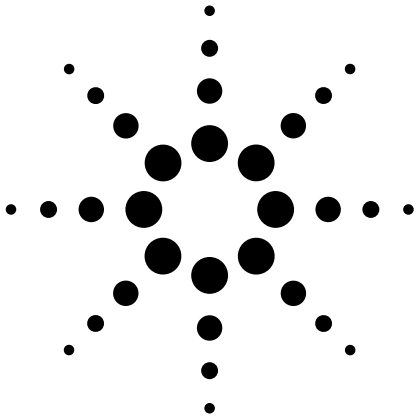
Creating hybrid test systems with PXI, VXI and LXI

Gaining leverage across the product lifecycle



Application Note 1465-23

It's common to associate certain types of instrumentation with the stages of your product's lifecycle. For example, benchtop instruments are often used in R&D because they enable interactive control of specific measurements and provide rapid feedback. As your product moves to manufacturing, modular solutions—PXI or VXI—are sometimes used because they can reduce the size of automated test systems.

Unfortunately, in the transition from benchtop to modular instruments, the lack of leverage—in hardware, software and test strategy—can be costly and time consuming. LXI offers the potential to change this situation by offering related or identical products in multiple form factors—benchtop, modular, synthetic instruments—and making it easier to leverage your existing test strategy and system software across your product's lifecycle.

Creating hybrid test systems with PXI, VXI and LXI is the fourth in a series of application notes that will help you manage the shift to LXI from GPIB, PXI or VXI. This note compares PXI and VXI with LXI, sketches hybrid system architectures that incorporate your existing test assets, and describes what will be possible in the future as you migrate to fully LXI-based systems.

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Assessing modular systems

With PXI and VXI, it takes several discrete elements—mainframe, plug-in cards, I/O, PC, software—to create the functionality of one standalone instrument or perhaps a complete rack-and-stack system (Figure 1). Achieving equivalent measurement and analysis capabilities requires that large amounts of data be moved within the mainframe (or chassis), various plug-in cards and the host PC. Some amount of programming—by the end user or a system integrator—is typically required to achieve the needed level of functionality. The resulting software application provides the user interface as well as most (if not all) of the measurement capabilities, data displays and data analysis routines.

Making all of that work with acceptable performance often requires a powerful PC that can process and analyze measured data while also controlling the hardware and providing the user interface. When an external PC is used as the system host, it will require the installation and configuration of an interface card if either MXI or GPIB is used for I/O. When an embedded controller is used, this may require a larger mainframe that can accommodate the controller and the various plug-in cards. While this approach eliminates the interface to an external PC, it still requires that a monitor, keyboard and mouse be connected to the embedded PC.

Although this somewhat complicated approach has become popular in certain applications, it is not a universally useful solution—and it has advantages and disadvantages that are worth a closer look.

Advantages of PXI and VXI

Both PXI and VXI have useful advantages in hardware, connectivity and programming when compared to rack-and-stack systems.

Hardware: One key advantage is the density of switching, sourcing and measuring capabilities that can be packed into a single mainframe. PXI and VXI will usually be smaller than a rack-and-stack system with similar functionality. PXI and VXI also have an edge over rack-and-stack in triggering and synchronization, thanks to their high-speed backplanes and included triggering capabilities.

Connectivity: PXI and VXI offer a variety of I/O alternatives: MXI, GPIB, Ethernet, USB, Firewire and serial. This allows you to make case-by-case tradeoffs between performance and convenience.

Figure 1. A typical VXI system

Programming: System creators can use graphical or text-based development environments to create the required measurement and analysis functionality. While it can be difficult to work with register-based PXI and VXI plug-in cards, the use of device drivers can greatly simplify communication and programming (see sidebar). The resulting measurement solution may be smaller and faster than an equivalent rack-and-stack system built with benchtop GPIB instruments.

Programming register-based devices

Because PXI and VXI are leveraged from computer buses (e.g., VME, ISA, EISA), their plug-in cards usually depend on register-based operations to read or set attributes, initiate measurements, load or unload data, and so on. While this type of low-level programming enables detailed computer control of each module, it can be quite complicated and time consuming.

One popular solution is device drivers, which handle the low-level details and enable programming at a higher level. The best choice of driver depends on the type of hardware or software being used. For example, National Instruments uses IVI-G drivers with LabVIEW and IVI-C drivers with LabWindows. While IVI-C and IVI-G drivers are available for many Agilent instruments, Agilent and others have provided IVI-COM drivers. These are language- and platform-neutral and one version will work in all Microsoft® COM (and compatible) environments, and with Microsoft Excel. Not only does this provide additional flexibility—you can work in your preferred development environment—it can enhance your productivity through features such as IntelliSense pop-up menus that provide onscreen command-completion help.

Disadvantages of PXI and VXI

Both PXI and VXI have shortcomings that can affect your ability to create a system that fully satisfies the budgetary, technical and lifecycle requirements of a test specification.

System host: Unlike a typical rack-and-stack system, a PXI- or VXI-based system can be heavily dependent on the performance of the host PC—and higher performance commands a higher price. What's more, the PC-dependent approach does not scale well for large, complicated systems: as more modules move more data more often, the PC can become a processing bottleneck that slows overall system performance.

Embedded controllers come with their own set of shortcomings. Because these are a specialty item produced in limited quantities, they typically cost three to eight times as much as an equivalent desktop PC. They also tend to lag behind the latest advances in performance and capabilities.

Hardware: In addition to the high entry cost of PXI and VXI, you may need to buy a mainframe that has more slots than needed if you want to allow for future expansion. Once a mainframe is filled, there is also the potential cost of adding another mainframe if the system needs just one more plug-in card.

When the required functionality isn't available in a modular format it will be necessary to add bench-type instruments to the system. Examples include many RF measurements as well as high-wattage power supplies. The inclusion of standalone instruments can increase the complexity of both system integration and programming. It may also negate the size advantages of VXI or PXI.

Connectivity: Using either MXI or GPIB as the interface adds hardware cost and configuration complexity to an external host PC.

Programming: Because most PXI and VXI devices lack any sort of built-in user interface—front panel or browser-based—you typically have to purchase, install and configure some type of software to control even the simplest device. Additional programming may be required to perform a measurement, manipulate the data and analyze the results. What's more, T&M-specific software that provides these capabilities tends to be much more expensive than commercial programming environments available from Microsoft and other vendors.

Exploring LAN-based hybrid systems

LAN is rapidly gaining favor as the interface of choice for automated test systems. While the earliest LAN-enabled instruments offered inconsistent implementations of the interface, the LXI standard now ensures a consistent approach that makes it possible to use compliant instruments from multiple vendors.[1]

In most cases, it is relatively straightforward to create hybrid systems that utilize LXI devices alongside GPIB, PXI and VXI hardware. A hybrid structure lets you harness the advantages of each architecture within a single system. In addition to saving money by protecting your existing investments in test assets, this approach also helps you save time because you can continue using familiar hardware, interfaces and software.

A typical LXI-based system starts with a host PC and its built-in LAN port, which provides a connection to local and remote LXI-based devices through commercially available LAN switches or routers. This is also the starting point for hybrid configurations that include LXI devices working alongside a VXI or PXI mainframe. Today, four possible scenarios are likely and feasible.

Scenario 1: VXI and GPIB

If a VXI mainframe contains a GPIB slot-0 card, it can be connected to the PC via LAN by adding an interface converter such as the Agilent E5810A LAN/GPIB gateway (Figure 2). With the gateway connected between the VXI mainframe (GPIB) and the router (LAN), any application running on the PC will be able communicate transparently with the VXI hardware as GPIB devices.

- **Advantages:** This hybrid structure eliminates the need to install a GPIB card in the PC. With the gateway, addressing can be kept the same so no software changes will be required.
- **Disadvantages:** System performance may decrease if the gateway cannot keep pace with the demands of any high performance measurement cards installed in the VXI mainframe.

Scenario 2: VXI and LAN

When a VXI mainframe is equipped with a LAN slot-0 card, adding it to the system network is as simple as connecting it to the LAN router (Figure 3). Even if the LAN-equipped VXI system is not LXI compliant, it can coexist on the network with any LXI devices.

- **Advantages:** Every instrument in the system—LXI or VXI—can utilize LAN's I/O speed. If the system software is already programmed to communicate with the VXI hardware via LAN, addressing should remain the same so few or no software changes will be required. Any required programming changes should be relatively modest, even when you replace an MXI or Firewire slot-0 card with a LAN slot-0 card.[2]
- **Disadvantages:** Depending on the devices installed, this configuration may provide less performance than a purely backplane-based system (e.g., one that uses an MXI interface) but should be faster than the LAN/GPIB configuration described in Scenario 1.

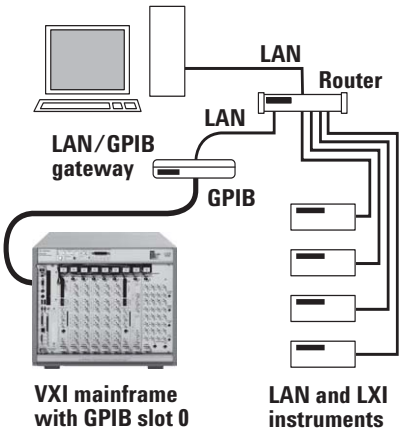

Figure 2. A router plus a LAN/GPIB gateway enables creation.

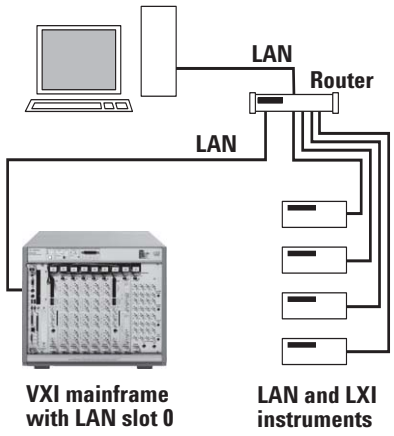

Figure 3. Add a LAN slot-0 card to a VXI mainframe to create a LAN-based hybrid VXI/LXI system.

1 To learn more about LXI and the LXI Consortium, please **visit www.lxistandard.org.**

2 One example is the VXI Technology EX2500 LXI-VXI Gigabit Ethernet Slot-0 Interface.

Scenario 3: Embedded controller

If a PXI- or VXI-based system is using an embedded controller within the mainframe, the controller can be connected to the test-system network through its built-in LAN port. The PXI or VXI portion of the system would still be controlled by the existing software running on the embedded PC. To simplify the overall system structure, the existing software could be modified to control the LXI devices, eliminating the need for an external PC that controls only LXI devices (Figure 4).

- **Advantages:** This is a straightforward way to add the advantages of LXI to a PXI- or VXI-based system. If suitable modular LXI devices are available to provide functionality that isn't available in PXI or VXI formats, the resulting system may also be simpler and more compact than one that uses GPIB instruments.
- **Disadvantages:** Modifying the existing software to control the LXI devices could hinder system performance by putting an additional burden on the embedded PC; however, this may have a modest impact given the built-in intelligence of most LXI devices. This system structure also requires the addition of a LAN router, which will cause a slight increase in system cost and complexity.

Scenario 4: LXI-compliant mainframe

Some manufacturers of PXI-based instrumentation are actively supporting the LXI standard. To ease the transition from PXI to LXI, at least one vendor has created Class C LXI-compliant mainframes that support a wide variety of switching modules.[3] With this approach, you simply install the switching cards in an LXI-compliant mainframe equipped with a PXI slot-1 interface, which is connected (through its LAN port) to the system router (Figure 5).

- **Advantages:** This solution provides the advantages of existing PXI switching cards—high density, various capabilities—within an LXI-based system. For new systems, this approach is also likely to be less expensive than an all-PXI solution that uses either an embedded controller or a PC-to-PXI interface.
- **Disadvantages:** Currently, this approach is supported only for PXI switching cards. Future developments may make it possible to support the demands of register-based PXI measurement cards.

All four of these scenarios enable a cost-effective transition that protects your current investments in system hardware and software. However, these hybrid structures also entail compromises that may be most easily remedied in the future with a LAN-centric, all-LXI system architecture.

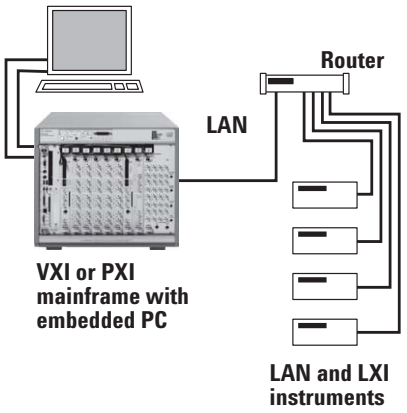

Figure 4. An embedded PC with a LAN port can be used as the system controller in a hybrid VXI/LXI or PXI/LXI system.

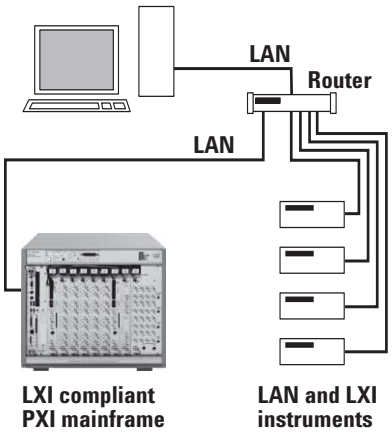

Figure 5. An LXI-compliant mainframe brings the benefits of PXI switching to a hybrid PXI/LXI system.

3 The Pickering Interfaces 60-100 and 60-101 are seven-slot chassis that support a variety of 3U PXI modules.

Going beyond hybrid to all-LXI

As an alternative to PXI or VXI, LXI eliminates the overhead and complexity of system development with a backplane. When using bench-top and modular LXI instruments to create a system, the conceptual approach is akin to using GPIB instruments: each device contains built-in measurement functionality (and intelligence) and provides specified measurement accuracy. However, LXI adds triggering and synchronization capabilities that go beyond GPIB—and can rival or exceed PXI or VXI. With these capabilities built into LXI instruments, your programming effort can focus on test management and the management, analysis and reporting of results.[4]

As more LXI-based products become available, it will be possible to evolve to an all-LAN structure. These systems will include one or more LAN routers as needed to accommodate local and remote LXI instruments (Figure 6). Every instrument will be able to take advantage of LAN's speed while utilizing low-cost network cabling. The browser-based interface within every LXI instrument will help speed and simplify instrument or system configuration and troubleshooting. The long reach of LAN and the synchronization made possible by the IEEE 1588 precision time protocol (PTP) will enable a variety of new capabilities and applications.

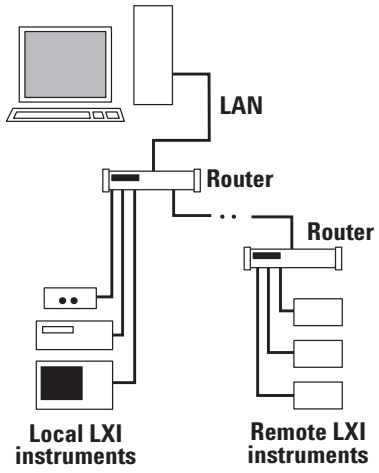

Figure 6. Using multiple routers enables easy connection of local and remote LXI devices to a PC's LAN port.

4 The use of LXI-based synthetic instruments is more similar to PXI and VXI in philosophy and approach. This topic is covered in detail in Application Note 1465-24.

Creating new possibilities with LXI

LXI-compliant devices open up a number of useful new possibilities that are difficult—and in some cases impossible—to implement with rack-and-stack or cardcage systems. The following concepts are just five examples of what is possible with LXI.

Leverage across the product lifecycle

Developers can utilize LXI-compliant benchtop instruments in the R&D phase, using the display and keypad to quickly access a wealth of measurement and analysis capabilities. In manufacturing, a system containing an equivalent instrument in a faceless, modular form can use the same software and routines developed with the standalone instrument. In addition to the hardware and software leverage, you don't have to sacrifice functionality, accuracy or performance when space is at a premium.

Long-distance operations

Through the LAN interface, LXI makes it possible to place instruments far from the PC and from each other. As an example, instruments can be placed near the devices or processes they are monitoring or controlling—and be connected to existing LAN ports in a test lab or near a manufacturing line.[5] LXI devices can even be placed inside a text fixture, minimizing cable runs and enhancing measurement results.

Distributed testing

Current-generation systems use a PC-centric approach in which the computer controls basic instruments or "dumb" plug-in cards. Next-generation systems, as embodied in LXI, make it possible to apply a distributed approach that utilizes the intelligence built into each instrument. Much of the analysis and synchronization can be performed in the measurement hardware, offloading those chores from the PC. Data flow is reduced because only the results of the analysis are sent to the PC. Timing is simplified with LXI Class B and A devices that can start their activities at a specific time or when they receive messages from other instruments. Instruments also can exchange information using peer-to-peer and multicast messaging. With this architecture, the PC and its I/O path are less likely to become bottlenecks in large, complex systems.

Peer-to-peer triggering

By making it possible for one instrument or device to send triggers and information to another (over LAN or the trigger bus), LXI frees up the PC to perform other, higher-level tasks. Peer-to-peer triggering can help eliminate the need for an expensive real-time controller to issue precise triggers to the instruments in a system. Ultimately, overall test time can be reduced because techniques such as wait states and status queries will be used less often in system software. When intelligent instruments can easily signal each other via LAN or hardware triggers, computer polling and wait states can be minimized, simplifying programming and speeding test-plan execution.

Time-based triggering

With the IEEE 1588 PTP, time-based triggering may prove to be a revolutionary way to synchronize measurements within systems and between instruments. For example, this method can eliminate the need for trigger-specific external cabling so is not limited by the distance between instruments. All measured data can be time stamped, making post-test analysis easier, more efficient and more meaningful.

5 Long connections are also possible with GPIB bus extenders (though performance may suffer) and via MXI-4 with fiber-optic cabling.

Transitioning to the future of test

LXI solves the key problems faced by system developers: it cuts costs, reduces system size, simplifies integration, accelerates throughput and provides more opportunities for reuse of both hardware and software. These benefits make LXI a compelling architecture for both today and the future.

To help you fully realize those benefits, we've adopted LXI as part of the Agilent Open concept. The strength of Agilent Open is in more than just instruments—it's in the way we help you simplify the entire testing process with PC-standard I/O and open software tools (Figure 7). As technology moves forward, our reliance on widely used standards makes it easy to extend system longevity and incorporate new developments such as LXI.

Simplify system connectivity

Choose the I/O connection that fits your test requirements: most Agilent Open instruments are available with GPIB, LAN and USB ports. This flexibility lets you select the interface that works best with your system now—and switch to another one in the future. We also make it easy to incorporate GPIB instruments into LAN- and USB-based systems by offering a variety of interface gateways and converters.

Create versatile measurement solutions

Selecting an Agilent Open instrument for your test system is an easy choice because it's designed for faster throughput as well as easy integration into your test software and your system rack. Whether you choose traditional, modular or building-block instruments, you can connect them quickly and correctly with our IO Libraries Suite. In minutes, its Agilent Connection Expert installs automatically, configures the interfaces, discovers connected instruments from hundreds of manufacturers, and verifies communication.

Achieve efficient development

You shouldn't have to spend time struggling with an unfamiliar programming language just to set up a test. Agilent Open lets you work in the test-software development environment you already know. The key is open software tools such as standard instrument drivers and links to Microsoft Excel or popular programming languages such as Visual Basic, C, Agilent VEE Pro, MATLAB®, LabVIEW, Visual Basic.NET, Visual C++, Visual C# and others. Work where you prefer—and focus on your product, not the code you need to test it.

Through the combined capabilities of Agilent Open and LXI, Agilent can help you and your team open the door to simplified system creation—and new possibilities in testing.

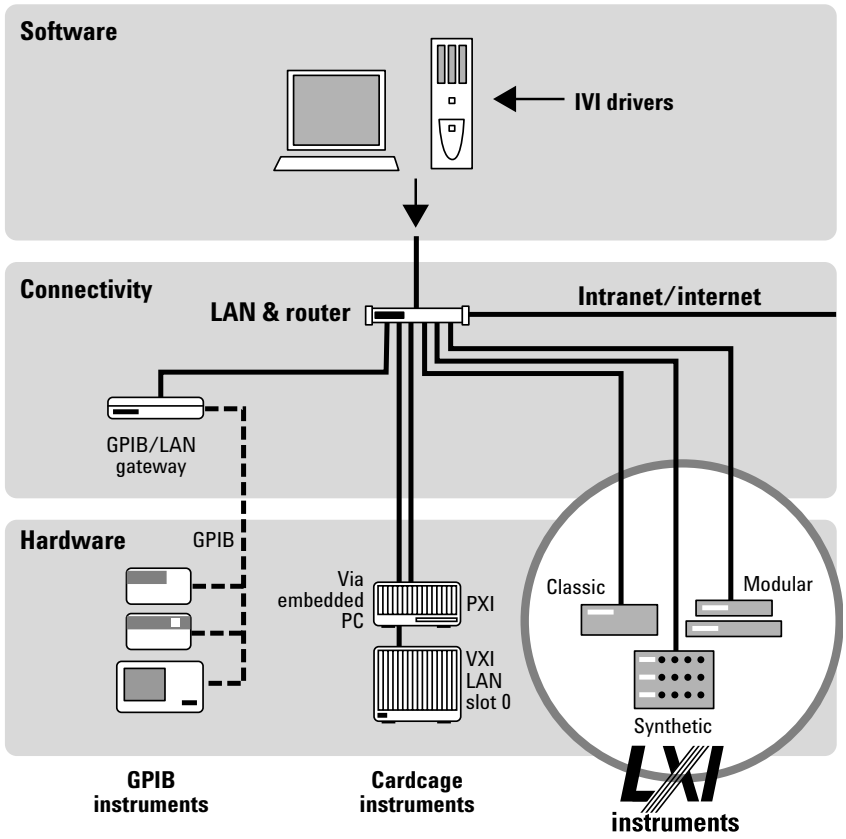

Figure 7. With Agilent Open and LXI, LAN becomes the backbone of test systems that easily incorporate present and future test assets.

Related literature

The 1465 series of application notes provides a wealth of information about the creation of test systems, the successful use of LAN, WLAN and USB in those systems, and the optimization and enhancement of RF/microwave test systems:

Test System Development

- *Test System Development Guide: Application Notes 1465-1 through 1465-8* (pub no. 5989-2178EN)
  http://cp.literature.agilent.com/litweb/pdf/5989-2178EN.pdf
- *Using LAN in Test Systems: The Basics,* AN 1465-9 (pub no. 5989-1412EN)
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- *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)
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- *Using LAN in Test Systems: Applications* AN 1465-14 (pub no. 5989-1416EN)
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- *Using LAN in Test Systems: Setting Up System I/O* AN 1465-15 (pub no. 5989-2409)
  http://cp.literature.agilent.com/litweb/pdf/5989-2409EN.pdf
- *Next-Generation Test Systems: Advancing the Vision with LXI* AN 1465-16 (pub no. 5989-2802)
  http://cp.literature.agilent.com/litweb/pdf/5989-2802EN.pdf

RF and Microwave Test Systems

- *Optimizing the Elements of an RF/Microwave Test System* AN 1465-17 (pub no. 5989-3321)
  http://cp.literature.agilent.com/litweb/pdf/5989-3321EN.pdf
- *6 Hints for Enhancing Measurement Integrity in RF/Microwave Test Systems* AN 1465-18 (pub no. 5989-3322)
  http://cp.literature.agilent.com/litweb/pdf/5989-3322EN.pdf
- *Calibrating Signal Paths in RF/Microwave Test Systems* AN 1465-19 (pub no. 5989-3323)
  http://cp.literature.agilent.com/litweb/pdf/5989-3323EN.pdf

LAN eXtensions for Instrumentation (LXI)

- *LXI: Going Beyond GPIB, PXI and VXI* AN 1465-20 (pub no. 5989-4371)
  http://cp.literature.agilent.com/litweb/pdf/5989-4371EN.pdf
- *10 Good Reasons to Switch to LXI* AN 1465-21 (pub no. 5989-4372)
  http://cp.literature.agilent.com/litweb/pdf/5989-4372EN.pdf
- *Transitioning from GPIB to LXI* AN 1465-22 (pub no. 5989-4373)
  http://cp.literature.agilent.com/litweb/pdf/5989-4373EN.pdf

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