Test Systems Using LXI

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1 Introduction

LXI Devices (LAN eXtensions for Instrumentation) are LAN-equipped instruments that conform to a comprehensive set of rules detailed in the LXI Standard (www.lxistandard.org). Major Electronic Test Equipment Manufacturers and Technical Consultants formed the LXI Consortium in 2004, and about 40 companies currently participate and maintain that standard. LXI provides the basis by which test systems built from multiple vendors provide a common interface and experience.

LXI brings LAN into the test system and provides a wide range of flexibility to the test system engineer. In particular, LXI Devices benefit from these major LAN features:

- The ubiquitous nature of LAN
- Its high performance data transfers
- Low cost, readily available infrastructure
- Flexibility for wired or wireless communication
- Local and Remote (synchronized) access
- Abundance of multiple protocols for varied functionality
- Ability to embed Web servers within each instrument

The current number of LXI conformant products surpassed 2600 in June 2014, and there 50 broad categories with many specialized products within those categories:

AC/DC Power Supplies	**Electronic Load**	**LXI Event Detector**	**Power Meter**	**Solar Array Simulator**
Amplifier	**EMI Receiver**	**LXI Trigger**	**Power Supply Monitors**	**Sound and Vibration**
Attenuation Control Units	**Frequency Counter**	**LXI-PXI Controller**	**Scanning/Measuring System**	**Source Measure Unit**
Audio Analyzer	**Function / AWG**	**Mezzanine Carrier**	**SI - Downconverter**	**Source/Measure Switch**
Baseband Generator	**Function Card Carrier**	**Microwave Tuner**	**SI - Function / AWG**	**Spectrum Analyzer**
Capacitance Meter	**Impedance Analyzer**	**Multifunction Mainframes**	**SI - IF Digitizer**	**Switch**
Data Acquisition	**Interface Module**	**Multiple App Platform**	**SI - Upconverter**	**System Source Meter**
Digitizer	**JTAG/Boundary Scan**	**Network Analyzer**	**Signal Analyzer**	**System Switch / DMM**
DMM	**LCR Meter**	**Optical Power Meter**	**Signal Generators**	**Thermocouple Instrument**
Drawer Fixture	**LXI Bridge**	**Oscilloscopes**	**Signal Source Analyzer**	**Wireless Comm Tester**

Test systems for virtually every application draw from this broad range of product categories, which means that test systems built completely with LXI is a very real solution.

The focus of this paper is on illustrating the typical test system components and then presenting application summaries of real-life test systems consisting of solely of LXI products and ones consisting of a hybrid of LXI and other interfaces.

The LXI Consortium has written other documents to help test system developers: ***LXI Primer***, ***LXI Getting Started Guide***, ***Building LXI-based Test Systems***, ***Introducing LXI to Your Network Administrator***, and ***Maximizing Performance of LXI-Based Test Systems*** located on the LXI Consortium Website at GuidesForUsingLXI. Please refer to these documents for detailed information about LXI, how to connect multiple LXI Devices into a Test System, how LXI Devices behave on the LAN, how LXI can improve overall performance, and the importance of working with your Network Administrator to meet test system and company LAN requirements.

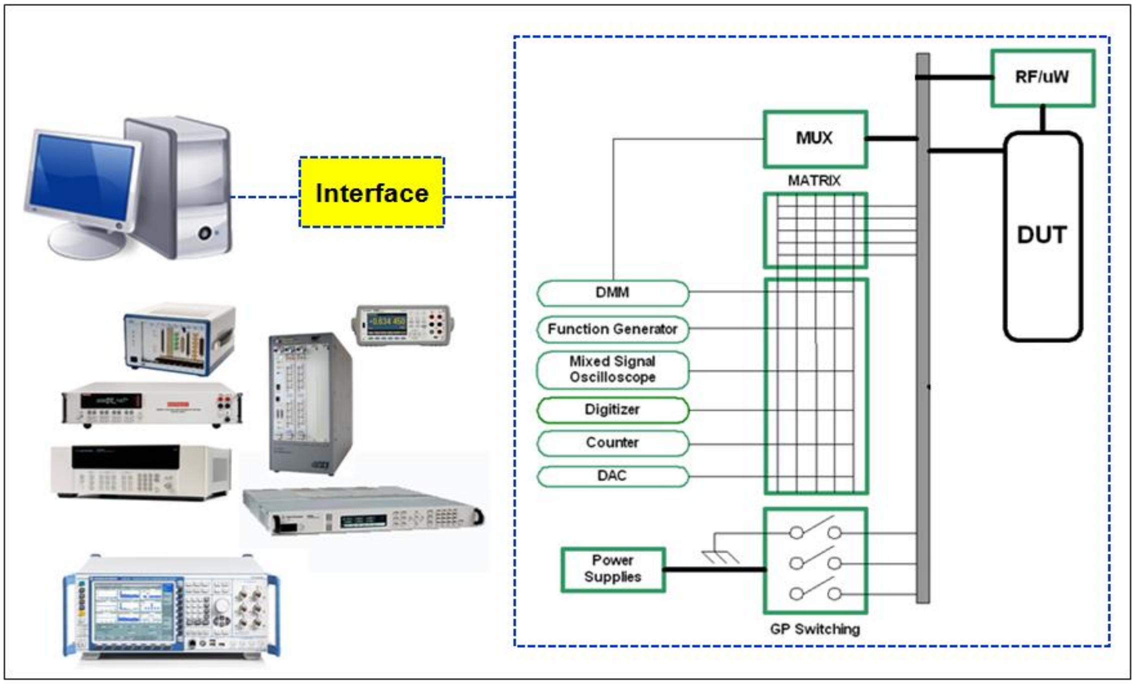
2 Test System Components and Architecture

The architecture of a test system involves the interconnection of computer, measurement, and stimulus devices, and it includes the interconnection of signals between these devices. Test system integration of varied instrumentation requires early planning to achieve desired measurement, performance, and ease of test program development. This section will identify the varied instrumentation solutions often used in test systems, which forms the basis for understanding real-world test systems.

2.1 Typical Test System Configuration

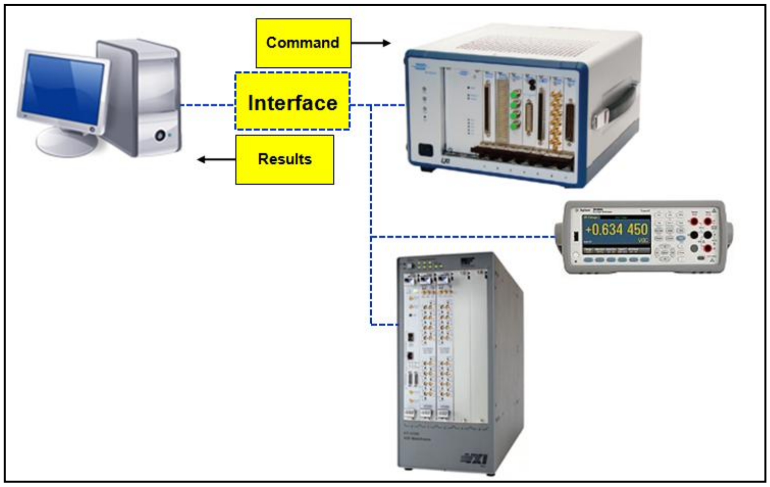
A typical test system configuration provides matrix, general purpose, multiplexing, and even RF and microwave switching to connect between the instruments and the Device-Under-Test (DUT). Such a system may use instruments mounted in a rack, each with their own LXI conformant LAN communication interface, display, and power supply. The system may also be composed of VXI, PXI, AXIe, or proprietary mainframes, with instruments and switches residing on modules plugged into one or more mainframe slots and a single communication interface to the computer. Many such mainframe products are available with an LXI conformant LAN interface, as can be seen in the figure below.

With 50 product categories and over 2600 LXI products, one can expect test systems built solely using LXI. However, some test systems use a hybrid approach, mixing GPIB, PXI, VXI, USB, etc., due to specialized needs or due to legacy instruments without LAN interfaces. The Test System Applications section of this document will illustrate such examples.



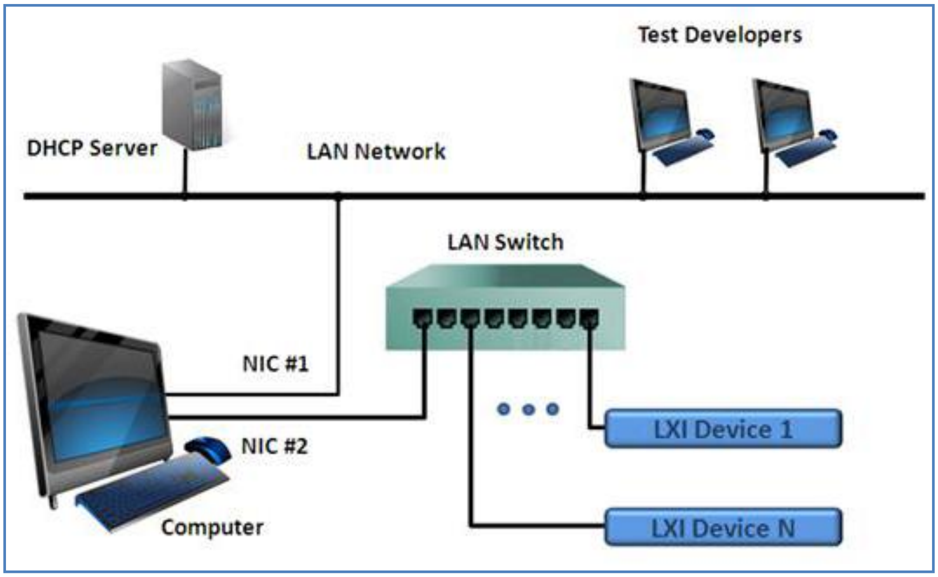
General Purpose Test System

The Interface illustrated in the figure above can be singular or multiple interfaces to communicate with the various instruments making up the test system. The figure below illustrates the commands or interface control messages propagate from the computer to the various instruments, and results are returned.



Computer Controls Instruments and Receives Results

When LXI conformant devices make up the test system, the interface is the computer's built-in LAN, and the computer connects to a multi-port Switch to each of the LXI devices. This solution is inexpensive and reliable. In most test systems using LAN, there would be a second LAN interface. One LAN interface gives remote access of the computer from Test Developers, and the other interface isolates the LXI devices from the corporate LAN.



Isolating Test System from Corporate LAN

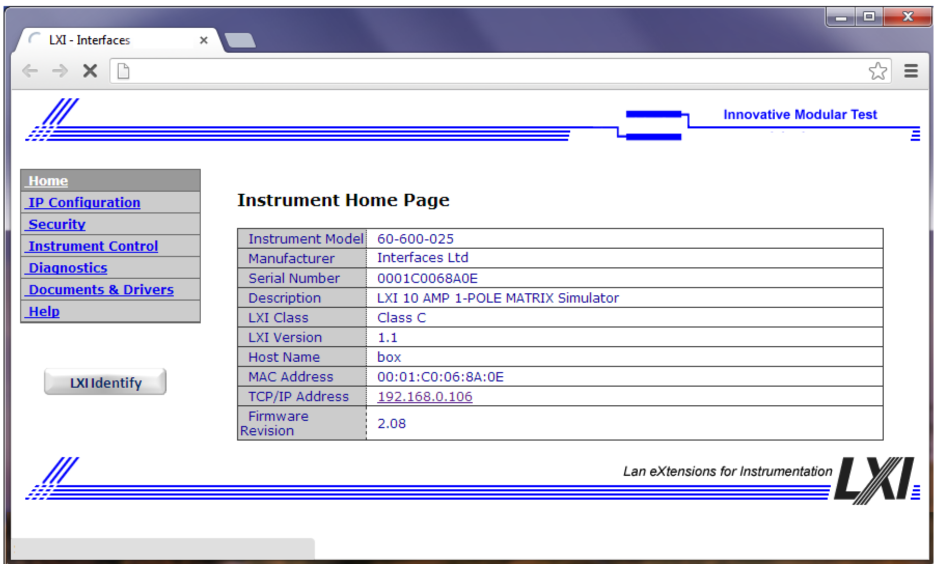
The test system computer is located on the corporate LAN, which permits backup, sharing of test data, remote access for development, and security control. The LXI devices are isolated from LAN traffic and from un-authorized access during testing.

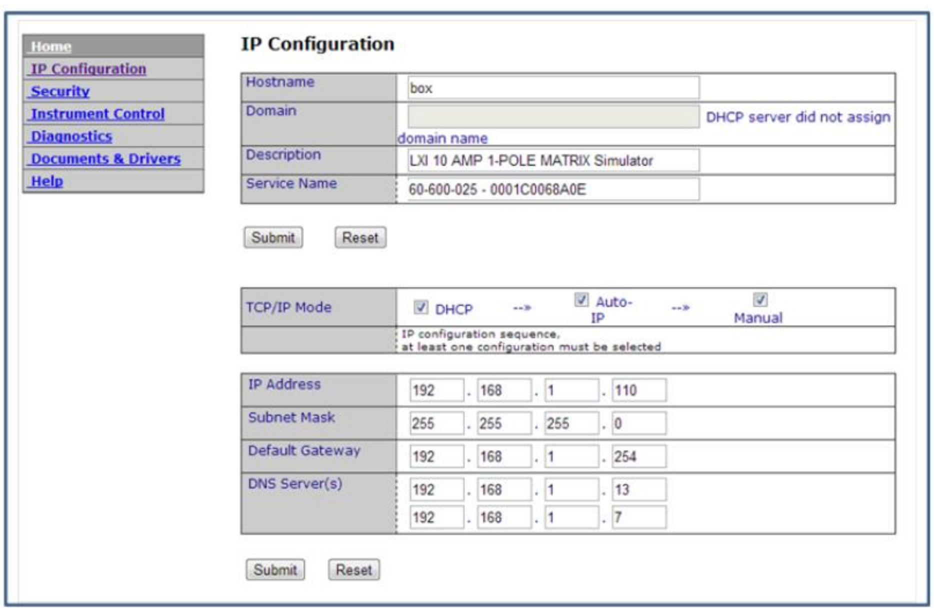
Building LXI-Based Test Systems, found at [Guides for Using LXI](), illustrates this and other configurations.

2.2 Test System Setup Insights

Instrument I/O control is usually provided by an I/O Library installed on the computer. The two most popular I/O Librations come from Keysight Technologies (formally Agilent) and National Instruments. The LXI Consortium provides an [LXI Discovery Tool] to search for LXI devices, but the I/O Library software typically provides this service and then provides easy access using VISA to access instrumentation and control.

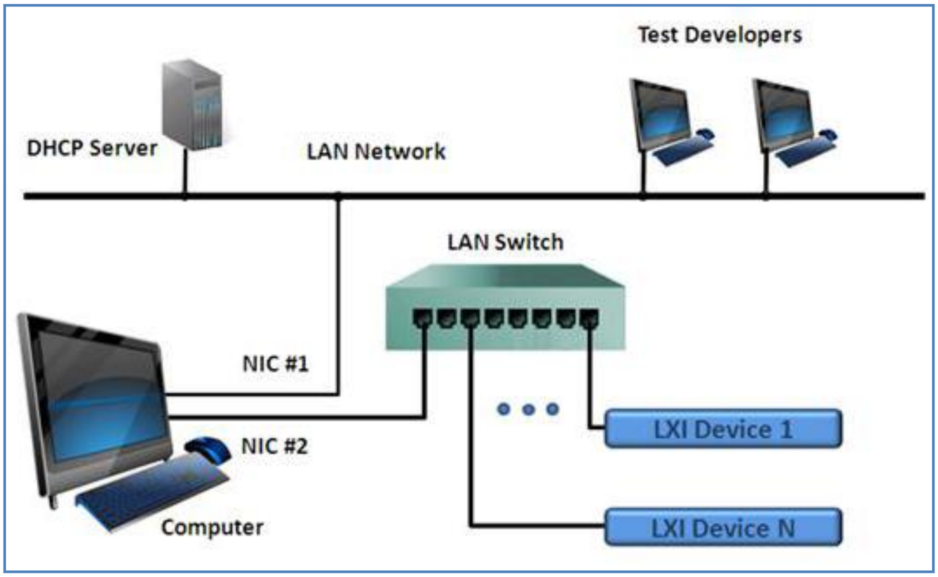
Since LXI devices all behave in the same manner when connecting them to LAN, it is easy to find them using one of these tools. Once found, each has a Web page for identification of capabilities and another for re-configuring the device, as illustrated below:





LXI Device Information and Configuration

The test system configuration below would typically be set up to use a DHCP server to assign an IP address to the test system computer, but the isolated LAN would select static private IP addresses for each of the LXI devices, such as 169.154.10.1, 169.254.10.2, etc.

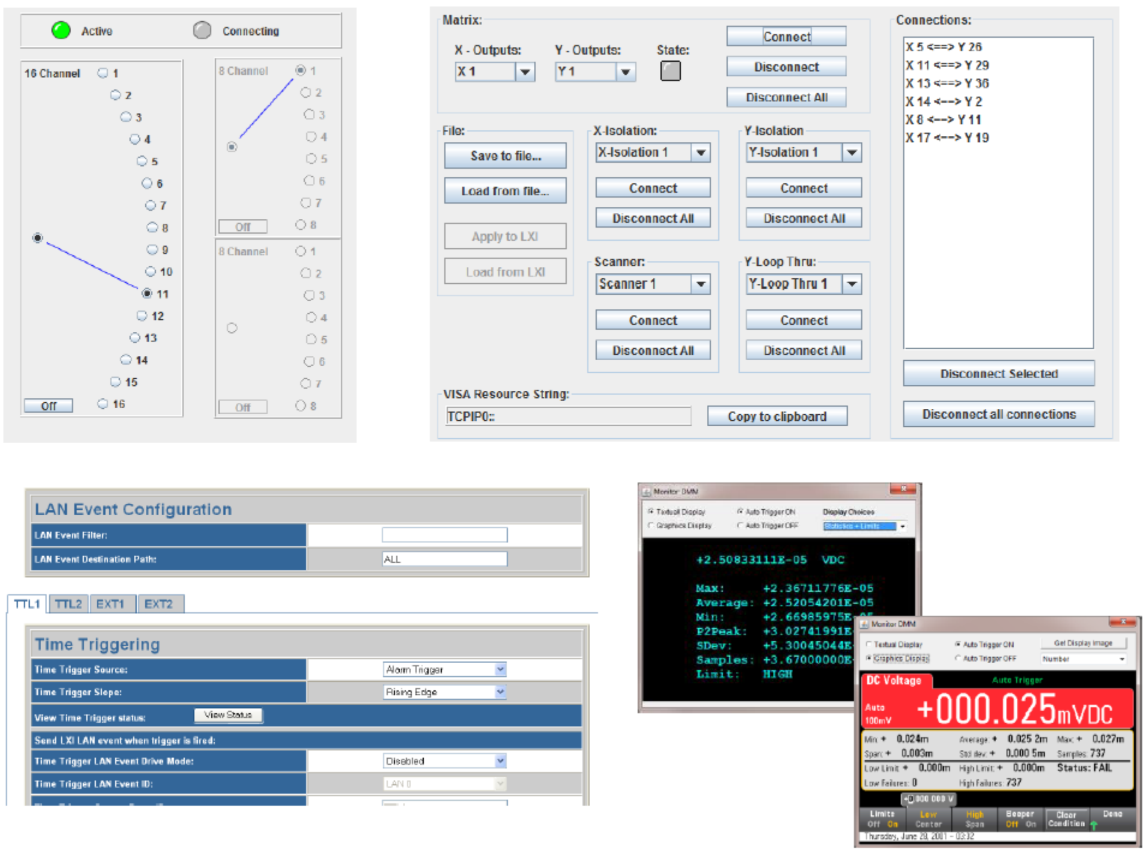


Test System IP Address Configuration

Test developers can access the test system computer via IP address or Host Name and can remote login to the computer for test development, and one developer typically has access at a time.

2.3 Built-In Web Server For Control-Monitoring

Almost all LXI devices provide another Web page or pages for controlling and monitoring the device. This is invaluable to the test developer, since he is often sitting in his cubicle and not in front of the test system. The Web page provides a soft front panel, a visual representation of the front panel, but it can also be a window-oriented interface showing the complete configuration of the device. With LAN, you can have multiple Web pages up on different devices or to a single device for viewing, as illustrated below.



Various examples of LXI Device Web Page Control and Monitoring

Test system developers who have used LXI devices rave about the Web pages provided by these devices. With these pages, the test developer can step through his program and verify the device is properly configured – correct channels closed, correct range of DMM, etc. With LXI devices, they always provide distributed intelligence, which means you can observe operations while the computer test program is running.

These insights and benefits of LXI become evident when walking through various real-world test systems found in the next section. Refer to Guides for Using LXI for more information on first-time use of LXI, building test systems, improving performance with LXI, and working with Network Administrators.

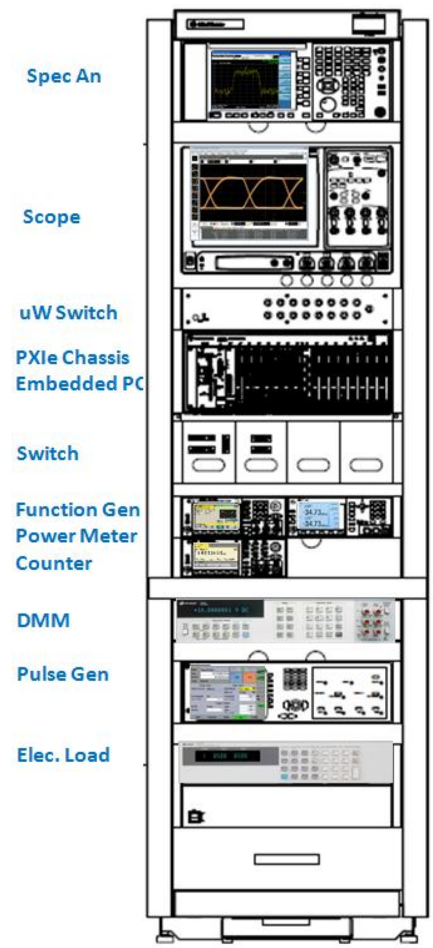
3 Test System Applications

This section provides examples of real-world test systems using LXI devices. A common theme for all examples is the benefit of remote access of instruments via Web pages for configuration and monitoring.

3.1 PXIe Module Tester

This test system has a wide variety of instrumentation used to test various PXIe modules. The PXIe modules operate from DC to multi-gigahertz and must have each of their key specifications verified during production. This requires precision switching and precision instrumentation from DC to multi-gigahertz. Accuracy of a PXIe module requires the measurement or stimulus instruments have greater accuracy. This often dictates stand-alone box products with lots of space for isolation of signals and their own power generation. This particular system also has electronic loads for testing module power supplies, which requires significant power dissipation and dictates a stand-alone solution. An additional requirement for this test system included visibility of measurements on the Scope, Spectrum Analyzer, DMM, Counter, and Power Meter. These are important troubleshooting helps for the test operator when failures occur.

The PXIe modules tested include both analog and digital and providing both input capture and output waveforms. High-frequency digital signals require Jitter, Skew, and power testing, requiring signal analyzers like oscilloscope, frequency counter, spectrum analyzer, and power meter. High frequency signal generators provide precision differential and single ended signals for input capture testing. A function generator provides low frequency and DC signals for testing level comparators on trigger circuits, and a 6.5 digit or better DMM provides DC voltage, current, and resistance measurements for calibration and verification.

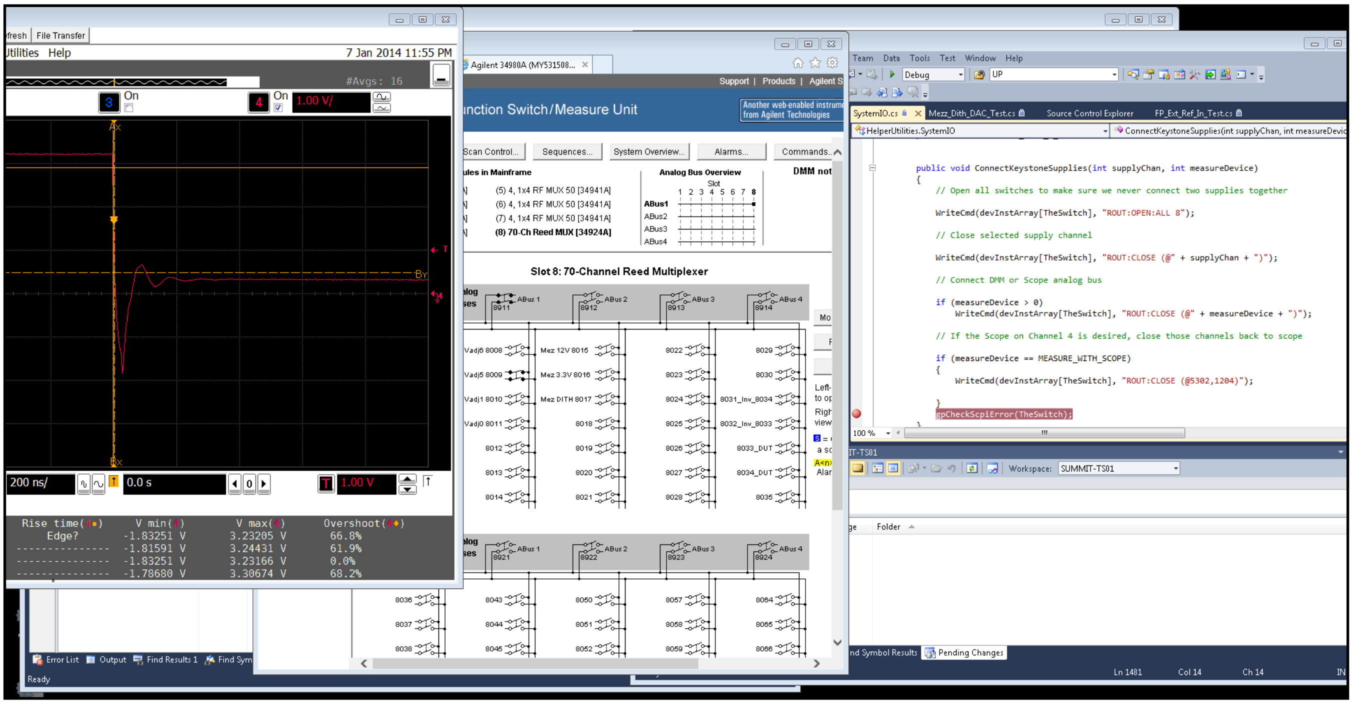


The test system utilizes an embedded computer in the PXIe mainframe. This gives direct control of the PXIe modules using the PXIe IVI Driver. Each instrument connects to a multiport LAN Switch, which then connects to one of two LAN ports on the embedded computer. The other LAN port connects to the corporate LAN giving access to the test developers.

Test developers remote login into the embedded computer and develop their code using Microsoft Visual Studio and C#. All the instruments provide IVI Drivers; however, for this particular system, the developers utilized leveraged code from previous test systems and developed using the SCPI language for programming.

Web page support using LXI devices was an absolute must for this test system. The production team built two of these test systems, where one located in an environmental lab and the other in a test lab, 120 yards apart from each other. The test developers programmed the devices from their cubicles, about mid-way between the two systems. Remote login gave the developer easy access to the Visual Studio environment and desktop of the computer. Web page access for each instrument from the embedded computer gave the developer visibility of important images such as switch positions, oscilloscope, and the spectrum analyzer. Working directly in front of the test system was only necessary until verifying wiring connections.

The figure below gives an image of the typical test developer remote desktop for the embedded computer. As you can see in the figure, switch settings in graphical format along with a representation of the oscilloscope captured signal are visible after having reached a breakpoint in the in the test program



Desktop screen capture of embedded computer

For this test system, communicating with the instruments over LAN was easy, and the use of LAN cables instead of bulky cables found when using GPIB provided more space in the back of the cabinet. Initial trouble shooting of wiring was particularly easy since the Web page for the Switch products allowed closing and opening of multiplexers, general purpose, RF and uWave switches. This allowed manual connection between the DUT and the various instruments. Since the instruments all had Front Panel keyboards, developers could just manually configure each instrument when standing in front of the test system. However, the Web pages for each instrument also provide full manual control of the device.

The following are key points made by test developers of this test system:

- The test system is about 100 yards from my desk. It is also located in a noisy and somewhat chilly climate-controlled Test Lab, and the test station environment does not provide a desk and monitors for test code development near the system. Remote access is critical.
- I need to be able to run and troubleshoot test programs on both remote systems quickly.
- Two instruments were GPIB only – DMM and Electronic load. The Pulse Generator had GPIB and LAN, but was not LXI conformant. Those three instruments were the most difficult to use, since I had to rely upon interrogating them with interactive SCPI or monitor the front panel interface to understand it they were properly configured.

For this particular test system, unless there is a need to modify connections, cycle power, or to install another DUT for testing, virtually all test development takes place in the comfort of the test engineer's cubicle. Productivity is very high, and when running tests that last for hours or days, the test developer can even monitor activity remotely from home via a VPN connection with the company network.

3.2 Satellite System Testing

Satellites are involved in a wide range of applications including scientific research, weather prediction, navigation, and military/aerospace. The greatest numbers of satellites that orbit the earth today are used for communications, enabling people across the globe to communicate with one another. In fact, more than half of the satellites in space are used for telecommunications. Beyond telecommunications, satellite communications are intrinsically tied to almost every aspect of our daily lives whether we realize it or not.

LXI is particularly favored by the aerospace/defense industry where strict adherence to standards and compliance is a necessity. All LXI products are certified compliant with the LXI standard, ensuring test engineers that a combination of LXI products will integrate well together and that there is a consistent user experience between products.

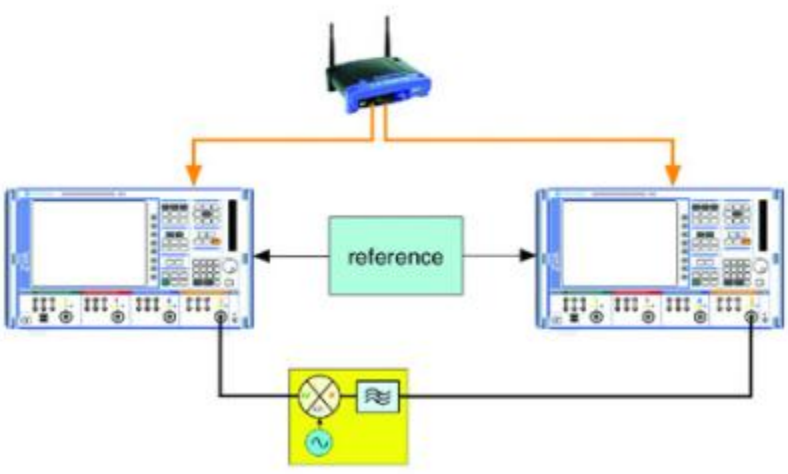
By standardizing and extending the LAN to instrumentation support, LXI simplifies the use of Ethernet for test systems, providing a low-cost, cross-platform computer interface that can be controlled at any distance.

In this case, the phase of the transmission coefficient cannot be measured directly because the input and the output signals have different frequencies. Moreover, the phase of the output signal is influenced not only by the DUT, but also by the frequency and phase drift of its LO. Additionally, in the case where input and output of the transmission system are located far apart, the group delay and phase are very difficult to measure.

The two-tone method1 overcomes these problems. This method stimulates the DUT with a two-tone signal, whereby the network analyzer measures the phase difference between the two carriers, both at the input and the output of the DUT. From the resulting phase differences and the carrier frequency offset, the analyzer calculates the group delay. As a result, the influence of one or more inaccessible LOs of the transmission system is eliminated.

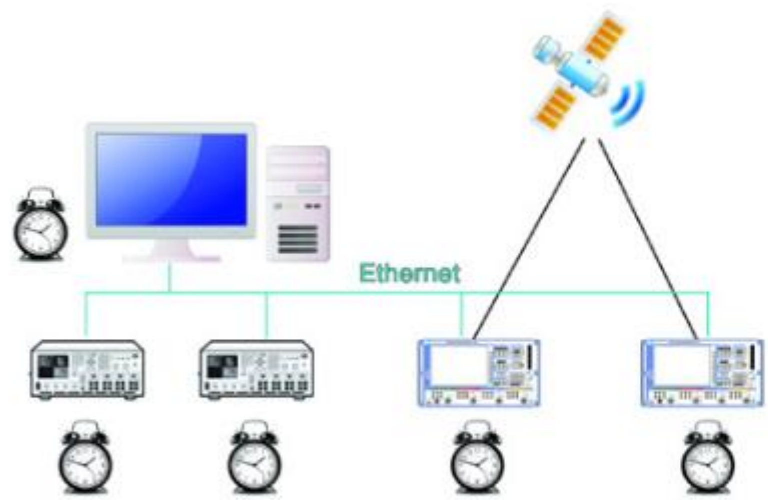
It also is possible to measure group delay on a transmission system by means of two LXI-based network analyzers, one at the transmitting end and the other at the receiving end, that communicate with one another using LAN messages. The LXI network analyzers are connected to one another via a LAN router with an integrated DHCP server that assigns the IP addresses to the devices. Alternatively, the devices can use fixed IP addresses.

The figure below shows the test setup where one LXI network analyzer acts as a master, the other one as a slave. The master controls the slave via a LAN/WAN connection and processes and displays the results.



Synchronization with IEEE 1588

The LXI clock synchronization extended function inherits IEEE 1588-2008 Precision Time Protocol used to synchronize real-time clocks with sub-microsecond accuracy in devices of a networked distributed system. This allows common timer events to be tied to absolute times for very precise triggering and synchronization and enables the correlation between instruments to aid monitoring and debugging. In the two-tone measurement example of the figure below, LXI clock synchronization enables the LXI network analyzers to be synchronized with one another as well as with their PC controller.



All LXI instruments are required to provide a browser-based web interface to be compliant with the LXI standard. Each device incorporates a standard set of web pages that offers useful information about the instrument and allows you to configure the LAN interface. Unlike traditional GPIB or other modular test systems that require the user to be nearby to monitor and control the system, LXI enables complete control over the test system from anywhere in the world, significantly lowering operational and maintenance costs. You can review and modify settings, examine acquired data, and operate the instrument from an intuitive graphical user interface that significantly improves user experience and simplifies the basic tasks of instrument control and interactive operation.