

Making the Transition From GPIB to LXI

BY MIKE DEWEY, EDITOR

For more than 30 years, automating test and measurement instrumentation has relied upon the ubiquitous GPIB standard. Developed by Hewlett-Packard in the early 1970s, the HP-IB evolved to become a de facto industry standard.

With its adoption by the IEEE in 1987 as IEEE 488, HP-IB became the standard instrument control bus for the test and measurement industry. Today, there are literally thousands of different instruments that support the IEEE 488 or GPIB interface.

There are several reasons for the longevity and universal acceptance of GPIB within the test and measurement industry. A simple and well-defined method for physically connecting a GPIB device to a system controller and an industry-accepted set of software commands for communicating with GPIB devices are two primary reasons.

LXI is based on these same concepts and uses current technology such as TCP/IP for connectivity, IVI for software interfaces, and Web-based communications for instrument setup and control. It also leverages IEEE 1588 LAN triggering facilities for Class B devices and offers a more robust hardware triggering facility with Class A devices.

As a result, setting up and controlling an LXI instrument are remarkably similar to how you would set up and control a GPIB instrument. There is one exception: An LXI instrument can offer extended functionality beyond those features found in a GPIB device.

Connectivity

Both GPIB and LXI instruments require a hardwired connection between the device and the system controller. In the case of GPIB, a relatively large and somewhat expensive shielded 24-conductor cable is used to connect a GPIB device(s) to the system controller.

The connectors support the stacking of cables which allows up to 15 devices to be part of a GPIB network with the connection topology being a linear, star, or linear/star configuration. The IEEE 488 bus specification accommodates a maximum cable length of 20 meters with a maximum separation of 2 meters between devices. The maximum data transfer rate for the IEEE 488 bus is 1 MB/s.

GPIB interface cards are available from several vendors and typically installed in a system controller's PCI slot. Alternately, cards are available that can be controlled via USB, Firewire, cPCI, or even a LAN host interface. The interface cards include a driver, which provides the necessary functionality to control and monitor GPIB devices per IEEE 488.2.

For LXI devices, the control interface is provided by a LAN connection: typically, a 10 or 100Base-T Ethernet physical interface although the LXI spec supports Gigabit Ethernet interfaces as well. Unlike GPIB, LXI devices use unshielded and inexpensive twisted-pair cabling with RJ45 modular connectors to connect a device and controller.

This cabling, which bears the designation of Category 5, is widely used for interconnecting various network devices and supports 10 and 100Base-T with Cat 5e cable recommended for 1000Base-T electrical interfaces. The maximum cable length for any segment of a LAN is 100 meters with 10/100Base-T hubs extending this distance to approximately 1,600 meters. With routers, switches, bridges, and repeaters, a LAN segment can essentially have unlimited length, a clear advantage over a GPIB network topology.

Since LXI devices leverage LAN as the control interface, they also use the same networking components that are required for configuring data networks. LXI and LAN devices utilize point-to-point connections.

Connecting more than one LXI device to a controller will require hardware to interconnect devices to a LAN network, unlike a GPIB network of devices where you can just daisy-chain devices with no additional hardware. Depending on the specific requirements of the network, LXI devices can be interconnected using a hub, router, or switch, which are common and generally inexpensive networking components.

Networking Basics for LXI Devices

To assemble a network for controlling LXI devices, a network adapter providing the electrical connection between the controller or PC and the network is required. Like GPIB, these network adapter PC cards interface to a variety of buses such as PCI and cPCI.

Continued on page 22

Most PCs today incorporate a LAN connection as a standard interface port. Virtually all LAN adapters support both 10 and 100Base-T interfaces and automatically adapt to be compatible with the speed of other devices connected to the network. For LXI devices, 1000Base-T also will support 100 and 10Base-T interfaces, and 100Base-T devices will support the 10Base-T interface.

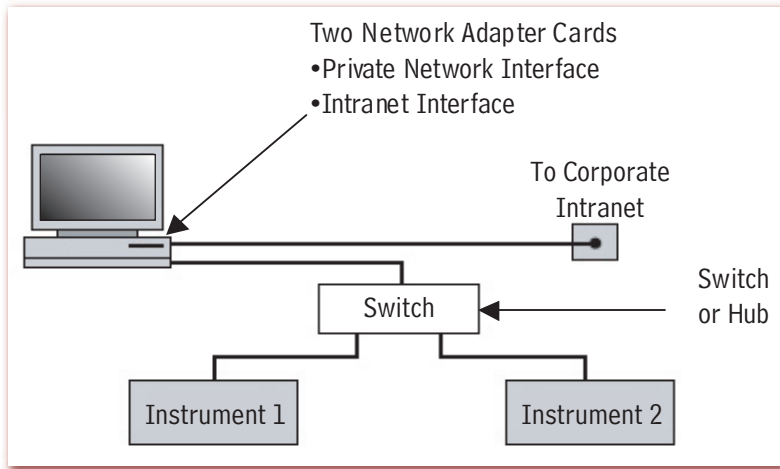


FIGURE 1A. SWITCH-BASED PRIVATE NETWORK

If connecting only a single LXI device to a PC's LAN port, all that is needed is a LAN cable that crosses the Tx and Rx paths. If the LXI device supports the automatic medium dependent interface crossover (Auto-MDIX) function, then a normal LAN cable can be used since the device will automatically interchange the Tx and Rx ports.

LXI devices that accommodate the Auto-MDIX function must display a label on the unit indicating this capability. All 1000Base-T interfaces support Auto-MDIX.

When connecting more than one LXI device to a network, a network hub can be an inexpensive implementation. A hub is a small, stand-alone unit that connects multiple devices together, usually in a star topology. In this configuration, any device can discover and talk to any other device on the LAN although only one device can successfully transmit at any one time. Consequently, if network traffic is heavy, the effective bandwidth of the network will be reduced.

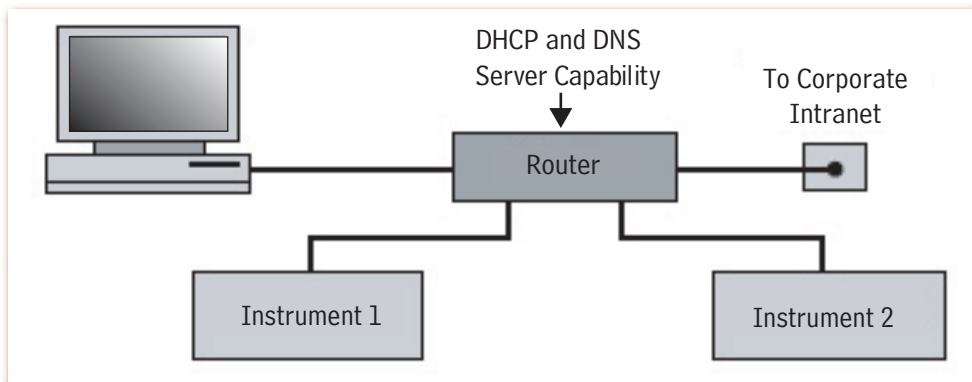


FIGURE 1B. ROUTER-BASED PRIVATE NETWORK

Four-port hubs are available for \$30 or less and offer the most cost-effective means to interconnect multiple LXI devices. Hubs are available in 10, 10/100, or 100Base-T versions.

Unlike USB hubs, LAN hubs require an external power source, normally an AC-to-DC power adapter powered by 120/240 VAC. The same holds true for switches or routers.

Network switches also can be used to interconnect LXI devices. These physically small devices, classified as layer-2 devices, create a dedicated switch path based on an Ethernet device's transmit and receive medium access control (MAC) addresses.

Switches typically provide better network performance than hubs since they maintain bandwidth regardless of network traffic loads. Today, four-port 10/100Base-T switches can be purchased for less than \$50, making them an attractive alternative to hubs when interconnecting multiple LXI devices within a simple network.

Network routers can interconnect LAN devices as well as isolate multiple networks by supporting high-level protocols such as TCP/IP. Routers allow one- and two-way communications between devices and enable awareness among the devices on a network. They also allow devices to hide their presence, enabling the creation of small, private networks.

Routers typically include the capability to dynamically assign IP addresses and domain names to devices connected to the network. Depending on the number of ports needed, routers are more expensive than switches although the capability to create a subnet of LXI devices that can be connected or isolated from other subnets could be a desirable feature. Routers also can incorporate LAN switch functions; a DSL router with multiple LAN ports is an example of a router/switch device.

Creating a subnet or private network for all LXI devices that are part of a test system, particularly if all devices are physically collocated in a system, is strongly recommended and guarantees that device control will not be compromised by other non-test system LAN traffic. Additionally, a subnet protects against network viruses or worms by isolating the test system from the corporate intranet or Internet.

A properly configured router can create a subnet. Alternatively, dedicating a network card that interfaces to an LXI device network can be a viable option when combined with a switch or router. **FIGURE 1A** and **1B** detail both topologies for creating a private subnet.

Setup

After making the physical connection between the GPIB device and the controller, communicating with a GPIB or LXI device requires setting the device's address. For

GPIB instruments, the device’s primary address needs to be programmed.

Early-generation devices relied on physical switches to set the address while today’s instruments allow you to set an address via the instrument’s front panel and store it in nonvolatile memory. Each GPIB instrument on a network is required to have a unique address, which is analogous to LXI devices where each device has a unique and fixed MAC address.

For GPIB devices, if two or more instruments are set to the same address, the bus will hang. There is very little you can do to debug the problem aside from methodically checking and testing each device to verify operation and address assignment. Assuming that each device on the bus has a unique address, the GPIB commands *IDN? and FINDLSTN offer some base level of functional verification by providing a status of which devices are active on the bus as well as identifying model and manufacturer.

A successful response to the *IDN? command usually is a good indication that each GPIB device is communicating properly with the controller and ready to receive/transmit data. LXI devices retain this same functionality and support the *IDN? command as well as the VXI-11 discovery protocol to identify all LXI devices on the network.

To set up or configure LXI devices, each device requires its own IP address that maps a device to its MAC address. Since all LXI devices are required to support TCP/IP, communications to a network device are via IP addresses that can be set statically or dynamically depending on the device’s capabilities and whether the network supports dynamic host configuration protocol (DHCP).

default hostname, which will be specified in the manufacturer’s product manual. As shown in **FIGURE 2**, an LXI device’s web page provides the following network information and control options:

- Host Name
- MAC and TCP/IP Address
- VISA Resource String
- Configuration of the TCP/IP Mode: DHCP or static IP assignment; default will be DHCP if the device supports automatic IP assignment
- Configuration of the Static IP Configuration, Set Values for IP Address, Subnet Mask, and Default Gateway
- Configuration of the dynamic domain naming system (DNS) (if the device supports this mode) and specification of the DNS Server; default will be dynamic DNS enabled

If a network uses a switch or router with DHCP capability such as shown in Figure 1, then using dynamic IP assignment will be the easiest way to configure each device on the network. However, for a test system with a relatively static instrument configuration, you may want to have the DHCP server provide infinite IP leases, which can be part of the DHCP server’s IP policy configuration.

It also is probably preferable to configure the DHCP servers to always return a particular IP address for a given client MAC address, essentially assigning a static address to each LXI device. Infinite lease times can make it harder to change network configurations, making short leases or static IP addresses a preferred implementation.

Issuing infinite leases or static IP addresses from the DHCP server ensures that every device located on the LAN will have the same IP address assignment each time the system is powered up even though IP addresses are normally retained by a device upon shutdown. This is critical if you are explicitly using VISA IP string names. Without having static IP addresses, VISA IP string names must be modified if an IP lease expires and a different IP address is assigned.

If a server also supports DNS capability and the LXI device does as well, then VISA string names can use the specific host name instead of an IP address value. This negates the need to maintain static IP addresses since instruments are referenced by name instead of an IP address. Alternatively, you can rely upon the VXI-11 discovery mechanism to locate devices and IP addresses.

If a system configuration is limited to a PC and a single LXI device or a hub or switch with only a few LXI devices with no DHCP capability, all devices can be configured with static IP addresses. As an example, static IP address assignment for a PC and two LXI devices would be assigned as follows:

- Computer IP address: 192.168.1.50
- Computer subnet mask: 255.255.255.0
- LXI device1 IP address: 192.168.1.51
- LXI device1 subnet mask: 255.255.255.0
- LXI device2 IP address: 192.168.1.52
- LXI device2 subnet mask: 255.255.255.0

IP addresses should only be assigned in the last field of the address, such as 192.168.1.x. And if a router were part of the configuration, its IP address in this example would be 192.168.1.1.

Instrument Model	LXi-1
Manufacturer	Pickering Interfaces Ltd
Serial Number	65193
Description	Example LXI Instrument
LXI Class	Class A
LXI Version	1.0
Host Name	lxidevel.pickeringtest.com
MAC Address	00-0C-6E-76-5B-C8
TCP/IP Address	192.168.1.10
Firmware Revision	1.0
Current Time	12:45pm - 2nd September 2005
Current Time Source	IEEE-1588 PTP
VISA Resource String	TCPIP0::192.168.1.10::2-11.1::INSTR
Asset Number	PIL-0126

FIGURE 2. INSTRUMENT HOME PAGE

Configuration is performed after interconnecting all LXI and LAN network components and powering up all devices. Initial network configuration information and any subsequent modification of the device’s network configuration can be accessed via the instrument’s front panel or the device’s web page, a feature supported by all LXI devices.

Accessing the instrument’s home page requires entering the device’s IP address. If the device’s IP address has been dynamically assigned and the network supports DNS, you can enter the device’s

Continued on page 24

Assigning static IP addresses raises the possibility of duplicate addresses. However, unlike GPIB devices, LXI devices provide some level of diagnostics and protection should a duplicate IP address be encountered. If an LXI device detects a duplicate address, it disconnects itself from the network, and the LAN fault condition will be displayed as a steady red indicator on the instrument's front panel.

For the case where a PC is directly connected to an LXI device with DHCP capability but the network has no DHCP server, the device, after failing to obtain an IP address, will configure itself using the Auto-IP protocol which will result in the device negotiating with the PC for an IP or Link Local address. Link Local addresses are assigned randomly from 169.254.1 to 169.254.254.255.

For some users, Auto-IP may be the preferred method to configure a simple network since it requires no administration and offers a simple way to establish communications with an LXI device with very little user intervention. Communications with the device cannot commence until you know its IP address, and due to the nature of the Auto-IP process, subsequent connections will likely result in a different IP address being assigned to the device. Consequently, the device should be reconfigured to a static IP address, or you can use the VXI-11 discovery mechanism to identify the device's address, which then can be used to access the device via the VISA I/O library.

GPIB and LXI Device Control

Once you've connected and set up a GPIB or LXI device, you can control and program the instrument. Controlling or programming GPIB or LXI devices relies upon VISA, an industry standard software I/O component that makes the transition from a GPIB instrument to an LXI instrument very easy. In addition, many instruments now offer both GPIB and LAN interfaces and support the same set of SCPI commands, making the user's task of migrating to LXI that much easier.

Regardless of the programming development environment that you may be using, VISA or I/O libraries built on VISA, such as Agilent's IO Library or National Instrument's NI-MAX, provide a consistent method for identifying and communicating with an instrument, regardless of the type of control bus.

VISA supports a broad range of buses including GPIB, TCP/IP, VXI, RS-232, and USB. To change instrument control from a GPIB- to an LXI-based interface requires changing only the VISA resource string.

For example, a GPIB instrument resource string might be "GPIB::22::INSTR" which defines a GPIB instrument with an address of 22. For an LXI device, the instrument resource string would be TCP/IP::10.0.41.6::INSTR or TCP/IP::HOSTNAME::INSTR where the value 10.0.41.6 is the device's IP address. Once these changes are made and the appropriate host address value inserted, the same test program code can be used where the instrument supports both GPIB and LAN interfaces.

An additional benefit associated with the use of VISA and instrument I/O libraries is the functionality provided by the VXI-11 discovery protocol, which all LXI devices support. The VXI-11 protocol

in conjunction with I/O libraries provides the capability to identify all LXI devices that are located on a subnet via a discovery tool, which can be particularly useful when all devices are configured for dynamic IP address assignment.

By invoking the discovery mechanism, a device's response will include information such as manufacturer, model number, serial number, and IP address. This information then can be used to access instrument web pages and populate resource tables for other applications and utilities.

All LXI devices are supplied with an IVI driver, and if appropriate, the instrument will be supplied with an IVI class driver. This feature can be a key benefit if you are considering transitioning from GPIB to LXI if the current instrument is in the same IVI class but a different device. Even without the benefits of instrument interchangeability, providing LXI devices with an IVI-COM or IVI-C driver will help ensure that existing GPIB software environments can be easily adapted and migrated to support LXI devices.

Summary

Migrating from GPIB to LXI instruments for test systems can offer many performance and cost benefits. Many of the features and capabilities associated with LXI devices are based on well-established technologies and standards that will help minimize the technical effort and risk associated with adapting current and new applications to LXI devices.

While you may need to spend some time getting comfortable with networking basics, in most cases, the design and default operation of LXI devices within a network minimize the need to become an expert. Once you make the transition and move up the learning curve, the benefits of LXI will be very clear, and you probably will wonder why you waited to make the move.

Additional Information

1. www.lxistandard.org
2. www.agilent.com
3. Dewey, M., "Integrating LXI Devices Into Hybrid Test Systems", *LXI ConneXion*, July 2006, pp. 18-24.

ABOUT THE AUTHOR

Mike Dewey, the marketing product manager at Geotest-Marvin Test Systems, previously has held various positions in design engineering, engineering management, marketing, and product management with GenRad/Teradyne, ADR Ultrasound, and Motorola Government Electronics Group. He is a member of the IEEE and has served as a board member for both the PXI Systems Alliance and the VXI Consortium and been an LXI Consortium advisory member on the marketing, technical, and physical working group committees. Mr. Dewey received a B.S.M.E. from Syracuse University and an M.S.E.E. from Georgia Institute of Technology. e-mail: miked@geotestinc.com

