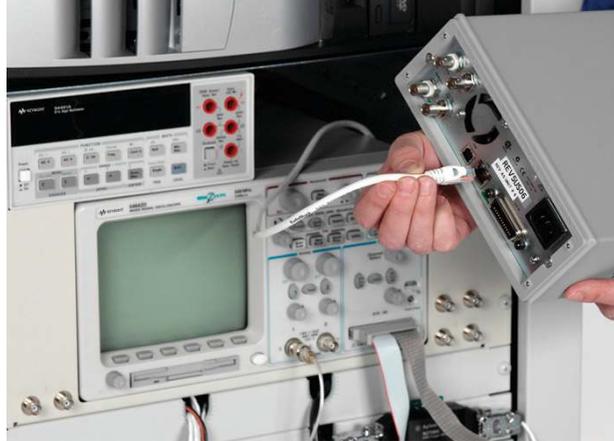# Keysight Technologies
Modifying a GPIB System to Include LAN/LXI
A step-by-step example

![KEYSIGHT TECHNOLOGIES]

Introduction

In most cases, the process of replacing a GPIB instrument with a similar LXI-based device will be relatively quick and easy. This is a major strength of LXI, which has been designed to simplify instrument set up and configuration.

A LAN interface is a standard part of practically every PC. That interface can provide significant speed improvements, and can be simple to use. With LXI, it is possible to use virtually any LAN-equipped PC, connect it to an LXI instrument, bring up the instrument Web page, configure the instrument, and start using it in just a few minutes.

Modifying a GPIB system to include LAN/LXI is the seventh application note in a series designed to help you manage the shift from GPIB to LXI. This follow-on to application note 1465-25 *Migrating system software from GPIB to LAN/LXI* takes you through the process of replacing one instrument in a typical GPIB test system and shows how simple changes to the system software make it possible. For additional background information about migrating to LXI from GPIB, please refer to the companion application notes 1465-22, *Transitioning from GPIB to LXI, and 1465-25*, and *Migrating system software from GPIB to LAN/LXI.*

The Target Test System and Instrument Selection

We'll use a typical system that is 6-10 years old. This is a test system used to test an electronic control module. The DUT (Device Under Test) must be powered and requires a number of DC and AC stimulus signals and loads to emulate its operation in the final environment. It is beyond the scope of this note to venture further into this application, since the goal is to replace one instrument in an existing test system. Here is the configuration of the test system:

- Hewlett-Packard 800MHz Pentium III Computer
  - Keysight Technologies, Inc. 82350A PCI GPIB Card
  - LAN port connected to company network
  - Installed Keysight I/O Libraries Suite 14.2
  - Using Visual Basic 6.0 Development Environment
- Keysight 34401A 6 ½ Digital Multimeter
- Keysight 33120A 15MHz Function/Arbitrary Waveform Generator
- Keysight 3499A 5-Slot Switch Control System
  - Configured with Matrix, Multiplexer, and General Purpose Switching
  - Also contains Digital I/O and analog outputs
- Keysight 54622D Mixed Signal Oscilloscope
- Keysight 3632B DC System Power Supply

On the computer side, we will add another LAN interface card and LAN Switch to create a subnet for LXI instruments. See Application Note 1465-22 *Transitioning from GPIB to LXI Examining Similarities, Differences and Best Practices* for more information.

We'll focus on replacing the 34401A DMM in this test system, which is used to make DCV, DCI, ACV, Frequency, and Resistance measurements. The new 34411A High Performance Digital Multimeter is a direct replacement for the 34401A. It also offers many new capabilities that will enhance the current test system:

- 34401A Compatibility mode, if needed, to emulate the operation of a 34401A
- Same positioning of front and rear terminals
- Command processing is significantly faster
- Can make 6-digit measurements at 1000 readings per second
- Can make Peak-to-Peak measurements simultaneously with DCV and ACV
- ACV measurements are 4 to 10 times faster
- Waveform capture at 50K readings/sec with pre and post triggering
- Has GPIB, USB, and 100Mbit Ethernet LAN ports
- Reading storage buffer of 1 million readings
- LAN transfer rates from memory up to 270K readings/sec while making measurements

There are many more features illustrated in Application Note 5989-4038EN, *Replacing the Keysight 34401A in Your Test System with the New Keysight 34410A and 34411A High-Performance Digital Multimeters.*

Comparing Programming of GPIB vs. VXI -11 LAN

More than 30 years ago, GPIB (IEEE-488) was designed to enable automated control of test instruments. With 16 parallel lines—eight for control and eight for data transfer—it has been sufficiently powerful to address a wide range of demanding and sophisticated test applications. Today, GPIB remains the most widely used way to communicate with electronic test equipment.

When interfacing a PC to GPIB devices, I/O library software is used to enable instrument control from the test program. Keysight IO Libraries offer programming via both VISA and its predecessor, Standard Instrument Control Library (SICL). Keysight IO Libraries provide unified programming access to various interfaces such as USB, RS-232, GPIB, VXI, and LAN.

LAN offers two principle ways (protocols) to program instruments: VXI-11 and Sockets. VXI-11 is based on Remote Procedure Calls (RPC), a higher-layer protocol which is powerful but at the same time adds overhead. Direct socket communication is a lighter protocol that is significantly faster than VXI-11. As used with VISA, both protocols include provisions for emulating GPIB-specific operations such as serial poll, trigger, clear and SRQs.

Many Keysight instruments support both VXI-11 and Sockets. Although it is not a re-quirement, often the easiest approach is to install the VISA IO Libraries on the computer (it offers a consistent programming model, independent of the chosen protocol). However, both sockets and VXI-11 give the added flexibility of being native to every computer platform: Windows, Linux, UNIX, Mac OS etc, and do not require the VISA IO Libraries. We'll discuss Sockets later. For now, let's concentrate on VXI-11.

In moving from GPIB to emulation of GPIB over LAN, several things must be in place for the shift to LAN to work properly:

  – If you are replacing an existing instrument, the new one must implement a similar
  – (or identical) command language set. If not, you will need to revise the program to include commands specific to the new instrument.
  – The I/O libraries must support VXI-11 and/or sockets. Both the Keysight and National Instruments VISA libraries provide this support.
  – The instrument must support VXI-11 and/or socket programming. Virtually every Keysight instrument with a LAN interface supports at least one of these protocols; however, you should verify the capabilities of non-Keysight instruments before attempting to program them via LAN.

Table 1 lists the most common GPIB operations found in test programs—and also lists the VXI-11 implementations of those same functions. GPIB uses a combination of its Command Mode and eight control lines to implement the various functions listed in the table.

VXI-11 emulates the GPIB Command Mode and the control lines by creating additional RPC links between the client and the server. For VXI-11, there are three such connections: one is for all ASCII and binary traffic; one is for SRQ emulation; and the third is for the Device Clear, Trigger and Serial Poll functions.[1]

Table 1. Common GPIB operations and their implementation in VXI-11

Function	VISA/SICL GPIB	VISA/SICL VXI-11
Write ASCII command	Yes	Yes
Read ASCII/binary data	Yes	Yes
Write ASCII/binary data	Yes	Yes
Device Clear	DCAS	DCAS
Serial Poll	SPOLL	SPOLL
Trigger	GET	GET
SRQ	SRQ	SRQ

1. When adding an LXI instrument to a system using the Keysight Connection Expert (part of Keysight IO Libraries) either VISA or SICL is used to automatically set up these virtual connections over LAN.

Making Simple Changes to the Test Program

Your test program will use either Direct I/O with VISA-COM or SICL using SCPI commands, a driver like IVI-COM (or IVI-C which is often based upon VXI*plug&play* driver), or a combination of both. A combination of both is fairly common since often times, there are SCPI commands supported by the instrument that are not specifically accessible by a driver call. In that case, you could use an IVI-COM pass-through routine or simply set up a Direct I/O session in addition to the IVI-COM session. Since the instrument—rather than the driver—keeps track of its own state, this is not a problem.

The example test system program used Direct IO with SCPI commands to program the 34401A. Follow-on paragraphs describe changes necessary to use IVI-COM drivers. To replace the Keysight 34401A with the 34411A, the following changes were made to the test program (see Figure 1).

As you can see, the change necessary was the address string passed to the Resource Manager. The address string can be acquired from the Keysight IO Libraries Connection Expert, where the 34411A can be discovered and added to the system environment. A VXI-11 session will be opened and will emulate the GPIB operations of the program according to Table 1.

Original VISA COM Direct IO declarations and initialization:

```
Dim DMMIO As Keysight34401
Dim mgr As KeysightRMLib.SRMCls
Set mgr = New KeysightRMLib.SRMCls
Set DMMIO = New VisaComLib.FormattedIO488
Set DMMIO.IO = mgr.Open("GPIB0::23::INSTR")
```

New VISA COM Direct I/O declarations for LAN VXI-11:

```
Dim DMMIO As Keysight34401
Dim mgr As KeysightRMLib.SRMCls
Set mgr = New KeysightRMLib.SRMCls
Set DMMIO = New VisaComLib.FormattedIO488
Set DMMIO.IO = mgr.
Open("TCPIP0::169:254:4:10::inst0::INSTR")
```

Figure 1

Making Simple Changes to the Test Program (continued)

If the program had been written using SICL instead of VISA-COM, a similar change would have been made to the open call for establishing the connection to the instrument (see Figure 2).

If the program had been written using IVI-COM instead of Direct IO, the changes in Figure 3 would be made.

There are several key points worth noting in this conversion:

– The VISA Address for GPIB is replaced by the VISA Address for VXI-11
– Instrument ID string is not checked by setting first parameter to "`False`"
– The `QueryInstrStatus` is set `True` to force error checking

Since the 34411A uses a superset of the same SCPI language as the 34401A, you can leave the 34401A declarations in the test program and use the 34401A driver. This is a good idea to get your test system running as before, and it will likely run much faster. Setting the ID string check to "False" allows the ID query to ignore the fact that this is not a 34401A. Adding the optional parameter QueryInstrStatus allows you to check for errors after every IVI-COM call. This way, if there are any language compatibility problems, you will discover that when running your program. For performance reasons, this added parameter can be eliminated from the program after conversion.

```
dmmio = iopen("lan1[169.254.4.10]:inst0")
```

Figure 2

Original IVI-COM Declaration for 34401A:
```
Dim DMM As VisaComLib.FormattedIO488
Set DMM = New Keysight34401
DMM.Initialize "GPIB0::23::INSTR", True, True, ""
```
New IVI-COM Declaration for 34411A when using VXI-11:
```
Dim DMM As VisaComLib.FormattedIO488
Set DMM = New Keysight34401
DMM.Initialize "TCPIP1::169.254.4.10::inst0::INSTR",
False, True, "QueryInstrStatus = True"
```

Figure 3

Differences Between GPIB and Sockets

For many LXI instruments from various vendors, the main LAN programming interface is Sockets. VXI-11 must be present in the instrument to support LXI instrument identification through the "*IDN?" command. However, the full VXI-11 protocol may not be implemented such that other SCPI commands and GPIB control operations such as Device Clear, Serial Poll, and Trigger are not available through VXI-11. In those cases, the instrument would definitely support Sockets as the primary LAN programming interface.

Many Keysight instruments present both VXI-11 and Socket programming interfaces over LAN. Sockets provide a faster means of data transfer—as much as nine times faster than GPIB (using Fast Ethernet—Gigabit Ethernet will show even more dramatic improvements) and three times faster than VXI-11. The use of the higher-level RPC protocol does significantly impact VXI-11 speeds, even if it is two times faster than GPIB for data transfer operations. See Application Note 1465-25 for more information on performance.

Table 2 illustrates there is no difference between GPIB and Sockets when sending commands and transferring data to the instrument. To perform a Serial Poll, or Trigger, the SCPI form of the command is used. With VXI-11, these commands are sent via other connections, so the write performance is about the same as sending the command over the primary interface. However, the auxiliary VXI-11 connections provide immediate operation; whereas, the SCPI commands must wait for the SCPI command parser to complete its existing commands before processing any new command.[1]

Therefore, similarly to VXI-11, sockets can also use a separate connection (the control port) for messages such as SRQs and Device Clear that require immediate attention. As mentioned above, sockets also have the benefit of being able to be used without the need for a VISA IO Library. Every modern operating system supports socket communication.

Sockets do have one unfortunate limitation as of the writing of this application note—most IVI-COM drivers do not support opening a Socket connection. This is actually a minor limitation from an implementation standpoint and is due to the nature in which most industry IVI-COM drivers were written. Work is being done to correct this issue. Only minor changes are needed to use Sockets for Direct IO with VISA instead of VXI-11 (see Figure 4).

Table 2. Common GPIB operations and their implementation in Sockets

Function	VISA/SICL GPIB/VXI-11	VISA/SICL Sockets
Write ASCII command	Yes	Yes
Read ASCII/binary data	Yes	Yes
Write ASCII/binary data	Yes	Yes
Device Clear	DCAS	–
Serial Poll	SPOLL	*STB?
Trigger	GET	*TRG
SRQ	SRQ	–

1. Some instruments, like the Keysight 34411A, allow the Sockets programmer to set up the auxiliary connections as other Socket connections. This permits full functionality of Device Clear, Serial Poll, Trigger, and SRQ. However, it is a lighter protocol that is still much faster than VXI-11. This topic is beyond the scope of this app note.

VISA-COM changes to program to permit Sockets:

```
Set DMMIO.IO = mgr.Open("TCPIP0::169.254.4.10::5025::
      SOCKET")
```

SICL changes to program to permit Sockets:

```
dmmio = iopen("lan1,5025[169.254.4.10]")
```

Figure 4

Example Commands in VISA–COM and SICL

The following are examples of both VISA COM and SICL calls using Visual Basic 6.0 for the various operations described in Table 1 and 2. The results of how the commands affect the Keysight 34411A are noted below. The results were obtained by a unique capability in many Keysight instruments—the ability to monitor IO traffic to and from the instrument by using the built-in Web Server (see Figure 5).

VISA COM Calls:

VXI-11 and Socket initialization as indicated in previous sections

```
DMMIO.IO.Clear
DMMIO.WriteString "*RST"
DMMIO.WriteString "*CLS"
stb = DMMIO.IO.ReadSTB
DMMIO.WriteString "TRIG:SOUR BUS;:INIT"
DMMIO.IO.AssertTrigger
```

SICL Calls:

VXI-11 and Socket initialization as indicated in previous sections

```
Call iclear(dmmio)
Call iwrite(dmmio, "*RST" + Chr$(10), 5, 1, 0&)
Call iwrite(dmmio, "*CLS" + Chr$(10), 5, 1, 0&)
Call ireadstb(dmmio, stb)
Call iwrite(dmmio, "TRIG:SOUR BUS;:INIT" + Chr$(10),
     20, 1, 0&)
Call itrigger(dmmio)
```

Data to and from 34411A over VXI-11 or GPIB:

```
"<DCAS>"
"*RST<NL+END>"
"*CLS<NL+END>"
<SPOLL>
<data from serial poll>
"TRIG:SOUR BUS;:INIT<NL+END>"
"<GET>"
```

Data to and from 34411A over Socket:

```
"*RST<NL>"
"*CLS<NL>"
"*STB?<NL>"
"<data from serial poll>"
"TRIG:SOUR BUS;:INIT<NL>"
"*TRG<NL>"
```

Figure 5

Transitioning to the Future of Test

To help you fully realize the benefits of LAN-based I/O, we've adopted LXI as part of Keysight Open, a combination of proven standards and time-saving tools for test automation. The power of Keysight Open is in this underlying assumption: your test system architecture should give you choices. Its range of possibilities should fit your requirements, your preferences and your existing test assets—hardware, software and I/O (Figure 6). Keysight Open accelerates the creation of cost-effective measurement solutions and enables testing, your way.

Simplify system connectivity

Choose the I/O connection that fits your test requirements: most Keysight 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 a Keysight 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 Keysight Connection Expert installs automatically, configures the interfaces, discovers connected instruments from hundreds of manufacturers, and verifies communication. What's more, the Web server built into all LXI-compliant instruments provides a convenient way to configure and troubleshoot your system.

Achieve efficient development

You shouldn't have to spend time struggling with an unfamiliar programming language just to set up a test. Keysight 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, Keysight 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 Keysight Open and LXI, Keysight can help you and your team open the door to simplified system creation—and enable testing, your way.
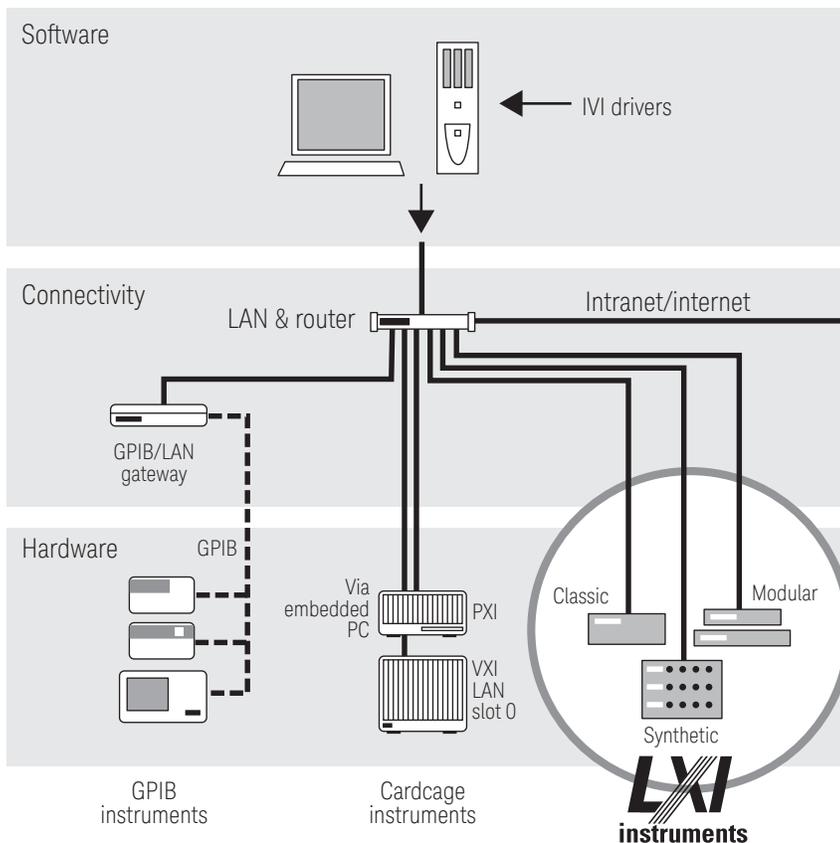

Figure 6. With Keysight Open and LXI, LAN becomes the backbone of test systems that easily incorporate present and future test assets

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. All of the individual notes listed below are also available in a compilation:

– *Test-System Development Guide: A Comprehensive Handbook for Test Engineers* (pub no. 5989-5367EN)
http://literature.cdn.keysight.com/litweb/pdf/5989-5367EN.pdf

Test System Development

– *Test System Development Guide: Application Notes 1465-1 through 1465-8* (pub no. 5989-2178EN)
http://literature.cdn.keysight.com/litweb/pdf/5989-2178EN.pdf

– *Using LAN in Test Systems: The Basics*, AN 1465-9 (pub no. 5989-1412EN)
http://literature.cdn.keysight.com/litweb/pdf/5989-1412EN.pdf

– *Using LAN in Test Systems: Network Configuration*, AN 1465-10 (pub no. 5989-1413EN)
http://literature.cdn.keysight.com/litweb/pdf/5989-1413EN.pdf

– *Using LAN in Test Systems: PC Configuration*, AN 1465-11 (pub no. 5989-1415EN)
http://literature.cdn.keysight.com/litweb/pdf/5989-1415EN.pdf

– *Using USB in the Test and Measurement Environment*, AN 1465-12 (pub no. 5989-1417EN)
http://literature.cdn.keysight.com/litweb/pdf/5989-1417EN.pdf

– *Using SCPI and Direct I/O vs. Drivers, AN 1465-13* (pub no. 5989-1414EN)
http://literature.cdn.keysight.com/litweb/pdf/5989-1414EN.pdf

– *Using LAN in Test Systems: Applications*, AN 1465-14 (pub no. 5989-1416EN)
http://cliterature.cdn.keysight.com/litweb/pdf/5989-1416EN.pdf

– *Using LAN in Test Systems: Setting Up System I/O*, AN 1465-15 (pub no. 5989-2409)
http://literature.cdn.keysight.com/litweb/pdf/5989-2409EN.pdf

– *Next-Generation Test Systems: Advancing the Vision with LXI*, AN 1465-16 (pub no. 5989-2802)
http://literature.cdn.keysight.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://literature.cdn.keysight.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://literature.cdn.keysight.com/litweb/pdf/5989-3322EN.pdf

– *Calibrating Signal Paths in RF/Microwave Test Systems*, AN 1465-19 (pub no. 5989-3323)
http://literature.cdn.keysight.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://literature.cdn.keysight.com/litweb/pdf/5989-4371EN.pdf

– *10 Good Reasons to Switch to LXI*, AN 1465-21 (pub no. 5989-4372)
http://literature.cdn.keysight.com/litweb/pdf/5989-4372EN.pdf

– *Transitioning from GPIB to LXI*, AN 1465-22 (pub no. 5989-4373)
http://literature.cdn.keysight.com/litweb/pdf/5989-4373EN.pdf

– *Creating hybrid systems with PXI, VXI and LXI*, AN 1465-23 (pub no. 5989-4374)
http://literature.cdn.keysight.com/litweb/pdf/5989-4374EN.pdf

– *Using Synthetic Instruments in Your Test System*, AN 1465-24 (pub no. 5989-4375)
http://literature.cdn.keysight.com/litweb/pdf/5989-4375EN.pdf

– *Migrating system software from GPIB to LAN/LXI*, AN 1465-25 (pub no. 5989-4376)
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Formerly published as Application Note 1465-26.

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