LAN eXtensions for Instrumentation LXI

# LXImate

A practical guide to the

**LXI Standard**

and

Getting Started with

**LXI Devices**


3rd Edition

pickering

*Cover photographs courtesy of Agilent Technologies and ZTEC Instruments*

# LXImate

*As the LXI Standard enters into its 8th year as a test platform, it is clear by the number of products – over 2,000 as of publication – that LXI is an accepted platform. But there are still many test engineers who do not understand what LXI is and its impact on their test strategy. This book provides an overview of the LXI Standard and is intended to be of help to users of equipment conforming to it, as well as companies considering design of new LXI instruments.*

*The LXImate provides a practical overview of the standard, shows how users can communicate with an LXI Device and describes the technical aspects of the standard. In many instances in this book, Pickering's experience with LXI is documented in the various chapters. In almost every instance, a similar experience will be seen when using other LXI devices.*

*At the time of writing, the LXI standard is at revision 1.4 and the LXI Consortium has published Extended Functions for HiSLIP and IPv6.*

*This is a document that Pickering Interfaces will continue to develop in support of the LXI Standard and its future evolution. We welcome any feedback from readers and any suggestions for topics to include in future editions.*

*The LXImate is a companion book to our PXImate which describes the PXI standard.*

*Opinions presented in this book are the opinions of Pickering Interfaces and not necessarily that of the LXI Consortium. Photos of Pickering switching systems are included in this book as a courtesy to readers needing switching in their test systems. For further information on our LXI products, go to www.pickeringtest.com.*

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*Created by the team at Pickering Interfaces, May 2013*

*Further copies or new editions of the LXImate can be obtained from*

**pickeringtest.com/lximate**

## About Pickering Interfaces

*Pickering Interfaces is a market innovator in signal switching and conditioning for a broad range of applications and architectures and offers the largest range of switching solutions in the industry for PXI, LXI, PCI, VXI and GPIB applications. Pickering Interfaces provides solutions for commercial and military applications.*

*Pickering Interfaces operate globally with direct operations in the US, UK, Germany, Sweden, France, Czech Republic, and Engineering support in China, together with additional representation in countries throughout the Americas, Europe and Asia.*

*Pickering Interfaces is a Strategic Member of the LXI Consortium and has actively participated in the LXI Consortium's activities since its inaugural meeting in Salt Lake City, November 2004. Pickering Interfaces was amongst the first companies to demonstrate their commitment to the standard by launching product just 13 months after the first meeting.*

*More information about Pickering Interfaces can be found on our web site:* ***pickeringtest.com***



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# *SECTION 1*

# *INTRODUCTION TO LXI BASICS*

*This section provides an overview of the LXI standard, concentrating on the physical and electrical principles involved.*

## Contents

## Introduction to LXI

In November 2004 work started on a new open standard, the LXI standard, for controlling test and measurement products with the inaugural meeting of the LXI Consortium (www.lxistandard.org). The objective was the creation of a standard method of controlling Ethernet (LAN) connected devices.

After a frantic first year the consortium published the first version of the LXI standard at Autotestcon September, 2005, a remarkable achievement accomplished by an organization whose members could be fierce competitors in the market place, but who were dedicated to creating a new standard through their collaborative efforts.

Since those early days the standard has strengthened and products have been continuously introduced, 7 years after the introduction of the first products, over 2,000 distinct products from 30 different vendors were available and the number has grown steadily since that time. Test systems can easily be created that just use LXI Devices, all the key elements are present to make an entirely LXI controlled test system. LXI devices work well in hybrid systems with other test platforms as well.

LXI is a major interface standard for instrumentation, steadily taking over the former role of GPIB. It's taking time for this to happen (test and measurement control interfaces take time to gain adoption), but there is little doubt that it is happening as all the major test and measurement companies continue to promote the standard's advantages and user commitment to LXI continues to expand.

Many products are launched with LXI compliant control interfaces, but this aspect is not often in the headline for the product - it has become the de facto standard interface for non-modular instrumentation and the only standard for Ethernet (LAN) control of instrumentation.

Not since the introduction of the GPIB (or HPIB, IEEE488) in the early 1970's has such a change in instrumentation control principles occurred.

## Built on Standards

The LXI Standard describes a control interface for test and measurement products based on an Ethernet interface with web access for configuration management and manual control. The Ethernet interface has had a long history of development to arrive at its current state; it is the dominant external interface used by the computer industry and is present on all computing platforms without the need for the installation of additional hardware or software.

Ethernet has been present since the mid 1980's and has been well supported by all operating systems since then. It has a migration path to seamlessly increase speed to 10 Gbits/s and beyond with both copper and optically connected variations.

The LXI Standard is largely built on existing standards; much of the work on the standard has been adopting open standards and specifying how an LXI Device should behave within them, ensuring that the devices are all 'good neighbors' in the system.

Just some of the key standards used by LXI are:

- Ethernet connectivity (physical and protocols)
- TCP/IP (IPv4 and IPv6)
- Discovery Protocols (VXI-11, mDNS)
- W3C web browser standards
- IEEE1588 precision timing protocol
- M-LVDS TIA/EIA-899
- IVI Drivers.

The LXI Standard defines how these standards are used by LXI compliant devices with the aim of ensuring predictable behavior and common implementation principles by vendors designing to those standards.

## The Historic Class Model

In the earlier versions of the LXI Standard (Version 1.3 and earlier) the documentation described a hierarchy where products were described as being Class A, B or C according to the features they supported. The principal features were a basic conformance with the LAN interface requirements (Class C), support of the IEEE1588 timing standard with associated features concerning trigger models and event logs (Class B) and the Wired Trigger Bus (WTB) (Class A).

The class structure was based in part of an assumption that IEEE1588 (more information on which is given later in this publication) would be a key part of future test measurement systems. In reality, despite being a very powerful tool which can solve problems that are hard to address by other means, the vast majority of applications have been adequately served by the “Class C” products with their standardized LAN interface. The need to support IEEE1588 may even have been a barrier to exploitation of the WTB feature which provides a hardware based trigger interface that connects LXI Devices together using a cable and in so doing emulates the characteristics of backplane busses on modular platforms such as VXI and PXI.

The Class structure prejudged what features were hoped to be the most attractive to users, a judgement that in hindsight for various reasons became misaligned with the market experience.

The situation on IEEE1588 was further confused when the IEEE standard was updated from IEEE1588-2002 to IEEE1588-2008 which created backward compatibility problems between the two versions, 1588-2008 being adopted at Version 1.3 of the LXI standard. The improved IEEE1588 standard allowed timing accuracy to be maintained in the presence of heavy LAN traffic, but required a more complex solution requiring a hardware element to be present in the Ethernet interface chip. Usable solutions for 1588-2008 on 1Gb/s Ethernet have been slow to appear and have had an adverse impact on IEEE1588 adoption for test and measurement.

Effective use of IEE1588 in controlling systems also required the users of LXI systems to think differently about how they program the system. Although programming by time has many advantages in some systems (reduction of LAN traffic at critical times and support of distributive applications being two) changing the way users control test systems is not a quick process - it takes time for programmers to change the way they program systems particularly when a heavy investment already exists in current systems.

The consequence of this is that most vendors simply designed Class C products with some extra features added to suit their target market.

Other challenges have also arisen for the LXI Standard, perhaps the most important being the need to support IPv6 as well IPv4 as address space in IPv4 started to run out and the US Government increasingly required LAN connected equipment to support IPv6. Adding IPv6 clearly is a breaking change and needed to be managed in a coherent way.

So with the introduction of LXI Device Standard v1.4 the class model for the LXI Standard was abandoned. For historic reasons some products still refer to the class model, but products compliant with the latest version of the standard do not.

All Pickering Interfaces switching products are compliant with Version 1.4 of the standard.

## LXI Device Standard 1.4

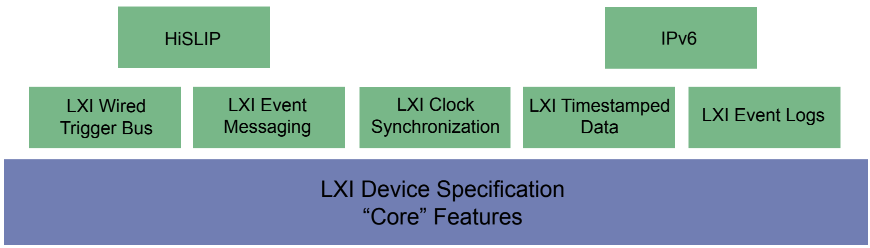



**Fig. 1.1 - The LXI 1.4 Structure showing the Extended Functions**

The 1.4 version of the standard fundamentally changed the organization of the documents. Previous versions were highly integrated, the standard included rules not just about the technical requirements of the product but also about issues such as conformance testing, trademark use and licensing. Other than removing the class model the 1.4 version is largely an editorial change compared to version 1.3 to make the standard easier to manage.

Version 1.4 splits the documents up so that, for example, the conformance testing regime can change without impacting the technical requirements for LXI Devices. This leads to a more stable and easier to maintain standard, one that can be adapted to new requirements as they arise, as was the case with IPv6, without having to undertake complex revisions of the core standard.

# 1 - INTRODUCTION TO LXI BASICS

The 1.4 standard brings in the concept of Extended Functions, features that are currently optional and add additional capabilities to the standard. Examples of Extended Functions include IPv6 support and a defined way of implementing the HiSLIP specification created by the IVI Foundation.

The 1.4 standard therefore has a set of core documents which describe the essential requirements:

- **LXI Device Standard 2011**. This document includes all the essential requirements for LXI Devices and for historic reasons describes 5 optional Extended Functions. It describes how the devices have to behave on the LAN, but defines nothing about the functions (for example switching functions in the case of Pickering Interfaces) which are vendor specific. The key parts of this document are:
    - **LXI Core Specification 2011.** This describes the mandatory feature set for all LXI devices to conform to.

  The optional Extended Functions contained within the LXI Device Standard 2011 are:

    - **LXI Wired Trigger Bus.** An optional Extended Function that allows LXI Devices to exchange trigger signals through a cable connection. It is an alternative to hardware based trigger facilities found on test and measurement instruments with additional capabilities for Wired OR functions.
    - **LXI Event Messaging.** An optional Extended Function for communicating messages between LXI Devices via the LAN connection. This includes the ability to provide LAN based triggers.
    - **LXI Clock Synchronization.** An optional Extended Function that requires LXI Devices to support IEEE1588.
    - **LXI Time Stamped Data.** An optional Extended Function that describes how LXI Devices exchange time information on events based on IEEE1588 or other time basis.
    - **LXI Event Log.** An optional Extended Function that requires LXI Devices to create a log of events that can be exported for analysis.
- **LXI IEE1588 Profile.** This document defines the profile used by LXI Devices in complying with the current version of the IEEE1588 Standard (currently at IEEE1588-2008).
- **LXI Schema.** This is an xml file required for LXI Devices so that supported features are readily identified.
- **LXI Wired Trigger Bus Cable and Terminator Specification.** This defines how cables and terminators are built for the LXI Wired Trigger Bus if the system is to behave as expected by the LXI standard. This document also includes the methods a vendor should use to check these parts are conformant.

- **LXI Conformance Policy.** This is a critical document that sets out what versions of the standard the Consortium currently supports for conformance testing purposes and the basis for testing practices. It sets the dates by which older versions of the standard will no longer be allowed for test purposes and sets end dates on when Technical Justification routes will stop being used for particular versions of the standard.

As the Ethernet and Test and Measurement market develops new requirements may appear, initially these will be introduced as additional optional Extended Functions. These functions have their own rules and compliance regimes for products that support the functions.

Since the publication of Version 1.4 two new Extended Functions have been added:

- **HiSLIP.** Adoption of the IVI Foundation created HiSLIP protocol that speeds up operation of devices using SCPI like control.
- **IPv6.** Defines how LXI devices should implement IPv6.

At future revisions of the LXI specification some of these new Extended Functions could become essential requirements rather than optional, and therefore be added to LXI Device Specification. However, these revisions are expected to be infrequent. The LXI Consortium has a declared objective to maintain backward compatibility and to ensure future revisions of the LXI Core Specification only occur as the result of “breaking changes”.

It should be noted that although over the years different versions of the LXI Standard have been created products that conform to Version 1.4 of the specification still remain interoperable with Version 1.1 Class C products. The only backward compatibility issues relate to the minority of products that support the old version of IEEE1588, and that is dealt with in a white paper from the LXI Consortium web site.

It should be noted that the LXI Logo is protected; use of the logo or the three letter acronym LXI to describe a product control interface requires the product to have been tested in accordance with the LXI Consortium’s procedures and for the vendor to license the logo or be a Consortium member.

There is an informative document **LXI Documentation Overview** that provides an overview of the currently valid documents. This is a useful document available from the LXI Consortium web site specification section since it describes how the different documents interrelate and is maintained to reflect new additions.

## LXI Device Conformance

The LXI Consortium requires products to be tested before they are introduced to the market. For LXI Devices at the present time that requires the product to be independently tested to ensure compliance, either at a plugfest organized by the Consortium or by an approved third party test house. The only part of the product tested is the LXI interface – the functionality of the product itself is not checked and is the responsibility of the vendor. This conformance process is unusual in the test and measurement industry but has been found to be a very necessary requirement - no new vendor has managed to provide a first time right LXI product when submitted for test. Even vendors with good experience in in LXI make errors which show at the time of test. At the time of writing (2013) there is no indication that this situation will change.

Vendors are able to run a test suite which partially automates testing for products conforming to the core standard and is encouraged to be run before applying for conformance testing. Access to the test suite requires membership of the Consortium.

The conformance test requirements ensure that users have a high degree confidence in LXI products, they will behave well on the LAN connection and they will be "good neighbors" and not interfere with each other. This requirement is a great strength for the standard and is valuable to users – even if it puts more pressure on the vendors product testing – since LXI systems simply work well together.

## *SECTION 2*

## *GETTING CONNECTED WITH LXI*

### Contents

## Introduction

Most users are familiar with connecting to GPIB systems and what was once a daunting task in the early years of development of GPIB became a routine operation, LXI has a similar learning phase but once learnt is easy to manage since all devices behave in the same way.

Early GPIB instruments had mechanical switches to set functions like their GPIB address and talker/listener functions, later GPIB instruments used non-volatile memory to set their address through a manual user interface. Like GPIB, LXI has a standard way of setting addresses but instead of a GPIB address the device has an IP address.

In addition to this book users may find it useful to read 'The LXI Primer' published by the LXI Consortium, available from the consortium's website.

## Direct (Wired) Controller Connection

A direct wired connection is not a common arrangement when using an LXI Device in a test system, but is a method that might be used for example when demonstrating a device.

> **Note:** If your PC has both wired Ethernet and a wireless access Ethernet it is usually best to turn off the wireless part when making a direct connection to avoid IP address range problems arising from having two network interface cards (NIC's).

**Fig. 2.1 - PC and LXI Device with direct Ethernet connection**

LXI Devices have an Ethernet connection that is almost always an RJ45 connector located on the rear panel of the device. This port can be connected to the Ethernet port of the controller using an Ethernet lead, but there is a minor complication. Some LXI Devices using 100baseT interfaces require that you use a lead described as a crossover lead to make this connection because they do not support the Auto MDIX function. If this is the case the rear panel will be clearly marked that Auto MDIX is not supported and a crossover lead must be used when making a direct connection.

Unfortunately crossover leads are not always clearly marked (those supplied as accessories with LXI Devices by Pickering Interfaces are). A crossover Lead can however be visually identified by holding the two connector ends together in the same orientation and visually checking the color codes of the wires visible through the connector. If they are in the same order the lead is not a crossover lead, if they are different the lead is a Crossover Lead.

For products that do support the Auto MDIX function either type of cable can be used, and all products with 1000baseT interface will support MDIX.

Crossover Lead

Conventional Lead

## Network Speed

Most Ethernet systems work at 100baseT (100 Mb/s) or higher. At the time of writing most deployed LXI Devices use 100baseT interfaces but there is a rapid migration towards 1000baseT on new designs occurring to increase data bandwidth and lower latency.

If a lower speed network connection is used the LXI Device will automatically drop to the lower speed. If a higher speed network device is used and connected to an LXI Device capable of only of lowers speeds then the network device will drop down to the lower speed standard. The user need not be concerned about the network functionality other than the reduced data bandwidth.

## Connecting Via Network Device

More commonly the physical connection will be via a network device such as an Ethernet switch.

In these circumstances any Ethernet leads can be used since the network device manages the Auto MDIX issues.

**Fig. 2.2 - Connection to an LXI Device through a network device such as an Ethernet Switch**

There are three types of network devices commonly found for expanding one Ethernet connection to multiple devices

- Ethernet Hub
- Ethernet Switch
- Ethernet Router.

A brief overview of these alternatives helps to make the right choice:

**Ethernet Hubs** were the device of choice for interconnection in the past but are increasingly less common. The device is simply the logical equivalent of tying all the network connections together. When one device starts transmitting the data is sent to all the ports on the hub. It is a simple device with low latency because it only has to reproduce the data being sent on all ports. The devices attached to it figure out when it is safe to transmit data and what action to take if two devices attempt to talk at the same time (a collision). As network traffic increases then the chances of collisions increase, and the hub transmitting all of the data on all of its ports become increasingly wasteful of system bandwidth.

**Ethernet Switches** behave a little differently. They record all the devices connected to their ports and inspect the traffic and route it down the correct ports. It reduces the probability of collisions and makes more bandwidth available on the network. Because the switch needs to inspect incoming data it has a higher latency than a hub. Switches form Local Area Networks and are commonly used in computer systems.

**Ethernet Routers** are deployed on the boundary of the system where it connects to another network. An analogy often used is Routers are the signposts on the main highway that indicate where particular streets are. It maintains routing tables that enable it to indicate the best routes to certain destinations. Routers are essential for distributed systems.

The Ethernet Switch may also provide support for the IEEE1588 Precision Timing Protocol (PTP), in which case it will be known as a Boundary Clock or a Transparent End to End Clock.

Test Systems that do not support IEEE1588 do not require the presence of a boundary or transparent clock. Systems that do support IEEE1588 may benefit from their inclusion.

## Wireless Link

It is also perfectly reasonable to include a wireless link in the system, something Pickering Interfaces have done on exhibition stands to show that a wireless connection is possible.

Wireless access permits a controller to operate a system via a wireless access point that usually contains an Ethernet Switch. The standard does not support the LXI Devices themselves having wireless connectivity, but it is certainly useful to have wireless elements in a system for some applications. Some user organizations will not permit wireless systems because of security concerns even if security protection is applied to the link.

## Connecting the WTB

If the system is required to support trigger operations via the Wired Trigger Bus then connections need to be made between those devices that support it.

Connecting the devices requires the use of WTB Cables and terminators. Each LXI Device that supports the WTB will have two WTB connectors on the rear. The connectors are interchangeable - there is not a defined in or out. The devices are simply daisy-chained with cables. The devices at each end of the daisy-chain have to be terminated, so each daisy-chain requires the use of two terminators. The terminators can be cable terminators on the end of a cable or can be terminators in a connector back shell that connects directly to the LXI Device.

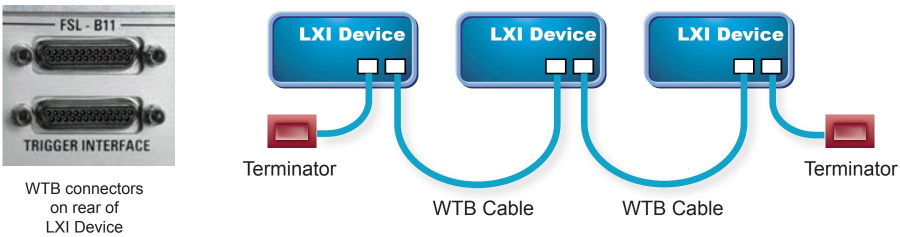



**Fig. 2.3 - LXI Devices with a daisy chained Wired Trigger Bus connection**

In some cases the user may want to allow devices that do not have a WTB capability (or even be LXI Devices) to participate in Wired Trigger Bus operation. In this case a WTB Adaptor can be added to the system that allows the simple inclusion of such a device in the system.

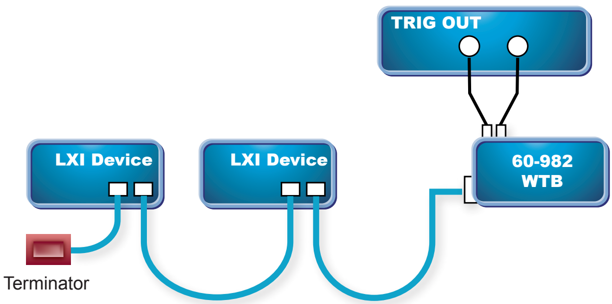



**Fig. 2.4 - A Pickering Interfaces WTB adaptor allowing inclusion of a legacy product in a system**

## Power Up

With all the connections now in place the system can be switched on.

One great feature of LXI systems is that there is no need for a defined power up order. It makes no difference what devices are turned on first, and indeed when a system is already powered new devices can be added or removed and their new status will be automatically detected.

The WTB (as well as the LAN) will tolerate the presence of un-powered devices connected into the daisy chain – the WTB interface of that device will not prevent normal bus operation other than the fact that a device without power is not participating in wired trigger events.

Once power is applied the LXI Devices will go through their boot cycle.

## LXI Standard Indicators

Each LXI Device has a set of standard indicators on the front, they will often be LED's but can also be incorporated into other display systems. The standard allows the indicators to be presented in different ways, and also allows other indicators to be present that have a specific meaning for the product.

**Power indicator.** Indicates that power is applied and will be off when the unit has no power, orange when in standby and green when power is on. In standby mode the LAN will not be usually active, but frequency standards and references may be operating.

**LAN Status Indicator.** This fulfils a number of different functions. When green it indicates the device is functioning normally and is ready to operate over the LAN. The LAN Status Indicator can be flashed from a web page control to aid the physical identification of the LXI Device, a feature that is particularly useful when a number of identical products are in the system. When it is red it indicates there is a fault on the LAN. Faults could be caused by failure to acquire an IP address, the device being set to a fixed IP address not expected by the system, detection of a duplicate IP address, failure to renew a DHCP lease or that the LAN is disconnected. The fault condition and the active state can be shown by a separate indicator, such as Error and Active.

**IEEE1588 Indicator.** This status indicator may also be present on LXI Devices that do not support the IEEE1588 function in case a future upgrade provides that facility. If present but off it indicates it is not synchronized, if it blinks once per second the device is synchronized to the IEEE1588 master, if blinks twice per second it is the IEEE1588 Grandmaster and if red it indicates a fault with the 1588 system.

With all the connections now in place the system is ready for the next stage – device discovery.

## LXI Device Discovery

Having physically connected the system hardware the system controller(s) needs to start exchanging information with the LXI Devices. It is essential to understand that there are some differences between LXI and traditional test systems that demand a slightly different approach to establishing communication, one that takes into account the potential for LXI systems to be distributed. LXI Devices are accessed through their IP addresses, just like other devices on an Ethernet network. The IP address can be found through a process referred to as Discovery.

## Traditional Test Systems

The majority of traditional test systems have a system controller and a set of measuring devices usually connected by a specialist cable and/or backplane.

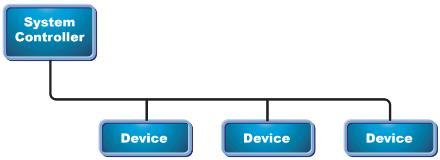



**Fig. 2.5 - Traditional test systems**

There is usually only one controller active on the system at any time and there is a limit of 32 devices that may be connected to one GPIB bus. The devices each have an address which may be assignable to each device (e.g. GPIB) or be automatically assigned by its physical position (backplane systems such as PXI) and bus enumeration.

## LXI Test System

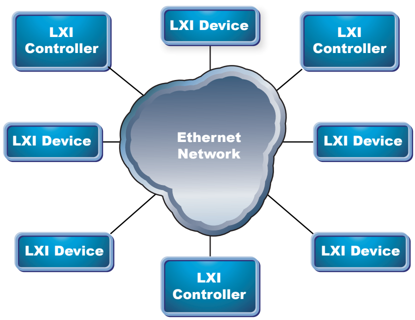



**Fig. 2.6 - LXI systems are more distributed in nature and are connected by network devices that can have long or short connection distances**

In contrast, an LXI system may have access to unlimited numbers of devices and controllers connected by an Ethernet network. This brings the advantages of the extensive technology of Ethernet to the test system.

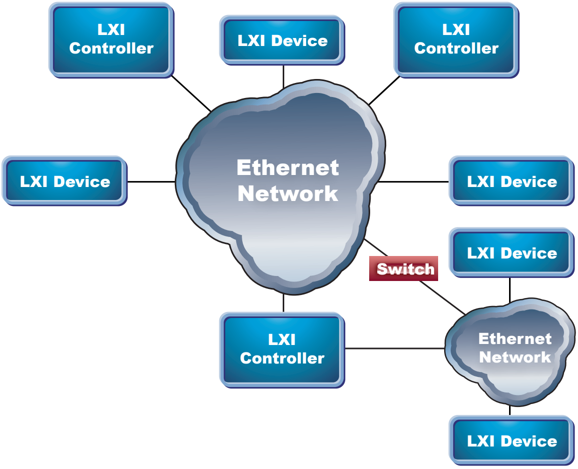



**Fig. 2.7 - LXI systems may have a distributed connection with different ways connecting devices together**

In large installations, the system may be partitioned by separating devices onto different subnets. Access to the wider network may be made using a separate Ethernet port on the controller or by using a switch (or similar) device which, when properly configured, will enable communication between the various elements.

The impact of this network topology on the system controller is to require additional addressing information in order to identify the location of a device. There is also a potential resource management problem since a device may already be in use by another controller and therefore unavailable.

An LXI Device is addressed using its IP address which must be unique on a given network. The user must establish the IP address of a device before any operation can be carried out. For this purpose the LXI specification defines a discovery protocol which all LXI Devices must support.

## Discovery

The default behavior for an LXI Device is to use DHCP to determine its IP address. Without having access to the DHCP server, a user cannot know the IP address a device was assigned when it powered up. For this reason the LXI standard includes a discovery protocol based on the VXI-11 protocol and Version 1.2 onwards requires support of mDNS (Multicast DNS) tools, alternatively described as the Apple trademarked Bonjour Print Service or Rendezvous.

The VXI-11 discovery tool is likely to remain a mandated part of the standard to ensure backward compatibility until the adoption of IPV6 forces it to become optional. (VXI-11 cannot be supported over IPv6, mDNS can).

## 2 - GETTING CONNECTED WITH LXI

After unpacking and powering an LXI Device, if there is no front panel to allow the user to locate the IP address the user must use a discovery tool to find the IP address. Since the LXI specification requires a discovery protocol based on VXI-11 protocol, all LXI Devices are required to respond to a VXI-11 identify (*IDN?) command by providing its IP address in a message response. LXI Devices from Version 1.2 can provide this information using a schema which avoids the problem of the device switching to remote that VXI-11 *IDN requests can create.

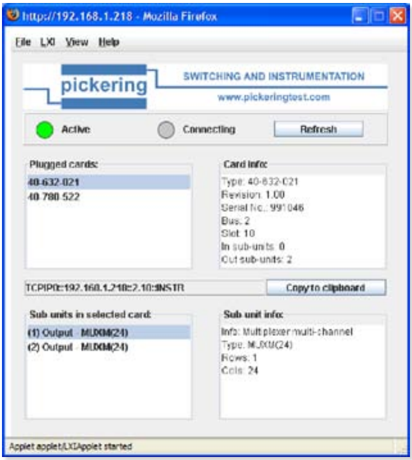
For Pickering Interfaces products three tools are provided for discovery, each tool being available on the DVD supplied with the product and can be downloaded from our web site:

- **VXI-11 Discovery protocol.** Tools such as Agilent IO Library, provide a VXI-11 protocol discovery tool. This may be used to establish the address of any connected LXI compliant device.
- **mDNS discovery protocol.** By default, LXI devices have the mDNS service switched on, by using a suitable client on your computer (for example Bonjour Print Services), you can search for and configure an LXI device without knowing its TCP/IP address beforehand. Use the MAC address on the rear of the device and that present on the LXI Device home page to confirm you are configuring the correct device if you have more than one LXI Device running, or alternatively ping the LXI Device to identify it by its flashing LAN Status Indicator. (Using the "-t" function allows the system to ping the address continually until the command is halted)".
- **LXI Consortium Discovery Tool.** Pickering Interfaces has created an LXI Discovery Tool which has been donated to the LXI Consortium. It does not require the installation of software vendors proprietary tools (but has dependency on Open Source software and Bonjour Print Services) and is able to discover LXI Devices using VXI-11 or mDNS. It provides access to the LXI Devices web pages and provides information on their IP address and host name. Copies of this useful utility program can be obtained from the LXI Consortium website.

Of the two basic discovery tools mDNS is generally much faster and is the most strongly recommended procedure, but it may not find older devices that use Version 1.1 of the standard.

There is one point to remember when dealing with devices such as the Pickering Interfaces 60-102 or 60-103 series LXI/PXI modular chassis. This type of device can be a host to a number of products. In the case of the 60-102 or 60-103 series chassis they host a set of PXI modules which contain multiple switching functions that are available to the user. When using the 60-102/3 series with IVI drivers the VISA resource string for any given card is constructed by replacing the 'inst0' field of the resource descriptor listed in MAX by a string identifying the location of the required card.

Open the instrument web pages at the IP address and navigate to the instrument control page to obtain a list of the individual resource descriptors. For those familiar with PXI the string follows the PXI bus/device naming convention.




In this example the 40-632-021card has a resource descriptor:

TCPIP0::192.168.1.218::.2.10::INSTR

the inst0 element has been replaced with 2.10, which corresponds to PXI bus2 device 10.

## *SECTION 3*

## *LXI WEB AND LAN*

### Contents

## Introduction

Having discovered the LXI Devices on a system using the Discovery Tools the user can now access individual LXI Devices through a web browser.

The LXI Standard requires that all LXI Devices include a web server that provides web pages that are compliant to the W3C standards. That ensures that the web server is compatible with all the common web browsers, including Internet Explorer, Safari, Netscape and Firefox. The minimum content of these web pages is also specified, so the configuration controls of all LXI Devices are consistent regardless of vendor. There may be differences in appearance and how they are organized, but the content is similar.

To demonstrate the controls available we can explore a specific LXI Device web page, in this case Pickering Interfaces 60-102-001 LXI Chassis, using Internet Explorer. To get started exploring the LXI Device simply insert the IP address of the product in the browser address field, press <Enter> or alternatively if using the LXI Consortium Discovery Tool, click on the listed product.

## Home Page

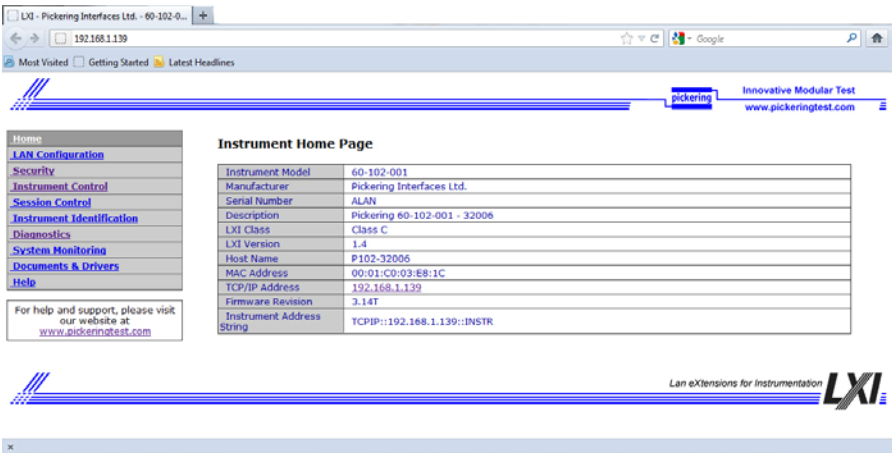



**Fig. 3.1 - Typical Home Page for a Pickering Interfaces LXI Device**

Every LXI Device starts with a home page which shows some important information. The page is read only – the information cannot be changed. It must contain the LXI logo, implying that the product is LXI Conformant. It provides information on the model number of the device, who manufactured it, its serial number and a product description.

If the LXI Device is conformant to 1.3 or earlier it will show what class it belongs, if it is conformant to 1.4 or later it will show any Extended Functions the device supports.

It will also show its Host Name. This can be a very useful feature since it allows you to communicate with the device using a name (for example “matrix 1”) instead of using the IP address if the system has a Dynamic DNS (Domain Name System) server present.

The MAC (Media Access Control) address of the LXI Device is also shown. This number is unique to an individual product, there are never any duplications regardless of whether it is a computer, printer or LXI Device (for example). The standard in addition requires that the MAC address is physically shown on the product so it can always be found even if the user has problems discovering the product. The MAC address cannot be changed by the user.

The page will also show the TCP/IP Address, the Firmware revision of the LXI Device and the current time (optional for devices not supporting IEEE1588) and its source.

## Configuration Pages

From the Home Page the user can access the pages that can edit the device configuration. The configuration pages provide a simple graphical interface that allow their contents to be changed in a simple and clear fashion, just like most modern IT products.

An example is an IP Configuration page, in this case selected by clicking the link on the left of the home page.

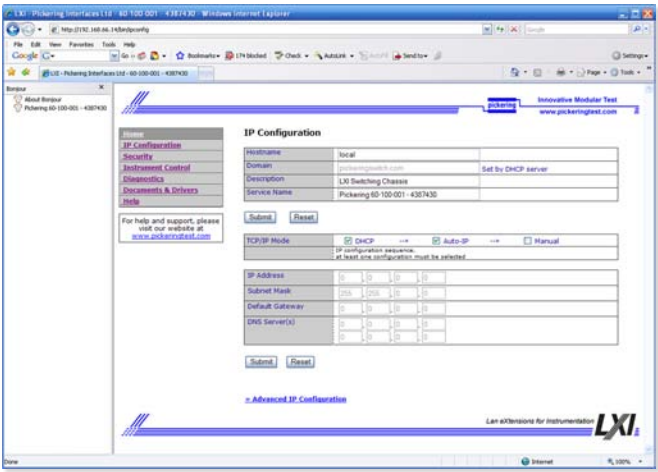



**Fig. 3.2. - Typical Configuration Page for a Pickering Interfaces LXI Device**

In this example page the user, with guidelines from the IT department where necessary, can set a host name (e.g. local) and a domain name (e.g. pickeringswitch.com) managed by DNS server if available.

The next selection available is to set the TCP/IP mode:

- Manual allows the user to fix the IP address. The user needs to manage the allocation of IP address so that no duplicate addresses are created. This is a useful way of operating a system where the user wants to access through fixed IP Addresses.

- Auto IP setting can be used on small networks that do not have DHCP servers, a common situation on ad hoc networks without network administrators. A typical example is the simple case where a computer is connected directly to an LXI Device through a crossover cable.
- DHCP setting can be used where the network has DHCP servers which are usually present on corporate LANs or Routers.

The LXI Standard provides a very useful graphical guide to represent these use cases for each of the modes.

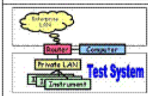
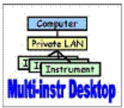
| | Automatic IP Configuration Methods | | Manual IP Configuration Methods |
|---|---|---|---|
| Network Topology | DHCP | Dynamic Link-Local Addressing | Manual IP Address Configuration |
|   | Works on nearly all site/enterprise LANs because they are built with DHCP | STOP Auto-IP not likely to be used here | Works in all network topologies |
|   | Works on network built with Ethernet router with integrated DHCP server (or equivalent) | STOP Auto-IP not likely to be used here | Works in all network topologies |
|   | Works on network built with Ethernet router with integrated DHCP server (or equivalent) | Works on network built with Ethernet switch/hub (i.e. w/o DHCP) | Works in all network topologies |
|   | STOP DHCP not likely to be used here | Works on 2-node network built with a crossover cable (no DHCP) | Works in all network topologies |

**Fig. 3.3 - Graphical guide to setting IP address extracted from the LXI Device standard**

## LAN Errors

Note that if LAN errors are detected the LXI Device is required to indicate an error on its status display. Errors that cause a failure to be indicated include:

- Failure to acquire a valid IP address
- Detection of duplicate IP addresses
- Failure to renew an already acquired DHCP lease (normally timed at 30 seconds)
- LAN cable is disconnected
- Being set to a fixed IP address that is not expected by the system.

LXI Devices are required to support through their web pages a facility that flashes the LAN Status Indicator in order to confirm that the device is connected and to provide a physical identification of the product (important if you have more than one of them for example).

Through the web browser many of the LXI Device configuration parameters can be set through different web pages. The content will vary according to the type of product that the LXI Device is, but it should all have the simple look and feel of web pages.

## Instrument Control through the Web Server

Users frequently find it useful to be able have manual control of devices when they do not have manual front panel interfaces. Even devices that have manual interfaces benefit from the ability to remotely control them without using the normal API interface.

The LXI Standard recommends that devices are provided with a web based control interface, something which is available on all Pickering Interfaces products. This control interface is accessed from the Home Page by a simple click through. This selection loads a Java based soft front panel to the controller that provides a web graphical interface that is easy to use.

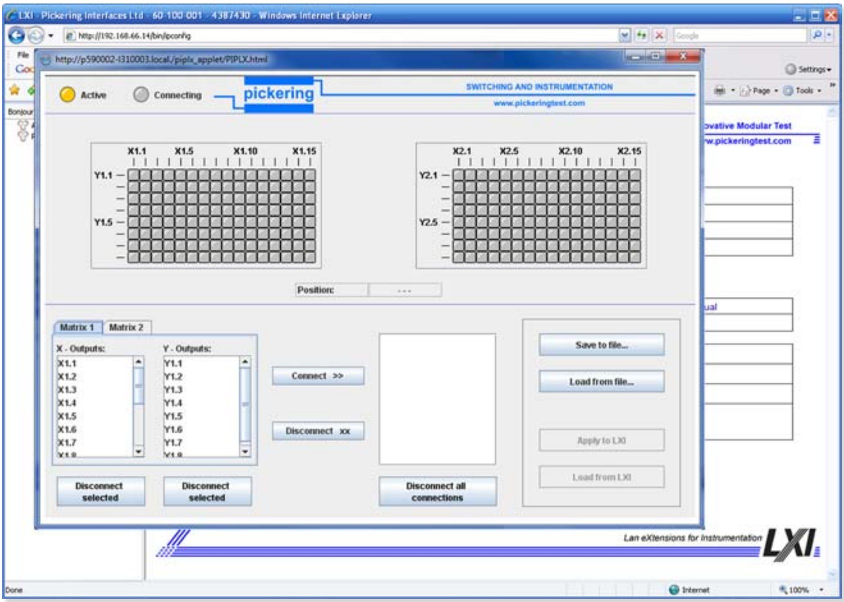



**Fig. 3.4 - Example Soft Front Panel for an LXI Device**

## Documentation

Many LXI Devices include the ability to supply the user with documentation. By storing documents in the embedded controller in the LXI Device and providing the user with access to them by the web interface every device can carry a copy of the data sheet, manuals and software drivers it was originally supplied with. Lost copies of manuals and data sheets become a problem of the past with this facility. If you have the functional LXI Device you also have copies of these valuable documents that you can simply download.

Clearly having web based access to LXI products offers these devices uniquely friendly ways of accessing configuration and documentation features that previously were only supplied on an ad-hoc proprietary way. The LXI Standard has adopted the best practice from many experts in test and measurement to provide an elegant and friendly way of managing users investment in LXI Devices.

## LCI or LAN Reset

If users have experimented in setting different IP Addresses and other LAN configuration information it is possible that a unit will be placed in a condition which is hard to diagnose or connect to. For this situation the LXI standard requires an LXI Device to include a LAN Configuration Initialize (LCI or LAN Reset) function that returns all settings to the manufacturers' default values, a condition that will be defined in the manual. The LCI may be a physical button, as it is on Pickering Interfaces products, or it may be supported by some other mechanism described in the manual.

For Pickering Interfaces products the LCI is a recessed button on the rear panel. Pressing the button momentarily is the equivalent of turning the power off and then back on again. If the button is pressed for more than 5 seconds the LXI Device is reset back to the manufacturers default condition and all configuration information will have been reset to its default value.


**Fig. 3.5 - Detail showing the LAN Connection Socket and LAN Reset Switch on the back of the Pickering LXI High Voltage 2-Pole Matrix 60-310**

## *SECTION 4*

## *TRIGGER OVERVIEW*

### Contents

## Introduction

Many test systems make use of trigger facilities in a test process, and having a suite of defined trigger capabilities is considered to be essential for test and measurement.

Triggers can be used in a variety of ways to enhance a test process:

- To respond to an event from the UUT
- To respond to an event in the test equipment
- To synchronize measurements across a number of instruments
- To speed up a measurement process by using "last device ready" or "first device to detect an event" indications.

The LXI Standard includes a complete suite of trigger systems, more than is available on other instrumentation standards. The trigger facilities are not compulsory on basic LXI Devices that conform to the core standard but become a requirement for devices that support some Extended Functions.

The triggering model for LXI is based on the use of a system having 8 trigger lines in each of the trigger systems supported.

## Trigger Capabilities

The standard defines three basic trigger interfaces, LAN based triggers, IEEE1588 based triggers and Wired Trigger Bus triggers.

- **LAN based trigger.** A LAN based trigger behaves in a similar way to trigger modes on GPIB. A trigger message is sent over the LAN by the controller or an LXI Device to a recipient device which then acts on the trigger instruction. Although a controller to LXI Device is the most common trigger, LXI Device to LXI Device triggering is supported. The trigger signals are transported over the Ethernet cable, so no other connection is required between the devices. The messages can be sent through driver commands or as direct device to device messages.

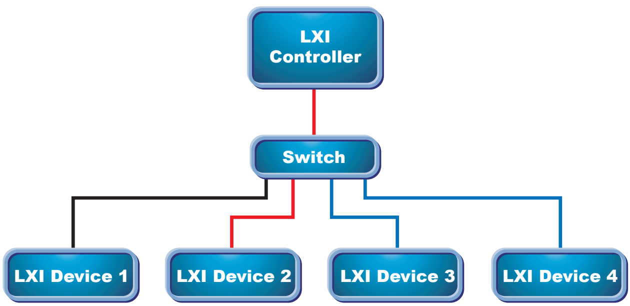



**Fig 4.1 - LAN based driver triggering from controller to LXI Device (red) and Device to Device (blue)**

- **IEEE1588 Triggers.** The LXI Standard has adopted the IEEE1588 Precision Timing Protocol (PTP) as a timing reference for an entire test system. A master clock synchronizes all the LXI Devices with IEEE1588 capability in the system so they all have a common understanding of what the time is. Time can be expressed in any way the user wants (a user defined system time or a time related to time of day).

Once a system has a sense of the time of day it opens many possibilities for triggers to be defined that occur at a time of day with great precision on multiple devices, a unique capability. LXI Devices that detect events (for example a transient state) can date stamp that event and use it to trigger to other devices in the system.

Triggers can be sent over the LAN for devices to execute the trigger when a certain time is reached, the receiving device times when to perform the task required. In most cases this will be in the future, but if the device has a circular buffer arrangement for capturing and storing data the event could be in the past.

The IEEE1588 triggers can also be set to occur after an incremental time from an event, an action which is quite hard to do with precision by any other trigger method short of providing specific hardware support.

This is a unique capability and requires users to think in different ways to develop a program. Until LXI adopted IEEE1588 test systems did not have an absolute understanding of time across multiple devices.

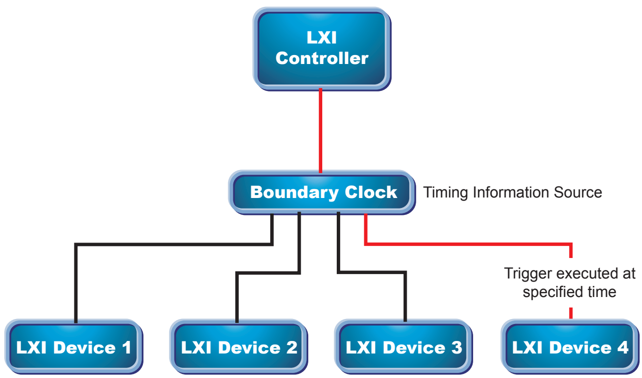



**Fig 4.2 - 1588 triggering using a Boundary Clock to give the system a knowledge of a common time reference**

- **Wired Trigger Bus.** Many systems exchange trigger signals between devices using discrete point to point connections. An event, for example, might initiate an oscilloscope to capture data when it receives a trigger on its front panel trigger input connector. Historically these triggers have been ad hoc arrangements for bench instruments, if the trigger needed to be re-routed a switching system has to be added and controlled. Modular platforms, such as VXI and then PXI, adopted a backplane based trigger model to improve on this arrangement. For LXI a Wired Trigger Bus standard has been created that allows signals to be exchanged between devices using a cable based trigger bus supporting 8 separate physical channels. The LXI Devices are required to be able to send or receive a trigger event on any of the 8 channels, eliminating the need to switch triggers if connections need to be changed – the routing is electronically performed in the LXI device. The Wired Trigger Bus has two modes of operation (besides disabled):

- Point to Multipoint. One active device sends triggers down the bus to one or more recipients. This is known as the Driven Mode.
- Multipoint to Multipoint. Several devices drive the trigger bus and one or more devices receive the composite signal. This is known as the Wired Or Mode. Its functionality is similar to that implemented on the VXI standard but is much faster. It enables users to have a simple hardware execution of the "last device ready" or "first device to detect an event" scenarios that initiate a measurement cycle.

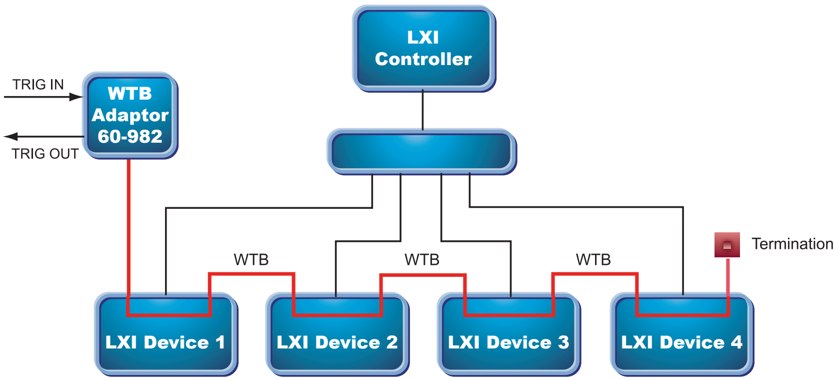



**Fig 4.3 - The WTB provides a hardware trigger between LXI Devices that support it.**

## Trigger Summary

LXI has a rich mixture of trigger capabilities in the most able devices. These capabilities are not isolated. The trigger facilities are specified to be constructed on a similar basis, allowing users to easily convert from one trigger method to another with little change in programming.

Vendors are strongly encouraged to support a capability of transferring signals from (for example) the LAN triggers to the WTB triggers on products that support both functions.

LAN triggers are the simplest and most universal way of exchanging trigger signals. As with GPIB there is latency in both the sending and a receiving of a trigger event, but it meets the requirements of most systems.

IEEE1588 triggers offer the ability to initiate events at specific times or time offsets. The instruction can be sent any time before (and sometimes even after if based on captured data) the action is required and the LXI Device then performs the required action at the specified time. This can considerably reduce the timing uncertainty of a trigger event compared to the LAN based triggers. A simple description of how IEEE1588 operates is included in Section 6 of this book.

WTB triggers offer the lowest timing uncertainty of all since the signals can be exchanged in hardware between devices with no software latency. More information on how the WTB works is included in Section 5 of this book.

## Trigger Management

The LXI standard requires that LXI Triggers (in this context receipt of a trigger signal) and LXI Events (in this context a device sends a trigger signal) if implemented are supported by an API that conforms to IVI specifications (IVI-3.15 IviLxiSync) to ensure a common level of experience of LXI Triggers.

Where implemented the trigger systems also have to support a minimum of 8 LXI Triggers and 8 LXI Events, matching the number of trigger lines on the WTB. Triggers on the LAN are identified by a resource string of the form LAN0, LAN1….LAN7 while triggers on the WTB are identified as the LXI0, LXI1….. LXI7, where the numbers 0 to 7 identifies each of the trigger lines.

The standard also describes a trigger and arm model, extracts of which are included in the following pages, that the device is recommended to use for all features that are implemented. Not all of the ARM and Trigger state machine has to be implemented in LXI products, those areas not supported can be omitted in order to simplify operation.

Using this approach ensures a consistency between the LAN and WTB signals.

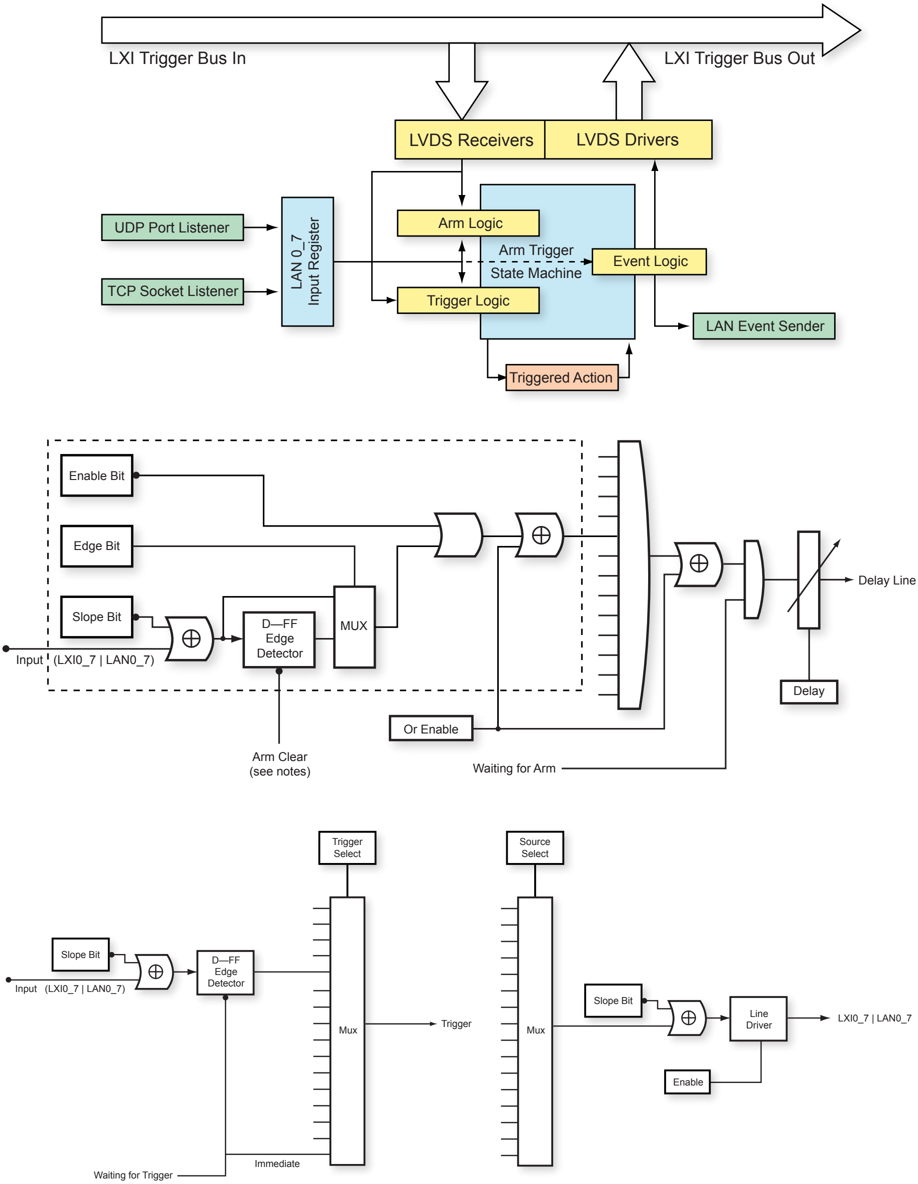



**Fig 4.4 - Example Trigger and ARM models extracted from the LXI Specification**

# 4 - TRIGGER OVERVIEW

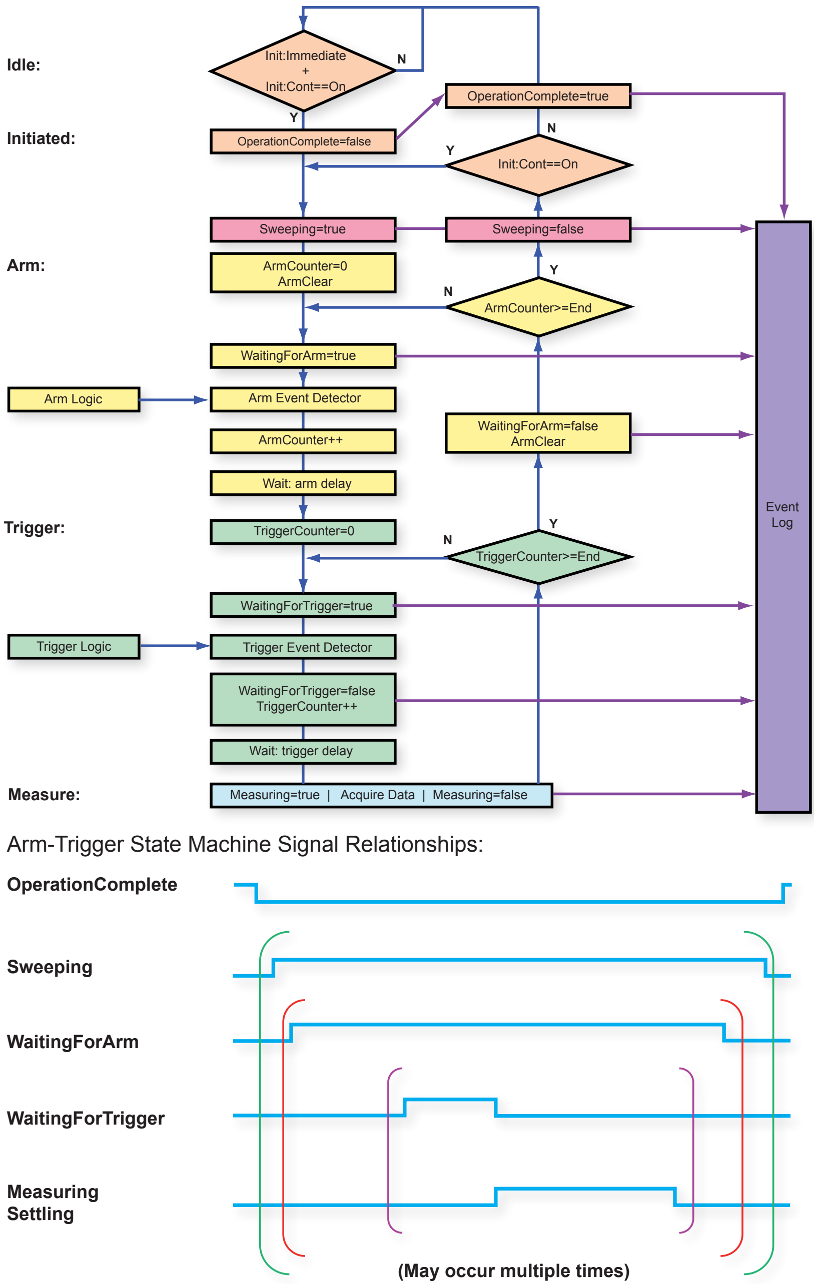



**Fig 4.5 - Example Trigger State Machine extracted from the LXI Specification**

## Event Log

LXI Devices are required to also support an Event Log which records all the events it receives or sends as a string. At present it is undefined what form the log is but there are some minimum requirements, there is a proposal for an Improved Event Log to be introduced as an Extended Function that defines the form of the log and provides more web visibility, but there is no commitment or time scale for this work.

The Event Log is useful for debugging systems using the LXI trigger system since each device includes a record of all the actions that took place from both the event generator and the event receiver perspective.

## Impact of IEEE1588 Based Triggers

The operation of the LAN and the WTB has a familiar feel for most users since they reflect models that commonly occur in GPIB systems, the ad hoc communication between modules on BNC leads for bench systems, and the triggering experienced on the PXI or VXI backplane system. The IEEE1588 introduces a new concept to triggering, one based on executing a trigger at a specified time for a system which is populated with devices that support the LXI Clock Synchronization Extended Function.

IEEE1588 support in LXI products gives a system a common sense of time, and that common sense of time is used to set up measurements whose actions are set up before action is needed without the need to generate LAN traffic at the moment of action.

For many applications this will require a change of mind-set for system designers, programming for actions at a given time (especially to the precision expected of IEEE1588) is not what most system designers have experience of. The applications this can be applied to are varied, but an obvious case is the setting up of measurements to occur at specific times during a test, including mundane actions like measuring system or device temperature.

Devices with circular buffers that record results can retain not just a record of the result but also a record of the time, allowing users to capture information from multiple instruments and aligning their data after the event to provide an indication of their relationship. The devices in question do not have to be co-located since IEEE1588 provides synchronization over network distances, so the creation of distributed test systems becomes relatively easy.

Whole sequences of measurements can be set to start at specific times, including the generation of trigger events by LAN or WTB to non-IEEE1588 devices and non-LXI devices.

The number of LXI products supporting IEEE1588-2008 remains small, so its use has had limited impact on the test and measurement industry so far.

## Comparing Trigger Operations

To demonstrate the differences between triggers operated by basic LAN and the more sophisticated trigger mechanisms it is useful to describe a simple example where a controller has three LXI Devices connected to it, identified A, B and C.

In the case of simple LAN operation all activities are centred on the system controllers. A sequence of events could be described as follows:

1. Controller Arms Device A, B and C
2. Device A detects an event in the device under test
3. Device A sends a trigger over LAN to controller
4. Controller receives the trigger and sends trigger to Device B and Device C.

The trigger time before B and C start can be reduced by A sending a trigger directly to Device B and Device C (peer to peer operation), but clearly there is still a timing difference that involves LAN delays. In some applications this will be of little consequence (for example switching systems will usually be much slower than this), in other cases it may be unacceptable.

If the LXI Devices also have WTB support the timing difference can be considerably shortened by Device A sending a WTB signal to Device B and Device C. The timing differences are then reduced to the propagation delays of the WTB cabling and the internal hardware delays of the device trigger systems. There are no LAN traffic related delays. This delay could be relatively short if the devices have short connection distances, typically measured in tens of nanoseconds.

The delay will be consistent, so can be corrected for providing nothing changes (like cable lengths or internal delay changes).

If the devices are all IEEE1588 capable with circular buffers to capture data the situation is different:

1. Controller Arms Device A, B and C with their circular buffers
2. Device A detects an event in the device under test and time stamps it
3. Device A sends a multicast message with an event ID and time stamp
4. Device B and C receive the event ID and time stamp, find the data corresponding to it and execute the actions required of it.

The timing differences are now reduced to the errors in the IEEE1588 time reference. This could be tens of nanoseconds for closely connected devices which use IEEE1588-2008, or greater if the distances involved are much longer or devices with software implementations (IEEE1588-2002) are used.

Whichever implementation is used it is evident that the use of peer to peer triggers, WTB and the IEEE1588 time stamps can reduce the amount of LAN traffic required at a critical instant in time (i.e. a trigger event) and can improve system performance.

## *SECTION 5*

## *LXI WIRED TRIGGER BUS EXTENDED FUNCTION*

### Contents

## LXI Wired Trigger Bus Extended Function

The Wired Trigger Bus (WTB) provides a simple method of exchanging hardware based triggers between LXI Devices. It replaces the conventional ad hoc hardware triggers that can be exchanged between GPIB instruments or other instrument platforms with a unified trigger exchange mechanism supporting 8 channels of connectivity.

To exchange the trigger signals the LXI Device that supports WTB has two connectors on the rear panel which are identical. These connectors are connected by LXI compliant cables to other LXI Devices that support the WTB. The WTB cables form a transmission line that is terminated at each end by a WTB Terminator. Inside each LXI Device the two connectors are simply wired together using traces characterized as 100 ohm differential transmission lines.

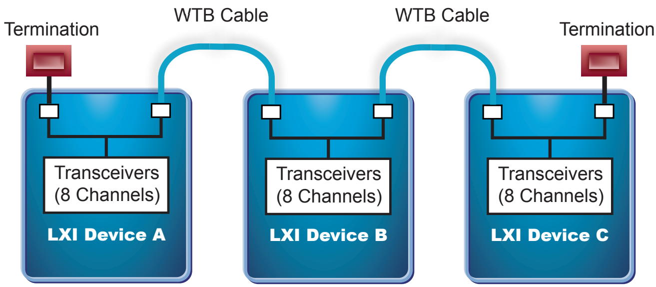



**Fig 5.1 - WTB forms a transmission line with internal connections in the LXI Devices and external WTB cables**

To make use of the WTB a user simply needs the following items:

- More than one LXI Device that supports the WTB
- The required number of LXI conformant WTB cables
- Two LXI conformant WTB Terminators.

Knowledge of how the WTB Bus works is helpful, but not essential, to make use of its capability.

## How the WTB works

The WTB uses a terminated transmission line to transmit signals from one device to another. The description that follows concentrates on just one channel of the WTB, users need to remember that the WTB has 8 independent channels in total. Each channel can be set to operate in a different way and each channel can be connected in the LXI Device to the LAN and IEEE1588 system.

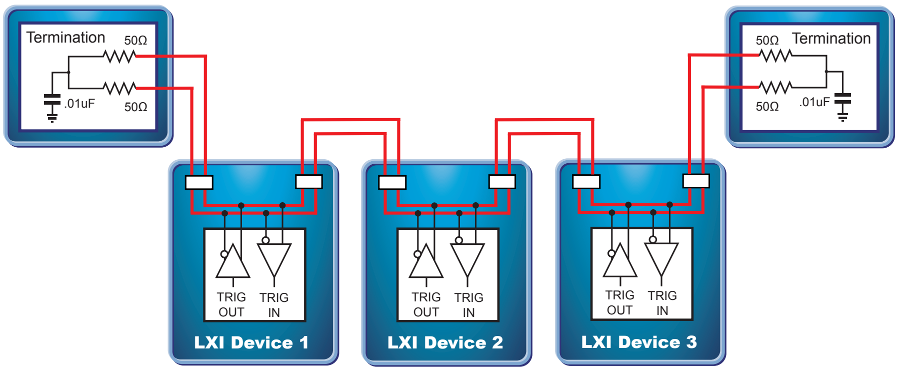



**Fig 5.2 - The WTB forms a differential transmission characterized at typically 100 Ohms**

Each LXI Device includes M-LVDS Drivers which drive a transmission line and M-LVDS receivers which respond to the signals on the transmission line. The transmission line is a shielded twisted pair with transmission line differential impedance of approximately 90 to100 ohms. The signal from the driver splits into two paths, one going left and one going right.

At the end of each transmission line it is terminated by a load 100 ohms formed by two series 50 ohm resistors. Any common mode disturbance is terminated by the two 50 ohm resistor centre tap to ground via a 0.01uF capacitor. The M-LVDS drivers have to support a differential load impedance of 50 ohms (the two 100 ohm terminated transmission lines in parallel).

To maintain the transmission line characteristics it is important that stubs and other parasitic components are minimized. Reflections on the transmission line could cause false trigger events or cause timing jitter. This imposes some constraints on the WTB connector arrangement. The bus has to use an “input” and an “output” connector directly wired together within the LXI Device by a differential transmission line that has minimal parasitic stubs. There is no significance in which connector is which since they are wired together.

The transmission line is then as shown in Figure 5.2, each LXI Device has two connectors connected to adjacent LXI Devices with a cable. The connectors are inter-changeable; there is no significance in which one is which (no designated input or output) so they have no additional identification.

> **Note:** Although it may seem desirable to try to use just one stacking connector (like those used for GPIB) to minimize panel space and connector count for the WTB this is not viable. The drivers would all be on the end of a transmission line stub and that would substantially degrade the WTB performance. For that reason the WTB specification uses the two connectors linked by equal line transmission lines and routed to minimize connection stubs to the driver IC’s.

The connectors used by the WTB are commercial versions of the 25 way Micro D connector (not to be confused with the military specified versions which are very expensive). These connectors are physically small; minimizing the space they occupy on the panel, and provide a reasonable transmission line match for the WTB. The screw locks ensure the cable is secure when fitted into an ATE system.

## Transmission Line Cable and Termination

The cable that connects LXI Devices with the WTB together is critically important for correct operation of the system. It contains 8 twisted pairs (for the 8 channels) each of which has a shield around it to minimize crosstalk between the channels which would otherwise cause problems on longer WTB connections.

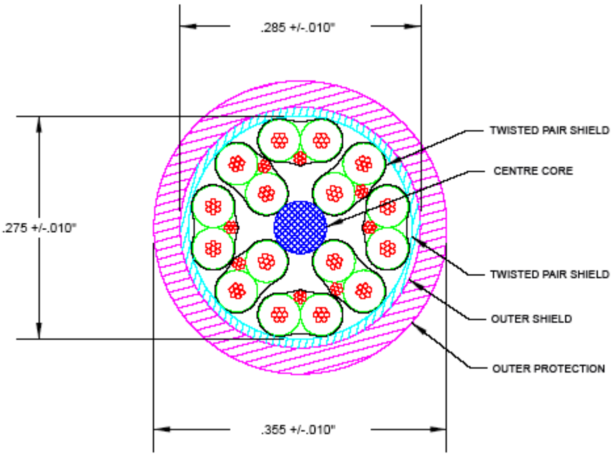



**Fig 5.3 - Cross section of the WTB cable showing 8 twisted pairs, each with their own shield to manage crosstalk**

To connect LXI Devices over reasonable distances it is essential that the cable has a low loss. The cable characteristics have been carefully specified through their own specification document “LXI Trigger Bus Cables and Terminator Specification” to ensure that it can conduct narrow pulses and fast edges over long cable distances (10 ns pulses over 10 m) with low channel crosstalk. The Terminators are simple devices that provide the termination for all 8 channels at the end of each segment.

Cable assemblies and terminators can carry the LXI logo if they conform to the specification, and are commercially available. Tests at the LXI Plug Fests have shown that compliant cables can support 10 ns wide pulses over a distance of at least 10 meters. Use of anything but a certified compliant cable, cable assembly or terminator can cause the performance of the WTB to be degraded.


60-983
Cable Terminator

LXI Device
Terminator

**Fig 5.4 - Examples of a Cable Terminator and LXI Device Terminator**

It is not obvious how the WTB can support more than one LXI Device driving a particular channel but it is clear that one device can be used to assert the logical state of the LVDS interface if no other device is attempting to drive it. When this is the case the mode is referred to as the "Driven Mode". It is a point to multipoint connection method similar to PXI backplane triggers. A single driver is used to set the channel to its low or high state in response to an event, multiple receivers monitor the bus logical state.

The "Wired OR Mode" takes advantage of the fact that M-LVDS drivers are actually current source drivers rather than voltage source drivers, a feature that also helps it manage common mode voltage sources between LXI Devices without introducing errors. Historically wired OR operation was done using open collector transistors in parallel with a pull up resistor that sets the default (transistors turned off state) to a logic high. Any one of the transistors turning on asserts a low state, performing a logical OR function. This is a feature included on the VXI backplane.

The LXI WTB has to work slightly differently in order to improve speed and increase the distance that can be achieved.

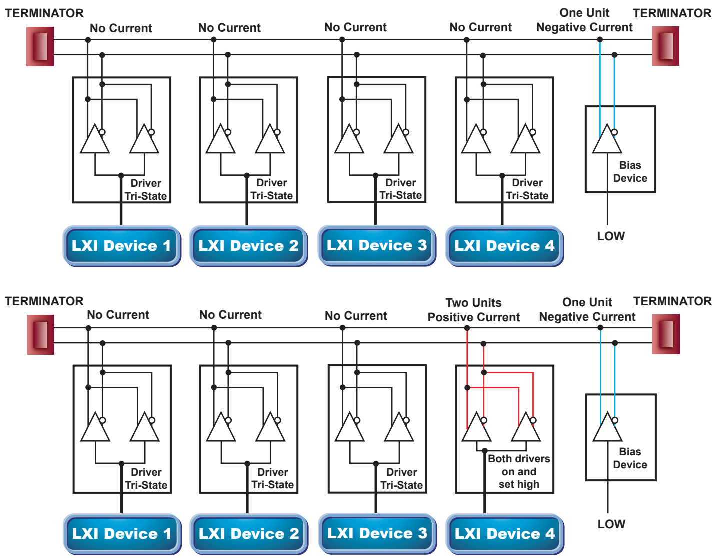



**Fig 5.5 - WTB Wired OR condition with just the bias device setting the bus logically low (top) one of the devices (in red) driving it high (bottom)**

In the LXI WTB Wired OR mode two drivers are used in parallel and the driver has two states, it is either disabled or it forces positive current from the two drivers into the WTB channel. A Wired OR bias device is used to bias the channel with the negative current from one driver as illustrated. If all the LXI Devices on one channel are disabled the net current in the channel is negative by one driver's current (the bias current). The first LXI Device to turn its driver from disabled to enabled (two drivers worth of positive current) overcomes the bias device and sets a high state, precisely the functionality required for Wired OR functionality. As with the VXI open collector arrangement, setting the starting condition with all the drivers enabled and changing their state to disabled can implement the "last device ready" scenario.

The Wired OR Bias Device should normally be a separate device not participating in the trigger event, though it is possible to make a device participating in the trigger event the bias device by setting it to Driven Mode (when set low it produces one negative unit of current, when high one positive unit of current, which is what is required of a Wired OR device plus a bias device).

> **Note:** Using a participating device as the bias device is not strongly recommended as there are circumstances where the distributed nature of the WTB can cause a brief transitory change of state to occur. If the bias device is participating it is best to make sure the receiving devices do not respond to narrow pulses.

Clearly in Wired OR mode more than one device could be setting the channel high and this will cause a larger voltage to appear across the LVDS receiver's inputs, however this has no impact on the WTB since the receivers (and drivers) are designed to handle such conditions.

One disadvantage with the Wired OR mode is that the LVDS drivers do not operate as quickly to/from the enabled/disabled conditions as they do in the Driven Mode. When many drivers are putting current into the WTB they also start to operate in a nonlinear region which takes longer for them to recover from. As a rough guide the minimum pulse width for trigger operation has to be doubled in Wired OR compared to Driven Mode, consequently both modes are supported by the standard since the Driven Mode has a clear speed advantage The M-LVDS standard recommends that a maximum of 32 devices are connected onto a bus.

Since the LXI WTB has two drivers per LXI Device, 16 LXI Devices can be connected together on a single WTB segment.

## Adapting Devices to the WTB

Devices that do not support the LXI WTB (such as instruments based on older platforms) can be easily adapted to the LXI WTB through the use of simple adaptors available from Pickering Interfaces. These devices allow external triggers to be converted to the WTB, or WTB signals to be converted single ended triggers. Use of these adaptors allows the easy integration of these older trigger standards into the LXI trigger system.

# 5 - LXI WIRED TRIGGER BUS EXTENDED FUNCTION

## WTB Capability

So what is the WTB capable of doing? The key capabilities are listed below:

| Function | Characteristic | Comments |
|---|---|---|
| Number of Channels | 8 | LXI Device triggers can be routed to any receiver and transmitter |
| Number of Devices in a Chain | 16 | Can be expanded using a Star Hub to provide connectivity between chains each having up to 15 LXI Devices |
| Number of Connectors per LXI Device | 2 | |
| Trigger Bus Width Supported | 10ns in Driven mode<br>20ns Wired OR mode | If a device is not able to respond to a 10ns trigger it must detail the minimum pulse width in the documentation |
| Cable Length | 10m | Can be longer if the device and system always use trigger pulse lengths greater than 10ns. Approximate guide is to double the pulse width with each doubling of the cable length. |
| Cable Propagation Speed | 74% speed of light in vacuum | |
| Cable Impedance | 85 Ohms to 110 Ohms | Typical cables are 90 Ohms |
| Logo Use | Used on cables and terminators | Lack of logo may indicate parts may not operate correctly. |

## Gaining Experience of WTB

To get a good understanding on how the WTB works it is not necessary to use LXI Devices, using a few Pickering Interfaces products a complete hardware WTB test bed can be assembled. It allows the user to non-intrusively monitor the WTB signals and provides access to input and output triggers.

Combining Adaptors, Probes, Cables, Terminators and Extenders allows all the key elements of the WTB to be reproduced, and LXI Devices supporting the WTB can be included to allow a user to experiment and gain experience of the LXI WTB control. A test bed created from these parts can be used to test a LXI Device for WTB conformance - refer to the conformance procedures and test suites defined by the LXI Consortium for more information.

Information on how to create a WTB test bed can be found in Pickering Interfaces manuals for its WTB support products. Go to the Pickering Interfaces web site www.pickeringtest.com, search for 60-981, click through and select the manual for downloading.

## *SECTION 6*

## *LXI CLOCK SYNCHRONIZATION BY IEEE1588*

### Contents

## Introduction

While it is not strictly necessary to understand in detail how IEEE1588 works it can be helpful to understand the general principles so that an informed decision can be made as to whether it offers a way of solving test challenges. This section gives a very brief overview of IEEE1588 and what it can achieve.

## IEEE1588 Purpose

The IEEE1588 standard was created largely from work supported by Agilent Technologies within the IEEE. It is not specific to the LXI standard; it was developed to provide a timing reference in any interconnected distributed system to ensure the IEEE1588 devices have a common sense of time. It relies on devices communicating with each other over a data interface (for LXI this is an Ethernet connection), timing the delays in the communication, adopting one device as the timing master and then correcting the clocks in all the slave devices after correcting for the time delays in communication. The timing correction acts as a servo on the LXI Device's real time clock system.

The regular exchange of timing data allows the system to lock its clock to the master clock. The timing standard is set by the master clock and could use any convenient timing reference including proprietary time definitions or UTC.

It should be made clear that the protocol does not necessarily provide a control system to align items like frequency standards that are built in to many devices. These are frequency references and have no understanding of time even though they are accurate in frequency. The 1588 timing system could be used to align the frequency, but there may be timing jitter present that could affect the performance of any hardware, such as a signal generator or spectrum analyzer. In these examples the user should rely on the normal coaxial connector distribution of frequency standards between devices.

Once a system has a common sense of time it opens new possibilities for that system. The most obvious is that events can be initiated at a specific time, not just at a time related to some transaction that occurs in a system (e.g. capture a signal after a period of time has elapsed from an instruction sent). There is an obvious advantage when collecting data at regular times, but there is a more subtle advantage in being able to send an instruction to devices to perform tasks at a specific time to make sure they all start their defined tasks together irrespective of when the instruction was sent. The distances involved do not have to be short. It is perfectly feasible for devices to be synchronized on different parts of the test area, even in different buildings, factories and even continents. As the distances increase the timing uncertainty will increase and more care has to be taken about the elements in the network but it is clear that 1588 timing provides a powerful feature for aligning distributive measuring systems.

## IEEE1588 Implementation

The adoption of 1588 in test and measurement has not been as rapid as many would have hoped, and for early adopters some issues were created as the result of the IEEE improving on the 2002 release by releasing a new version in 2008 with improved timing accuracy, particularly in the presence of heavy communication traffic over the physical interface (in the case of LXI the LAN connection). There are interoperability issues between the two versions which require users who have IEEE1588 enabled products of both types to carefully manage two networks. Guidance on this is given in a Consortium document "Recommendations for LXI systems containing devices supporting different versions of IEEE1588" available from the Resources section of the Consortium web site.

IEEE1588-2002 could be implemented either in software or hardware, the latter giving by far the best performance. For IEEE1588-2008 the implementation requires hardware support and the availability of Ethernet chip sets with the required hardware support and the right level of hardware access to implement an effective system. Chip sets for this, especially for 1000BaseT interfaces, are limited at the time of writing.

## IEEE1588-2002 and IEEE1588-2008 Overview

The purpose of this section is not to give a detailed description of IEEE1588 but rather provide a general feel for how it works. If you want a more detailed description try reading:

> Measurement Control and Communication by IEEE1588, John Eidson,
> ISBN 1-84628-250-0 which describes the IEEE1588-2002

In an LXI system supporting IEEE1588 timing various enabled LXI Devices are connected together by an Ethernet network. Each of the LXI devices has a real time clock embedded within it. One device in the system has to be allocated as being the Best Clock, or "Grandmaster", a role assigned by an algorithm designed to find the best clock in the system.

There are always two types of clock in the system, one called an Ordinary Clock that has just one connection port (such as a typical LXI Device) and the other called a Boundary Clock which has multiple connection ports and behaves as an Ethernet Switch. The network is a hierarchy of master and slave clocks, and some devices behave as slaves to an upstream master and as master to a downstream slave.

A network can have multiple Boundary Clocks, and a boundary clock might be the Best Clock in the system and take on the role of Grandmaster.

Most Ethernet Switches do not contain Boundary Clocks, in which case the Ethernet Switch behaves as a "passive" device. The presence of the Ethernet Switch is invisible for the purpose IEEE1588, though of course it does provide a fan out to multiple LXI Devices.

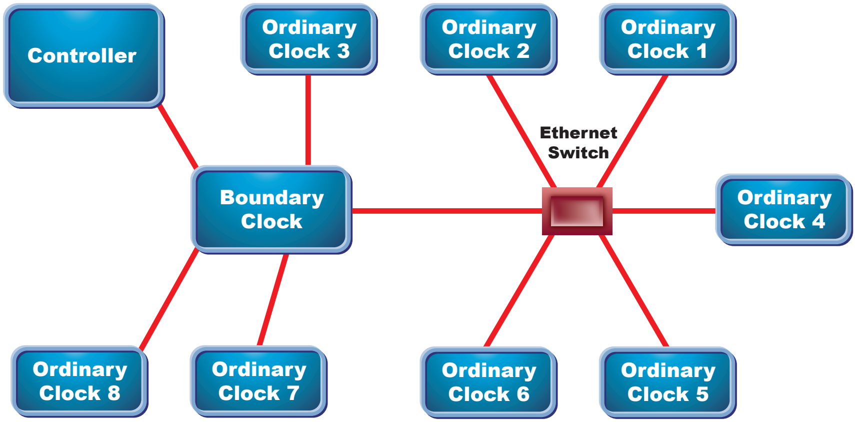



**Fig. 6.1 - Network system with a Boundary Clock and a switch without an IEEE1588 Clock**

LXI systems do not have to contain both Ordinary Clocks and Boundary Clocks, some may simply have Ordinary Clocks (in the LXI Devices). At the opposite extreme some may have clocks referenced to GPS or a similar standard.

When the system is first started the clocks exchange messages with their connection ports and establish a hierarchy according to a complex set of rules. The user does not need to worry too much about the details of the rules used to determine the hierarchy; it is designed to be an administration free system. The rules have to cope not only with a starting system but also a system where clocks can unexpectedly be removed from the system (e.g. Ethernet cable unplugged) or new devices being added, perhaps including a device that could be better than the existing best clock in the system and therefore needs to take over the Grandmaster role.

Once the network is established the critical timing messages are exchanged that are used to synchronize the system. There are just four of these messages:

- Sync message
- Follow up message indicating when the sync message was sent
- Delay request message
- Delay response message.

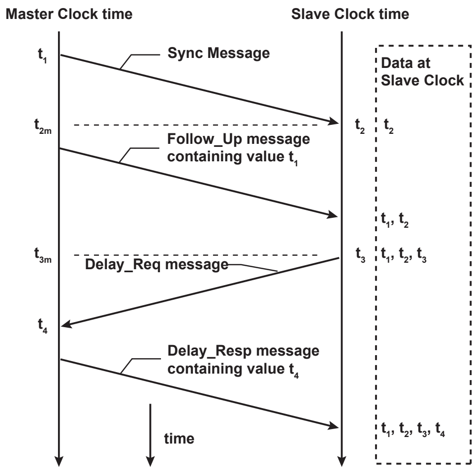



**Fig. 6.2 - Critical Timing Messages**

These four messages are sent to the next slave device – another Boundary Clock or to the LXI Device (ordinary clock) - the request is not sent beyond the next Boundary Clock into the next part of the network. The next part of the network uses its Boundary Clock to explore the delays in that part of the network.

The sequence of events is deceptively simple:

- The master clock sends a sync message to all its directly connected slaves at t1
- The slave clocks receive the Sync message and timestamp it at t2
- The master sends a Follow Up message telling the slave what time it sent the sync message
- The slave sends a Delay Req message to the master time stamped by its local clock
- The master receives the Delay Req, time stamps it and sends the information back to the slave as a Delay Resp message.

At this point the slave has four pieces of timing information that it can use to work out the errors between the master clock and itself. It can then correct its real time clock. In working out the delays the slave assumes the delays are always the same and symmetric.

In reality neither of these assumptions may be true, so some impairment of accuracy can be expected. In particular Ethernet Switches have queuing systems to avoid loss of data which lead to additional delays when the network is heavily loaded.

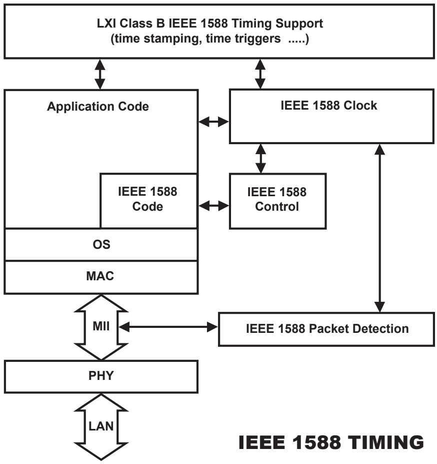



**Fig. 6.3 - Stylized schematic of IEEE1588 implementation in an LXI Device**

In the IEEE1588-2008 standard the concept of the Boundary Clock is altered with an End to End Transparent Clock being introduced to overcome the uncertainty created by traffic queues and to measure timing of entire chains of devices in the LAN rather than the individual delays in each connection. When the timing messages are sent the message goes straight through the Transparent Clock, but the clock measures the time of arrival and the time it exits the Transparent Clock (indirectly measuring the queuing time). The timing information can either be added to the message as it passes through a correction field in the message, or it can be sent later as a separate message. The timing exchanges propagate through the tree structure, with the Grandmaster clock at its start to the devices at the far branches. Timing information is sent back from the end of the tree back to the Grandmaster.

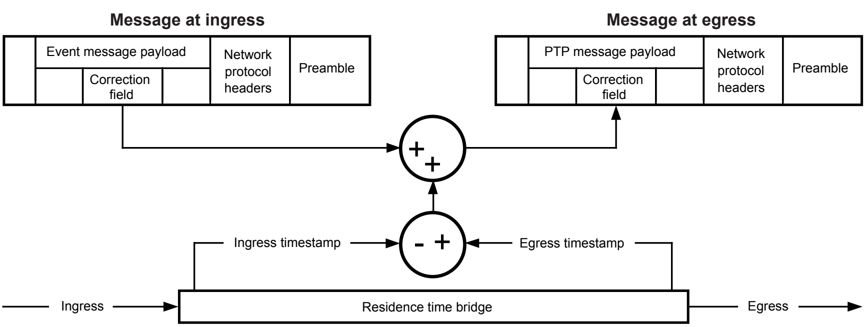



**Fig. 6.4 - Stylized schematic of an End to End Transparent Clock**

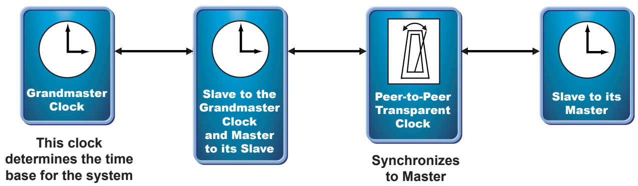



Fig. 6.5 - Clocks that could be present in a IEEE1588 Version 2 system

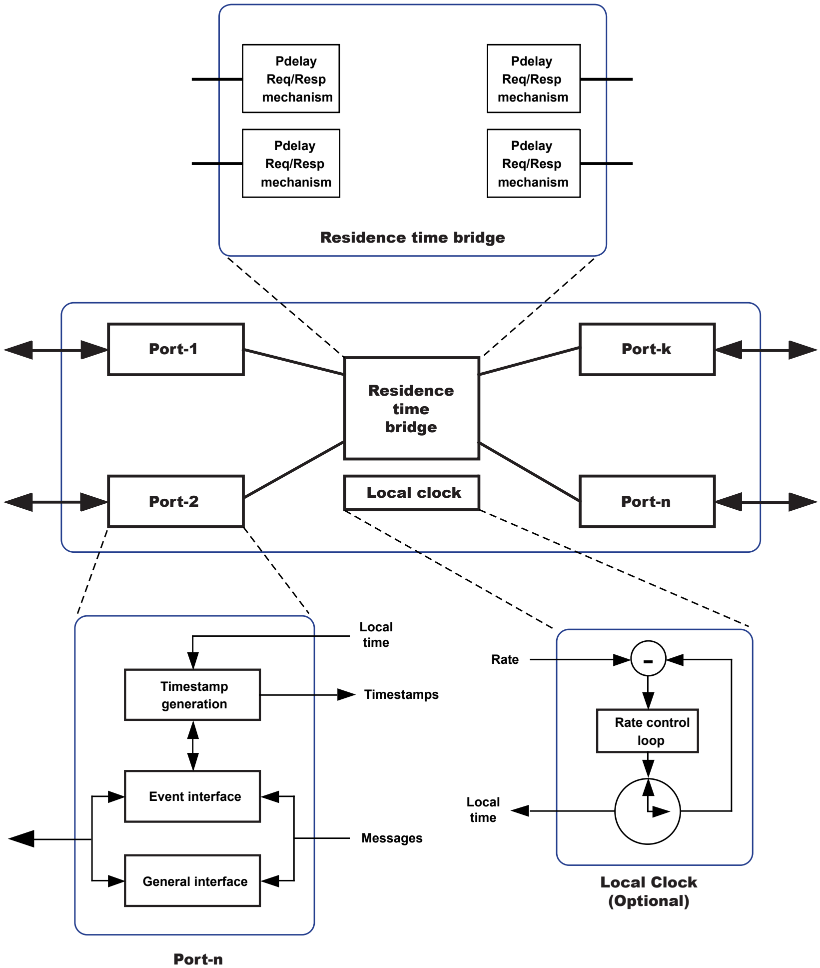



Fig. 6.6 - Stylized schematic of a Peer to Peer Transparent Clock

Every attempt has been made to make IEEE1588-2008 compatible with IEEE1588-2002 within the IEEE, but there are clear differences in how they work. In particular IEEE1588-2008 requires a Correction Field to be inserted in the message payload to correct for the transit time through the Transparent Clocks, and to take advantage of the improved timing the resolution of that field has very fine time resolution.

The architecture is also challenging for the Grandmaster Clocks. In IEEE1588-2002 they only dealt with a few connected devices, in IEEE1588-2008 they recover data from all the connected clocks. There are other complications for IEEE1588-2008, for example Ethernet Switches appear as 1:N devices. Clearly 1:N devices mean multiple path lengths appear in the system adding complication to the implementation. Boundary Clocks will be able to exist in IEEE1588-2008 systems, but act as a time transfer boundary in the system for end to end timing.

For LXI Devices the complications of IEEE1588-2008 are not as difficult to deal with as for the infrastructure devices. LXI Devices are generally end devices and do not have the challenges faced by Grandmaster Clocks.

IEEE1588-2008 also has some other flexibility introduced. In IEEE1588-2002 parameters such as how often timing messages are exchanged over the LAN are fixed. In IEEE1588-2008 many of these fields can be changed. The LXI IEEE1588 Profile defines the ranges of parameters that an LXI Device must support.

For most users they should not need to know the details of the timing transactions being performed, they just need to know that it’s happening, that the clocks are locked and to avoid the mixing of two different versions of IEEE1588 without following the consortiums recommendations.

*SECTION 7*

# *OTHER OPTIONAL EXTENDED FUNCTIONS IN LXI*

## Contents

## Other Extended Functions in the LXI Device Specification

So far the WTB and IEEE1588 have been described in some detail, but there are three other Extended Functions embedded in the LXI device Specification which can provide valuable features in some applications. These are:

- LXI Event Messaging. A feature that allows direct messaging between LXI Devices without involving the system controller.
- LXI Time Stamped Data. A feature that allows data exchanges to contain a time stamp that indicates the time the data was exchanged. The required timing data source is IEEE1588 if implemented.
- LXI Event Log. An internally generated log file that describes the events that a device participates in and is particularly useful in the debug phase for system development.

Many vendors and end users consider LXI Event Messaging as a potentially valuable function for extending the performance of LXI test systems. By initiating direct communication between devices it avoids the overhead of working through the controller and minimizes system delays.

Some vendors also include scripting in their products, a facility where Event Messaging can initiate a sequence of events within the device, the sequence of events being defined by a scripting language.

## HiSLIP

The LXI HiSLIP Extension defines use of the IVI HiSLIP protocol (IVI 6.1) created by the IVI Foundation for fast instrument communication.

HiSLIP has the following features:

Sockets-like IO speed (approaching LAN saturation rates for large binary blocks)

VXI-11-like Instrument-like behavior

- Reliable ‘EOM’ (end of message) signaling, regardless of data content
- Asynchronous SRQ (service request) signaling
- Read instrument Status byte
- Asynchronous Device Clear support
- Group trigger
- Remote/local mode switching
- Better lock support:
  - VISA-compatible shared and exclusive locks with nesting
  - Locks honored across PC’s: Locks held in instrument
  - Locking programs can coexist with lock-unaware programs
  - Short term locks only delay other program’s instrument operations

- Interrupted error detection/correction (MEPE message exchange control protocol subset for LAN).

IPv6 Support - It is usable on IPv6 or IPv4 networks

## IPv6

The LXI Consortium has reacted to the shortage of IPv4 addresses by creating an Extended Function for LXI Devices to follow if they operate in an IPv6 environment.

At the present time this is an unlikely situation for most users since local networks (subnets) are able to continue using IPv4, and IPv4 networks can be handled within IPv6 networks (as always in Ethernet backward support is absolutely critical to organization with large Ethernet investments). However, purchasing agencies may specify that Ethernet capable devices must support IPv6 as insurance against increasing cases where networks may be IPv6, or may be upgraded to IPv6.

This has encouraged some LXI vendors such as Agilent and Rohde Schwarz to introduce IPv6 capable devices which conform to the new Extended Function. The availability of these products has allowed the new Extended Function to be tested using the Test Suite.

As experience is gained of IPv6 networks it is possible that some minor changes will occur but it is very unlikely that these will create significant issues for users - as is the case for the IT industry in general IPv6 is on a learning curve and backward compatibility will be maintained.

## *SECTION 8*

## *SECURITY*

### Contents

## Introduction

The fact that LXI is LAN based has led to questions about security of LXI systems, many expressing unfounded fears that systems based on LXI will be less secure than those which are based on alternative control technologies.

There are a number of important security issues to consider in a system, but in reality they are no different to the considerations that should be applied to any systems that contain a controller. Any system that has a controller (PC) at its core is likely to find that principal concerns are focussed on the security of the controller and not the instrument products it controls, and that controller will likely have a connection to the LAN.

Issues that might need consideration include:

- Management of resources where an item can be shared between more than one application
- Protection against unauthorized external challenges
- Protection against unauthorized internal challenges
- Protection of data
- Loss of data.

No matter how many security measures are taken within a building, nothing will prevent an informed insider from being able to cause problems in a system. The principal focus of the measures to be taken by the test system designer should be against the accidental problems caused by uninformed insiders and the challenges of protecting the systems from unauthorized outsiders.

## LXI Device Management

LXI Devices that do not contain an embedded PC running a Windows operating system are unlikely to find themselves being attacked by viruses and other challenges from outside the application area. These challenges are generally confined to the most popular platforms and operating systems (for example it is claimed that fewer attacks occur on the Apple platforms compared to Windows based PC's). Many LXI Devices (including all Pickering Interfaces devices) are based on proprietary hardware which is locked to proprietary software so in reality attacks on LXI products are very unlikely.

There are a number of instruments available that do use Windows based operating systems (for example scopes and spectrum analyzers). These products should take the same security measures that any PC is encouraged to take, and the user may need to consider how issues such as Windows patches are handled (automatic updates may require the instrument to have a network connection that makes it visible to the corporate IT department).

LXI Devices do have a basic level of security that locks the configuration information from changes by use of passwords, and this should be used to protect against uninformed users accidentally making configuration changes.

Pickering Interfaces LXI Devices use embedded controllers running a Linux operating system. The operating software is stored on a memory card rather than a hard disk drive so that the unit can be turned on and off without worrying about the housekeeping normally associated with Windows products at power down. Software upgrades can either be by replacement of the memory card or by performing software download via the LAN to the memory card.

## Local Network Management

The key to secure operation of an LXI system is to make sure the network is correctly setup. This is relatively straightforward for a local network and is a little more complex for a distributed network.

The simplest system is where no external connection to the corporate LAN is required, which of course also means that there is no connection to the outside world. A network can be set up which simply connects LXI Devices and controllers together with no shared traffic with other systems. The network simply uses hubs or switches to provide the Ethernet connectivity between the devices. Such a system is very secure, you need to have physical access to it to influence or change the system operation. As long as the devices that you connect in are in themselves trusted there should be few security issues. This is not the most common test scenario, most systems want to take advantage of Ethernet connectivity to allow remote access. However, there are some very sensitive applications where remote access is not a permitted configuration.

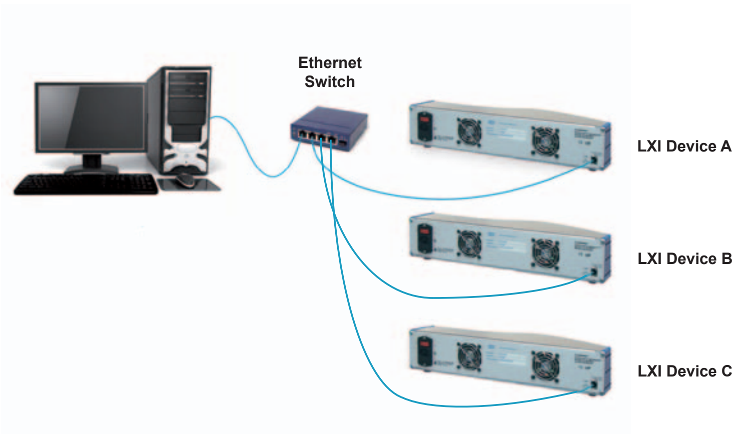



**Fig 8.1 - LAN based network**

More commonly the system will have access to the corporate network, and through that network it may have access to the outside world. Connection to the corporate network adds a few more challenges to the system, one of which is that the user may need to involve the corporate IT department, an issue not confined to LXI systems since it is also the case with PC dependent test systems. The corporate network will be carrying a great deal of traffic that you do not want to see on your test system network, and the IT department certainly does not want to see unnecessary local test system traffic on its corporate network. From both users perspective unnecessary traffic consumes bandwidth on the LAN and raises security issues.

For this reason a router is usually deployed between the corporate network and the test system network. The router segregates the traffic, passing across the connection only that traffic which is directed to the outside world and confining local traffic to the local network.

The router can also contain a Firewall which can be configured to protect the local network from unwanted access. In much the same way as users protect their internet activities, the Firewall will block certain types of communication and warn the user of suspicious events.

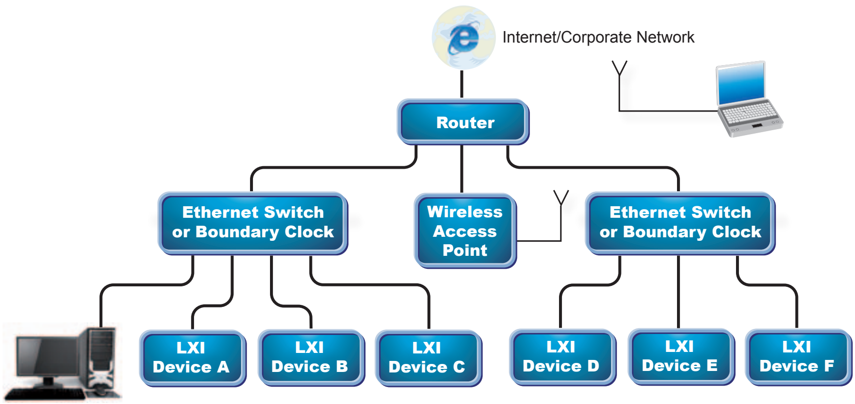



**Fig 8.2 - Network with external connection to the corporate network and the internet through a router and including a wireless access point.**

## Distributed Network Management

System designers may not want to limit their systems to being just locally controlled, there are applications where a user may want to directly control equipment that is remote from them. The equipment may be in a different part of the same building, in a different factory or even on a different continent. Few applications can afford the cost of a private Ethernet connection, but similar results can be obtained by setting up a Virtual Private Network (VPN) through the routers and into the external internet connection.

A VPN provides encrypted communication across the public network that prevents eavesdropping by others. Different strengths of encryption can be used that ensure that even if data is intercepted it takes months or years for even the fastest computing platforms to decode the information.

## Wireless Access

The use of wireless links in a system can provide the user with a degree of mobility; the test system can be accessed readily from any point within reach of a wireless access point (WAP). The WAP is a potential security weakness in the system since the airborne signal can be monitored.

WAP's have the capability to encrypt the signal over the air interface using Wired Equivalent Privacy (WEP) as a barrier to casual eavesdropping but some may leave it for open access to simplify the process of connecting. If security is of concern the encryption should be on. Older devices support 64 bit WEP but there have been concerns that a suitably motivated person could intercept and decode transmissions based on 64 bit WEP, consequently newer systems use 128 bit WEP. Many WAPs support both formats. In extreme cases users may want to check if the signal from sensitive WAP's can be detected from outside the secure areas of the building.

## Loss of Data

Ethernet systems come with different bandwidth capabilities. The 10 Mb/s systems (10baseT) have gone from most installations, and most are now capable of at least 100 Mb/s (and more usually 1000Mb/s with 10Gb/s, 40Gb/s and even 100Gb/s coming in the future). This bandwidth is shared between all the devices connected to the network. The way that signals are routed can ensure that traffic is only routed down the correct cables, so maximizing the usefulness of that bandwidth. However, it is inevitable that occasionally traffic will collide and data transmission is delayed. The more heavily loaded the system is the more likely this is to happen.

The use of Ethernet Hubs in a system can increase the chances of collisions in a system because data is routed to all ports of the hub. An Ethernet Switch is often a better choice since it will selectively route the signals, making more use of the available cable bandwidth and reduces the chances of data collisions.

However, eventually the loading on the network can be increased so that collisions become more frequent. When this happens data is queued in the switch in a buffer. Eventually buffers fill up and there could be potential loss of data depending on how the data is sent.

If data is exchanged by User Datagram Protocol (UDP) it can result in the loss of data. UDP is a low overhead means of exchanging data, it is fast to execute and is ideal for short messages (such as IEEE1588 messages) since it has a low protocol overhead. However, UDP transmissions are not guaranteed to arrive, and they can arrive out of order in some circumstances. The data could also sometimes be corrupted. Lost or corrupted data is very unlikely on modestly loaded networks, but becomes more likely on heavily loaded systems. Most test and measurement systems are not heavily loaded if they have been well designed. Generally UDP is used to send broadcast messages (sent to all on the local network) or multicast (send to all subscribers) over the network, it is the transport mechanism used for key messages on IEEE1588 timing.

If data is sent by Transmission Control Protocol (TCP) then data cannot be lost and is always assembled in the correct order. It is well suited to applications where data is vital and data is sent in relatively large blocks. If a receiving device indicates that data was lost or corrupted it will automatically ask for a resend, so providing a guarantee of successful delivery.

## Further Information:

An extensive guide to network and IT issues is available from the Resources section of the LXI Consortium web site.

# *SECTION 9*

# *LXI CONFORMANCE TESTING*

## Contents

## LXI Device Compliance

The LXI Consortium has been careful to protect the users from misleading claims about products that are LXI conformant (compliant) and has legal protection on the use of the logo.

All products that are declared to be LXI Conformant are required to be tested for conformance against a set of test procedures, and vendors are also not permitted to use the logo on a product unless it has been tested in an approved way. The vendor has to be a member of the LXI Consortium, alternatively if they are not a member then the vendor has to still test the product and take out an annual license to use the logo. No vendor has taken this licensing route and the expectation is that this will continue to be the case.

LXI Device conformance testing can occur through a third party or by bringing the product to a meeting at which compliance testing is being supported. At the present time suitable meetings occur 3 times per year at the face to face meetings of the LXI Consortium. The testing is performed in parallel with other activities, typically involving the committees and working groups of the Consortium in face to face discussions. Go to the Events page of the Consortium web site to see when and where the next meeting is scheduled.

## LXI Meetings

The testing activities at LXI meetings have two principal objectives:

- To verify that the LXI Standard documentation is correct and clear enough for vendors and users to design to. The main specifications have passed through this process but as specification migration occurs and optional new functions are added these require on-going assessment.
- To develop and confirm test procedures for new functions of the standard.
- To test prospective LXI Devices against the standard using a defined test procedure that allows the product to be certified as LXI Conformant.

The consortium has a set of rules on how devices are tested to demonstrate that they comply with the specification. Like most test procedures the testing is not a 100% guarantee that there are not unforeseen problems, but it does give a high degree of confidence that the vendor has understood the requirements and correctly implemented them. It also insures the end user that the LXI devices they select will work together in their test system.

The testing only covers the LXI aspects of a product, it does not, for example, attempt to check that the product performs the device's functions and accuracy that the manufacturer claims. So a switching system undergoing Stimulus and/or Measurement testing has its LXI interface tested, but no attempt is made to check that the switches operate unless it is an essential part of testing the LXI interface.

All issues concerning Compliance Testing are managed by the Compliance Committee of the LXI Consortium.

## Early PlugFest and Conformance Testing

The earliest PlugFest and Compliance testing events saw vendor's prospective LXI Devices being brought to the event for testing by experts and creators of the LXI Specification. Some of these devices were at an advanced stage of development with a high expectation of passing most or all of the tests, others were prototypes where a vendor did not expect to pass but wanted to get feedback and clarification of what still needed to be done.

Companies who normally competed with each tested each other's products in an open and transparent way. Each product went through a set of tests and the results recorded on a spreadsheet that accompanied the product. In some cases aspects of the specification relied on a manufacturer's declaration in order to avoid dismantling the device as part of the test (for example to confirm that the WTB traces on a PCB use 100 ohm differential lines). The tests results and declarations were then summarized across all the products that were offered for testing. The final report disclosed to the broader membership did not identify individual results. The engineers conducting the tests did this as you would expect of engineers – in an open and constructive way – with failures being identified along with constructive suggestions on how to fix them. More than one product entered a PlugFest with problems but left the event the following day with new software that worked. The test results were recorded on an interactive spreadsheet which circulated between the test stations using a USB memory stick.

When the testing raised questions about the specification and its interpretation the information led to revisions and clarifications in the specifications.

## Current Conformance Procedures

Testing has moved on from those early days. Spread sheets have now been replaced with semi-automated test suites (copies of which are available to the LXI membership).

The October 2006 meeting for the first time was conducted with a paid independent expert rather than relying on the vendor experts. Independent third party testing was introduced to permit testing at any time. The test houses used for third party testing must be approved to be competent by the LXI Consortium, and the Consortium provides a list of approved third parties.

As progress is made it is expected that eventually testing will be primarily carried out by approved test houses and independent companies based in USA, Europe and China. However, demand for testing at LXI Consortium meetings is still present. As with the earlier testing meetings vendors are encouraged to bring products for testing even if they are not complete, this is a particularly useful route for new vendors wanting early feedback on their compliance needs.

In the long term it is possible that under certain circumstances vendors may not have to subject their products to third party testing, however the first time pass rate for current tests does not indicate that this will be in the near future. Even experienced vendors find they have minor issues to deal with from time to time.

## If a Device Passes

If a product passes the tests and the vendor is a member of the consortium, or has taken a licence for logo use, the vendor can then make a formal application to the Conformance Committee for the product to be declared LXI Conformant. Once approved the vendor is then entitled to use the LXI logo on the product and its documentation. The product can also be added to the LXI Consortium web site list of compliant products. The test results are archived to the member's only part of the site controlled by the Conformance Committee.

## If a Device Fails

Clearly in these cases corrective action has to be taken. If the failures are relatively minor then the vendor can make the corrections and submit evidence to the Conformance Committee of the corrections carried out. If they agree then the device can be accepted as being conformant to the standard.

If the failures are more significant the product may have to return to a future meeting event, or be independently tested by an approved test house.

## Migration Products and Technical Justification

Many new products are variants of existing ones, so if the LXI interface has not changed the vendor has the option of submitting a Technical Justification, using the successful testing of a previous product as justifying the acceptance of a new product. This route provides a powerful argument for the development of products which have a common proprietary LXI interface across a wide range of products.

The use of Technical Justification is at the time of writing limited to product conforming to Version 1.3 or later of the standard. It still requires that the vendor runs the conformance test suite themselves and provides the test result, with the conformance application.

Pickering Interfaces LXI products use a common LXI interface, which means that as new features are added all the Pickering Interface devices gain those features and conform to the latest version of the specification.

## WTB Cables and Terminators

One exception to the requirement for independent testing is the WTB accessories. These parts are governed by a separate standard which includes a test procedure. During the early testing phase of the LXI Standard these accessories (including those from Pickering Interfaces) were tested at a PlugFest event. The current version of the standard now permits these accessories to be tested by the vendor and for the vendor to make a declaration that they have tested in accordance with the procedures. To be marked as LXI accessories the vendor must still be a member of the Consortium.

## Misuse of the logo

Users and vendors are strongly encouraged to report any misuse of the LXI logo. To display the logo a vendor must be a member of the LXI Consortium or have taken an annual license to use the logo (the cost of the most basic form of membership and the annual license fee are the same).

The consortium has tackled infringements of the logo and intends to continue to protect it.



Products that do not use the correct logo on their documentation may not be fully LXI compliant and should be avoided as they may not operate correctly according to the specifications and may compromise your test system.

The logo can only be put on products (printed or displayed on screen) and documentation that has been shown to comply with to LXI standard. For prototypes the logo can be displayed before full compliance testing, but the devices cannot be shipped with the logo until testing is complete and accepted by the consortium.

## LXI Product Listing

The LXI Consortium web site provides a list of products that have passed the conformance criteria. These products can be sorted by a variety ways to simplify searching for a specific product type. This is unique in test and measurement, no other standard protects the user interest in this way. It means users can be confident of the Ethernet interface on LXI Devices.

## *SECTION 10*

## *COMPARING LXI TO OTHER STANDARDS FOR SWITCHING APPLICATIONS*

### Contents

## Introduction

LXI is of course not the only relatively new instrumentation control standard. The following is a short description of some of the alternative standards. In reality many test systems will contain examples of different instrument platforms within different parts of the system, for example the switching part may use a different platform to the instrumentation part. Users are able to use whatever is best for different parts and create hybrid test systems. Modern software tools make the creation of hybrid systems relatively easy.

## PXI

**Fig 10.1 - A populated 3U PXI Chassis**

Unlike LXI, PXI is inherently a modular standard with defined module sizes that plug into a backplane that provides power and control. The control interface is based on the use of PCI (or PCIe). The chassis requires a controller which can either be embedded in the left hand slots or has a bridging interface which connects the chassis to the PCI or PCIe bus of an external controller (PC).

In general PXI provides a good platform for switching products, especially if the switching is mixed with instrumentation products. The ability of the chassis to support multiple vendor products is a key objective of the standard so it allows users to put test systems together using the best from a variety of vendors with minimal coexistence problems.

For switching systems PXI is at its best when the switch applications are smaller and more diverse. For larger switching systems LXI tends to work better (more integrated hardware design with fewer cable interconnects) and is more cost effective.

Some applications also benefit from using PXI modules in an LXI environment since the LAN interface (like GPIB) provides more system (including operating system) independence than is possible with the PCI based solutions where the modules are seen as an extension of the PCI bus and therefore deeply embedded in the PC. For Pickering Interfaces PXI modules the 60-102 and 60-103 series LXI/PXI Modular chassis allow PXI to be operated in an LXI environment over greater distances and with a more robust interface that is less dependent on the PC infrastructure.

LXI can also use a proprietary modular structure that differs in size and uses a different infrastructure connection between modules. The Pickering Interfaces 65-110 is one example where the module size and infrastructure has been specifically designed to implement a high bandwidth matrix.

Pickering Interfaces remains committed to supporting both the PXI and LXI standard for switching system development, it is very much a question of letting the market (users) decide what works best for them.

## VXI

VXI is an older modular standard that is based on the VME bus. The modular footprint is much larger than PXI and the principle success of the standard has been its widespread adoption by US led military requirements where the large size and modularity enabled flexible test systems to be created that addressed the need for common test systems that could address a large number of different test devices.

There have been attempts to upgrade the VXI standard, but there are few new adopters of the standard and many leading companies have withdrawn from supporting it. The platform is seen as being relatively expensive to both design (to a complex specification) and manufacture. Most commercial users have now migrated to other platforms and even military users have been migrating designs to other standards, notably PXI and LXI, which provide more modern feature sets based on later and more widely used interface specifications.

Pickering Interfaces does support VXI switching products but has no plans to introduce new designs.

## USB

Oscilloscope    Power Sensor    Data Acquisition

**Fig 10.2 - USB Test equipment**

Like LAN connectors USB connectors are found on almost every controller that will be considered for a test system. For that reason USB has emerged as an interface for use in controlling products in test and measurement.

USB is considered to be less robust than LAN connections for a number of reasons.

- No latches on the standard USB connectors, so leads can become detached.
- USB Cables are not screened so can be subject to interference problems.
- USB devices do have a tendency to occasionally become detached electrically, eliminating instrument communication and requiring the lead to be removed and then reinserted to restart the device communication. Pickering Interfaces has introduced solutions such as the 40-738 to manage such issues.
- The physical range of the connection is more limited.
- USB devices, like PXI have no peer to peer capability without involving the controller to which they are connected.

- There has so far been no very successful standard for test and measurement. The USBTMC standard which standardizes USB for test and measurement has met limited success in the market.

Even so USB instruments are successfully deployed to create compact bench test systems which provide very useful capabilities. The systems can be easily put together and dismantled and the test instruments involved are generally small and light weight. Inevitably there are some applications where either LXI or USB could be used, but in general most users are clear that medium and high complexity systems, or ones that work over larger distance or in noisy environments, are better served by LXI based solutions.

Like LXI, USB is not a modular standard, there are no constraints on mechanical size. The USB standard mandates 5V supply distribution but this may not be enough to power a product and an AC wall plug is needed to provide an external power source.

Some users do use USB to LAN converters to operate LXI devices, but this is not always a simple approach.

USB is an inherently low cost solution – it has to be in order to support the consumer products that it is primarily aimed at – so where USB is appropriate it can provide a very cost effective solution. The introduction of USB3 may have an impact on the use of USB for test systems where high data throughput is required.

## AXIe

**Fig 10.3 - An Agilent AXIe 40 Channel Digitizer**

AXIe is a relatively recent standard introduced to provide a high end modular test solution.

Modules have a large footprint size – much larger than PXI and more closely aligned with VXI on size. In a real sense the AXIe has picked strong elements of both the LXI standard and the PXI standard since each module can have a control interface based on Ethernet or PCIe.

The target applications for AXIe generally require very high computing capabilities and large data bandwidths. The power supply is appropriately scaled to ensure it can power such products using a 48V DC distribution system.

Modules and the supporting chassis tend to be more expensive and complex than LXI or PXI and not ideal for applying to switching systems where high power, fast operation and high data BW are not significant factors.

So far adoption of AXIe has not been widespread, but there are a number of very capable products with unique performance attributes available that are particularly relevant to high end applications where the highest data rates, computing power and measurement performance are required.

Given the heritage from PXI and LXI and the fact that Pickering Interfaces LXI and PXI have common software driver heritage then AXIe products are a simple addition to either an LXI or a PXI test system.

## *SECTION 11*

## *PICKERING INTERFACES, LXI AND SWITCHING*

### Contents

## Introduction

Pickering Interfaces has successfully used the LXI Specification to create a family of switching products that would be hard to emulate in alternative platforms. For Pickering Interfaces LXI is seen as one of a number of platforms that can be successfully used for supporting switching systems, and the test systems themselves often have to exist with more than one platform present in the system.

Users will often try to stay with platforms they know and have familiarity with, but certainly for switching there are a number of alternatives that are viable. The reasons encouraging change can be:

- **Simple obsolescence.** The instruments and switching systems are no longer available. Possibly software drivers for newer programming environments are not available.
- **Upgrading a test system to accommodate new Test Programs.** Perhaps the original products didn't have the bandwidth or the switching system is not expandable to address new needs.
- **Size and ease of use.** Adapting older platforms to address new needs, or taking a platform that does not lend itself well to a new application could create a system that is physically too large, which can be potentially unwieldy. In addition cabling must be considered – will the platform create interconnection issues that can effect reliability and add cost?
- **Cost.** Whether we like it or not, management may require change to address a smaller budget – as profit margins get squeezed, test needs to adjust as do other areas of manufacturing.
- **Evolution of manufacturing technology.** As manufacturing and the products evolve the test requirements and objectives change.

Making a change, for example from VXI to PXI or LXI involves crossing a barrier, requiring the learning of new control systems and requirements.

LXI adoption does involve learning about new methods, but the standard is designed to make that easy and to ensure a common experience from different vendors with no compatibility surprises and no obsolescence issues brought upon by changing operating systems and interconnect systems – Ethernet has been and will continue to be an interface where backward compatibility is paramount for both hardware and software aspects.

In many cases, the above considerations suggest that a system with multiple platforms, or rather a hybrid system may be required, for example implementing part of the system in LXI, and part in PXI or USB.

The following applications talk about companies that made platform changes and incorporated LXI in their test strategy after considering the issues.

## Switching and Safety Protection Devices

**Customer** - A world leader in the development and supply of intrinsic safety explosion protection devices.

**Application** - The customer wanted to develop a fully automated version of their existing functional test rig for a new range of Intrinsic Safety Isolators. One aspect of this was the replacement of the existing VXI-based low-thermal EMF switch matrix due to its slow switching speed and obsolescence considerations.

**Problem** - Constructing a matrix of this size (55x33) is cumbersome using small form factor modules such as those used in PXI. Connecting multiple modules together to expand the X and Y axis dimensions requires many modules and awkward cable assemblies that result in the solution being both large and expensive. The large size and complex interconnect would create the opportunity for the generation of thermal EMF's - a parameter the user was concerned about since the matrix was to be used to work with low voltage signals as well as larger voltage signals.

**Solution** - With no COTS solutions available on the market, Pickering agreed to design a new product to suit the specific switching requirements. Due to the large number of crosspoints (>1800) and the stringent thermal considerations, the new matrix was housed in a 2U high 19" rack-mount LXI-compliant chassis. LXI was chosen over a modular form/factor as LXI does not add physical constraints – we could design the matrix using an optimal layout. The rest of the test system consisted of several GPIB based instruments that were used on the original tester and a VXI DMM.


**Fig. 11.1 - 60-511 2U high 19" rack-mount LXI chassis**

## Test Systems for Voice Routing

**Customer** - This is an example of an application outside of the traditional Test and Measurement markets for LXI. The application was within the UK Financial Sector, and the customer was CyberTech International, a global provider of voice logging and communications recording solutions to the public safety, financial services and call centre markets.

**Application** - A major international bank tender for a digital voice recording system to record dealer room activity included the requirement that if a recorder was to fail, the trunk line circuits to that recorder needed to be switched automatically to a standby recorder. To minimize cost, power and footprint of their proposed system, CyberTech wanted each standby recorder to be capable of supporting multiple primary recorders, and thus needed a multiplexer switch that would automatically route the phone channels of the faulty primary recorder through to the standby under appropriate alarm conditions. To facilitate integration and control of the switch in the recorder server, CyberTech's preferred method of communication was Ethernet.

**Solution** - Following joint technical discussions and field trials, it was determined that Pickering's high density PXI multiplexer modules with screened reed relays were ideally suited to the switching task. The ability to use these in our modular LXI chassis together with shielded module-mounted connector blocks provided CyberTech with an easy to integrate, scalable solution which has now become their standard switching option for standby recording at a much lower cost than traditional systems.

## VNA Multiplexing

**Customer** - A leading aerospace company (systems integrator and manufacturer of military aircraft and defence electronics).

**Application** - Customer needed to replace an existing dual VXI 90 channel RF multiplexer switching system used for testing PCB backplanes. The multiplexers were used to multiplex a VNA to characterize different paths on a PCB backplane. Not only was the VXI platform large, it is also expensive.

**Solution** - A modular LXI solution was proposed which gave the customer the flexibility to change the size of the multiplexers by just adding or removing a module from the chassis. An evaluation unit comprising of a 7 slot LXI chassis with a 16x1 MUX was provided to back up technical discussions and it proved to be ideal for the application.

For the application the customer is using an LXI based VNA and one 18 slot LXI chassis with sixteen 16 X 1 MUX modules and one dual 8x1 MUX allowing for two 128x1 multiplexers for connection to each port of the VNA (as shown in image below).

The use of LXI here provided a system that was much smaller than the existing VXI system and at a lower cost.

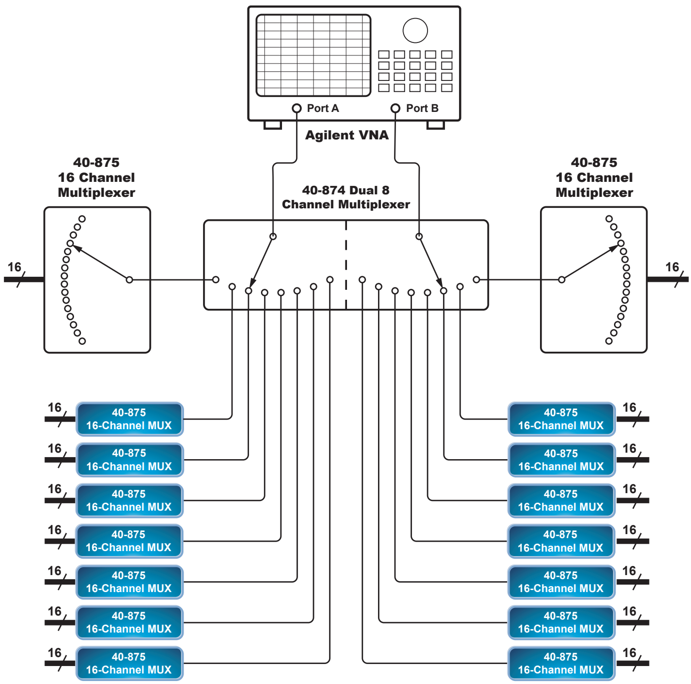



Fig. 11.2 - A Modular LXI Multiplexing Solution

## Large Matrix for Aircraft Testing

**Customer** - A leading Integrator for Aerospace applications who provides functional testers for Civilian and Military Aircraft.

**Application** - The customer needed to replace an old specific VXI system by a generic tester which could test a range of cards for several different aircraft ECUs. This system required more than 9000 points of switching to test all the different cases. Covering a large variety of applications with a single tester is more economical than creating several smaller testers, and logistically easier to manage. One of the main objectives was also to reduce the size of the full cabinet and the quantity of cabling in order to get the best flexibility and repeatability at a competitive price.

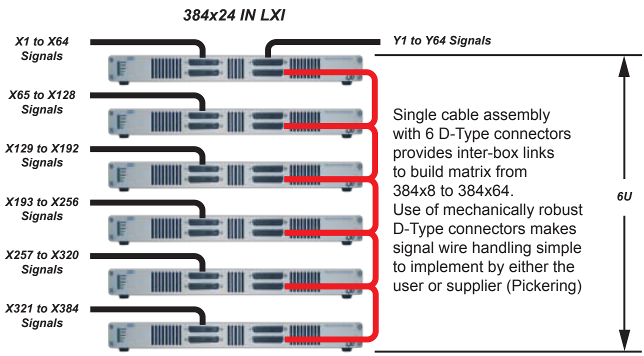



**Fig. 11.3 - 384x24 LXI and PXI Cabling Comparison (1)**

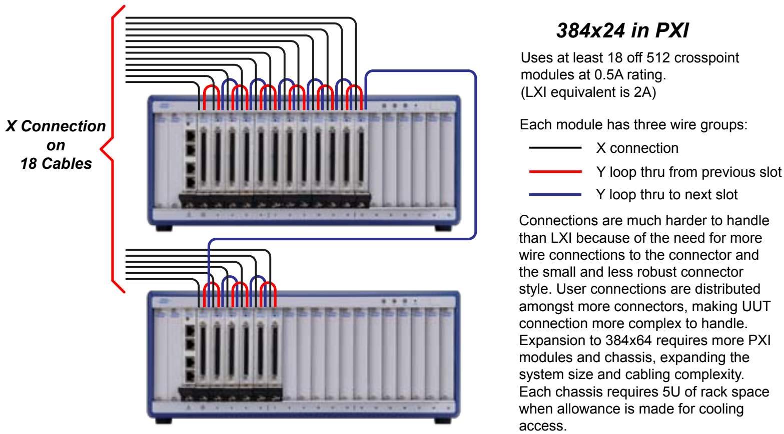



**Fig. 11.4 - 384x24 LXI and PXI Cabling Comparison (2)**

**Solution** - Despite the fact that the customer was attracted by PXI modularity and effectiveness, the customer came to the conclusion that building a tester with 9000 points of switching would be less effective, labor cost would be higher and it would take much more space than a LXI solution. A PXI solution for the matrix switching part would require more than 18 PXI cards with 512 relays and many cabling connections between the modules to implement the full matrix.

For this application, the customer has used a PXI chassis for all the one slot resources (DMM, Serial, Scope, DIO and Avionic cards) and six LXI 64 X 24 Matrix modules configured as a 384 X 24 using integral loop thru connections that were designed into the matrix – again, the mechanical freedom of LXI allowed the designers to add loop through connections which greatly simplified the cabling compared to a PXI solution. The resulting system has much less cabling with better performance than the original VXI system and is an example of a user selecting two different but complimentary platforms (PXI and LXI) to implement different parts of the system to obtain the most effective test solution.

## Matrix for Healthcare Production

**Customers** - A provider of medical equipment, specifically X-Ray systems, and their systems integrator.

**Application** – The customer needed to check electrical cabinets at the end of production line. These cabinets drove the X-Ray machines being produced on the production line. The Systems Integrator was required to implement a test to check electrical continuity and absence of short circuits between the different pins of different connectors. There were more than 1000 resistance measurements to perform in an automatic self-test.

**Solution** - The main difficulty was the number of resistor measurements and the precision of these measurements. So the Systems Integrator used an Agilent LXI DMM with a Pickering LXI matrix. The full matrix was composed of nine 128 X 2 matrices to create a 1152 X 2 matrix in a LXI switching chassis. The built in automatic self-test measures all the switch paths for assurance of an accurate test.

To connect the test bench to the cabinet, the Systems Integrator used two cabinets. The first contained the data processing devices such as PC and printers etc. The second contained the measuring devices which were in an enclosed cabinet containing the LXI DMM and LXI chassis. This solution was developed in three months from the start of the work and was duplicated in a second system.

The Systems Integrator commented “LXI was a great technology to switch a lot of channels. Integration was relatively simple as the connectors were large and robust.”

## Flexible Matrix for Avionics Use

**Customer** - Avionics System Integrator

**Application** - A new generation of flexible and easy configurable Test Systems for the Avionics Industry have been requested from the Integrator's end customer. The main goal was to simplify test installations and to cover all functional tests for a very high variation of units under test at high voltage up to 750V and within much faster test time.

**Problem** - The size of the test system's switching system is driven by the amount of UUT pins, instrument leads and concurrent interconnected signals. Previous switching systems were either too large (and therefore very expensive) or they were too small to meet all requirements in one setup. Use of small switching systems resulted in long test times because of the lack of concurrent signal switching.

**Solution** - With no COTS solutions available on the market, Pickering agreed to design a new product to suit the specific switching requirements. Each test system's switching network was made configurable out of multiple 75 X 4 2-pole high voltage matrices in an LXI Chassis. Each of the 75x4 matrices has its own isolation relays on both the X and Y axis to allow the overall matrix to be configured to the size required by the different test targets.

Examples of configurations are shown in the images below:

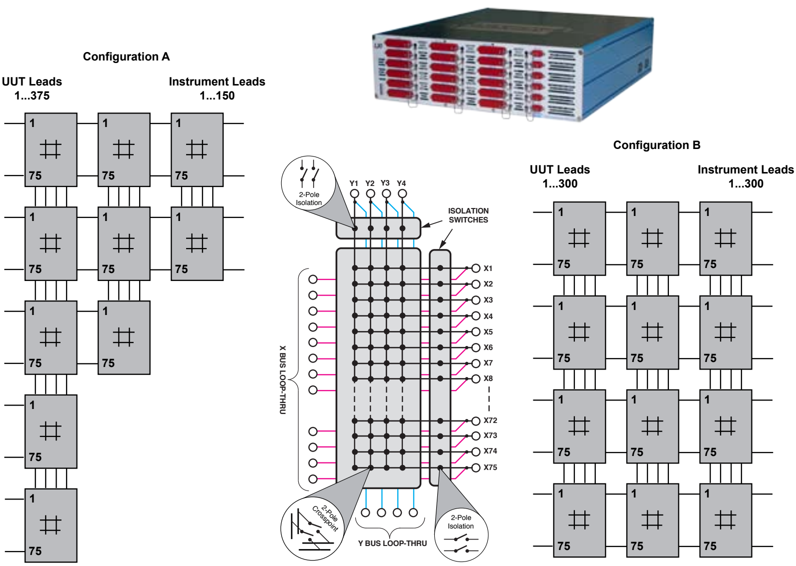



**Fig. 11.5 - LXI 75x4 Matrix Configurations using 60-311**

## Large Matrix Streamlines Avionics Test

**Application** - A large manufacturer of private aircraft was in the process of streamlining their test process of various Aircraft Electronics subassemblies. The plan was to replace many separate test systems with one common core tester. To achieve this, it was realized that a large matrix would be able to configure multiple instruments and test hardware, allowing for a single test system. This would save bench space, reduce the number of wire bundles as the unit would have a universal connector, simplify test procedures, and reduce maintenance in the long run. It was determined that the matrix needed to be a configuration of 100 X 100, and carry voltages up to 250 VAC at a maximum of 2 Amps. Bandwidth was not critical as the highest frequency would be about 100 KHz for the ARINC Serial busses.

**Solution** - Initially the customer looked to a solution in PXI. That was dismissed for several reasons. First, the form factor limited the number of relays per module, which meant that the systems would require four PXI Chassis, creating a test system that was 18 U high. Second, the custom cabling to interconnect the modules and create the large matrix would be very complex and expensive.

In the end, the customer chose Pickering Interfaces and purchased four 50 X 50 matrices with easy to use loop through connections to allow for easy expansion. The total system was only 4U high versus 18U for a PXI equivalent. Four low cost loop-through cables interconnected the X axis' and Y axis' together to achieve the 100 X 100 configuration. The end result was about 40% lower in cost than the PXI solution and less than one quarter the size.


**Fig. 11.6 - LXI Matrix 60-552**

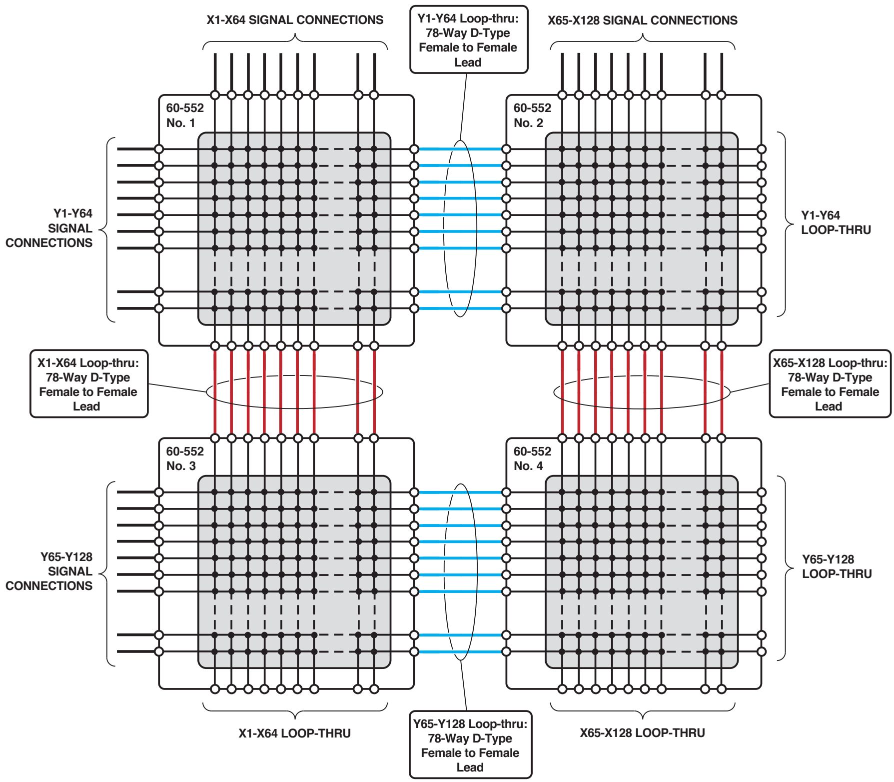



Fig. 11.7 - 100x100 Matrix using 4 x 60-552 LXI Units

## Cable Testing in Airframe

**Customer** - Aviation Application for Systems Integrator in France supporting a major airline.

**Application** - After a specified number (thousands) of flying hours, every airplane, be it private or commercial, has to be dismantled and fully checked to ensure it continues to be airworthy. A commercial airplane company required a switching system that would provide the ability to test for continuity and insulation integrity of cables in the entire aircraft. Insulation tests needed to be performed to 1kV. The switching system used for the test had to support cold switching at 1kV and also be suitable for use with low voltages consistent with continuity testing. The switching system needed to be an 800 X 2, 2-pole matrix.

**Problem** - The first approach was based on GPIB backplane chassis with several switch cards using high voltage Reed Relays. This solution was much too expensive and occupied more than 18U of rack space. There was also a solution based on the use of PXI modules. The PXI solution required 4 chassis since 52 PXI cards were required, the 4 chassis needing around the same rack space as a GPIB solution. The end cost of the PXI solution was also prohibitive.

**Solution** - Pickering Interfaces proposed an LXI solution to reduce both the cost and space required. The application required a great number of crosspoint switches and LXI solutions are much more effective at implementing these large matrix systems because of the lack of restrictions of the mechanical aspects when compared to modular solutions. With no LXI solution in the market, Pickering Interfaces decided to develop a standard product for this type of application. A 2U box with 3 density options at 100x2, 200x2 to 300x2, each with 2 poles, was developed.

The entire system was implemented in 6U of rack space. The system could be implemented using just three 2U LXI Devices to construct a 800x2 2 pole matrix with simple and cost-effective inter-Device cabling to link the products.

This solution was 30% cheaper than the alternatives and occupied just one third of the space of alternative approaches.

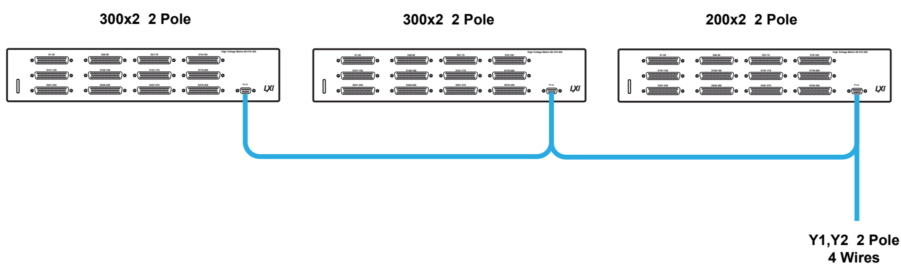



**Fig. 11.8 - 800x2 2 Pole Matrix using 3 x 60-310 LXI Units**

## Large Switching System for Data Acquisition

**Customer** - CERN.

**Application** - The customer needed to acquire a large number of analogue signals and convert them to digital format using a digitizer. The signals could vary considerably in amplitude between channels but the project budget and the system could not connect a digitizer to every one of the channels. What was needed was a switching system that would allow 16 digitizers to be connected to a number of different sources, the number of sources being variable according to the experiment being run. Some experiments could run with 100 sources. It was critical that the switching system caused minimal degradation in the analogue signal and in particular that the sources did not degrade because of crosstalk or noise. The digitizers were sampling as 25Ms/s, but there were also plans to increase the digitizer sampling rate.

The experiment was also physically large and there could be significant distance between the test system and the operators.

Experiments could also take a long time, so there was a desire to have a self-test system that established the matrix was working before the experiment was run.

**Problem** - The requirement for a large 100x16 matrix could not be implemented in a modular system. The matrix size was simply too large and trying to create a matrix from smaller matrices was too complex and expensive - and had a high performance risk that could only be tackled by the use of coaxial connectors.

**Solution** - Pickering Interfaces created a new LXI matrix (65-110) which provided the user with a scalable x16 matrix solution. The matrix used a proprietary platform which allowed a usable BW of greater than 300MHz to be achieved and had very low crosstalk between channels. The scalable design allows the user to set up a system with appropriate size for the experiment being run through the use of plug in modules. The user simply buys the chassis parts and the modules required to make the matrix.

The software treats the matrix as a single entity, it checks the modules fitted and adjusts its dimensions accordingly.

the 65-110 was also designed with a self-test facility that was able to check the matrix while external coaxial connectors were still attached, making it unnecessary to detach the 100+ cables that could be attached to the matrix.

The LXI interface made Ethernet control simple and control from a long distance easy to achieve.

The 65-110 offered had a performance and cost that could not be matched by other methods considered.

Fig. 11.9 - LXI Matrix 65-110

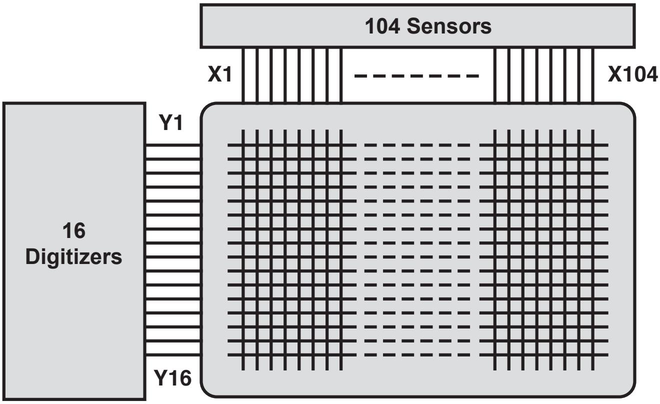



Fig. 11.10 - 104x16 Matrix using the LXI Wideband Modular Matrix 65-110

### Summary

The examples show that users considered different platforms – some were rejected for technical reasons and others for commercial reasons. Where it made sense, multiple platforms were selected in the test system to provide the best systems level performance and effectiveness.

So as you plan your next test system, or assess the requirements for an existing systems upgrade, look at LXI where it makes sense but don't discount other platforms either. Hardware and software vendors should be aiming to support all of the platforms relevant to their business.  As a vendor of many platforms, Pickering Interfaces believes in the "survival of the fittest" – and the fittest will depend on the application.

**60-103 Series, Switching Chassis**


- Supports a large variety of Pickering Interfaces PXI switch modules in an LXI environment
- Up 18 modules supported from a single chassis
- Browser accessed SFP for all supported modules

## *SECTION 12*

## *OVERVIEW OF PICKERING INTERFACES LXI SWITCHING SOLUTIONS*

### Contents

## 12 - OVERVIEW OF LXI SWITCHING PRODUCT SOLUTIONS

We offer switching product ranges with LXI conformant interfaces suitable for solving a wide range of test and measurement switching problems:

**LXI Switch Systems.**

For large switching systems we offer a range of dedicated chassis which typically have a single large switching entity embedded in them. These devices are designed for direct rack mounting or bench top operation and provide the most cost effective solution for applications requiring large switching systems with the highest density and lowest cabling costs. These solutions use a modular construction which permits factory based upgrades.

**LXI/PXI Modular Chassis.**

For more diverse switching applications we offer a LXI/PXI Modular chassis which can accept any of our 3U PXI switching modules. A single chassis can readily support a variety of different switching functions and some Pickering Interfaces' instrumentation modules. Besides support for general purpose switches, matrices and multiplexers the product range supported includes variable resistor modules, power supplies, RF and microwave solutions. Diverse does not mean the switching solution cannot be large, our modular chassis also fully supports our range of BRIC switching solutions. Users can buy the chassis and add or remove Pickering Interfaces PXI modules to or from the chassis at any time. This approach is perfect for diverse switching applications where users want the flexibility of Ethernet control.

**LXI Modular Chassis.**

A scalable switching system using a proprietary footprint which allows users to expand, contract or change the functionality of a switching system by simply adding or removing plugin modules. As with the 60-102 and 60-103 series users can change the switching system by simply purchasing more or different modules. The large footprint size ensures the product can implement large switching systems and the proprietary analog backplane bus simplifies the cabling and reduces cost compared to PXI modular products.

**LXI System Level Tools.**

A range of solutions for aiding the development of WTB systems in LXI and for remotely controlling AC power to the Test system.

The following sections give a brief overview of the switch products available from Pickering Interfaces, a range which is being continually expanded.

## LXI Switch Systems

Pickering Interfaces offers a range of LXI compliant switching solutions each of which implements a large switching system and presents itself to the user as a simple functional entity, such as a single matrix or a set of multiplexers.

Use of internal interconnections reduces connection costs and improves performance at a systems level compared to implementing as a set of smaller externally connected sub-assemblies. Interfacing via a single Ethernet connection lowers the infrastructure costs of the system and the presentation of the solutions as a single entity eases the complexity of programmable control.

The range of solutions is extremely broad, varying from microwave switching systems through to large RF matrices to 2.4GHz and including a range of very large low frequency matrices with over 4000 two pole crosspoints. High current and high voltage switching systems are also available.

Each LXI switching system is offered in a variety of different build sizes so users can select a partially populated version which is capable of being factory upgraded to a fully populated build state. All are designed for ease of use with a full range of connection accessories to ease system integration time and cost.

All the LXI solutions include soft front panels that are accessible from any web browser and all comply to the latest version of the LXI standard.

60-772 2.4GHz RF Matrix

60-600 10A High Power Matrix

60-550
2A High Crosspoint Count Matrix

60-800 Microwave MUX
Switching Solution

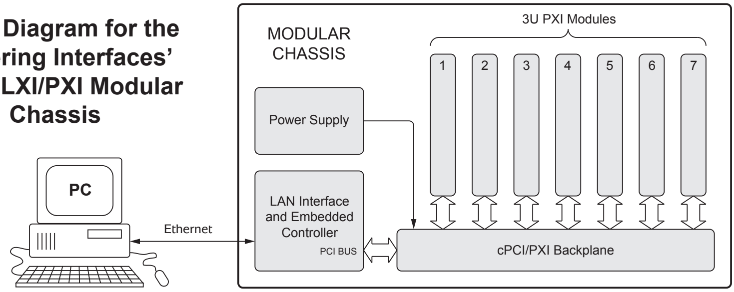
60-850
Optical Switching Platform

## 60-102 and 60-103 series LXI/PXI Modular Chassis

For applications requiring diverse switching functions but preferring an LXI interface, look no further than Pickering Interfaces' LXI/PXI modular platform.

The chassis **can support all of the 3U PXI switching functions** available from Pickering Interfaces – the largest range of PXI switching solutions available from any vendor. Optical, RF and low frequency switching can be mixed together in the same 4U chassis for bench top or ATE use. The chassis provides support for each module from a single IP address, and can provide a Java based soft front panel for any of the modules fitted.

**Block Diagram for the Pickering Interfaces' 7-Slot LXI/PXI Modular Chassis**

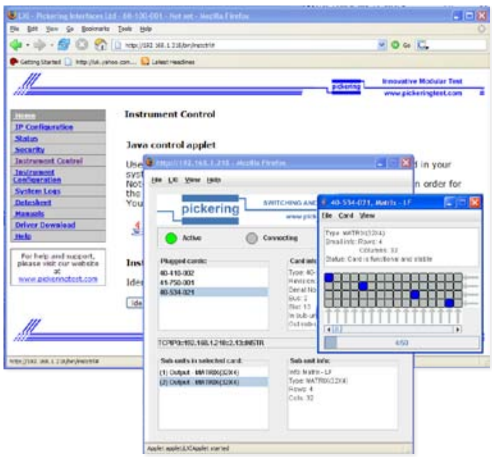



An industry standard web browser can be used to explore the chassis configuration and download the SFP (no need for SFP installation for each module), and the chassis can be controlled at almost any distance through the use of Ethernet connectivity.

Pickering Interfaces modular products are the perfect solution for high diversity switching systems.

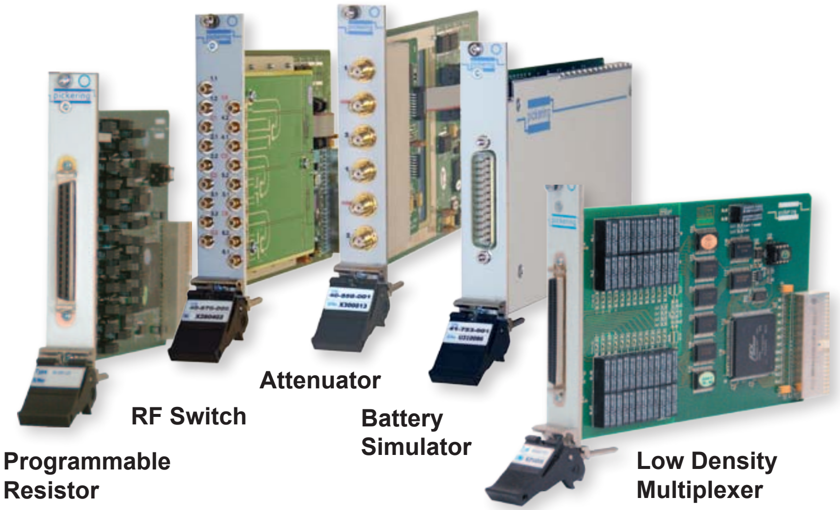
60-102 series 7-Slot
LXI/PXI Modular Chassis

60-103 series 18-Slot
LXI/PXI Modular Chassis




The Graphical Interface Included with the LXI/PXI Modular Chassis allows manual control of PXI Modules over an Ethernet connection

## A Few Pickering PXI Modules Suitable For LXI



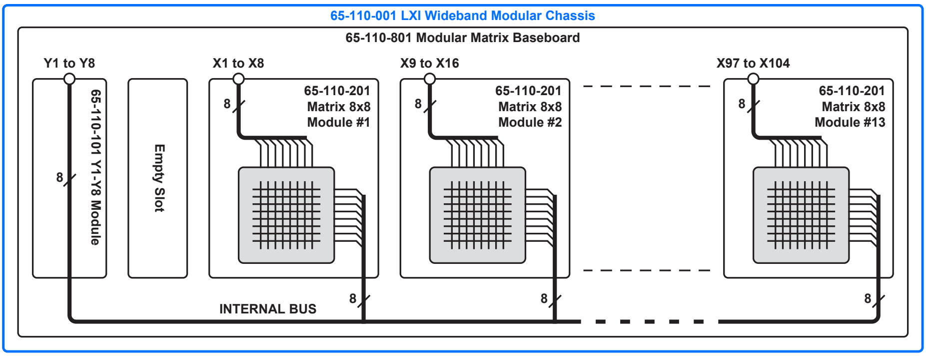

## 65-110 Wideband Modular Matrix

The 65-110 provides a wideband modular matrix platform with a matrix bandwidth in excess of 200MHz and excellent crosstalk performance.

Matrices are created by populating the 65-110 chassis with plugin modules that provide access to the X and Y connections on SMB connectors. The chassis is capable of supporting matrices with Y axis sizes of 8 or 16 connections and X axis size up to 104 connections in increments of 8. Users can specify as many or as few plugin modules as they require in constructing a matrix and can field upgrade the chassis to extend the matrix size.

The 65-110 has been designed to ensure it has low crosstalk and good VSWR performance over its entire operating frequency range, making it ideal for applications where high quality data acquisition is required on dynamic signals. It is particularly useful in applications where signal levels between channels vary significantly, making the application sensitive to crosstalk performance between channels.

The 65-110 includes a self test feature that checks the functionality of all the paths that the matrix supports while user connections are still attached but not applying signals.




**65-110 Configured as a 104x8 matrix using 65-110-001 LXI Wideband Modular Chassis, 65-110-801 Baseboard, 65-110-101 Y Module and 65-110-201 Matrix 8x8 Modules**

## LXI System Level Products

Pickering Interfaces provides a range of products to support other functions in a system.

The 60-200 provides an elegant solution for controlling the power on/off switches of other LXI Devices - or non LXI Devices. The 60-200 can control the AC power supply for up to 8 devices, allowing the power to each device to be turned on or off individually, or initiating a controlled power down or power up sequence in an ATE system. The sequences can be timed accurately to reduce inrush currents and ensure that order sensitive systems (such as PXI) are correctly sequenced.

Pickering Interfaces also manufactures adaptors and accessories for the LXI Wired Trigger Bus. They are designed to help debug a WTB system or provide conversion of signals to or from the WTB to products that do not support the WTB. LXI approved WTB cable assemblies and terminators are available to interconnect LXI Class A products together or to connect Class C products that support the WTB.

Power Management Switch

WTB Scope Adaptor

WTB Cables

Other Wired Trigger Bus Adaptors

| Name | Description | Product Code |
|---|---|---|
| Power Management Switch | Remote power switching of up to 8 devices | 60-200 |
| Wired Trigger Bus Probe | For monitoring the 8 WTB signals | 60-981 |
| Wired Trigger Bus Adaptor | Converts the 8 WTB signals into Low Voltage TTL | 60-982 |
| Wired Trigger Bus Terminator | For terminating the end of a WTB cable | 60-983 |
| Wired Trigger Bus Extender | Interconnects two WTB cables for greater reach | 60-984 |
| Wired Trigger Bus Cables | WTB compliant cables with lengths from 0.3m to 20m | 60-985 |
| Wired Trigger Bus Scope Adaptor | Allows all 8 WTB signals to be displayed on an Agilent DSO | 60-990 |

## *APPENDIX A*

## *THE LXI CONSORTIUM*

**Contents**

# About the LXI Consortium

The LXI Consortium is a not-for-profit corporation, its primary purpose is to promote the development and the adoption of the LXI Standard, an open standard created by the consortium for the control of test and measurement products.

The LXI Consortium is managed by a Board of Directors consisting of Strategic Level members of the consortium and currently elected members from the Participating membership level.

The Technical Committee manages the development of the standard through subsidiary working groups.

The Marketing Committee is responsible for the promotion of the standard.

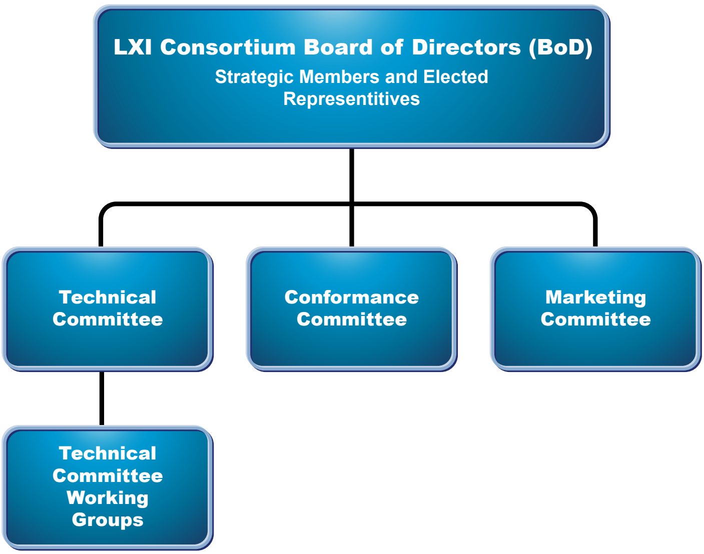
The Conformance Committee is responsible for establish the conformance test regime for the standard

| | |
|---|---|
| November, 2004, Salt Lake City | Inaugural meeting of LXI Consortium |
| September, 2005 | Publication of Version 1.0 of specification |
| December, 2005 | Agilent and Pickering launch first LXI Compliant products |
| September, 2006 | Publication of Version 1.1 of specification |
| October, 2006, Munich | First European meeting of LXI Consortium |
| June 2007, Beijing | First Asian meeting of LXI Consortium |
| November, 2007 | Publication of Version 1.2 of specification |
| October 30, 2008 | Publication of Version 1.3 of the specification |
| May 18, 2011 | Publication of Version 1.4 of the specification |
| October 20, 2011 | LXI HiSLIP Extended Function |
| March 14, 2012 | LXI IPv6 Extended Function |
| May 2013, Beijing | Second Asian meeting of the LXI Consortium |

More information on the consortium's activities can be found on the web site *www.lxistandard.org*.

## Membership Levels


## LXI Consortium Stucture



## *APPENDIX B*

## *GLOSSARY*

The following section contains a list of acronyms and other terms used in the LXI Standard. They are arranged in alphabetical order.

A listing of useful website addresses is included at the end of the section.

*Glossary of Terms used in the LXI Standard*

## API

API stands for Application Programming Interface.

## Auto-MDIX

Auto-MDIX is a protocol which allows two Ethernet devices to negotiate their use of the Ethernet TX and RX cable pairs. This allows two Ethernet devices without Auto-MDIX to connect without using a crossover cable. This feature is also known as Auto-crossover. 1000 base T interfaces always support Auto-MDIX.

## ARP

The address resolution protocol (ARP) is a protocol used by the Internet Protocol (IP), specifically IPv4, to map IP network addresses to the hardware addresses used by a data link protocol. It is used when IPv4 is used over Ethernet. The term address resolution refers to the process of finding an address of a computer in a network.

## Default gateway

A configuration item for the TCP/IP protocol that is the IP address of a directly reachable IP router. Configuring a default gateway creates a default route in the IP routing table.

## DHCP

See definition for: Dynamic Host Configuration Protocol (DHCP).

## Discovery

Process by which a controller can search for other devices on the network and find their IP address.

## DNS

See definition for: Domain Name System (DNS).

## DNS server

A server that maintains information about a portion of the Domain Name System (DNS) database and that responds to and resolves DNS queries.

## Domain name

The name given by an administrator to a collection of networked computers that share a common directory. Part of the Domain Name System (DNS) naming structure, domain names consist of a sequence of name labels separated by periods.

## Dynamic Host Configuration Protocol (DHCP)

The Dynamic Host Configuration Protocol provides a framework for passing configuration information to hosts on a TCPIP network. DHCP is based on the Bootstrap Protocol

(BOOTP), adding the capability of automatic allocation of reusable network addresses and additional configuration options. DHCP captures the behavior of BOOTP relay agents, and DHCP participants can interoperate with BOOTP participants. DHCP provides safe, reliable, and simple TCP/IP network configuration, prevents address conflicts, and helps conserve the use of client IP addresses on the network. DHCP uses a client/server model where the DHCP server maintains centralized management of IP addresses that are used on the network. DHCP-supporting clients can then request and obtain lease of an IP address from a DHCP server as part of their network boot process.

## Front Panel User Interface

A front panel user interface is defined as consisting of control and displays functions, located on the front panel of a device that can be used to set up critical aspects of the LXI interfaces and instrument operation.

## Hostname

A hostname is the unique name by which a network attached device is known on a network. The hostname is used to identify a particular host in various forms of electronic communication such as E-mail or Usenet.

## HTML

Hypertext Markup Language. A simple markup language used to create hypertext documents that are portable from one platform to another. HTML files are simple ASCII text files with codes embedded (indicated by markup tags) to denote formatting and hypertext links.

## HTTP

Hypertext Transfer Protocol. The protocol used to transfer information on the World Wide Web. An HTTP address (one kind of Uniform Resource Locator [URL]) takes the form: http://www.pickeringtest.com.

## ICMP

Internet Control Message Protocol (ICMP) is a required protocol tightly integrated with IP. ICMP messages, delivered in IP packets, are used for out-of-band messages related to network operation or mis-operation.

## IEEE

Institute of Electrical and Electronics Engineers. A global technical professional society and standards-setting organization serving the public interest and its members in electrical, electronics, computer, information and other technologies.

## IEEE 1588 (PTP)

IEEE 1588 is a standard for a precision clock synchronization protocol for networked measurement and control systems. It is also known as the Precision Time Protocol (PTP).

## Internet Protocol (IP)

A routable protocol in the TCP/IP protocol suite that is responsible for IP addressing, routing, and the fragmentation and reassembly of IP packets.

## IP address

An address used to identify a node on an IP internet network. Each node on the IP internet network must be assigned a unique IP address, which is made up of the network ID, plus a unique host ID. This address is typically represented with the decimal value of each octet separated by a period (for example, 192.168.7.27). You can configure the IP address statically or dynamically by using DHCP.

## IVI

IVI stands for Interchangeable Virtual Instrument. The IVI Foundation is an open consortium founded to promote specifications for programming test instruments that simplify interchange ability, provide better performance, and reduce the cost of program development and maintenance.

## LAN

Local Area Network. A communications network connecting a group of computers, printers, and other devices located within a relatively limited area (for example, a building). A LAN allows any connected device to interact with any other on the network.

## LCI

LAN Configuration Initialize (LCI) is a LXI devices recessed reset mechanism (e.g., a button) on the rear or front of the module that when activated places the module's network settings to a default state.

## LVDS

LVDS stands for Low-Voltage Differential Signaling.

## LXI

LXI stands for LAN eXtensions for Instruments. LXI is the next generation instrumentation platform based on industry standard Ethernet technology and provides modularity, flexibility and performance to small- and medium-sized systems.

## LXI Device

Any device that has been tested and confirmed as being conformant with the LXI standard.

## M-LVDS

Multipoint Low-Voltage Differential Signalling conforming to the TIA/EIA-899 standard, which allows multiple transmitters and receivers to be interconnected on a single, balanced, doubly terminated media pair. Multipoint operation allows for bidirectional, half-duplex communication between multiple devices connected to the same transmission line.

## M-LVDS Type-1

One of two classes of M-LVDS receivers, having a differential input voltage threshold centered about zero volts. Differential input signals below -50mV are defined by the TIA/EIA-899 standard to be in the low state, and signals above +50mV are defined to be in the high state. When the input of a Type-1 receiver is connected to an undriven twisted pair, the differential input voltage is defined to be in the threshold transition region. This condition will result in a stable, but undefined, output.

## MAC

Media Access Control. A sub layer of the IEEE 802 specifications that defines network access methods and framing.

## MAC Address

Media Access Control address. A unique hardware number that identifies each device on a network. A device can be a Instrument, computer, printer, etc.

## mDNS

Multicast DNS. A Discovery protocol originated from Apple that is the basis of Bonjour/ Rendezvous.

## MIB

Short for Management Information Base, a database of objects that can be monitored by a network management system. Both SNMP and RMON use standardized MIB formats that allows any SNMP and RMON tools to monitor any device defined by a MIB.

## NIC

Network Interface Card, such as an Ethernet adaptor.

## Ping

A utility that verifies connections to one or more remote hosts. The ping command uses the ICMP echo request and echo reply packets to determine whether a particular IP system on a network is functional. Ping is useful for diagnosing IP network or router failures.

## PoE

IEEE 802.11f Power Over Ethernet is a technology for wired Ethernet LAN that allows the electrical current, necessary for the operation of each device, to be carried by the CAT5 data cables instead of a traditional power cord.

## PTP

Precision Time Protocol.

## SCPI

The Standard Commands for Programmable Instrumentation (SCPI) defines a standard set of commands to control programmable test and measurement devices in instrumentation systems. The SCPI Standard is built on the foundation of IEEE-488.2, Standard Codes and Formats.

## SNMP

Simple Network Management Protocol (SNMP). A network protocol used to manage TCP/IP networks. In Windows, the SNMP service is used to provide status information about a host on a TCP/IP network.

## SOAP

Simple Object Access Protocol. A protocol defined by the XML Protocol Working Group of the W3C. It can be used to exchange structured data between peers in a distributed system It can be used to control LXI Devices.

## Star Hub

An LXI Device that can be used to connect Wired Trigger Bus chains together, in doing so providing electrical isolation between the chains. They can be used to extend the maximum number of LXI devices that can participate in a wired trigger event by providing a mapping function between the Wired Trigger Bus chains. Star Hubs can be stand alone devices or can be embedded LXI devices having other functionality. They are the only LXI device that is permitted to have an embedded termination for a Wired Trigger Bus.

## Subnet

A subdivision of an IP network. Each subnet has its own unique subnet network ID.

## Subnet Mask

A 32-bit value that enables the recipient of IP packets to distinguish the network ID and host ID portions of the IP address. Typically, subnet masks use the format 255.x.x.x.

## TCP/IP

Transmission Control Protocol/Internet Protocol (TCP/IP). A set of networking protocols widely used on the Internet that provides communications across interconnected networks of computers with diverse hardware architectures and various operating systems. TCP/IP includes standards for how computers communicate and conventions for connecting networks and routing traffic.

## UDP

The User Datagram Protocol (UDP) is one of the core protocols of the Internet protocol suite. Using UDP, programs on networked computers can send short messages known as datagrams to one another.

### URL

Uniform Resource Locator (URL). An address that uniquely identifies a location on the Internet. Generally an URL specifies the connection protocol and a file name. The connection protocol can be: telnet, ftp, gopher, etc., and for web pages, http is the usual protocol as in the URL http://www.pickeringtest.com.

### UTC

Coordinated Universal Time (abbreviated UTC) is the basis for the worldwide system of civil time. This time scale is kept by time laboratories around the world, including the U.S. Naval Observatory, and is determined using highly precise atomic clocks.

### VISA

Most of the instrument drivers communicate to the instrumentation hardware through an I/O Library. The VISA library is used for the GPIB, VXI, PXI, Serial, Ethernet, and/or USB interfaces, while other buses can either utilize VISA or another library.

### W3C

The World Wide Web Consortium (W3C) develops interoperable technologies (specifications, guidelines, software, and tools) to allow the World Wide Web to exploit its full potential as a forum for information, commerce, communication, and collective understanding.

### Useful website addresses:

Pickering Interfaces Ltd ...................................................... www.pickeringtest.com

Institute of Electrical and Electronics Engineers (IEEE) ....... www.ieee.org

IVI Foundation ..................................................................... www.ivifoundation.org

LXI Consortium .................................................................... www.lxistandard.org

PXI Systems Alliance .......................................................... www.pxisa.org

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