LXI Reference Design Overview

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Introduction

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

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

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

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

LAN instrument vs. LXI instrument

A LAN-enabled instrument is one that can be connected and controlled over LAN by a computer. Instruments have had LAN interfaces for many years, but the **LXI Standard** establishes a standardized behavior for all conformant devices when connecting to LAN. This means you can connect a wide variety of products from one or many companies together using LAN, and they all behave in a standardized manner to simplify Test System configuration and communication. Here are major aspects of instruments that are conformant to the LXI Standard and can display the LXI Logo:

- Consistent set of LAN communication services
- LAN discovery and configuration support
- Standard Web page for configuration and control
- IVI driver
- Interoperability testing

This list of requirements to be LXI conformant is not trivial to achieve and significant effort by each vendor occurs for their products to become and remain LXI conformant.
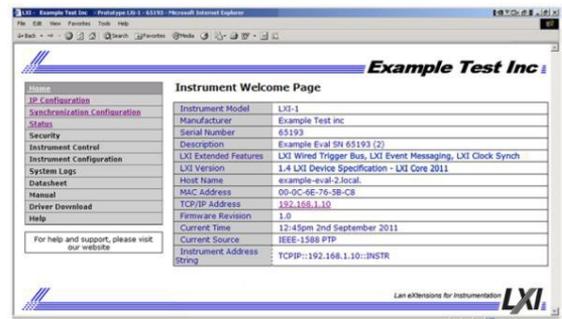
Purpose of LXI Reference Design

One of the strategies of the LXI Consortium to achieve its vision of LXI global adoption and utilization is to provide a "technical blueprint" for vendors to use when building LXI instruments. Several goals were established:

- Ensuring more Test & Measurement (T&M) LXI-conformant instruments are available to our customers, enabling them to have a lower cost, consistent, predictable, and multi-vendor interoperable experience when building network-based T&M test systems.
- Enabling existing and new LXI Consortium members to cost effectively, develop and maintain LXI instruments that support the LXI "Core" and "Extended Function" capabilities.
- Enabling the LXI Consortium to more easily work with its membership to evaluate new and emerging network technologies as additions to the LXI Standard and deploy the additions to the membership through the LXI Reference Design and Implementation.

The LXI standard has reached a stable version number with a set of *Extended Functions*: ***LXI Device Specification 2011 Version 1.4***. This latest specification is perceived to create an entry barrier for some new vendors, and some existing vendors have products that have not migrated beyond earlier versions of the LXI Standard.

Significant improvements in LAN discovery of LXI Devices occurred with LXI Standard 1.3, since it introduced the support of mDNS Discovery. Version 1.4 adopted Extended Functions to provide vendors with the ability to pick-and-choose various advanced features such as LXI Wired Trigger Bus, LXITiming, LXI Event Logs, and LXI Event Messaging.

LXI Devices conformant to versions before LXI 1.3 are prevented from introducing newer products through technical justification to the older standard. The effort to migrate those products to the current revision of LXI is significant. In addition, existing vendors of products conformant to 1.3 and 1.4 periodically update their hardware platforms and have to adapt their LXI designs to the new hardware and re-apply for LXI conformance due to changes in operating systems, LAN hardware, and LAN drivers.

The LXI Reference Design, funded by the LXI Consortium and its membership, can be used by the majority of vendors to aid transitioning of versions of the standard, ease platform migration, encourage the adoption of Extended Functions and attract new LXI vendors by lowering the entry barriers.

The LXI Reference Design will be released March 17, 2016. Members will be able to evaluate the reference design beginning at that time.

Benefits of the LXI Reference Design

The following pulls together the overall benefits of the LXI Reference Design and specifically calls out the common and group-oriented benefits:

- Lower barriers to LXI entry
- Reduces design cost
- Makes it more likely to pass the LXI Conformance test the first time
- Use of LXI logo gains more market acceptance
- Fewer support issues since members can use the support documents created by the LXI Consortium

Members who make Software Products

- Creation of test platform allows testing of software products
- Fewer software support issues if vendors are basing on a reference model

University Members

- Porting of Reference Design into hardware and software platforms as university

Vendors who only make products prior to LXI 1.3/1.4

- Lower barriers to product migration
- Ensure support for mDNS Discovery as VXI-11 Discovery is eventually removed
- Lowering long term design costs
- Easier to create new products that are 1.4 Conformant

Vendors who have progressed to 1.3/1.4

- Provides a route to migrate new hardware platforms to LXI
  - Reduce design costs
  - Reduce barriers to Extended Functions inclusion
 - More surety of fist time conformance test pass
- Provide support across more variety of hardware and operating systems
- More cohesive approach to LXI across divisions of the company
  - Reduction in engineering costs and easier support

LXI Reference Design Components and   Architecture

Each LXI Device is required to supply an IVI Driver to control LXI Devices. The IVI Driver provides a common interface between LXI Devices and shields the programmer from the specific command language (native language) used in various LXI Devices. A concept called Native Driver also exists for software such as NI's LabVIEW or MathWorks' MATLAB, where developers write a specific driver using the LXI Device's command language. This gains the benefit of creating a driver interface that is well adapted for the particular Application Software.

If a particular Application Software does not use a driver to control the LXI Device, the terminology Direct I/O applies. Instead of interfacing with an API (Application Programming Interface), the LXI Device's command language embeds directly into the source code of the Application Software.

The Figure below illustrates a summary view of using the IVI Driver or Direct I/O. The IVI Driver can communicate through VISA or other vendor-supplied interface software. Replace the Application Software with NI LabVIEW, and the IVI Driver box with an NI LabVIEW driver, and you have another method of driver control. Place the LXI Device command language directly into the source code of the Application Software and interface through VISA, the Client Side API, or the Socket, and you have Direct I/Ocontrol.
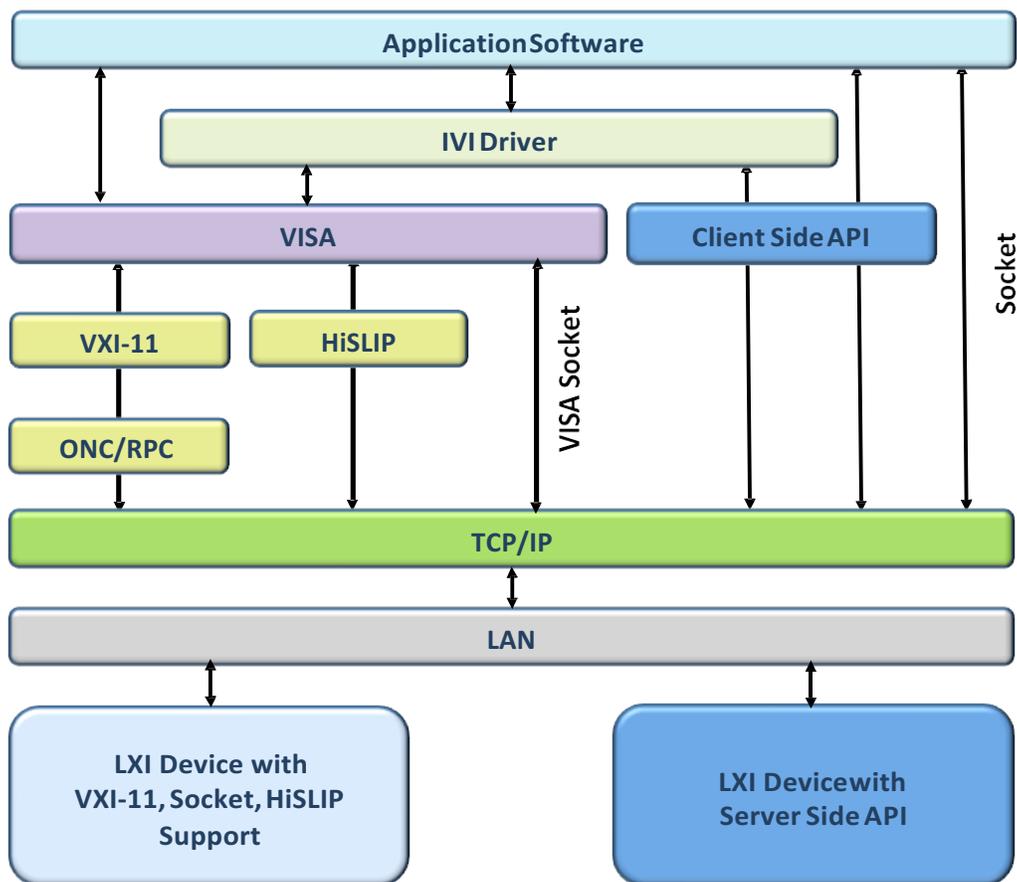
The LXI Reference Design focuses effort on the lower interaction between TCP-IP layer and the LXI Device's LAN interaction. It is a significant effort to implement the interactions between the layers of LAN protocol, provide LAN discovery, general communication, Web-page setup of proper LAN configuration, etc. The LXI Reference Design addresses these base and more advanced capabilities.

The following diagram focuses on the LXI Reference Design interaction with the previous diagram:
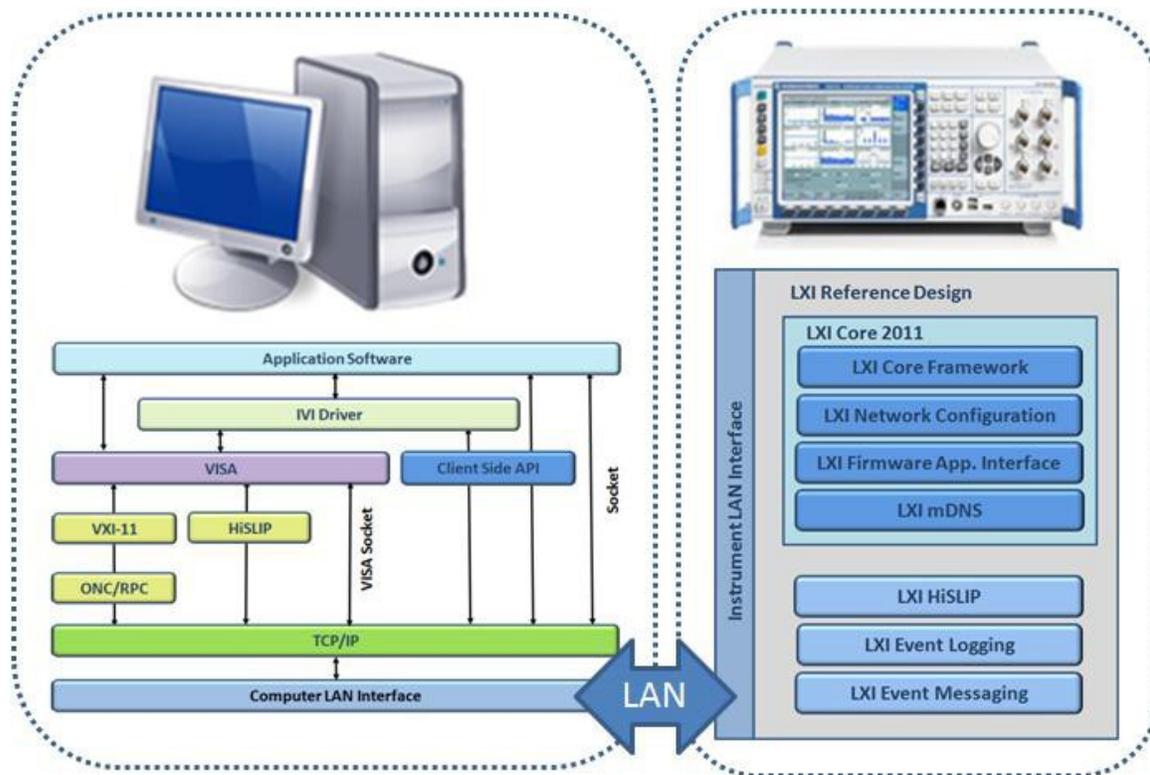
Basically the system design bases on the idea, that all LXI extended functions are placed in separate modules, which can be loaded independently during start-up. A small and simple LXI Core Framework handles this module concept. The communication between all modules is standardized and implemented in two separate classes (Provide Interface / Require Interface). The communication differs in asynchronous notification and synchronous commands/responses.

The system design identifies 10 different modules:

- LXI Core Framework

- LXI Network Configuration Module

- LXI Firmware Application Interface Module

- LXI mDNS Module

- LXI HiSlip Module

- LXI Event Logging Module

- LXI Event Messaging Module

- LXI Wired Trigger Bus Module

- LXI Timestamped Data Module

- LXI Clock Synchronisation Module

The following modules are mandatory and represent the LXI Core 2011 functionality:

- LXI Core Framework

- LXI Network Configuration Module

- LXI Firmware Application Interface Module

- LXI mDNS Module

The following modules are optional, the vendor has the ability to configure and use these modules:

- LXI HiSlip Module

- LXI Event Logging Module

- LXI Event Messaging Module

Currently three modules depend on a dedicated hardware, which is not available. So these three modules are currently out of scope for the LXI reference design:

- LXI Wired Trigger Bus Module

- LXI Timestamped Data Module

- LXI Clock Synchronisation Module

Key Features

OS Independent Abstraction Layer

Due to the fact that the LXI Reference Design should be available on different operating systems, all OS specific APIs, calls and types must be encapsulated. For the LXI reference design the OS Abstraction Layer is split into three parts:

- LXI OS Abstraction Layer (Runtime)

- LXI OS Abstraction Layer (Network Config)

- LXI OS Abstraction Layer (Network Communication)

LXI Reference is designed for Low Ended Devices

All Resources within the LXI Reference Design can be controlled by the vendor. A large set von configuration items for the resources are defined.

Also the LXI Reference Design uses only a minimum of dynamically allocated memory. All containers works with predefined fixed sizes, so the vendor can control the memory usage of the LXI Reference Design.

To avoid complex C++ constructs, the LXI Reference Design avoid the following C++ constructs:

- Using template

- Complex inheritance

- Defining and using of operators

- Copy constructor and assignment operator

Web Server

Each vendor may adapt his implementation and use any Web Server of their choice, but the following two approaches are provided:

- The minimalist approach, - using Civitweb, a small free Web Server, which is directly embedded into the software with its source code
- The sophisticated approach – using NginX, a complex Web Server.

Additionally an interface definition is available for accessing the web server, so every vendor specific web server could be used. The implementation of the interface must be done by the vendor.

Network / IPv6

IPV6 is an optional extension in the LXI specification. Due to the fact, that this extension affects the complete OS Abstraction layer, the functionality cannot be added as a module (as the other extensions are). To avoid a complex design, the IPV6 functionality is part of the OS Abstraction layer and is implemented. Only the visibility of the IPV6 can be controlled via configuration. This means that all modules must implement both the IPV4 and IPV6 functionality, whether or not IPV6 is supported and whether or not IPV6

is configured at the interface or at the web pages.

IPV6 might be too expensive for some low end instruments. Thus a conditionally compile option will be provided to exclude IPV6 from source code. Note: Web pages must be adjusted manually by vendor to exclude IPV6.Pv6 can be activated or deactivated at compile time.

mDNS

The mDNS module uses Apple's free Bonjour implementation for Windows and Linux and works for both IPv4 and iPv6.

HiSLIP

The "LXI HiSlip Module" is responsible for the HiSLIP support. The HiSLIP Process and the LXI Reference Design run in different process spaces.
The HiSLIP process may run either in its own process space or in the firmware process space, depending on vendor's firmware implementation. It is intended to be integrated closely into the vendor firmware. The interfaces and the interactions between HiSLIP and vendor firmware have been the focus of testing by vendors such as Rohde&Schwarz and Keysight Technologies.

LXI Event Messaging

The LXI Reference Design includes a complete implementation of the LXI Event Messaging. So the vendor can easily use them in his firmware. With the LXI Event Message Extended Function the vendor has the ability to send and receive LAN events from other instruments.

Firmware Application Interface

The Firmware Application Interface is responsible for the data exchange between the LXI Reference Design and the vendor's firmware. The vendor have to implement the interface for their own needs and abilities.

Virtual Instrument

The LXI Reference Design includes a demo software called "Virtual Instrument", which shows all features of the LXI Reference Design to the vendor. This demo software demonstrates how the vendor can use the LXI Reference Design and the different Extended Functions. To use the LXI Event Message Extended Function the "Virtual Instrument" has included a small SCPI-Parser which provides basic tests functionality for the vendor. In addition, a basic IVI-Driver is also available, so the LXI Testsuite can be used for the LXI Event Messages Tests. Also shows the "Virtual Instrument" how the vendor can interact with the LXI Reference Design over "Firmware Application Interface".

LXI Reference Design Package

Lxi Reference Design Package is located on a secure area of the LXI web site and it includes the following files:

- UML Design Model, created with Enterprise Architect. It contains all requirements, all classes, and several sequence diagrams and state diagrams
- A Design Document as a PDF export of the model, enhanced with additional documentation
- The Source Code plus unit test source code, ready to use with Microsoft Visual Studio on Windows or Eclipse on Linux
- HTML documentation of the classes and their methods, created with Doxygen.
- A "How-To" document, helping users to get started
- A "System Calls " document helping users to get Privileged Calls within the
    o LXI Reference Implementation
- Scripts for your firewall configuration on Windows and Linux
- Microsoft Visual Studio settings files for user friendly debug
- Scripts for Start and Stop the Reference Design as Service on Windows and on Linux
- Scripts for Start and Stop your Nginx-Webserver on Linux

To get access to the LXI Reference Design please contact Bob Helsel at execdir@lxistandard.org.

LXI Reference Design Testing

As indicated in the Package Contents, there are unit tests included, covering the basic functionality of the modules. These unit tests can be used as regression tests. Ultimately, the LXI Conformance Test Suite is used to detect problems, of which the LXI Consortium will be performing these tests to verify the design. The Reference Design Testing will be realized using the documents "Software Test Plan" (STP) and "Software Test Report" (STR).

STP describes all the necessary tests for the LXI Reference Design. All test steps and their expected results are documented. Also the relationships between the test cases and the requirements are shown in this document. The Testing will be performed on the test PCs or a test virtual machine with the following test environment:

- Windows 7
    - Visual C++ Redistributable Packages for Visual Studio 2013
- Linux i386
    - Ubuntu 14.04 LTS
    - Qt5-Default
    - without Avahi-Deamon
- Linux Arm
    - Lubuntu 12.10
    - Qt4-Default
    - without Avahi-Deamon

In the STR will be reported the result of the LXI Reference Design software tests. This Document refers to all requirements from STP respectively LXI Reference Design.

LXI Reference Design Vendor Forum

LXI Reference Design Vendor Forum made possible the members to communication respectively to ask a question and sharing of information. The Members can share their knowledge on the LXI web site:

http://vendorforum.lxistandard.org/ . The vendors need to register with Bob Helsel at execdir@lxistandard.org before using the forum.

Actually, there are three main Spaces under LXI Ref Design which names are General, Support and Technical. The questions can be better allocated with the correct selected space. With this way, the Question is most likely to be answered. By means of "Ask an Expert" functionality you can ask your question to an expert who is sure to have the answer to this question.

LXI Reference Design Support

TSE Plazotta is the developing company contracted by the LXI Consortium to implement and document the LXI Reference Design, with the help and input of participating LXI Members. LXI Members can begin to integrate the LXI Reference Design into their firmware, and TSEP will provide support on a consultancy basis and can also offer training. This can cover the concepts, configuring the LXI Reference Design, introducing unit tests and giving an overview of the LXI Conformance Test Suite.

TSEP offers different support for the vendors, depending on their needs:

- On a consultancy base, TSEP can offer training for vendor developers. This can cover understanding the concepts, configuring the LXI Reference Design, introducing unit tests and giving an overview of the Conformance Test Suite. After that, vendor developers will be in charge of their respective projects, with TSEP assistance on demand.

- Premium support, which means vendors, may contact TSEP directly in case support is needed for integrating LXI Reference Design into their firmware.

- Full integration of the LXI Reference Design into vendor firmware

Base for all kinds of support is a NDA, because to integrate the LXI Reference Design into the vendor's firmware, TSEP has to have a close look into the vendor's firmware concept and implementation. To ensure the secrecy a NDA has to be established. TSEP can provide a NDA template, also a vendor's template could be used.