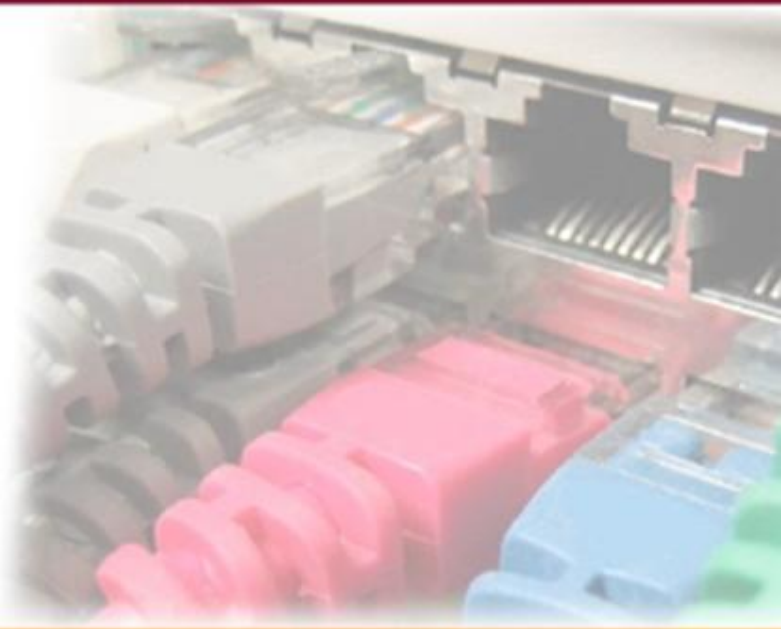
LAN eXtensions for Instrumentation



The LXI Primer

Version 1.2

Table of Contents

Introduction

If you are new to LXI, this document should help attain a better understanding of LXI Devices, their behavior, and the variety of instrumentation that supports this standard.

Further information can be found on the LXI Consortium Website (www.lxistandard.org), including full LXI conformant product listings, guides for using LXI, applications, test system examples, the LXI standard, LXI newsletter, and more.

What is LXI?

A LAN-enabled instrument is one that can be connected and controlled over LAN by a computer. Instruments have had LAN interfaces for many years, but LXI – LAN eXtensions for Instrumentation – establishes a standardized behavior for all conformant devices when connecting to LAN.

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 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 are 50 broad categories with many specialized products within those categories:

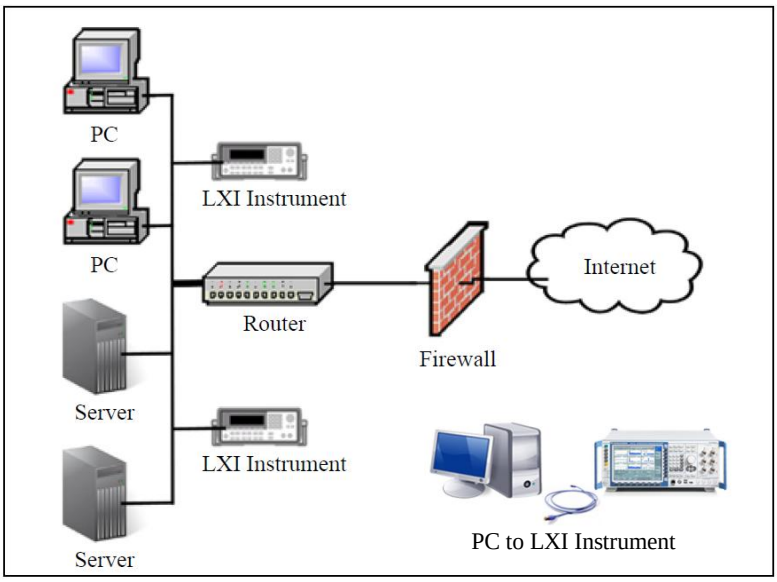
AC/DC Power Supplies	Electronic Load	LXI Event Detector	Power Meter	Solar Array Simulator
Amplifier	EMI Receiver	LXI Trigger	Power Supply Monitors	Sound and Vibration
Attenuation Control Units	Frequency Counter	LXI-PXI Controller	Scanning/Measuring System	Source Measure Unit
Audio Analyzer	Function / 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

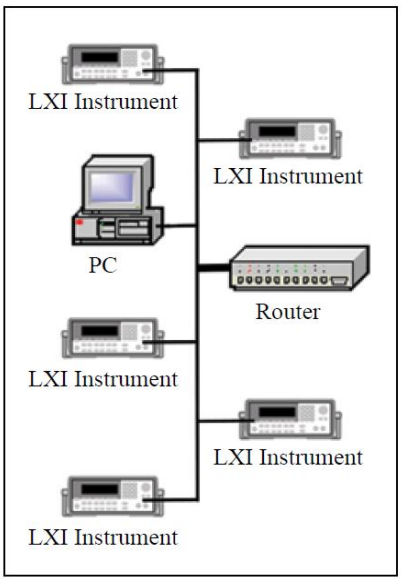
Test systems for virtually every application draw from this broad range of product categories. LXI meets the needs of R&D, design, validation manufacturing engineers delivering electronics for the aerospace & defense, automotive, industrial, medical, and consumer electronics markets. LXI is designed to be compatible with other instrumentation platforms, making it easy to create hybrid test system from multiple vendors.

Network Basics

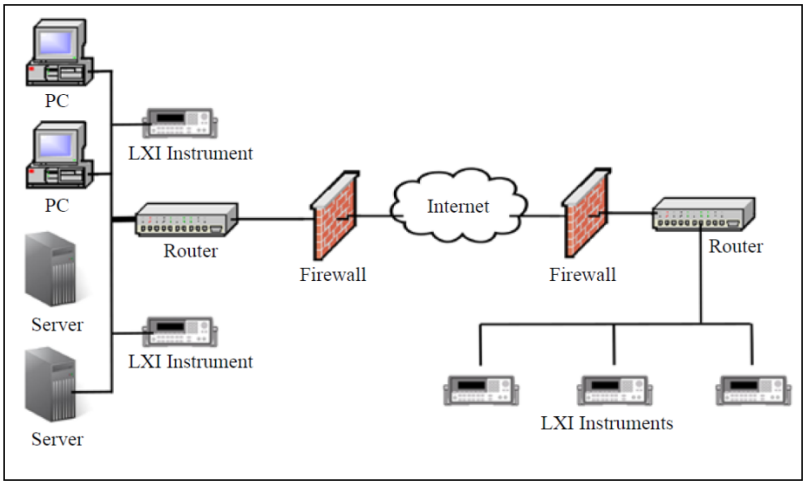
This section provides a short overview of Local Area Networks (LANs), the underlying technology of LXI. Additional guides for using LXI, including the best practices to connect LXI devices to the LAN, can be found in the ***About LXI*** section of the LXI Web site at www.lxistandard.org/About/Default.aspx.

A LAN is defined as a group of computers or instruments that are physically connected in close proximity to one another and communicate via Ethernet protocols. LANs can vary in size from just two interconnected devices – a computer with a direct cable to an instrument, to thousands, where a router enables communication between devices and other networks.





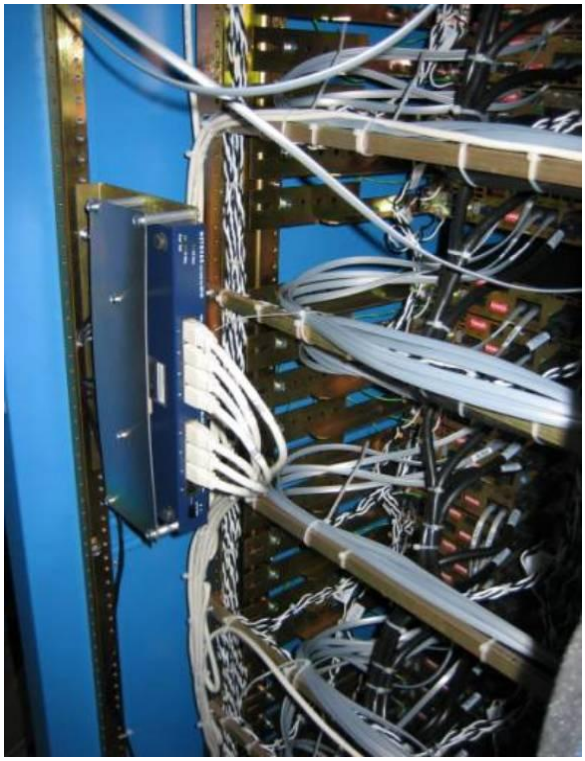
Sometimes it is preferred to create a private or isolated LAN, as in the upper right, where devices interconnect to each other but not to the Internet or any other networks by disconnecting the router from the Firewall and Internet. This keeps all outside traffic from interfering with the instrumentation and the test system computer. The test system computer, in this case, may be the only device connected to the company LAN, where developers can remotely login to develop tests.



For distributed applications or remote testing and diagnostics, where devices span different regions or countries, the use of the Internet is required, as seen in the figure to the right. Companies with multiple sites already have this method of communication between PCs, and LXI Devices act just like PCs for LAN interconnection.

LXI vs. GPIB

For more than 30 years, the General Purpose Interface Bus (GPIB) has been the standard communication interface between a controller and rack instruments, allowing test engineers to easily connect and control multiple devices from different vendors. The LXI standard, introduced in 2005, presents system integrators with a fast and efficient alternative for communicating with instruments. LXI overcomes many of the limitations and costs inherent to GPIB. GPIB systems require special cables and controllers, which add cost to the overall system. LXI systems based on LAN have an infrastructure comprised of low-cost Ethernet cables and switches that are readily available in the consumer electronic industry. The figure to the right comprises a test system with many LXI Devices interconnected by LAN cables and a LAN Switch – a very low cost and less bulky solution compared to interconnecting instruments with GPIB cables.



LXI instruments leverage all of the benefits of LAN technology. Unlike other bus technologies, an LXI-based test system can scale from a small network in a laboratory, all the way up to a distributed, global system connected to the Internet. Currently, LXI instruments are available with Ethernet speeds of 100 Mb/s and 1 Gb/s. The present Ethernet infrastructure features speeds up to 10 Gb/s and will be even faster in the future.

Thanks to backward compatibility requirements, present day LXI instruments will continue to operate in the future as network speeds continue to increase. Due to the increasing network speeds, LXI instruments have much faster block data transfer rates than instruments using slower buses such as GPIB. Some LXI instruments also support advanced intra-device synchronization and triggering mechanisms that improve test throughput efficiency.

Best of all, LXI devices integrate seamlessly into existing test systems that use GPIB or modular architectures such as VXI, PXI, PXI Express or AXIe. In many cases, the LXI device has multiple interfaces, such as GPIB, USB, and LAN. This allows you to migrate to LXI when you are ready.

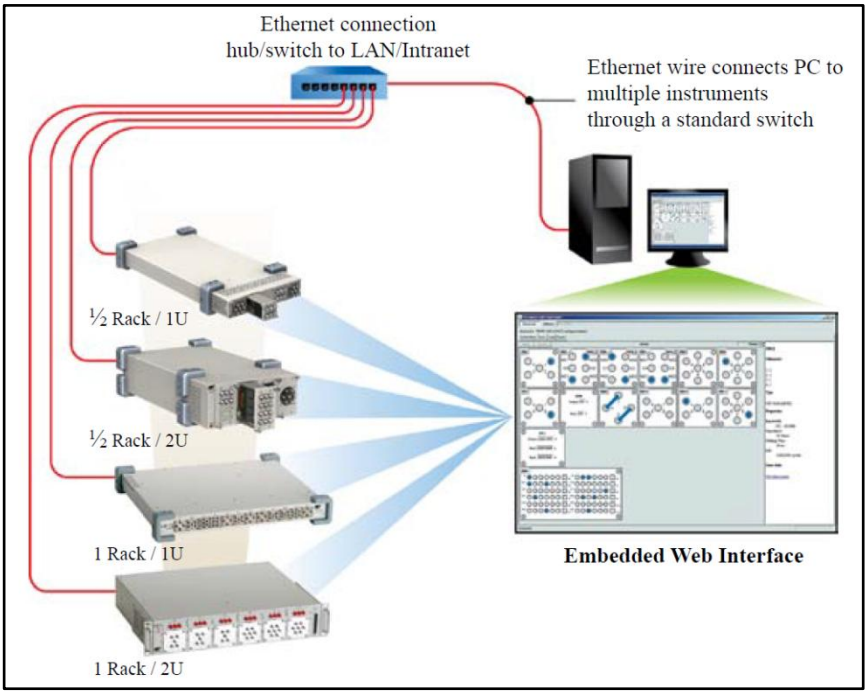
LXI Core Features

By standardizing and extending LAN, LXI offers new possibilities in system design – local, remote, and distributed. All LXI Devices conform to a base set of capabilities called LXI Core. This core set of features ensures that all LXI Devices connect to the LAN in the same way. This is critical for building test systems, where products may come from different vendors. Details regarding the LXI specification can be found in the ***Specification*** section at www.lxistandard.org/Specifications/Specifications.aspx. The following is a summary of the key features of the LXI Core specification:

1. **Open industry standards**. LXI is based on widely used industry standards such as TCP/IP Ethernet, IPv4/IPv6, Web browsers and IVI drivers.
2. **High-speed Ethernet I/O**. LXI is based on Ethernet technology, the most widely accepted communications interface in use today. Ethernet I/O provides backward compatibility and standard connections. Nearly every computer is manufactured with one or two integrated Ethernet interfaces, and networking hardware is becoming increasingly inexpensive.
3. **Built-in standardized Web interface**. Many test and measurement instruments provide Ethernet/LAN connectivity, but the LXI standard ensures that instruments support W3C-compliant browser-based information in order to be compliant with the LXI standard.

With the Web interface users can:

- Easily configure and operate the instruments from an embedded Web server graphical user interface (GUI)
- Collect and analyze data without software programming or using the Front Panel interface.
- Operate instruments remotely, either across the lab or across the globe



Interchangeable Virtual Instrument (IVI) drivers

All LXI devices include an Interchangeable Virtual Instrument (IVI) driver for programmatic control of LXI Devices. The IVI driver provides a consistent programming interface. The IVI standard ensures the driver works well in a variety of programming environments, provides high performance interfaces, and eases program development and maintenance.

LXI instruments optionally provide IVI class-compliant drivers. Class-compliant drivers also comply with common definitions for classes of instruments and simplify instrument interchangeability.

What is IVI?

The IVI standard is an open driver architecture set of instrument classes and shared software components defined by the IVI Foundation - www.ivifoundation.org.

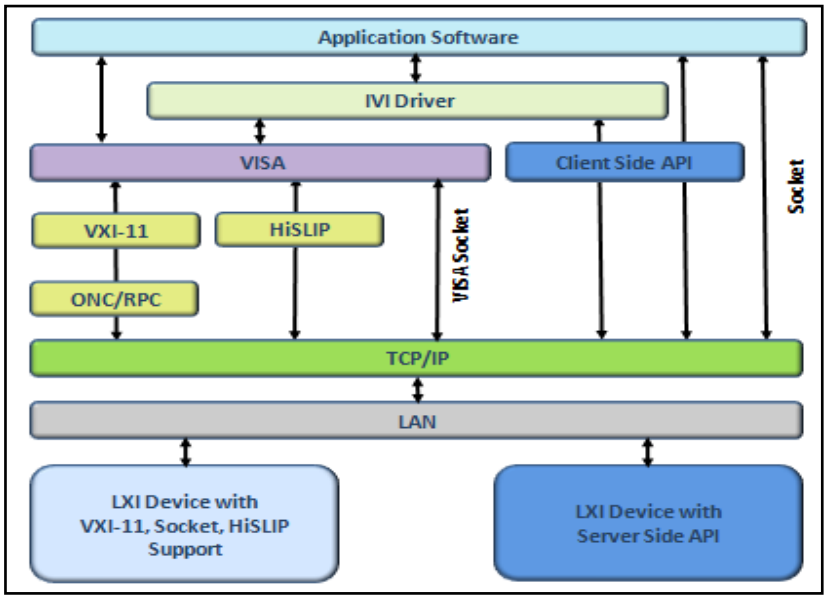
What are IVI drivers?

IVI drivers provide increased performance and flexibility to test instrument applications and define advanced features such as instrument simulation, state caching, automatic range checking, and multithread safety.

Benefits of IVI

IVI offers several benefits to test & measurement designers:

- Provides standard Application Programming Interfaces (APIs) to provide fast access to driver functions and reduce the time needed to learn a new LXI instrument
- Enables simulation of instruments to simplify testing of measurement applications
- Feature enhanced ease of use in popular Application Development Environments
- Reduces the time and effort needed to integrate measurement devices into new or existing systems by providing interchangeability



As seen in the figure, test developers can rely solely on the IVI Driver, or they can communicate directly with the LXI Device through multiple interfaces typically available when installing VISA (Virtual Instrument Software Architecture). VISA I/O Libraries come with instrumentation from all vendors of LXI Devices. You can learn more about these interfaces from ***Guides For Using LXI Devices***, found at the LXI Consortium site: www.lxistandard.org/About/Default.aspx.

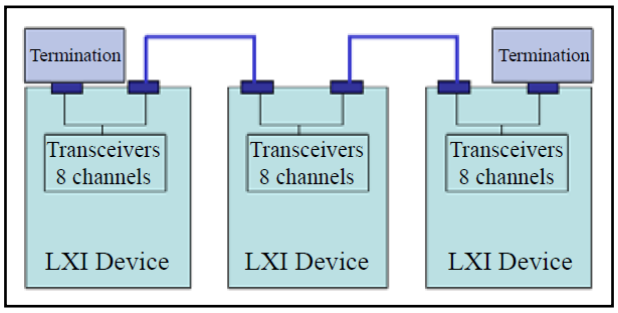
LXI Extended Functions

LXI Device Specification 2011 Version 1.4 is defined as a set of core features with optional Extended Functions, which have replaced the Class A, B, and C models in previous versions. Each extension has conformance requirements in addition to the Core Features, or base class. All LXI Devices have the Core Features, but there are a number of LXI Devices with one or more of the following Extended Functions:

1. LXI Wired Trigger Bus

The LXI Wired Trigger Bus (WTB) is a hard-wired interface to specify input or output configurability, wired-OR, and shielding and cabling for the most demanding triggering applications.

This method of triggering increases your accuracy to the nanosecond range compared to software triggering via the LAN, which is typically in the millisecond range.



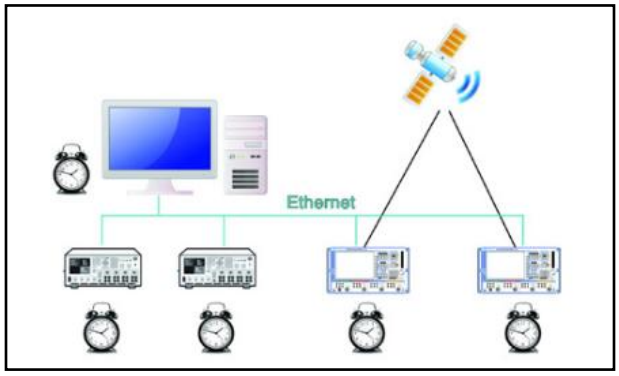
2. LXI Event Messaging

With LXI Event Messaging, an LXI Event message containing triggering information (including a timestamp) can be sent directly from one device to another over the LAN, without computer intervention, which improves execution speed.

LAN-based triggers provide programmatically triggered events through driver commands from the controller to the LXI device or by message exchange between LXI devices. They emulate traditional hardware triggers but can carry information that hardware triggers cannot - such as trigger slope and time stamps based on synchronized system clocks. Antenna Testing can make good use of this capability where a signal source and analyzer, separated by line-of-sight, can trigger each other over the LAN.

3. LXI Clock Synchronization

LXI clock synchronization inherits IEEE 1588-2008, a 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. This also enables the correlation between instruments in order to aid monitoring and debugging.



4. LXI Timestamped Data

LXI Timestamping enables the capability of marking a LAN event at a point in time – events such as triggering, measuring, or connecting channels. You can understand what happened in time sequence in your test programs.

5. LXI Event Logs

The LXI Event Log utility contains records of LAN events that have occurred, permitting observation of an instrument – or of an entire system – in action. The event log helps you understand what is happening in your instrument or system.

6. HiSLIP – High Speed LAN Instrument Protocol

The HiSLIP Extended Function leverages the HiSLIP standard, created by the IVI Foundation to create a fast control interface, extends the features provided by VXI-11 (a protocol used to emulate GPIB over LAN using the Ethernet RPC protocol), and emulates the capabilities of GPIB devices using the faster TCP/IP Socket protocol. HiSLIP also operates over IPv6 networks.

7. IPv6

The world is being forced to adopt IPv6 as IPv4 address spaces on the Internet run out. The IPv6 Extended Function has been adopted by the LXI Consortium to ensure that the LXI vendors approach IPv6 in a consistent way before its widespread use in test systems occurs and ensuring products can comply with government requirements for IPv6 readiness.

Benefits of LXI

Below are some of the key benefits of using LXI products.

1 Guaranteed Compatibility

Before a product is certified as LXI conformant, it must be tested by a certified third party to ensure that it conforms to the LXI specification. Test engineers are assured that combinations of LXI products will integrate well together and that there is a consistent user experience between products.

2 New Distributed Applications

LXI's seamless connectivity – local and global – enables new distributed applications. LXI overcomes the challenges of distributed test systems by offering:

Remote System Control: You can control your remote system, as well as provide support from a distance, which allows more efficient use of expert resources.

Distributed Systems: An LXI distributed system allows the instruments to be closer to the actual measurements. This reduces cable lengths resulting in less excitation voltage loss or variation.

3 Reduced Costs

Lower Costs for Equipment: LXI uses standard I/O for simplified connections. You can use off-the-shelf inexpensive LAN cables and routers or switches. There is no need for special I/O hardware, such as GPIB interface cards or cables.

Reduced Setup and Development Costs: With LXI, you have faster setup, operation that is easy to verify, and standard drivers available for easier test programming. LXI devices include a built-in Web interface to enable configuration and troubleshooting, as well as auto-discovery tools to minimize development time.

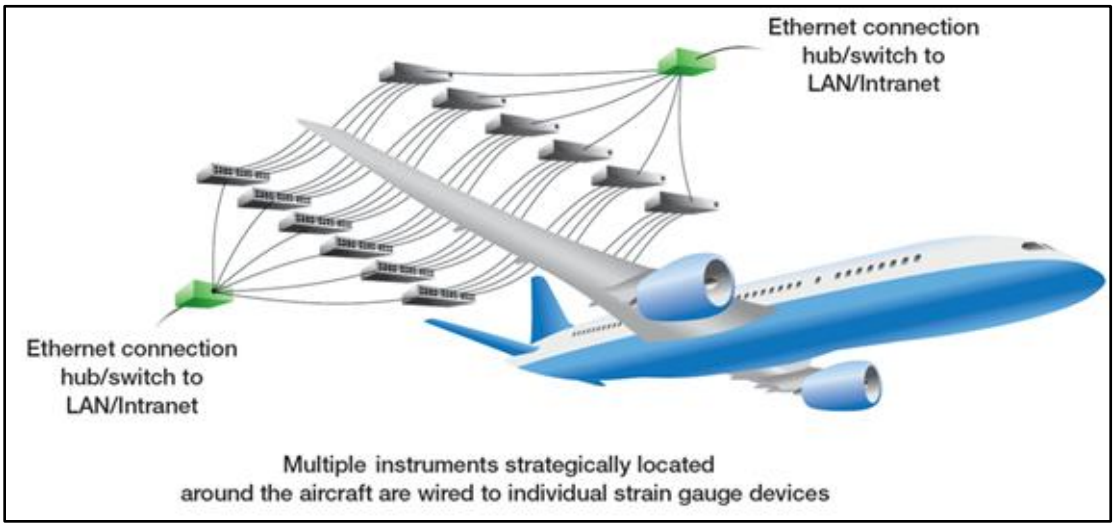
Lower Operational and Maintenance Costs: You can easily connect to test and corporate databases to save operational expense. With LXI, it is possible to perform remote execution, monitoring, and debugging, which saves on maintenance costs.

4 Easy Connect

LXI based instruments can be freely connected and disconnected to the test system controller without the need for powering down the controller - the Ethernet interface ensures connections can be "hot plugged" in the same way as GPIB systems without risking a controller malfunction. The Ethernet standard can work in noisy environments over long distances with robust error correction and re-try mechanisms.

LXI Applications

Since LXI is the standard for controlling instruments over Ethernet, it is well suited for a variety of applications. It can range from small local test systems isolated on a subnet to medium and high channel density applications. The instrumentation hardware can be distributed throughout a test system, lab, or separated by a significant distance from the host computer and connected to a company's corporate WAN or the Internet.



Typical test & measurement applications include: RADAR, communications, aerospace & defense, etc. LXI enables fast, efficient, and cost-effective testing as well as compatibility with the other main instrumentation standards such as GPIB, VXI, PXI, and AXIe for hybrid systems.

Recent application articles can be found in the ***Resources*** section of the LXI Web site at: http://www.lxistandard.org/Resources/Default.aspx.

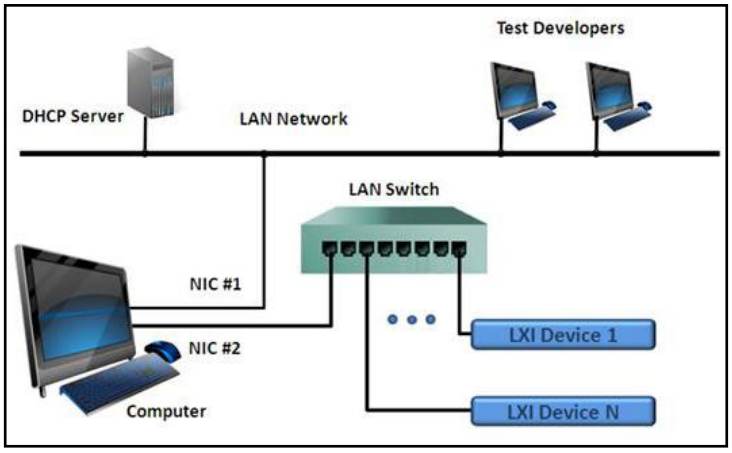
Using LXI Discovery Tools

Vendors such as National Instruments and Keysight Technologies (formerly Agilent Technologies) have discovery tools built into their I/O library configuration utilities. Discovery tools will help you find and identify the LXI instruments available to your computer on the network.

Measurement and Automation Explorer from National Instruments, and Connection Expert from Keysight Technologies, make it easy to discover LXI devices, connect to their Web interface, and configure them for VISA or IVI communications. If you only intend to communicate with the LXI device through its Web interface, you can also use the free ***LXI System Discovery*** Tool available from: www.lxistandard.org/Resources/LXIDiscoveryTool.aspx.

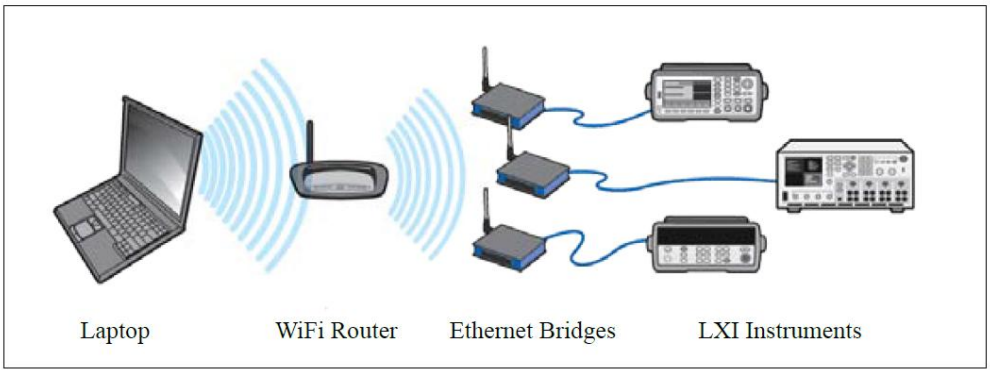
Connect to the Device

Connect one end of an Ethernet cable to the back of your LXI device and the other end to your computer, or to a free port on your hub or switch, if you are connecting to a network. ***Guides For Using LXI*** found on the LXI Consortium site at: www.lxistandard.org/Resources/GuidesForUsingLXI.aspx include examples of switch and router connections to setup LXI test systems



Example Setup of LXI System

The following is an example of a wireless test setup. Although many instruments do not yet have WiFi today, you can use low-cost, off-the-shelf wireless devices to connect LXI instruments wirelessly. The following figure illustrates how to create a wireless test setup by replacing the wired Ethernet switch or router with a WiFi router and using Ethernet bridges to convert the Ethernet signal to WiFi.

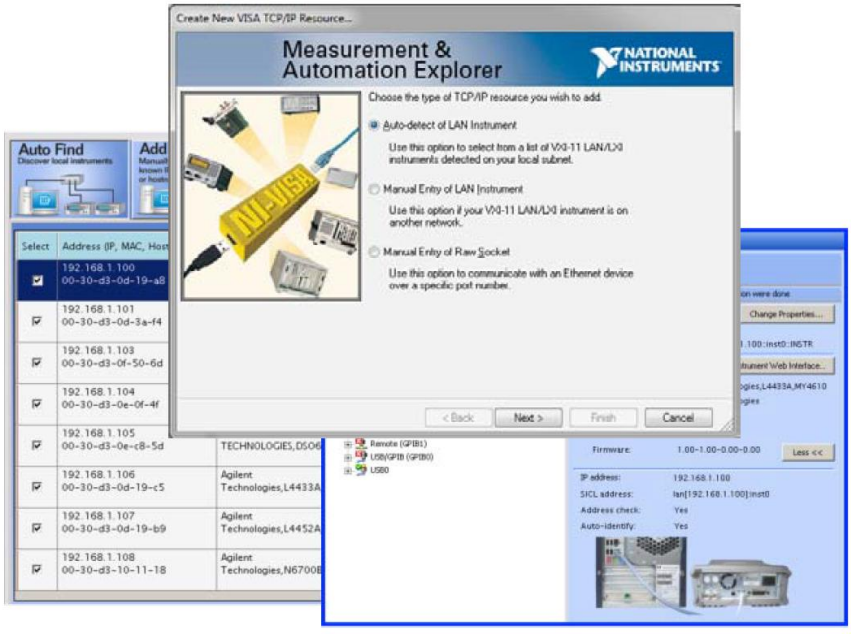


After the device has powered up and a connection to the LAN has been established, an attempt will be made to obtain an IP address as part of its boot-up process. The LXI specification requires every LXI device have a LAN status indicator. Once the connection status is good, this indicates that the LXI device has successfully booted up, obtained an IP address and can be discovered on the network.

Using Your LXI Device

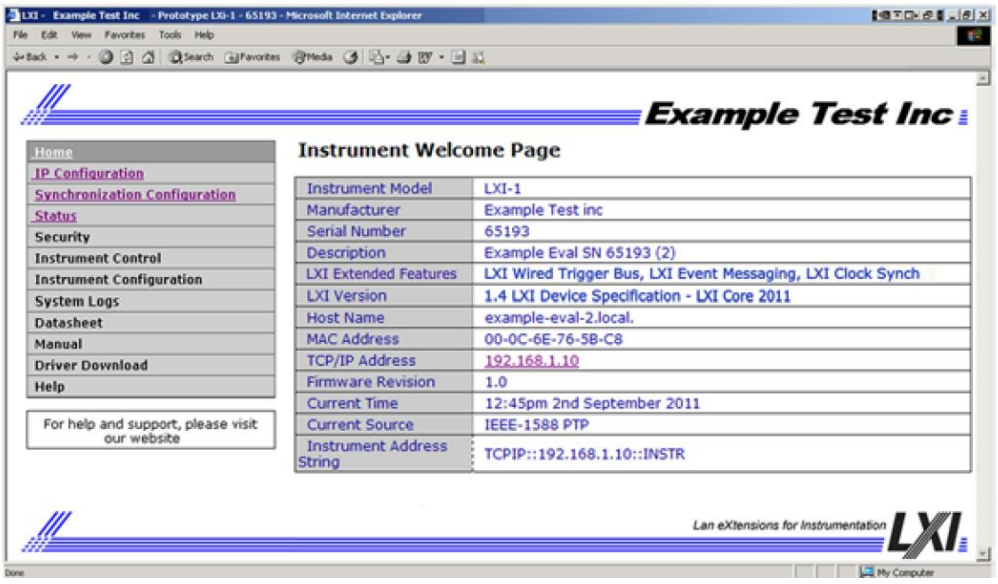
Discovering and Communicating with the Device

LXI instruments are required to have a browser interface that works with all W3C compliant browsers. Use one of the LXI Discovery tools automatically access the instrument's Web interface, or type its host name or IP address (refer to your device's documentation to determine the IP address of your device) in the address field of the browser on your PC.



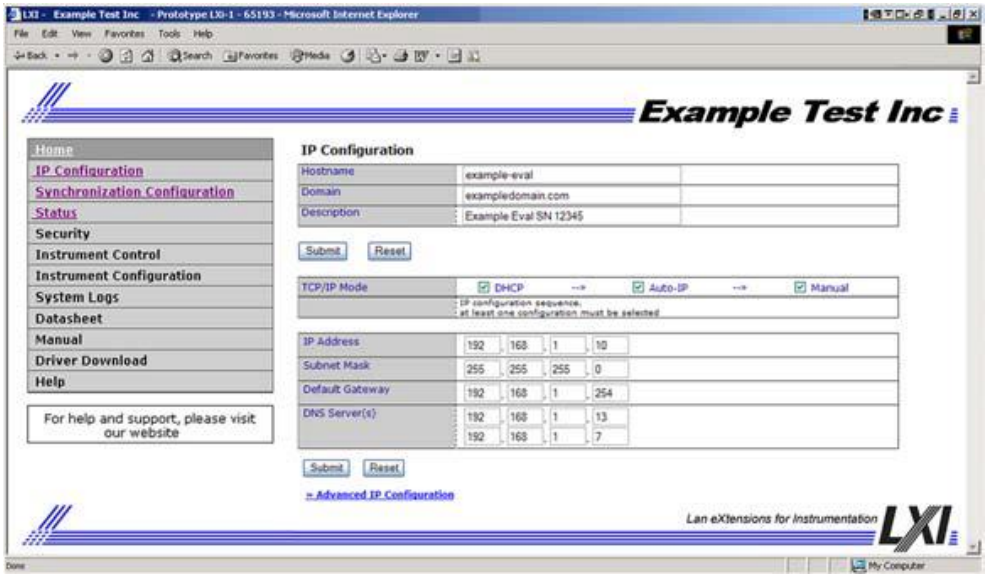
Web Interface

All LXI devices have a Web interface through which you can configure various instrument settings and control the device to generate and measure signals. In general, any page(s) that allows a user to change the instrument's settings are password protected. However, the device's default password may be left blank, and in this case, the Web interface may not prompt for a password.



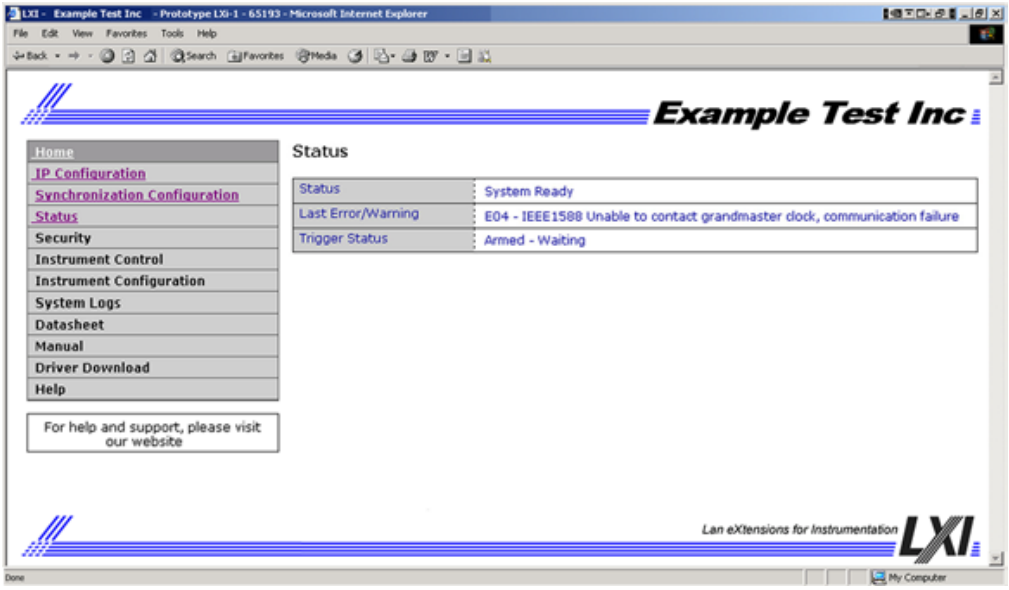
LAN Configuration

The LAN configuration page contains parameters to configure the LAN settings. The TCP/IP configuration field controls how the IP address for the instrument is assigned. For the manual configuration mode, the static IP address, subnet mask, and default gateway are used to configure the LAN. The automatic configuration mode uses Dynamic Host Configuration Protocol (DHCP) server or Dynamic Link Local Addressing (Automatic IP) to obtain the instrument's IP address.



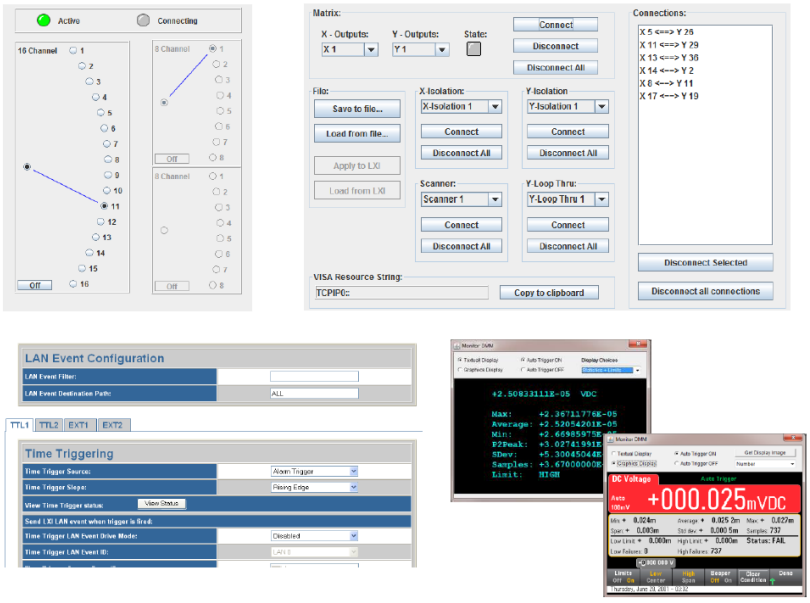
Optional Sync Configuration

For devices implementing the optional LXI clock synchronization Extended Function, the sync configuration page allows you to set parameters for IEEE 1588 - 2008, LXI Events, and the LXI Wired Trigger Bus. You can view the trigger status as well as any errors/warnings from the device's status page.



Device Control Using Web Interface

In addition to configuring the instrument, the Web interface enables you to control your LXI device. For example, you can read values and perform measurements, send output signals, and try out commands. Programmatic control of the device is also possible using its IVI Drivers.



Controlling LXI Devices with IVI Drivers

An IVI Driver is a required component for LXI conformance, so it will be available with every LXI Device. The IVI Driver presents a common programming interface for all LXI Devices, helping the programmer when dealing with different device types and from different vendors.

The following programming environments support the IVI Driver:

- Keysight VEE Pro®
- MathWorks MATLAB®
- Microsoft® Visual Studio C#, C++, and Visual Basic
- National Instruments LabVIEW® and LabWindows CVI

The IVI Foundation, www.ivifoundation.org, provides ***IVI Getting Started Guides*** for each of the mentioned programming environments. Those guides provide background information, installation instructions, and detailed examples. Each vendor typically supplies additional programming examples with the implementation of their IVI Driver. Please refer to the ***IVI Getting Started Guides*** for further information.

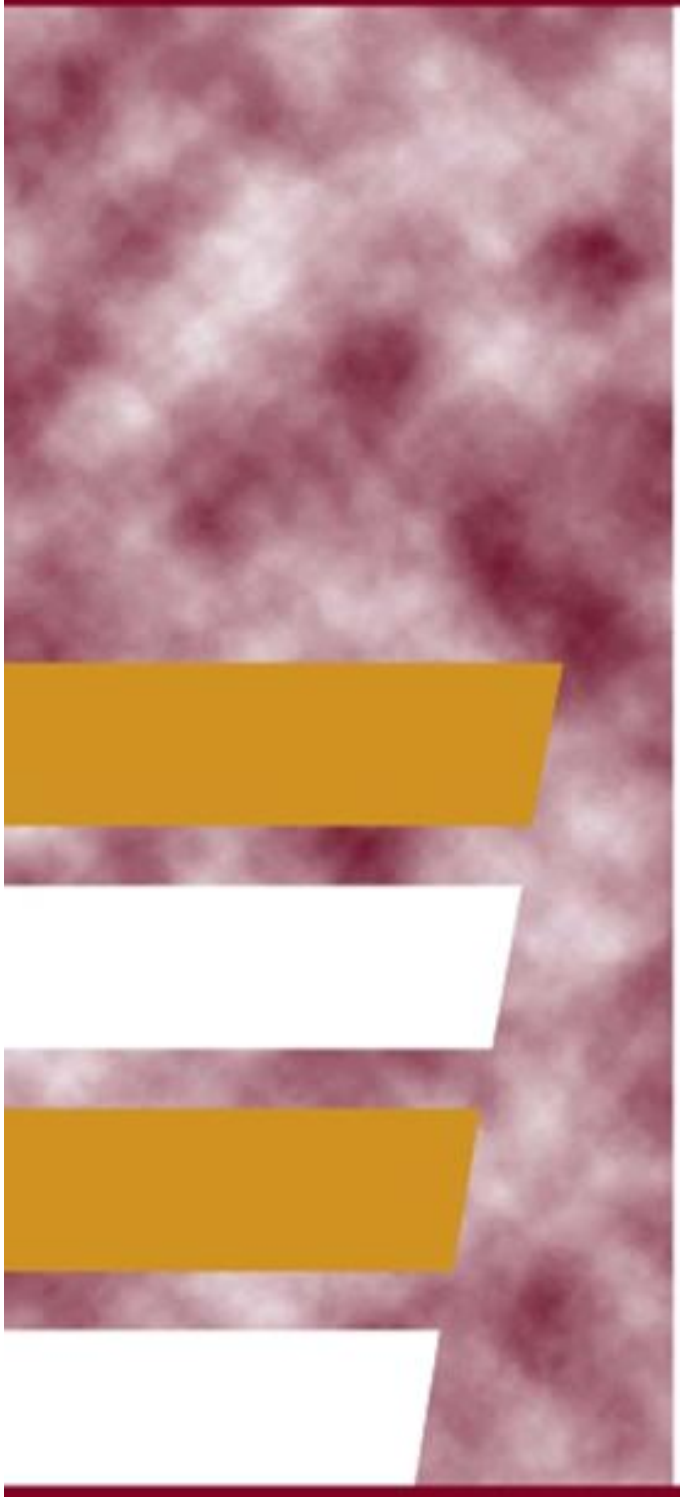
Here is an example segment of a program using C# and controlling an instrument with an IVI Driver:

```
// Configure Function Generator output
driverFgen.OutputFunction.Function = Abc3352xOutputFunctionEnum.Abc3352xOutputFunctionSinusoid;
driverFgen.Output.Frequency = 10E5;
driverFgen.Output.Voltage.Amplitude = 5;

// Configure DMM for measurement
driverDmm.Trigger.TriggerSource = Abc344xTriggerSourceEnum.Abc344xTriggerSourceImmediate;
driverDmm.Trigger.SampleCount = 1;
driverDmm.Measurement.Initiate();
```

Other Resources

LXI Consortium	www.lxistandard.org
LXI Device Specification 2011, rev. 1.4	www.lxistandard.org/Specifications/Specifications.aspx
LXI Discovery Tool	www.lxistandard.org/Resources/LXIDiscoveryTool.aspx
Guides for Using LXI • LXI Getting Started Guide • Building LXI-Based Test Systems • Introducing LXI to Your Network AdministratorPerformance of LXI-Based Test System	www.lxistandard.org/AboutLXI/GuidesForUsingLXI.aspx
LXI Application Articles and Videos	www.lxistandard.org/Resources/
IVI Foundation	www.ivifoundation.org
IVI Foundation Driver Registry	www.ivifoundation.org/registered_drivers/driver_registry.aspx
VXIbus Consortium	www.vxibus.org



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