instrumentation. This open access can be a valuable asset because it lets you remotely control instruments and systems almost as easily as if they were next door. You can use remote access capability to diagnose system and instrument faults from faraway locations. Multiple engineers can share the expensive test instruments and systems from remote locations.

However, this open access also can be a disadvantage. For example, if the site LAN is connected to the outside world to provide Internet access, you face a serious risk of exposure to undesired system accesses. Firewall software and/or using a router which requires specific device addressing rather than a switch or hub can provide protection.

If you want remote access to your test equipment, but security and controlled access are a system requirement, then you need a lockout feature. Some instruments, such as the 33220A function/arbitrary waveform generator mentioned earlier, provide this feature via an Allow List.

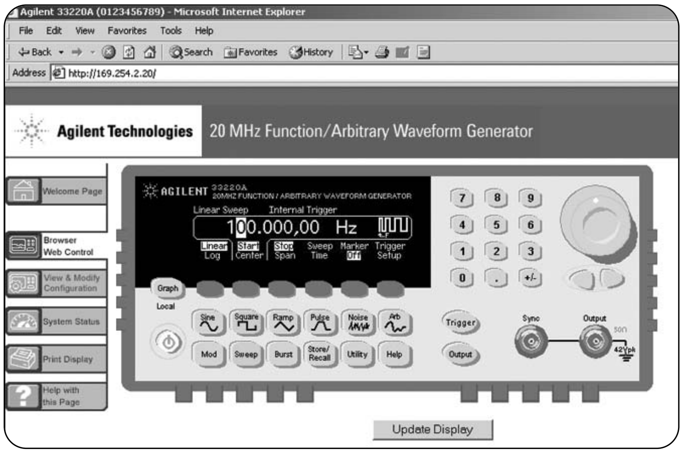
An *Allow List* is a list of remote LAN addresses that are permitted to communicate with the instrument. Any controller that attempts to access an instrument whose address is not on the *Allow List* is rejected. This feature provides a level of system security for those instances where your system is connected to a site LAN and is at risk for inadvertent access.

Instrument communication and operation over LAN

Instrument communication over an Ethernet-based LAN requires a software driver package if I/O is to be performed via Plug-and-Play, IVI-COM or VISA/SICL. It's also possible to use the TCP/IP's sockets or telnet to perform instrument I/O directly without a host-side driver. In fact, I/O operations using sockets provide the fastest data transfer rates, since the host-side driver is bypassed.

You can operate some LAN-enabled test instruments via a virtual front panel that appears on your PC screen. Typically, the display looks and acts like the actual instrument itself (see Figure 4), and you use your mouse to actuate buttons as if you were actually pushing front-panel buttons. The virtual instrument display mimics that of the actual instrument, that may be thousands of miles away.

Figure 4. Virtual front panel of the 33220A function/arbitrary waveform generator



Agilent 33220A (0123456789) - Microsoft Internet Explorer

Address http://169.254.2.20/

Agilent Technologies 20 MHz Function/Arbitrary Waveform Generator

Linear Sweep Internal Trigger

100.000,00 Hz

Which I/O interface should you use?

To decide which I/O interface or interfaces you use in your test system, you will need to consider many factors. These include data transfer rates and block sizes, and costs for cables, routers, hubs, and PC I/O cards. Other factors include I/O driver availability, and programming requirements, as well as the need for possible remote system access.

Keep in mind that you do not have to choose a single I/O interface. Systems incorporating multiple interfaces are particularly useful if you have a mixture of older GPIB instruments and newer instruments with other interfaces built in. Today's advanced software tools that include VISA technology eliminate the need to talk to different kinds of I/O in different ways. A minor change to a single line of code is typically all that is required. However, do not mix interfaces on a single instrument—the input and output must be on a single interface—and make sure your software drivers know which instrument is using which interface.

Gating factors on data rates

The data rates of a test system are determined by the slowest device/firmware/software in the system.

For example:

1. A high-speed instrument with integrated LAN controlled with an older 485 computer will be limited by the computer processor speed and possibly memory depth.
2. A USB2 interconnect will operate at a USB1 rate if the instrument and computer do not also support USB2.
3. An Instrument with a data transfer rate of 33K bytes/second will not transfer data any faster with USB, LAN or a computer that is able to transfer data at 1M bytes/second.

To see an example system that incorporates multiple interfaces (RS-232, FireWire, USB, GPIB and LAN), see the application note Test System Development Guide: Choosing Your Test-System Architecture and Instrumentation (AN 1465-5).

Real data rates

You will notice that individual I/O bus specifications for data transfer rates usually give only the theoretical maximum transfer rate. The actual data transfer rate that can be achieved for any given system depends on a number of factors. These factors include PC microprocessor speed, PC software and driver overhead, I/O card hardware, and instrument-specific hardware and firmware.

These variables make it difficult to predict the actual data transfer rate that might be expected for any given system configuration. Table 1 shows a relative comparison of data transfer rates for several data block sizes among GPIB, USB v1.1, USB v2.0, and LAN interfaces. These data were compiled using the Agilent Model 33220A function/arbitrary waveform generator and a Hewlett-Packard Kayak PC with an 800 MHz processor running on a Windows XP operating system.

For small data-block sizes of a few hundred bytes, there is no appreciable difference in bus speed, but the higher-performance buses (USB v2.0 and LAN) demonstrate a marked improvement in the time required to transfer large data blocks.

The differences in data transfer rates between small and large data blocks for any given interface are largely due to variations in the latency, or software overhead, required for each of the interfaces prior to the start of the actual data transfer.

If you're looking for high throughput in a test system, don't be swayed by the perception that high-speed interfaces will always get you there. In most test systems, the use model is one of "Close a channel; measure a point", then "Close another channel; measure another point." In this case, block transfer rate is meaningless. What really counts is the time to make that first measurement. This fact is one of the reasons that GPIB has lasted so long as an interface. It is quite good at executing this use model.

Table 1. Relative I/O times from a PC to an Agilent 33220A (data taken with a 1-meter cable on an HP Kayak XU800 with an 800 MHz processor running Windows XP)

Interface	Function change	Frequency change	4K arb	64K arb
GPIB	99 ms	2 ms	20 ms	340 ms
USB 1.1	100 ms	4 ms	10 ms	185 ms
USB 2.0	99 ms	3 ms	8 ms	100 ms
LAN (socket)	100 ms	3 ms	8 ms	110 ms

For a detailed look at data transfer rates of two different block sizes over the various interfaces, see Application Note 1475-1, *Modern Connectivity–Using USB and LAN Converters* (see sidebar below). One of the benefits of having an instrument that supports multiple interfaces is the ability to easily compare the actual data transfer rate for each of the I/O interfaces in a given application. This permits you to select the interface that offers the optimum performance.

If the application program's I/O calls are written with a driver interface that provides a common set of programming commands independent of the interface, such as Agilent's VISACom, then it becomes a simple matter to direct the I/O calls to any of the three interfaces.

Comparing costs

Today, many companies are looking for ways to lower the cost of test. If this is true of your organization, implementation cost will be an important consideration in selecting an I/O interface for your test system.

New PCs typically have several USB ports built in, but GPIB and LAN interfaces usually require a card that you must purchase separately. GPIB cards typically cost several hundred dollars and LAN cards usually sell for US$10 to US$50.

Also, if you plan to use USB or LAN interfaces to connect multiple instruments in your system, you will need hubs. These hubs can cost from US$25 to US$100 each, depending on features and the number of ports they support.

You also need to consider the cost of the cables for your test system. GPIB cables are relatively expensive, ranging in price from US$25 to US$100 each, depending on their length. USB cables, on the other hand, range from US$8 to US$30. LAN cables are usually the least expensive, typically costing less than US$10. Some can be found for as low as US$3.

You can make useful cost comparisons by assuming that all test instruments are able to support any of the three interfaces and computing the interface cost for your proposed test system. Today, few test instruments actually do support all three, since the industry is just beginning to provide instruments equipped with multiple computer-industry-standard interfaces. However, the I/O interface converters mentioned earlier permit GPIB-only instruments to be connected to USB- and LAN-based interfaces. For example, the Agilent 82357A USB/GPIB interface enables your PC to communicate with GPIB devices via the PC's USB port. Similarly, the Agilent E5810 LAN/GPIB gateway provides a means to connect GPIB devices to a LAN. (See sidebar and Figure 5.) These converters can save you the cost of replacing your existing GPIB test instruments if you decide you want to use industry-standard I/O. However, these converters are appropriate only for applications where measurement speed is not critical, as they do slow the data transfer rate.

Let's look at an example of a test system designed to test the Agilent 33220A function/arbitrary waveform generator. The test system consists of a controller, a local printer, seven rack-and-stack instruments, a fully loaded 13-slot VXI mainframe, and support for testing three 33220A waveform generators.

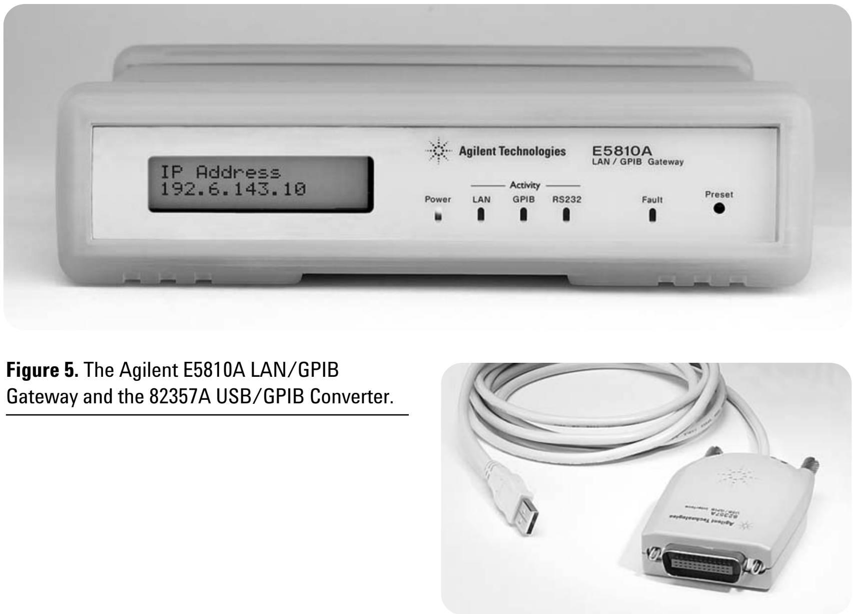


Figure 5. The Agilent E5810A LAN/GPIB Gateway and the 82357A USB/GPIB Converter.

Using USB and LAN I/O Converters

If you are considering using an I/O converter, be sure to read Application Note 1475-1, Modern Connectivity—Using USB and LAN I/O Converters: What is the Best Input/Output Interconnect for Your System? This application note compares the Agilent 82350B GPIB PC card, the 82357A USB/GPIB converter, and the E5810A LAN/GPIB gateway in terms of controller and operating system requirements, set-up steps, data transfer rates, allowable distances from instruments to the PC, etc. These details will help you choose the best interconnection method for your application.

As Table 2 shows, GPIB is the most expensive scheme to implement. Even with the added costs of USB and LAN hubs, their reduced cable costs and higher overall speed performance makes them more attractive alternatives.

From a systems perspective, hubs also offer some I/O interface operational feedback that is lacking with GPIB systems. Also, the much smaller USB and LAN cables and connectors take up much less rack space, making system cabling easier. They also weigh less.

Ease of implementation

USB is the simplest I/O to implement, and GPIB is also relatively straightforward, as long as you don't mind the hassle of opening your PC and installing an interface card. Using LAN interfaces typically requires more LAN knowledge and configuration effort. For many system developers, the advantages of LAN far outweigh the added development time required. You need to evaluate your own situation to decide if that is true for you.

For low-frequency test systems, Agilent offers the N1908A Test Automation Kit that simplifies the process of automating measurements. The kit handles driver issues, launches you into your preferred software environment and ensures reliable measurements. It is an inexpensive way to cut weeks off your system development time. The kit comes with an Agilent 82357A USB/GPIB converter, but the Test Express software also works well if you are using a LAN/ GPIB gateway.

Conclusion

With the new generation of test instruments offering a choice of interfaces, you need to decide which interface is best suited for your test system. Comparing costs, data transfer rates and ease of implementation will help you choose the interface most appropriate for your application. For R&D applications, where the number of instruments in a system is usually small and a quick and easy interface set-up is desired, USB is usually the best choice.

For design verification and manufacturing, USB 2.0 and Ethernet-based LAN are good choices, although LAN is typically the better of the two alternatives for larger systems because of its data-throughput performance, cost, remote access, and ease of system assembly.

The added flexibility, remote system access and control, performance on a par with USB, captive cable connectors (which aren't found on USB), and the capability for wireless operation offered by the LAN approach can make LAN the most attractive choice for many systems applications.

Get help configuring your I/O interfaces

Configuring an interface to connect your PC to an instrument or system can be a daunting task for someone who is not well versed in the intricacies of PCs, I/O technologies, and I/O interface configuration. In the past, this was especially so for LAN-based I/O that required a system to be connected to a site LAN. Fortunately, step-by-step guides such as Agilent's USB/LAN/GPIB Interface Connectivity Guide are now available to help you to configure your I/O interfaces. The USB/LAN/GPIB Interface Connectivity Guide describes in detail how to connect instruments to various interfaces, and how to configure your PC. It also includes programming examples and interface troubleshooting tips. You can view the guide at **http://we.home.agilent.com/upload/cmc_upload/connectivity_guide.pdf**

Table 2. Typical costs for GPIB, USB, and LAN interfaces

Interface	Single instrument		12-instrument system	
GPIB	PCI card + cable	$500	PCI card + cables	$750
USB 1.1	Cable	$10	Cables + 2 hubs	$125
USB 2.0	PCI card + cable	$60	PCI card + cables + 2 hubs	$225
LAN	PCI card + cable	$30	PCI card + cables + 2 hubs	$200

Table 3. Advantages and disadvantages of GPIB, USB, and LAN interfaces

Interface	Advantages	Disadvantages
GPIB	• Ubiquitous interface on test instruments • Maximizes throughput for all block sizes	• Expansion slot required • Must open PC housing to install card • Relatively expensive • Limited cable lengths permitted between computer and instruments
USB	• Quick, easy setup • Low cost • Good data-throughput performance	• Does not work with Windows NT
LAN	• Good data-throughput performance • Low cost • Remote access makes it easy to control system from remote location	• Requires LAN knowledge to set up

Glossary

C# (pronounced "C sharp") — a new C++-like, component-oriented language that was built to run on the .NET Framework

Dynamic Host Configuration Protocol (DHCP) — a protocol for assigning dynamic IP addresses to devices on a network

FireWire — a high-speed serial bus defined by the IEEE 1394 standard

Hub — a common connection point for devices in a network. A hub contains multiple ports.

Interface — a connection and communication media between devices and controllers, including mechanical, electrical, and protocol connections.

IVI — interchangeable virtual instruments — a standard instrument driver model allowing you to swap instruments without changing software. Learn more at **http://www.ivifoundation.org/**

IVI-COM — IVI-COM presents the IVI driver as a COM object in Visual Basic.

Router — a device that connects any number of LANs and determines where packets go

SICL — Standard Instrument Control Library — software used for I/O application programming

VISA — virtual instrument software architecture

VXI — VXI is a standard, open architecture for cardcage test systems. The VXIbus (VMEbus eXtensions for Instrumentation) was developed by a consortium of test-and-measurement companies to meet the needs of the modular instrument market.

References

1. Agilent I/O Libraries: **www.agilent.com/find/iolib**
2. Connectivity Resources: **www.agilent.com/find/ADN**
3. Connection, communication, and control of test instruments from a PC: **www.agilent.com/find/connectivity**
4. Agilent IntuiLink: **www.agilent.com/find/intuilink**

For information on how to streamline system development and lower the true cost of test, please visit **www.agilent.com/find/buildyourown**

Other Agilent literature

Data sheets

- *Agilent N1908A Test Automation Kit,* pub. no. 5989-0000EN
- *Agilent Connectivity Suite,* pub. no. 5988-5756EN
- *Agilent 82357A USB/GPIB Interface for Windows,* pub. no. 5988-5028EN
- *Agilent E5810A LAN/GPIB Gateway,* pub. no. 5988-5810EN
- *Agilent 82350A PCI GPIB Interface,* pub. no. 5966-2720E
- *Agilent 33220A 20 MHz Function/ Arbitrary Waveform Generator,* pub. no. 5988-8544EN

Application notes

Test-System Development Guide:

- *Introduction to Test-System Design* (AN 1465-1) pub. no. 5988-9747EN **http://cp.literature.agilent.com/litweb/pdf/5988-9747EN.pdf**
- *Computer I/O Considerations* (AN 1465-2) pub. no. 5988-9818EN, **http://cp.literature.agilent.com/litweb/pdf/5988-9818EN.pdf**
- *Understanding Drivers and Direct I/O* (AN 1465-3) pub. no. 5989-0110EN **http://cp.literature.agilent.com/litweb/pdf/5989-0110EN.pdf**
- *Choosing Your Test-System Software Architecture* (AN 1465-4) pub. no. 5988-9819EN **http://cp.literature.agilent.com/litweb/pdf/5988-9819EN.pdf**
- *Choosing Your Test-System Hardware Architecture and Instrumentation* (AN 1465-5) pub. no. 5988-9820EN **http://cp.literature.agilent.com/litweb/pdf/5988-9820EN.pdf**
- *Understanding the Effects of Racking and System Interconnections* (AN 1465-6) pub. no. 5988-9821EN **http://cp.literature.agilent.com/litweb/pdf/5988-9821EN.pdf**
- *Maximizing System Throughput and Optimizing Deployment* (AN 1465-7) pub. no. 5988-9822EN **http://cp.literature.agilent.com/litweb/pdf/5988-9822EN.pdf**
- *Operational Maintenance* (AN 1465-8) pub. no. 5988-9823EN **http://cp.literature.agilent.com/litweb/pdf/5988-9823EN.pdf**
- *Using LAN in Test Systems: The Basics* (AN 1465-9) pub no. 5989-1412EN **http://cp.literature.agilent.com/litweb/pdf/5989-1412EN.pdf**
- *Using LAN in Test Systems: Network Configuration* (AN 1465-10) pub no. 5989-1413EN **http://cp.literature.agilent.com/litweb/pdf/5989-1413EN.pdf**
- *Using LAN in Test Systems: PC Configuration* (AN 1465-11) pub no. 5989-1415EN **http://cp.literature.agilent.com/litweb/pdf/5989-1415EN.pdf**
- *Using USB in the Test and Measurement Environment* (AN 1465-12) pub no. 5989-1417EN **http://cp.literature.agilent.com/litweb/pdf/5989-1417EN.pdf**
- *Using LAN in Test Systems: Applications,* AN 1465-14 (available in February 2005)

www.agilent.com

Application notes, continued

- *Simplified PC Connections for GPIB Instruments,*
  AN 1409-1, pub. no. 5988-5897EN
- *Creating a Wireless LAN Connection to a Measurement System*
  AN 1409-3, pub. no. 5988-7688EN
- *Modern Connectivity—Using USB and LAN Converters.*
  AN 1475-1, pub. no. 5989-0123EN

Manuals

- *USB/LAN/GPIB Interface Connectivity Guide* available at **http://we.home.agilent.com/upload/cmc_upload/connectivity_guide.pdf**

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