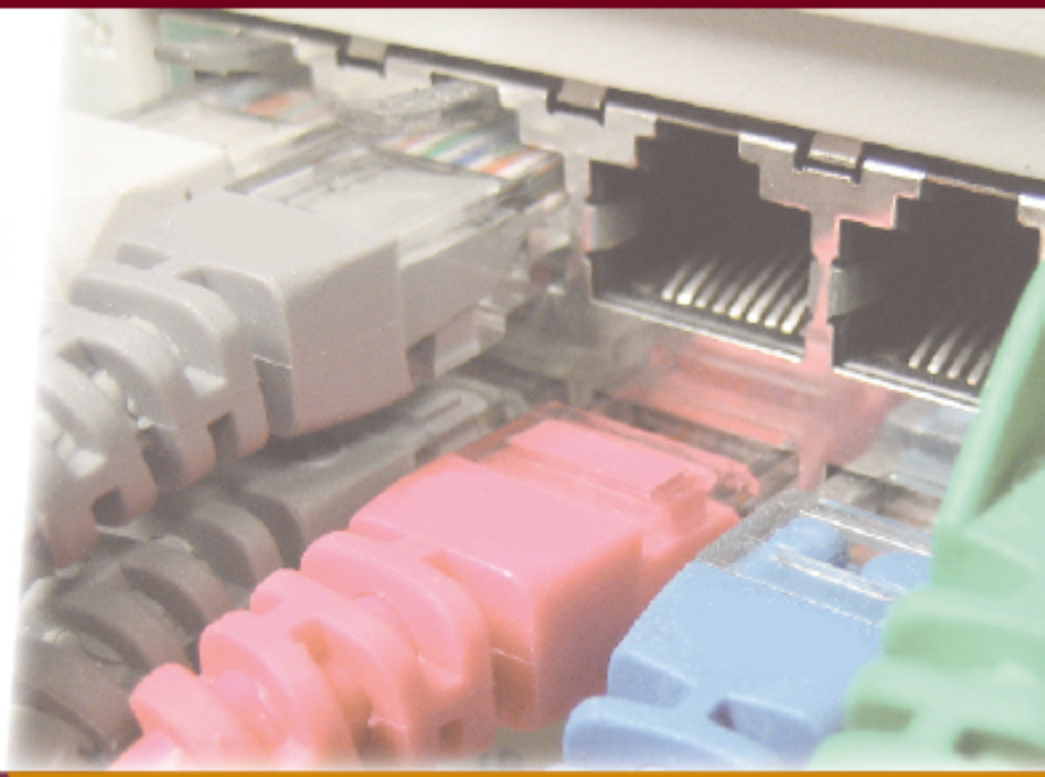
LAN eXtensions for Instrumentation



LXI Standard Rev. 1.3

October 30, 2008

LXI Standard

Revision 1.3

October 30, 2008 Edition

Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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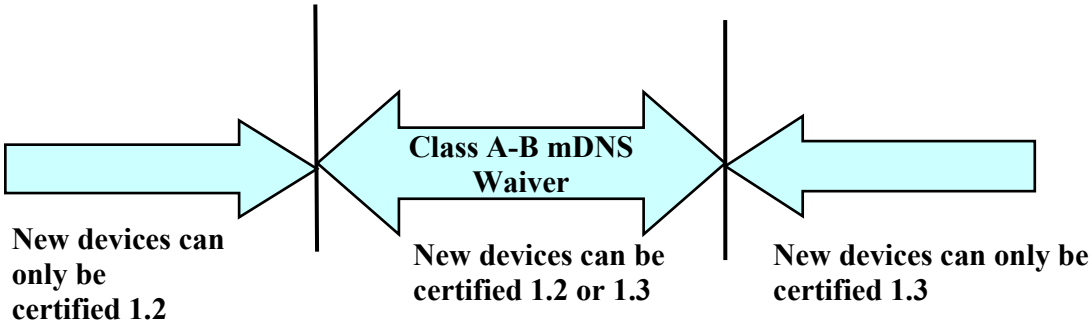
Provisional Conformance for IEEE 1588-2008 Class A and B LXI Devices.

Some vendors have developed new class A and B LXI Devices prior to the publication of the LXI specification 1.3. These LXI Devices may not be fully compliant to version 1.3 in the area of mDNS discovery protocol, but they are compliant to the new IEEE 1588-2008 specification and to the version 1.2 LXI specifications.

The Previous Version End (PVE) date is the date when the transition period ends. After the PVE Date, "New" devices can no longer be certified to version 1.2 of the LXI Specification. For Version 1.3 of the LXI Specification, the Previous Version End Date is 1 November 2009.



NVS Date 1 - Oct - 2008

PVE Date 1 - Nov - 2009

Waiver for mDNS support:

LXI Devices which are missing the mDNS support (paragraphs 10.3 through 10.8) and the associated web (paragraphs 9.5.6 through 9.5.8) and LXI Device identification schema (10.2) changes required by the 1.3 LXI specification can be provisionally approved as Class A and B at Revision 1.3. To attain this provisional approval, the vendor must declare that:

1. The mDNS changes will be available for retesting prior to PVE date (Nov 1, 2009).
2. The LXI Device must be capable of being upgraded in the field by a firmware upgrade routine or program.

Class A-B LXI Devices that are granted provisional approval need not be completely retested after implementing mDNS; however, vendors must re-submit the LXI Device for testing of mDNS and possible spot-checking of overall compliance prior to Nov 1, 2009. This retesting may be performed at a scheduled Plugfest, over the LXI VPN, or other arranged venue. Retesting is expected to take 10-20 minutes. Vendors are responsible to notify their customers that the LXI

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Devices have a waiver and are not fully 1.3 compliant. This could be announced on the home page of the LXI Device as an exception to the LXI compliance declaration. A possible example:

LXI Version:	LXI Version 1.3*

* At LXI compliance testing, this product received a waiver until Nov 1, 2009, to implement the mDNS discovery protocol.

Devices that are product refreshes of existing devices or that are new devices built on a platform designed for conformance with a previous revision of the specifications can be certified to the older version provided the devices meet the eligibility requirements for certification by technical justification. These cases are not subject to the dates specified above.

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Interpretations Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of LXI Consortium, the Consortium will initiate action to prepare appropriate responses. Since LXI Consortium Standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, LXI Consortium and the members of its working groups are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

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LXI is a registered trademark of the LXI Consortium, and this specification outlines the requirements needed to claim LXI compatibility. The specification strives to ensure compatibility among devices when used in a test system environment, and the authors tried to bias in favor of a simple user experience. It also strives to define interfaces rather than implementations, whenever possible, to preserve company-specific intellectual property.

This specification is the property of the LXI Consortium, a Delaware 501c3 corporation, for the use of its members.

The LXI Consortium draws attention to the fact that it is claimed that compliance with this document may involve the use of a patent or patents concerning technology described within the document. The LXI Consortium takes no position concerning the evidence, validity and scope of this patent right. The holder of this patent right has assured the LXI Consortium that he/she is willing to negotiate licenses under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right is registered with the LXI Consortium. Additional information may be obtained from the LXI Consortium's Web site:

http://www.lxistandard.org

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights other than those identified above. The LXI Consortium shall not be held responsible for identifying any or all such patent rights.

Comments for Revision Comments for revision of LXI Consortium Standards are welcome from any interested party, regardless of membership affiliation with LXI Consortium. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Comments on standards and requests for interpretations should be addressed to:

Secretary, LXI Consortium Standards Board
www.lxistandard.org

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Revision history

Revision	*Description*
1.0 Sept 23, 2005	Initial version was adopted 9/23/2005.
1.1 Apr 2006	For a complete list of changes between 1.0 and 1.1, please refer to the 1.1 version of the standard. The following is a summary of some of the most salient changes for easy reference. • Over-Current Protection (2.7.7.1) changed to a recommendation • Wired OR behavior modified to disallow bias source to signal • Event Log requirements clarified • Rule 8.6 deprecated and LAN Configuration and Status behaviors clarified (Section 8) • Minimum HTTP version modified to 1.0 and XHTML permitted (Section 9) • Conformance requirements and processes clarified (Section 14) • Hybrid Systems clarifications added (Section 15) • Cable and terminator specification (Appendix C) moved to separate document
1.2 Aug/Sept 2007	Notice of Effective Dates and Grandfathering added to document. Dropped references to Version 1.0 from testing requirements.
	Added descriptions of roadmap items and future rules.
	Replaced IEEE 1588-2007 with IEEE 1588-2008 throughout document.
	1.5 – Changed reference and related URL from LXiSync Interface Specification to IVI-3.15: IviLxiSync Specification. Updated URL for VISA Specification.
	2.8.3.2, 2.8.3.2.1, and 9.6 – Clarified LED usage for IEEE 1588 clock status
	3.1 - Added Roadmap item to Section 3.1 regarding conformance with IEEE 1588-2008, which will be required shortly after that version is approved by the IEEE.
	3.3.1 – Explained reason for deprecating this rule.
	3.3.2 – Clarified the meaning and behavior of LXI Event timestamp, T1, offset/delay, and T2 in Section 3.3.2. Reorganized itemized lists for parallel structure.
	3.4 – Clarified requirements for time-based triggering.
	3.10 – Narrowed requirements for internal event logs to module-to-module LAN messages. Changed reference in Observation from Recommendation 3.10 to Rule 3.10. Added Recommendation 3.10.1 to define significant events that should also be logged.
	3.12 – Added future rule for Pulse-Per-Second Output.
	4.4 – Clarified the following terms: Event ID field, Sequence, UInteger. Deprecated use of Bit 1 for retransmission. Clarified reference to table in section 6.4.4. Clarified use of Bit 2- Hardware Value and Bit 4 – Stateless Event.
	4.4.4 – Deprecated the rule for retransmitted LAN messages; explanation of change added.
	4.4.4.1 – Deprecated the rule for handling of retransmitted LAN messages; explanation of change added.
	5.4.4 – Changed reference from LXI Sync Interface Specification to IVI-3.15: IviLxiSync Specification.
	6.4.3 – Modified text to explain use of Flag Bit 2 and Flag Bit 4 in LXI Events.
	6.4.4 – Divided table of standard strings in two, one covering triggering and synchronization and one covering event generation. Added references to use of Flag Bit 4 in LXI Event messages.
	6.7.1 – Modified the rule to cover LXI Event interpolation and revised the text. Added an observation describing behavior improvements thus enabled.

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	6.8 – Updated the Event Log definition to meet Rule 3.10 and 6.8.1 requirements. Added cross-reference to 3.10.
	6.8.1 – Clarified event log semantics to add FIFO buffer behavior and support for operation when the buffer is full.
	8.14 – Added 10.7.1 to table entry for multicast DNS (mDNS) and DNS service discovery (DNS-SD). Added note clarifying mDNS and DNS-SD requirements in Version 1.2.
	9.15 – Added new rule that reserves all URLs beginning with "LXI" in any combination of upper- and/or lowercase letters.
	9.2.1 – 9.2.1.1 and Appendix A. Made changes to sections regarding InstrumentAddressString and related identification schemas.
	9.6 – Corrected table entry for "current observed variance of parent" and added new observation pertaining to the value. Added new entries for IEEE 1588 domain and LXI module-to-module parameters.
	10 – Changed chapter name to "LAN Discovery and Identification." Added sections 10.2 through 10.2.4.2 pertaining to Identification Schemas. Removed roadmap item.
	10.3 through 10.8 – Added an extensive series of future rules and permissions for the support of mDNS and DNS-SD.
	10.3.3.1 and following sections – Agreed upon use of "link local" host and service names.
	10.3.4 – Clarified wording of future rule on DHCP host name option.
	10.4.3 and 10.4.3.1 – Clarified use of empty TXT records.
	10.7.1 – Created future rule for hostname and service name default usage.
	14.5.1.2 and 14.5.1.4 – Deprecated these two rules specifying use of multiple devices for interoperability during conformance testing. Deprecated in favor of Rule 14.5.1.3.
	Replaced Synchronization Configuration image in Appendix A.
	Added new Appendix B that provides LXI Event packet and data payload examples.
	Added new Appendix C with XML Example Identification Documents. Added URL for location of LXI XSD Schema.
	Added new glossary entries for Schema, XSD, and LXI Identification XSD Schema.
1.2.01 Nov 2007	Fixed typographical error in Section 8.
1.3 Sept/Oct, 2008	Updated standard to mandate use of IEEE 1588-2008 and mDNS discovery. Removed LXI Unit in section 2. Deprecated and removed the following clauses from version 1.2.01: 2.1.1.4, 2.3.1.2, 2.3.1.3, 2.4, 2.5, 2.6, 2.10, 3.2.1, 3.3.1, 3.11, in 4.4 flags bit 1, 4.4.4, 4.4.4.1, 7.3.1, 7.3.1.1, 8.6, 9.14, 9.14.2, 11, 14.5.1.2, 14.5.1.4. Former future rules made rules: 3.12, 10.3, 10.3.1, 10.3.1.1, 10.3.3, 10.3.4, 10.4, 10.4.1, 10.4.2, 10.4.2.1, 10.4.2.2, 10.4.2.3, 10.4.3, 10.4.3.1, 10.4.3.2, 10.4.3.3, 10.4.3.4, 10.4.3.6, 10.4.3.7, 10.4.3.8, 10.5, 10.5.1, 10.6, 10.7, 10.7.1, 10.8 Removed all roadmap items. Replaced time stamp with timestamp everywhere. Revised for clarity on class definition as follows: Added 1.9.1.2 and subclauses defining exact requirements for each class and options. Old 3.11 and 3.12 moved to the end of section 3.2. Old 3.3 rewritten as new 3.3.1. Old 6.7, 6.7.2, 6.7.3, and 4.2 moved as subsections of 3.3.1. Old 6.7.1 moved to 3.3.8. Added new 3.3.7 to replace and augment portions of old 3.3.6. Old 3.3.5 generalized and made 3.4. Old 3.9 split with event-related part updated and move to new 3.3.7 and data-related part moved to 3.6.

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	Old 3.5, 3.6, and 3.7 consolidated in 3.5. Old 5.2 and 5.2.11 replaced by specifications in 1.9.1.2. Added 12.2.1 and 12.2.2 to clarify use of LXI Trademark with respect to LXI features. Augmented 12.2 with respect to use of LXI Functional Class descriptions using the LXI Trademark. Minor modifications made to 12.3 as a result. Removed all text and figures referencing the LXI Conformance spreadsheet, which no longer exists. Converted 13.5.1 to a rule and added new rule 13.5.1.1 clarifying role of conformance testing as a requirement for permission to use the LXI Trademark as specified in various parts of section 12. Changed "trigger-related" to "measurement-related" in rule 3.5.1 observation

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1 Overview and Class Definition

This standard has been written and is controlled by the members of LXI Consortium, a not-for-profit organization created for the development and promotion of a LAN (Ethernet) based standard for instrumentation and related peripheral devices. This LXI Standard details the technical requirements of LAN-based devices that are LXI conformant.

1.1 Intended Audience

This LXI Standard is intended for use by designers, integrators and users of devices that are designed to be LXI conformant.

1.2 Background and Terminology

LXI is an acronym for LAN eXtensions for Instrumentation. The LXI specification details the technical requirements of LXI Devices using Ethernet as the primary communications means between devices.

This standard makes use of a number of widely accepted acronyms that are defined in the glossary.

1.3 Purpose and Scope of this Document

This document defines a set of **RULES** and **RECOMMENDATIONS** for constructing a conformant LXI Device that interfaces to a local area network with Ethernet protocols. The specification covers physical, functional, electrical, and software aspects of conformant LXI Devices.

Key objectives in the development of this standard for test and measurement instrumentation have included:

1. Unambiguous communication amongst LXI Devices
2. A reduction in the physical size of test systems
3. Decreasing the cost of test system software development by the use of industry-standard protocols and interfaces
4. Provision of a standardized trigger and synchronization mechanism between LXI Devices
5. Increasing system performance by using high-speed, Ethernet protocols
6. Taking advantage of the simplicity of physical Ethernet connectivity.
7. Supporting the use of synthetic instruments
8. Supporting the use of other device interfaces, where appropriate, in systems having LXI conformant elements

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1.4 Definition of Terms

Throughout this document, you will see the following headings on paragraphs. These headings identify the contents of the paragraph:

RULE: Rules **SHALL** be followed to ensure compatibility for LAN-based devices. A rule is characterized by the use of the words **SHALL** and **SHALL NOT**. These words are not used for any other purpose other than stating rules.

RECOMMENDATION: Recommendations consist of advice to implementers that will affect the usability of the final device. Discussions of particular hardware to enhance throughput would fall under a recommendation. These should be followed to avoid problems and to obtain optimum performance.

SUGGESTION: A suggestion contains advice that is helpful but not vital. The reader is encouraged to consider the advice before discarding it. Suggestions are included to help the novice designer with areas of design that can be problematic.

PERMISSION: Permissions are included to clarify the areas of the specification that are not specifically prohibited. Permissions reassure the reader that a certain approach is acceptable and will cause no problems. The word **MAY** is reserved for indicating permissions.

OBSERVATION: Observations spell out implications of rules and bring attention to things that might otherwise be overlooked. They also give the rationale behind certain rules, so that the reader understands why the rule must be followed. Any text that appears without heading should be considered as description of the specification.

FUTURE RULES: See the LXI web site for documentation that specifies the scope of the technical work in progress that is expected to result in new rules and recommendations or changes to existing rules and recommendations in a future revision of the standard. The expected date or dates for completion of future work is also given on this web site to enable manufacturers to plan their design activity and for system integrators and users to more accurately anticipate changes in the capabilities of LXI Devices.

DEPRECATED CLAUSES: are clauses that no longer apply to the standard. Clauses deprecated since the previous edition no longer appear in the standard.

1.5 Applicable Standards and Documents

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used). Each referenced document is cited in the text and its relationship to this document is explained. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

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1.5.1 Standards and Specifications

1.5.1.1 IEEE[1,2], IEC[3], and ANSI/TIA/EIA[4] Standards

ANSI/TIA/EIA-568-B.2, Commercial Building Telecommunications Cabling Standard - Part 2: Balanced Twisted Pair Cabling Components

ANSI/TIA/EIA-899, Electrical Characteristics of Multipoint-Low-Voltage Differential Signaling (M-LVDS) Interface Circuits for Multipoint Data Interchange

IEC 60068-1, Environmental testing. Part 1: General and guidance

IEC 60297:

-1, Dimensions of mechanical structures of the 482.6 mm (19 in) series. Part 1: Panels and racks

-2, Dimensions of mechanical structures of the 482.6 mm (19 in) series. Part 2: Cabinets and pitches of rack structures

-3-101, Mechanical structures for electronic equipment - Dimensions of mechanical structures of the 482,6 mm (19 in) series - Part 3-101: Subracks and associated plug-in units

IEC 60603-7 Connectors for electronic equipment

IEC 61010-1, Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements

IEC 61326-1, Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 1: General requirements

IEEE Std 802.3™ IEEE Standard for Information Technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and physical layer specifications

Section 1: Type 10 BASE-T

Section 2: Type 100 BASE-TX

Section 3: Type 1000 BASE-T

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[1] The IEEE standards or products referred to in this section are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

[2] IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (http://standards/ieee/org). IEEE 802 standards are also available for download at http://standards.ieee.org/getieee802/

[3] IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembe, CH-1211, Geneva 20, Switzerland (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th floor, New York, NY 10036, USA (http://www.ansi.org/).

[4] EIA documents are available from the Telecommunications Industry Association at http://www.tiaonline.org/standards/catalog/index.cfm

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IEEE Std 802.3af, Specified in IEEE 802.3-2005 Section 2, Clause 33

IEEE Std 1588™ IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems

1.5.1.2 IETF RFC Documents[5]

IETF RFC 768, “User Datagram Protocol”, J. Postel, August 1980, (Status: Standards track)

IETF RFC 791, “Internet Protocol,” Information Science Institute, University of Southern California, September 1981, (Status: Standards track)

IETF RFC 793, “Transmission Control Protocol,” Information Science Institute, University of Southern California, September 1981, (Status: Standards track)

IETF RFC 1035, “Domain Names- Implementation and Specification”, P. Mockapetris, November 1987, (Status: Standards track)

IETF RFC 1738, “Uniform Resource Locators (URL),” T. Berners-Lee, L. Masinter, M. McCahill, December 1994, (Status: Standards track)

IETF RFC 2131, “Dynamic Host Configuration Protocol," R. Droms, March 1997 (Obsoletes RFC1541) (Status: Standards track)

IETF RFC 2132, “DHCP Options and BOOTP Vendor Extensions," S. Alexander, R. Droms, March 1997 (Obsoletes RFC1533) (Status: Standards track)

IETF RFC 2616, “Hypertext Transfer Protocol -- HTTP/1.1,” R. Fielding, J. Gettys, J. Mogul, H. Frystyk, L. Masinter, P. Leach, T. Berners-Lee, June 1999, (Status: Standards track)

IETF RFC 2874, “DNS Extensions to Support IPv6 Address Aggregation and Renumbering,” M. Crawford, C. Huitema, July 2000, (Status: Standards track)

IETF RFC 3364, “Tradeoffs in Domain Name System (DNS) Support for Internet Protocol version 6 (IPv6),” R. Austein, August 2002 (Status informational)

IETF RFC 3484, “Default Address Selection for Internet Protocol version 6 (IPv6),” R. Draves, February 2003, (Status: Standards track)

IETF RFC 3513, “Internet Protocol Version 6 (IPv6) Addressing Architecture,” R. Hinden, S. Deering, April 2003, (Status: Standards track)

IETF RFC 3596, “DNS Extensions to Support IP Version 6,” S. Thomson, C. Huitema, V. Ksinant, M. Souissi, (obsoletes RFC 1886 and RFC 3152), (Status: Standards track)

IETF RFC 3927, “Dynamic Configuration of IPv4 Link-Local Addresses," S. Cheshire, B. Aboba, E. Guttman, May 2005 (Status: Proposed Standard)

[5] IETF publications are available from the Internet Engineering Task Force on the World Wide Web at http://www.ietf.org/rfc.html

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1.5.1.3 Trade Association Standards[6,7,8,9]

IVI-3.1, "Driver Architecture Specification"

IVI-3.15, "IviLxiSync Specification"

IVI VISA specifications:

VPP-4.3: The VISA Library

VPP-4.3.2: VISA Implementation Specification For Textual Languages

VPP-4.3.3: VISA Implementation Specification For The G Language

VPP-4.3.4: VISA Implementation Specification For COM

LXI, "LXI IEEE 1588 Profile"

LXI, "LXI Trigger Bus Cable and Terminator specifications"

ODVA, "Volume Two: EtherNet/IP Adaptation of CIP, Edition 1.5"

VXI 11 Revision (7/17/1995), "TCP/IP Instrument Protocol Specification"

1.5.2 Supplementary Documents[10]

LXI, "Licensing Agreement"

LXI, "LXI Logo"

LXI, "LXI Conformance Documentation Template"

LXI, "Recommendations for LXI systems containing devices supporting different versions of IEEE 1588"

1.6 LXI Website

The LXI Consortium operates a website, www.lxistandard.org, for the standardization activities and promotion of the LXI Standard.

The website includes the latest version of the standard released by the LXI Consortium as a publicly available document.

New versions of the standard being defined, created or edited are available to LXI Consortium members from the "members only" part of the website. Access to this part of the site requires individuals to be associated with member companies of the LXI Consortium and to register with the site.

[6] IVI specifications are available from the IVI Foundation at http://www.ivifoundation.org
[7] LXI Standards are available from the LXI Consortium at http://www.lxistandard.org
[8] VXI-11 specifications are available from the VXI Bus Consortium at http://www.vxibus.org/
[9] ODVA specifications are available from the ODVA, 4220 Varsity Drive, Suite A, Ann Arbor, Michigan 48108-5006, http:// www.odva.org
[10] LXI supplementary documents are available from the LXI Consortium at http://www.lxistandard.org

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1.7 LXI Logo and conformance

The LXI Consortium licenses a registered name and logo for use in association with products that are conformant with the standard. In addition, the use of the logo requires that the manufacturer or distributor for the product either is a member of the LXI Consortium, or has agreed to pay any license fees that the LXI Consortium may choose to levy on the use of the logo.

Details of the logo and the Trademark License Agreement can be obtained from the LXI Consortium's website.

Specific requirement on the permitted usage of the LXI Logo are found in section 12.

1.8 Plug Fest and Conformance Testing

Manufacturers are required to demonstrate the conformance of LXI Devices by attending Plug Fest (or approved alternative) events organized by the LXI Consortium where they demonstrate product conformance through interaction with other LXI Devices. The Plug Fest is used to verify the accuracy of the standard and to ensure that manufacturers differing interpretations are kept to a minimum. Where Plug Fest testing highlights implementation issues or differences in interpretation the standard may be revised to expand, modify, or clarify the standard. Provision is made for manufacturers to declare conformance of other products that share the same generic interface by submitting supporting information to the consortium.

The LXI Consortium currently supports a series of regular meetings at which LXI Devices may be tested for conformance to the currently supported versions of the standard. The LXI Consortium also supports a method for approved third party testing of LXI Devices outside the regular meetings. At the time of publication of this version of the standard self-certification of conformance is not permitted, though a Technical Justification route is available for vendors making a family of products that use a common LXI interface. For more information on compliance testing, vendors should refer to Section 13 of this standard and the LXI Consortium web site. A list of acceptable third party test houses can be obtained from the LXI Consortium.

The LXI Consortium will maintain a register of conformant products and will operate a "grievance procedure" to resolve conformance issues raised by users that are not resolved by manufacturers. The Plug Fest also enables manufacturers to exchange views and information that will benefit users under rules of conduct that ensure a collaborative environment for testing.

1.9 Technical Overview

The LXI Standard defines devices using open-standard LAN (Ethernet) for system inter-device communication. The standard will evolve to take advantage of current and future LAN capabilities. It provides capabilities that go well beyond the capability of other test and measurement connectivity solutions. It will provide users with solutions that are denser, smaller, faster, and cheaper than other solutions.

The LXI Standard has three key functional attributes:

A standardized LAN interface that provides a framework for web based interfacing and programmatic control. The interface supports peer-to-peer operation as well as master slave operation. The LAN can also support the exchange of trigger signals.

A facility based on IEEE 1588 that enables modules to have a sense of time that allows modules to timestamp actions and initiate triggered events over the LAN interface.

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A physical wired trigger system based on an M-LVDS electrical interface that allows modules to be connected together by a wired interface using twisted pair transmission lines.

The LXI Consortium expects LXI Devices to be used in a wide variety of systems, often including devices that are not by themselves LXI conformant. These devices are likely to include GPIB, PXI, VXI, and LAN instruments with conversion devices, where required. The programming environment for such systems may be more complex, since each may present a different programming environment in order to comply with those standards.

Trigger events over the LAN can be sent by UDP to minimize the latency that can be experienced with TCP/IP protocols. The wired trigger and IEEE 1588 triggers are designed to address concerns about the latency that is sometimes seen in LAN-based systems. The defined wired trigger facility provides a triggered mode of operation that emulates trigger signals based on direct point-to-point connection between instruments. The IEEE 1588 facility allows triggers to be scheduled or events to be timestamped against a system clock.

LXI Devices include web pages that can be opened with a web browser to view and change various parameters.

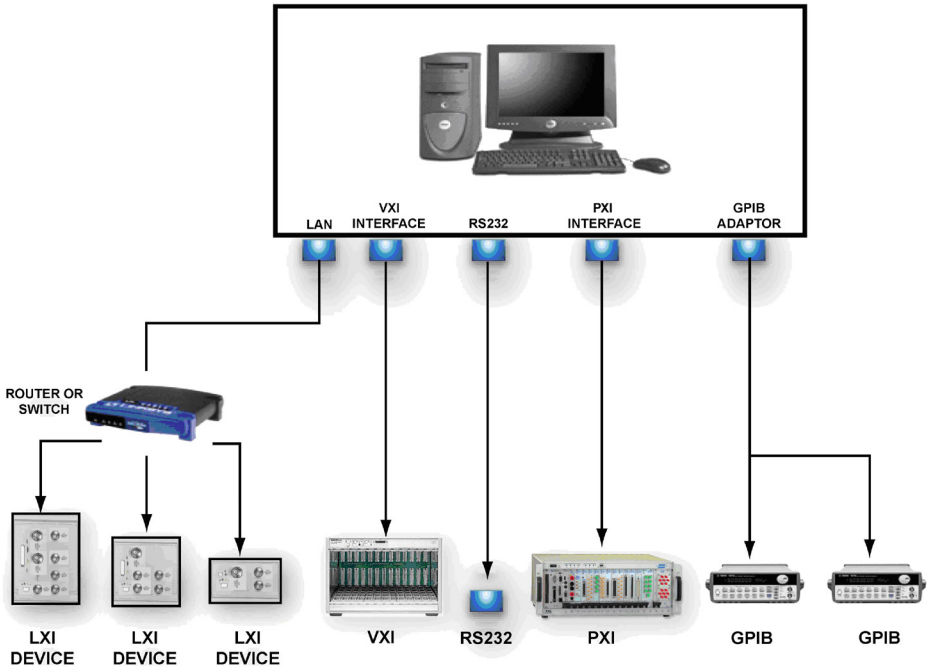

Figure 1. Example of an LXI system including conformant LXI Devices and non-LXI instruments, a configuration referred to as an Aggregate System. The non-LXI instruments include LAN instruments as well as GPIB, PXI, and VXI products connected via internal or external adaptors.

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1.9.1 LXI Functional Class Models

1.9.1.1 General Class Descriptions

The LXI Standard defines three functional classes of instrument.

The Functional classes do not imply any particular physical size for an LXI Device.

Functional Class C

Class C LXI Devices provide a standardized LAN and web browser interface that is conformant with the LXI Standard. This class is particularly suited to applications where non-LXI products have been adapted to the standard, but it is also well suited to applications where there is no necessity to offer triggered or timed functionality. This class may also include physically small products, such as sensors, that use battery power or PoE (Power over Ethernet) where simple device architecture, low cost and small size are key attributes.

Functional Class B

In addition to Class C features, Class B LXI Devices provide a standardized LXI Event interface, synchronization API and support the IEEE 1588 timing aspects. The IEEE 1588 interface allows devices to execute triggered functions equivalent to those available over GPIB and with similar or better timing accuracy.

Functional Class A

In addition to Class B features, Class A LXI Devices provide a wired trigger bus interface. The LXI Trigger Bus provides a standardized capability of supporting trigger events between devices whose timing accuracy is limited by the physical limitations of cables and LXI Device hardware. The trigger functionality is broadly equivalent to the backplane triggers of modular instruments in card cages, though cable lengths may typically be longer than backplane trigger lengths.

1.9.1.2 RULE – Class Conformance Requirements

The rules in this section define the conformance requirements for each LXI Class. LXI Devices shall conform to the rules in this section applicable to the declared class of the LXI Device. Implementers of LXI Devices should also consider the recommendations, observations, and permissions included in the sections cited for each LXI Class.

1.9.1.2.1 RULE – Class C Conformance Requirements

All Class C LXI Devices shall implement and conform to all rules in the sections cited in the following list (unless otherwise stated, subsections of cited sections are not included in the conformance requirement):

1. Sections 1.9.1.2, 1.9.2, and 1.9.3
2. Section 2 including all subsections
3. Sections 6.1, 6.2, and 6.8
4. Section 7 including all subsections
5. Section 8 including all subsections

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6. Sections 9.1 through 9.5 including all subsections, and sections 9.7 through 9.14 including all subsections

7. Sections 10 including all subsections

8. Sections 11through 14 including all subsections

1.9.1.2.2 Permission – Additional LXI Features

Vendors of LXI products may find it advantageous to implement some of the features of Class A and Class B LXI Devices on a Class C LXI Device for particular markets.

Class C LXI Devices may include one or more of the following LXI features. Each implementation of an LXI feature shall conform to all rules for the LXI feature in the sections cited in the following list (unless otherwise stated, subsections of cited sections are not included in the conformance requirement):

1. LXI Trigger Bus, see 1.9.1.2.3 (includes SyncAPI, Event Handling, and LXI Event Logs).

2. LXI Event Messaging, see 1.9.1.2.4 (includes SyncAPI, Event Handling, and LXI Event Logs).

3. LXI Clock Synchronization using IEEE 1588, see 1.9.1.2.5 (includes SyncAPI).

4. LXI Timestamped Data, see 1.9.1.2.6 (includes SyncAPI. and LXI Clock Synchronization).

5. LXI Event Logs, see 1.9.1.2.7 (includes SyncAPI, and LXI Clock Synchronization).

1.9.1.2.3 RULE – Class C LXI Trigger Bus Feature Conformance Requirements

All Class C LXI Devices implementing the LXI Trigger Bus as permitted by 1.9.1.2.2 shall implement and conform to the requirements of section 1.9.1.2.1 and in addition shall implement and conform to all rules in the sections cited in the following list (unless otherwise stated, subsections of cited sections are not included in the conformance requirement):

1. Section 3.5 and 3.7 including all subsections,

2. Section 5 including all subsections,

3. Section 6.1.1, sections 6.3 through 6.4.2 including all subsections, 6.4.4 including all subsections, and 6.4.6

4. Section 9.6 including all subsections

1.9.1.2.4 RULE – Class C LXI Event Messaging Feature Conformance Requirements

All Class C LXI Devices implementing the LXI Event Messaging feature as permitted by 1.9.1.2.2 shall implement and conform to the requirements of section 1.9.1.2.1 and in addition shall implement and conform to all rules in the sections cited in the following list (unless otherwise stated, subsections of cited sections are not included in the conformance requirement):

1. Section 3.3 through 3.5, 3.7, and 4 including all subsections of each

2. Section 6.1.1, sections 6.3 through 6.7 including all subsections

3. Section 9.6 including all subsections

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1.9.1.2.5 RULE – Class C LXI Clock Synchronization Feature Conformance Requirements

All Class C LXI Devices implementing the LXI Clock Synchronization feature as permitted by 1.9.1.2.2 shall implement and conform to the requirements of section 1.9.1.2.1 and in addition shall implement and conform to all rules in the sections cited in the following list (unless otherwise stated, subsections of cited sections are not included in the conformance requirement):

1. Section 3.2 including all subsections
2. Sections 6.1.1 and 6.5 including all subsections
3. Section 9.6 including all subsections

1.9.1.2.6 RULE – Class C LXI Timestamped Data Feature Conformance Requirements

All Class C LXI Devices implementing the LXI Timestamped Data feature as permitted by 1.9.1.2.2 shall implement and conform to the requirements of section 1.9.1.2.1 and in addition shall implement and conform to all rules in the sections cited in the following list (unless otherwise stated, subsections of cited sections are not included in the conformance requirement):

1. Section 1.9.1.2.5
2. Section 3.6 including all subsections

1.9.1.2.7 RULE – Class C LXI Event Log Feature Conformance Requirements

All Class C LXI Devices implementing the LXI Event Log feature permitted by 1.9.1.2.2 shall implement and conform to the requirements of section 1.9.1.2.1 and in addition shall implement and conform to all rules in the sections cited in the following list (unless otherwise stated, subsections of cited sections are not included in the conformance requirement):

1. Section 1.9.1.2.5
2. Section 3.7 including all subsections.
3. Section 6.7 including all subsections

1.9.1.2.8 RULE – Class B Conformance Requirements

All Class B LXI Devices shall implement and conform to all rules in the sections cited in the following list (unless otherwise stated, subsections of cited sections are not included in the conformance requirement):

1. All specifications listed for Class C LXI Devices in rule 1.9.1.2.1,
2. Section 3 including all subsections,
3. Section 4 including all subsections
4. Section 6.1.1, sections 6.3 through 6.7 including all subsections
5. Section 9.6 including all subsections

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1.9.1.2.9 RULE – Class A Conformance Requirements

All Class A LXI Devices shall implement and conform to all rules in the sections cited in the following list (unless otherwise stated, subsections of cited sections are not included in the conformance requirement):

1. All specifications listed for Class B LXI Devices in rule 1.9.1.2.8,

2. Section 5 including all subsections

1.9.2 RULE – Functional Class Declaration

Manufacturers of LXI Devices shall clearly declare the Functional Class that a device is conformant with in the data sheet and supporting documentation. The Functional Class shall be declared as one of the following:

- LXI Class C if the LXI Device is conformant to 1.9.1.2.1
- LXI Class B if the LXI Device is conformant to 1.9.1.2.8
- LXI Class A if the LXI Device is conformant to 1.9.1.2.9

No other Functional Class declarations shall be permitted.

1.9.3 RULE – Web Indication of Functional Class

The Functional Class shall be declared on the web interface and is the definitive source for Functional Class information for an LXI Device.

1.9.4 LXI Physical Overview

LXI Devices are designed to provide a dense and compact solution for test systems. Many LXI Devices will provide only minimal manual user interfaces to reduce device complexity and space. Many LXI Devices are expected to be 1U to 4U high and half rack width, but devices occupying a full rack width are expected to be implemented for many applications, particularly more complex functions. Some LXI Devices, such as sensors, may be much smaller and have mechanical dimensions not intended for rack mounting.

User connections to LXI Devices are recommended to be on the front while LAN, trigger and power supply connections are on the rear. Indicator lights on the front panel show the presence of power and have a LAN status indicator to ensure users can quickly spot simple functional or connectivity problems. A recommended indicator shows the operating condition of the IEEE 1588 clock system.

The LXI Device power can be provided by a standard AC power supply with automatic voltage selection or by a DC power source. Alternatively an isolated DC input connection can be provided (or a Power Over Ethernet source for lower power LXI Devices) for applications where AC supply operation is not desirable. A 48 V isolated supply is recommended for these applications to align with the standards for Power Over Ethernet, but other voltages are permitted.

LXI Devices are expected to conform to the relevant standards applicable for intended markets for safety and environmental standards.

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1.9.5 Reset Mechanism

LXI Devices must include a hardware reset mechanism for the LAN (LAN Configuration Initialize). The reset can be implemented as a separate button for devices without a manual user interface or can be provided by a sequence of key presses

The LAN reset provides a mechanism for recovering from incorrectly configured LAN settings that could render the device incapable of communicating over the LAN. Initiating the LAN reset restores the manufacturers default settings and passwords – settings that must be disclosed in the supporting documentation.

1.9.6 LXI LAN and Web Overview

The LAN interface for LXI Devices is intended to use 100 BASE-T or better connections based on the IEEE 802.3 standards. LXI Devices should be designed for fast boot times under all conditions (including circumstances where the network is disconnected). Network speed and duplex settings are automatically detected to simplify system integration.

The LAN interface is defined to minimize the amount of user intervention required for configuring the TCP/IP parameters and the standard ensures that instruments can be quickly ported from one system to another without risk of system hang-ups and with a minimal amount of user intervention.

Access to the instrument functions is via a web browser that provides essential information (such as instrument type, serial number, Functional Class) and about key settings on the device Welcome page. The web interface is required to provide an additional IP Configuration page and a Synchronization page (if the device implements IEEE 1588, LXI Event Messaging, or the LXI Trigger Bus). The Synchronization page includes information about the IEEE 1588 parameters. If the LXI Device allows the user to change any of the instrument settings these have to be password protected. Examples of sample web pages are available to show how the web pages might be presented by an LXI Device.

LXI Devices can be assigned aliases to make them easier for users to identify, particularly for circumstances where more than one of the same type of LXI Device may be in the system.

The LXI Standard allows LXI Devices to have automatic lookup for the latest firmware or software through a homepage created by the LXI Device manufacturer.

The LAN connection is made to the LXI Device with physical cables.

1.9.7 LXI Trigger Interface Overview

LXI provides three trigger mechanisms, one based on triggering over the LAN, the second based on IEEE 1588 Precision Time Protocol running over the LAN interface, and the third based on a wired trigger interface (LXI Trigger Bus).

The LXI trigger facilities use the principal of a uniform approach – within the performance limitations of each trigger mechanism, trigger functions can be performed by any of the methods and can be connected together. A trigger event on the LXI Trigger Bus, for example, can initiate an LXI or IEEE 1588 trigger event.

The LAN trigger provides a way of programmatically triggering events through driver commands either from the controller to the LXI Device or by LXI Event Message exchange between LXI Devices. This trigger mode is the simplest to implement but has the lowest performance because of the potential latency in the LAN communication.

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IEEE 1588 Precision Time Protocol is a service that provides a way of synchronizing clocks across many LXI Devices, giving the system a coherent understanding of time that can be used to set up triggered events based on the system time. IEEE 1588 can either be implemented entirely in software or can be supported by dedicated hardware that provides more accurate timing synchronization. Timing accuracy and uncertainty is dependent on the LXI Device and the IEEE 1588 implementation, but can be expected to be in the range of 10's of microseconds to 10's of nanoseconds.

Trigger or events (e.g. measurements, sending a LAN message, etc.) can be initiated at specified times or at times specified in a received LXI Event Message. These triggers or events can also be generated immediately on receipt of an LXI Event Message or driver call though in these cases the timing error of the trigger or event will be increased due to the greater latency in message generation, delivery, and processing.

Versions 1.3 and later of the specification require Class A and Class B LXI Devices to support the IEEE 1588-2008 or later versions of the IEEE 1588 standard. Versions 1.2 and earlier of the specification require LXI Devices to support the earlier version, IEEE 1588-2002. Recommendations for managing the incompatibilities between versions of IEEE 1588 are contained in a white paper "Recommendations for LXI systems containing devices supporting different versions of IEEE 1588" found on the LXI Consortium web site.

The LXI Trigger Bus is a service that connects LXI Devices by a daisy chain or star configuration transmission line system to provide a more deterministic trigger interface that can be event driven (by a device for example) or timed by IEEE 1588 (generating a trigger into the LXI Trigger Bus). The interface is based on an 8 channel Multipoint LVDS (M-LVDS) signaling system that allows LXI Devices to be configured as sources and/or receivers of trigger signals. The interface can also be configured to a Wired-OR configuration, permitting LXI Devices to respond to trigger events requiring the detection of an event by any of multiple devices initiates or where the last device to be ready initiates events.

The LXI Trigger Bus has an input and an output connector to allow easy daisy chaining of LXI Devices. The last device in a daisy chain must have its output connector terminated in a specified load to ensure that transmission lines are correctly terminated.

The LXI Trigger Bus provides a more deterministic inter-LXI Device trigger than IEEE 1588 or LAN triggers and more closely emulates the trigger facilities provided on instruments, such as oscilloscopes, connected directly by physical connectors. Trigger Adaptors can be used to translate triggers from the LXI Trigger Bus to other trigger levels, or to convey a trigger command from another trigger system to an LXI Trigger Bus event.

The LXI Trigger Bus can include a Star Hub that supports a number of LXI Device daisy chains from a single buffered hub. LXI Devices maybe connected to the Star Hub as a simple star network, or they can be set up as hybrid system of star and daisy chain connections. In addition to extending the capacity of the trigger system, the Star Hub can be used to translate a trigger from one channel to another which permits, for example, a device to send a trigger to other devices (including itself) with equal delay times if they are connected to the Star Hub with equal length cables. Star Hubs may be internally terminated, forcing them to be placed at the end of a chain, or they can use two connectors for each port and be placed near the centre of a chain.

The LXI Trigger Bus also permits the exchange of clock signals across one or more of the 8 channels available.

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1.9.8 LXI Programmatic Overview

The LXI Standard requires that LXI Devices have an IVI driver and requires that the relevant IVI class definition is used where applicable. LXI Devices are permitted to be supplied with other drivers to allow support of other operating environments. The IVI drivers are required to support VISA resource names.

The programmatic standard defines a way that trigger functions (LAN, IEEE 1588 or LXI Trigger Bus) are managed. It includes a comprehensive example state machine and architecture for the trigger functions, though LXI Devices may only implement the parts that are relevant to the functions it can usefully support.

There is a requirement that all representations of time derived from the IEEE 1588 are represented in a uniform way to ensure consistent interpretation of the information.

The programmatic section of the standard contains a considerable amount of detail on programming rules and resides in separate documents on the LXI website to help improve the clarity of the standard.

1.9.9 LXI Discovery

The process of discovering LXI Devices on a network is supported by two separate techniques on LXI Devices conforming to this version of the specification. The first method uses VXI-11 and was a requirement on LXI Devices from the first publication of the standard. Version 1.3 introduces a requirement for LXI Devices to support the mDNS and DNS-SD discovery mechanism.

1.10 Hybrid Systems

The LXI Consortium anticipates that some systems will use both LXI conformant devices and devices conformant with other standards. These systems are described in the Hybrid System section.

A system that contains both LXI Devices and other non LXI Devices accessed through non-LXI interfaces is referred to as an Aggregate System. If a system contains only LXI Devices and non-LXI Devices accessed through interfaces that make them conformant and indistinguishable from native LXI Devices, they are part of a Conformant Hybrid System.

The interface types that provide LXI conformant interfaces are identified as Bridges, Adaptors or Adaptor Toolkits.

Bridges provide an LXI conformant interface and means to control the devices connected to it. Although the Bridge is LXI conformant, the devices connected to it are not exposed through an LXI interface, and it is part of Aggregate System. The Bridge provides a different mechanism for controlling the devices being adapted.

Adaptors present a complete LXI interface the devices being adapted. The combination of the Adaptor and Adaptee is completely LXI conformant and provides the full LXI experience – it is indistinguishable from a native LXI Device. It can be part of a Conformant Hybrid System.

An Adaptor Toolkit is hardware and software that provides an adaptor function capable of presenting an LXI interface for adaptee(s), but it is provided as an incomplete solution. The user must invest additional effort to make the interface LXI conformant.

The interfaces that make a non-LXI Device appear to be LXI conformant can carry the LXI logo after conformance testing. The adapted products are not permitted to carry the LXI logo since they are not conformant without the additional adaptor interface.

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It is believed that it is not possible for a single physical adaptor interface to expose multiple devices as LXI conformant, but further work is anticipated to be carried out in this area.

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2 LXI Physical Specifications

2.1 Introduction

The LXI Physical Specifications define mechanical and electrical standards intended for both rack mount and non-rack mount devices. Although there are international standards for full width rack mounted devices, there are no standards for half-width racked devices and this has led to the emergence of a number of de-facto half-width standards introduced by various manufacturers to fill this need.

It is not the intent of this specification to exclude legacy full width rack mounted equipment or new half-width designs built to companies' de-facto standards. To this end, this specification acknowledges existing IEC Publication 60297. Section 2.2 deals with IEC full width mechanical standards while section 2.3 deals with established de-facto half-width mechanical standards.

Electrical Standards are covered under section 2.4 with Section 2.5 covering status indicators. Section 2.6 makes recommendations for environmental standards.

2.1.1 General Conformance with the Physical Specifications

LXI Devices can conform to the Physical Specifications in three categories:

- Non-rack mounted devices
- Full width rack mounted devices built to IEC 60297 standards
- Half-width rack mounted devices built to de facto standards

All locations of components, connectors, and switches are defined as viewed when facing the panel being described.

2.1.1.1 RULE – Non-Rack Mounted LXI Devices

Non-rack mounted LXI Devices shall conform to the following sections:

- Section 2.4 – Electrical Standards
- Section 2.5 – Electrical Standards – Status Indicators
- Section 2.6 – Environmental Standards

2.1.1.2 RULE – Full Width Rack Mounted LXI Devices

Full width rack mounted LXI Devices shall conform to the following sections:

- Section 2.2 – Full Width Rack Mounted Devices
- Section 2.4 – Electrical Standards
- Section 2.5 – Electrical Standards – Status Indicators
- Section 2.6 – Environmental Standards

2.1.1.3 RULE – Half-Width Rack Mounted LXI Devices Built to De Facto Standards

Half-width rack mounted LXI Devices built to de facto standards shall conform to sections:

- Section 2.3 – De Facto Half-Width Mechanical Standards

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- Section 2.4 – Electrical Standards
- Section 2.5 – Electrical Standards – Status Indicators
- Section 2.6 – Environmental Standards

2.2 IEC Full Width Mechanical Standards

2.2.1 General Specifications

2.2.1.1 RULE – Conformance to IEC Standards

Full width LXI Devices shall conform to existing IEC rack standards in accordance with the relevant sections of whichever version of those standards was current when the device was designed.

2.3 De Facto Half-Width Mechanical Standards

While no official standards exist for half-width rack instruments, vendors have provided instruments in these form factors for several years with significant worldwide installed bases. As a result, de facto standards have been established with system integrators and customers successfully utilizing these instruments in rack based environments.

2.3.1 General Recommendations

2.3.1.1 Recommendation – Half-Width 2U or Higher Dimensions

Half width LXI Devices built to de facto standards should conform to the basic dimensions outlined in the IEC standards defined in Section 2.2, and should be capable of being mounted in full width racks when provided with the necessary adaptor kits.

2.4 Electrical Standards

The Electrical Standards define the type and location of all electrical power standards, connectors, switches, indicators, and related components. The following rules shall guide the electrical design and characteristics of LXI Devices.

2.4.1 Safety

2.4.1.1 Recommendation – Safety conformance

LXI Devices should specify safety conformance to standards appropriate to the intended market (CSA, EN, UL, and IEC).

2.4.2 Electromagnetic Compatibility

2.4.2.1 RULE – Individual Device Shielding

Each LXI Device shall provide its own shielding from emitted radiation.

2.4.2.2 Recommendation - EMC Conformance

LXI Devices should conform to standards appropriate to the intended market, e.g. FCC, VDE, or MIL Spec. for far field radiated emissions.

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2.4.2.3 Recommendation – Conducted Emissions

LXI Devices should conform to the standards appropriate to the intended market.

2.4.2.4 Recommendation – EMI Susceptibility

LXI Devices should conform to the standards appropriate to the intended market

2.4.3 Input Power

It is intended that LXI Devices be primarily powered by single-phase 100-240 volt AC power. However, permissions are granted for the operation from DC power, PoE, or AC power of varying voltage, number of phases, and frequencies to allow for application in specific markets.

2.4.3.1 Recommendation – Universal AC Power

It is recommended that LXI Devices be capable of operating autonomously from a single-phase input of 100 to 240 VAC (RMS) +/- 10%, at frequencies from 47 to 66 Hz.

2.4.3.1.1 Permission – Non-auto switching AC Power

LXI Devices may operate from a single voltage to allow legacy devices with non-auto switching power supplies to be accommodated within the specification.

2.4.3.1.2 Permission – DC or PoE Power

LXI Devices may operate from DC power either as a direct input or by Power over Ethernet, PoE. PoE devices shall conform to IEEE 802.3af.

2.4.3.2 Recommendation: DC Power

If DC power is utilized, it should be an isolated 48VDC input.

2.4.3.2.1 Permission: Two and Three Phase Power

LXI Devices may operate from two and three phase power.

2.4.3.2.2 Permission: Other Line Frequencies

Other power line frequencies beyond 47 Hz to 66 Hz are permitted to allow for specific application environments.

2.4.4 Power Switch

A power switch is optional.

2.4.4.1 Recommendation – Power Switch Location

The power switch is optional, but when implemented it should be located in the lower right hand corner of the rear panel.

2.4.4.2 Permission – Front Panel Power Switch Location

Front panel power switch location is permitted.

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2.4.5 LAN Configuration Initialize (LCI)

2.4.5.1 RULE – LCI Mechanism

LXI Devices shall provide an LCI Mechanism that, when activated, places its network settings in a default state. The functions performed by this mechanism are defined in Section 8.13.

2.4.5.2 RULE – LXI Devices Without a Front-Panel Manual Data-Entry Method

LXI Devices shall provide an LCI mechanism by either:

a) A separate recessed mechanical LCI mechanism on the rear or front of the device (rear is preferred).

b) A soft LCI mechanism through a permanently attached user interface (e.g., a front panel, monitor, mouse, keyboard, et cetera) that does not use the LAN as the interface.

2.4.5.2.1 Recommendation – Not Using LCI Mechanism for Other Purposes

The mechanism (especially that described in RULE 2.4.5.2) that invokes the LAN Configuration Initialization should not be used for any other function.

If this mechanism is also used for something else, such as instrument reset, the two ways to actuate it should be distinct enough so that it is difficult for a user to invoke the wrong one, and the mechanism (e.g., "LAN RESET" Button) should be labeled to show it performs multiple functions.

2.4.5.3 RULE – LCI Mechanism Protection

The LCI Mechanism shall be protected by a time-delay, user query, or mechanical protection feature designed to prevent inadvertent operation.

2.4.5.4 Recommendation – LCI Mechanism Location

The LCI should be located on the rear panel of the device in the same general area as the power switch, if present.

2.4.5.4.1 Permission – LCI Mechanism Location

To address market specific requirements, the LCI may be located on the front panel of the device.

2.4.5.5 Recommendation – LCI Mechanism Label

The LCI Mechanism should be labeled "LAN RST" or "LAN RESET".

2.4.5.5.1 Permission – LXI Devices with a Front Panel

For devices with a front-panel manual data-entry method such as a keypad or touch panel user interface, the LCI functions may be executed by a single keystroke or a sequence of keystrokes.

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2.4.5.5.2 Permission – LCI Mechanism Lockout

For LXI Devices intended for deployment in critical conditions, manufacturers can include an LCI Mechanism Lockout function in the form of a protected or internal switch or jumper that prevents all reset functions from being accessed.

2.4.6 Power Cords and Connectors

2.4.6.1 RULE – Rear Panel Power Connector

The AC or DC power connector shall be located on the rear panel.

2.4.6.2 Recommendation – Power Connector Location

It is recommended that the power connector be located on the right hand side of the rear panel.

2.4.6.3 Recommendation – AC Power Connector Type

It is recommended that LXI Devices operating from a single-phase AC input, as recommended in Section 2.4.3, utilize an IEC 320 type connector.

Multi-phase AC input devices should use an AC input connector compliant with the safety and EMC standards applicable to the device.

2.4.7 Fusing or Over-Current Protection Device

2.4.7.1 Recommendation – Over-Current Protection

If a fuse or over-current protection device is required, it should be integral to or located adjacent to the input power connector.

2.4.8 Grounding

2.4.8.1 Recommendation – Unit Grounding

LXI Devices should conform to standards appropriate to the intended market.

2.4.9 LAN Connectors

This section deals with physical IEEE 802.3 LAN connectors.

2.4.9.1 RULE – IEEE 802.3

Physical Ethernet connections shall be IEEE 802.3 compliant.

2.4.9.2 Recommendation – LAN Connector Location

The LAN connector should be on the rear panel of the device at the right hand side as constrained by the location of the other connectors.

2.4.9.3 Recommendation – RJ-45 Connector

RJ-45 connectors should be used unless technical reasons require otherwise.

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2.4.9.4 Recommendation – M12 Style Connectors

If RJ-45 style connectors are not acceptable, M12 style connectors should be considered.

2.4.9.5 Recommendation – Non-Sealed Connections

For applications that do not require sealed connections, the following specifications should apply for the RJ-45 connections:

- Electrical: ANSI/TIA/EIA-568-B.2 (Category 5E), either shielded or unshielded
- Mechanical: IEC 60603-7

2.4.9.6 Recommendation – Sealed Connections

For applications that require sealed RJ-45 connectors, those connectors should adhere to the ODVA EtherNet/IP Adaptation of CIP specification for sealed RJ-45 jacks.

2.4.9.7 Recommendation – Shielded CAT 5 cable

Shielded CAT 5 cable should be used for devices installed in harsh environments requiring additional electrical or mechanical protection.

2.4.9.8 Recommendation – Integrated Magnetics

LXI Devices should utilize shielded modular jacks with integrated magnetics.

2.4.10 LXI Trigger Bus Connectors

2.4.10.1 RULE – LXI Trigger Bus Connectors

For devices incorporating the LXI Trigger Bus, the number and type of LXI Trigger Bus connectors shall be as specified in Section 5.

2.4.10.2 Recommendation – Connector Location

Location of the LXI Trigger Bus connectors should be on the rear panel of the device at the right hand edge as constrained by the location of the power connector.

2.4.10.3 Recommendation – Connector Orientation

The LXI Trigger Bus connectors should be vertically stacked with a minimum vertical, center-to-center, separation of 11.05mm (0.435 inches).

2.4.10.4 Permission – Connector Orientation

The LXI Trigger Bus connectors may be horizontally mounted immediately next to each other.

2.4.10.5 Permission – Vendor-Specific Triggers

Vendor-specific hardware trigger interfaces are permitted.

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2.4.11 Signal I/O Connectivity Interfaces

2.4.11.1 Recommendation – Signal Connections

Signal connections should be located on the front panel of the device.

2.4.11.1.1 Permission – Signal Connections

Signal connections are permitted on the rear panel of the device. This allows vendors to align with selected market segment and customer requirements.

2.5 Electrical Standards – Status Indicators

LXI Devices have LED status indicators for Power, LAN, and, where applicable, IEEE 1588.

The following table summarizes the recommendations for the color, location, orientation, and labeling of the status indicators:

	Power Indicator	**LAN Status Indicator**	**IEEE 1588 Clock Status Indicator**
LED Color(s)	Bi-Color (Orange/Green)	Bi-Color (Red/Green)	Bi-Color (Red/Green)
Front panel location	Lower left hand corner of the front panel Power	Next to and to the right of the Power Indicator Power LAN	Next to and to the right of the LAN Status Indicator Power LAN 1588
Horizontal Orientation Note: The status indicators are ordered in the LXI Device turn-on sequence.	Power LAN 1588 (Left LED) LXI Device turn-on sequence: First, enable power.	Power LAN 1588 (Middle LED) LXI Device turn-on sequence: Second, acquire LAN IP Configuration.	Power LAN 1588 (Right LED) LXI Device turn-on sequence: Third, acquire IEEE 1588 clock.
Vertical Orientation Note: The status indicators are ordered in the LXI Device turn-on sequence.	1588 LAN Power (Bottom LED) LXI Device turn-on	1588 LAN Power (Middle LED) LXI Device turn-on	1588 LAN Power (Top LED) LXI Device turn-on sequence: Third,

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	sequence: First, enable power.	sequence: Second, acquire LAN IP Configuration.	acquire IEEE 1588 clock.
Labeling [1]	Universal power symbol, or PWR, or POWER	LAN	1588

[1] The location of labels is not specified. They are left to the discretion of each vendor.

2.5.1 Power Indicator

2.5.1.1 RULE – Power Indicator

A Power Indicator shall be provided on the front panel of the device.

2.5.1.2 Recommendation – Power Indicator Color

Some LXI Devices may keep the power supply in stand-by mode while the device itself is turned off. From a safety perspective, it is recommended this state be identified by the power status indicator.

For LXI Devices that utilize a Standby Power state, the Power indicator should be a tri-state bi-color (Orange/Green) LED whose states are identified as follows:

State	**Status**	**Interpretation**
OFF No illumination	No Power	No power is applied.
STANDBY Solid Orange, steady illumination	Standby Power	The Standby state is used for safety purposes by those devices that keep the power supply hot while the device itself is turned off.
ON Solid Green, steady illumination	Power is ON	Power is applied.

For LXI Devices that do not utilize a Standby Power state, the Power indicator should be a single color (Green) LED whose states are identified as follows:

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State	Status	Interpretation
OFF No illumination	No Power	No power is applied.
ON Solid Green, steady illumination	Power is ON	Power is applied.

2.5.1.3 Recommendation – Power Indicator Location

The Power Indicator should be placed on the lower left hand corner of the device.

2.5.1.4 Recommendation – Power Indicator Orientation

The Status Indicators should be horizontally oriented as follows.

From left to right: Power Indicator, then LAN Indicator, then 1588 indicator.

2.5.1.4.1 Permission – Power Indicator Orientation

It is permitted for the Status Indicators to be vertically oriented as follows.

From bottom to top: Power Indicator, then LAN Indicator, then 1588 indicator.

2.5.1.4.2 Permission – Power Indication for Devices with a Front Panel

For devices with a front panel, the equivalent Power Indicator may be presented in a manner consistent with the design and capabilities of the front panel, such as a marked switch or an integrated display.

The use of symbols on a display, instead of LED status indicators, is permitted. Such indicators do not have to be permanently visible but could be accessed via some display navigation method.

2.5.1.5 Recommendation – Power Indicator Label

The Power Indicator should be labeled with the Universal Power Symbol, PWR, or POWER.

2.5.2 LAN Status Indicator

The LAN Status Indicator fulfills different functions from the standard LAN activity indicator often built into RJ-45 LAN connectors. The LAN status indicator should be a bi-color (Red/Green) LED providing two functions: LAN fault indication and device identification.

2.5.2.1 RULE – LAN Status Indicator

A LAN Status Indicator shall be provided on the device front panel.

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2.5.2.2 Recommendation – LAN Status Indicator Color and States

The LAN Status Indicator should be a bi-color (Red/Green) LED whose states are identified as follows:

State	Status	Interpretation
On – Solid green, steady illumination	Normal Operation	Normal Operation
On – Flashing Green	Device Identify	A Device Identification command was activated on the device's web pages or driver interface. The status indicator shall continue to flash green until told to do otherwise (this is not a one time flash, rather it is toggled on and off by a web interface control)
On - Solid Red, steady illumination	LAN Fault	See section 8.10 for LAN Fault Conditions

2.5.2.2.1 Permission – LAN Status Indicator Color and States

If an LXI Device's design precludes the use of a bi-color LED, the use of a single Green colored LED is permitted. In this situation, the LAN status states should be interpreted as follows.

State	**Status**	**Interpretation**
On – Solid Green, steady illumination	Normal Operation	Normal Operation
On – Flashing Green	Device Identify	A Device Identification command was received over the LAN. The status indicator shall continue to flash green until told to do otherwise (this is not a one time flash, rather it is toggled on and off by a web interface control)
Off	LAN Fault	See section 8.10 for LAN Fault Conditions

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2.5.2.3 Recommendation – LAN Status Indicator Location

The LAN Status Indicator should be placed on the lower left hand corner of the front panel, next to and to the right of the Power Indicator.

2.5.2.3.1 Permission – LAN Status Indicator Location

If an LXI Device's design precludes placing the LAN Status Indicator in the recommended front panel location, it may be placed on the rear panel.

2.5.2.4 Recommendation – LAN Status Indicator Orientation

The Status Indicators should be horizontally oriented as follows.

From left to right: Power Indicator, then LAN Indicator, then 1588 indicator.

2.5.2.4.1 Permission – LAN Status Indicator Orientation

It is permitted for the Status Indicators to be vertically oriented as follows. From bottom to top: Power Indicator, then LAN Indicator, then 1588 indicator.

2.5.2.4.2 Permission – LXI Devices with a front panel display

For devices with a front panel display, the equivalent indications may be presented in a different manner consistent with the design and capabilities of the front panel.

The use of symbols on a display, instead of LED status indicators, is permitted. Such indicators do not have to be permanently visible but could be accessed via some display navigation method.

2.5.2.4.3 Permission – Devices with limited or no front panel display

For devices with front panels with limited capabilities, or which are difficult or impossible to reconfigure, or devices with no front panel displays, the equivalent indications may be presented in a different manner consistent with the design and capabilities of the front panel. Recommended symbol bitmaps are provided by the LXI Consortium and are available on the LXI website. They may be re-sized as required for specific display resolutions.

2.5.2.5 Recommendation – LAN Status Indicator Label

The LAN Status Indicator should be labeled as LAN.

2.5.3 IEEE 1588 Clock Status Indicator

The IEEE 1588 Clock Status Indicator is designed to show both the status and the type of clock in the device. It is a multi-state device, in that it can flash at two different rates, and provide a steady or no indication depending on the type and status of the clock present.

2.5.3.1 Recommendation – IEEE 1588 Clock Status Indicator

An IEEE 1588 Clock Status Indicator should be provided on the front panel of the device.

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2.5.3.2 Recommendation – IEEE 1588 Clock Status Color

The IEEE 1588 Clock Status Indicator should be a single, bi-color LED (Red/Green) whose states are identified as follows:

State	PTP State of Port
Off	Not Slave, Not Master, and Not Faulty
On – Solid Green	Slave
On – Blinking Green once every second	Master but not Grandmaster
On – Blinking Green once every two seconds	Master and also Grandmaster
On – Solid Red	Faulty

2.5.3.2.1 Permission – IEEE 1588 Clock Status Color

If an LXI Device's design precludes the use of a bi-color LED, the use of a single Green colored LED is permitted. In this situation, the IEEE 1588 Clock states should be interpreted as follows:

State	PTP State of Port
Off	Not Slave and Not Master
On – Solid Green	Slave
On – Blinking Green once every second	Master but not Grandmaster
On – Blinking Green once every two second	Master and also Grandmaster

2.5.3.3 Recommendation – IEEE 1588 Clock Status Indicator Location

The IEEE 1588 Clock Status Indicator should be placed on the lower left hand corner of the device, next to and to the right of the LAN Status Indicator.

2.5.3.4 Recommendation – IEEE 1588 Clock Status Indicator Orientation

Orient the Status Indicators horizontally oriented as follows.

From left to right: Power Indicator, then LAN Indicator, then the IEEE 1588 indicator.

2.5.3.4.1 Permission – IEEE 1588 Clock Status Indicator Orientation

It is permitted for the Status Indicators to be vertically oriented as follows. From bottom to top: Power Indicator, then LAN Indicator, then IEEE 1588 indicator.

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2.5.3.4.2 Permission – LXI Devices with a Front Panel Display

For devices with a front panel display, the equivalent indications may be presented in a different manner consistent with the design and capabilities of the front panel.

The use of symbols on a display, instead of LED status indicators, is permitted. Such indicators do not have to be permanently visible but could be accessed via some display navigation method.

2.5.3.5 Recommendation – IEEE 1588 Clock Status Indicator Label

Label the IEEE 1588 Clock Status indicator "1588".

2.5.3.5.1 Permission - Application Specific Status Indicators

Additional application specific status indicators, beyond the basic ones already outlined, are permitted.

2.6 Environmental Standards

2.6.1 Recommendation – Standards Conformance

LXI Devices should meet the environmental and safety specifications appropriate to their target market. Unless otherwise dictated by the target market, LXI Devices should conform to the environmental, safety, and testing specifications in the following standards:

- IEC 61010-1 Safety Requirements
- IEC 61326-1-1998 EMC requirements T&M Equipment

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3 LXI Device Synchronization and Events

3.1 Introduction

The triggering and synchronization capabilities of an LXI Device enable system integrators to:

- Control the sequencing of states within an LXI Device or across the system
- Control the timing of issuing and handling of local and system events
- Order or correlate measurement data and significant events based on timestamps

LXI allows three modes of inter-module LXI Event communication:

- Via driver commands from a controller (or any other device that can function as a controller) to an LXI Device via the LAN
- Direct module-to-module messages via LXI Event Messages
- Hardware trigger lines from module to module

LXI allows five modes of triggering:

- Driver command-based: A driver interface on the controlling computer is used to directly transmit a command to an LXI Device.
- Direct LXI Event Messaging: An LXI Event message containing triggering information (including a timestamp) is sent directly from one module to another via the LAN.
- Time-based events: An IEEE 1588-based time trigger is set and executed internally in an LXI Device.
- LXI Trigger Bus-based: AN LXI Device function is triggered via a voltage on the LXI Trigger Bus (see section 5 of the LXI specification).
- Optional vendor-specific hardware triggers.

3.2 LXI Clock Synchronization Using IEEE 1588

This section specifies the use of IEEE 1588 to provide a system-wide common precision timebase created by including a synchronized real-time clock in each participating LXI Device. This timebase may be used for a variety of functions including:

- Timestamping data to expedite post acquisition analysis and ordering
- Generating LXI Events for precise triggering and synchronization within an LXI Device or system-wide
- Generating LXI Event Logs to allow total ordering of LXI Events occurring in all parts of a system
- Generating synchronous signals in multiple LXI Devices.

3.2.1 RULE – Implementation of IEEE 1588 Precision Time Protocol

Each LXI Device that implements IEEE 1588 shall provide functionality fully conformant to the current version of IEEE 1588 and the current version of the LXI 1588 Profile.

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3.2.2 Recommendation – Precision of LXI Device Clocks

IEEE 1588 should be implemented to a precision adequate for the timing performance of the device. It is further recommended that LXI Devices implement time to a precision of 40 nanoseconds or better.

3.2.2.1 Permission – Software implementation in controllers

Software implementations of IEEE 1588 may be used in controllers but is discouraged in LXI Devices.

3.2.3 Recommendation – Use of IEEE 1588 Boundary or Transparent Clocks

The timing precision of a system of LXI Devices will be limited by, among other things, the quality of the LAN bridges in the system. The use of LAN bridges designed as IEEE 1588 boundary or transparent clocks is highly recommended.

3.2.4 Recommendation – Traceability to UTC

The time base of an LXI system should be traceable to UTC.

3.2.5 RULE – Must Be Able to Set UTC Time

Any LXI Device implementing IEEE 1588 functionality shall be capable of being made traceable to UTC in the event that it is selected as the grandmaster clock by the IEEE 1588 protocol.

3.2.6 RULE – Must Be Able to Set UTC Time Manually

Traceability to UTC shall be, at a minimum, available by the use of IEEE 1588 management messages with managementId values of: TIME, CLOCK_ACCURACY, UTC_PROPERTIES, TRACEABILITY_PROPERTIES, and TIMESCALE_PROPERTIES.

3.2.6.1 Recommendation – Battery Backup for Clocks

It is recommended that devices capable of being a grandmaster clock provide battery backup time-of-day clocks to provide holdover in the event of power failure.

3.2.7 Recommendation – Include at Least One Highly Stable Clock

All LXI systems should include at least one module specifically designed to provide a very stable PTP time base.

3.2.8 RULE – Communication of Time Must Use IEEE 1588 Time Base

All time references communicated to or from LXI Devices in an LXI system shall be based on the system-wide IEEE 1588 timescale established by the IEEE 1588 clocks in each device. Translation between the IEEE 1588 time base and UTC in an LXI Device shall only occur at the interface to another subsystem external to the portion of the system operating based wholly or in part on time (e.g. a user interface or a database). All LXI Devices required to make this translation shall use the currentUtcOffset information distributed by the IEEE 1588 protocol.

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3.2.9 Recommendation – Controller Capability to Set Time

All LXI controllers should be capable of setting the IEEE 1588 time in the grandmaster via the use of IEEE 1588 management messages with managementId values of: TIME, CLOCK_ACCURACY, UTC_PROPERTIES, TRACEABILITY_PROPERTIES, and TIMESCALE_PROPERTIES.

3.2.10 RULE – Inclusion of IEEE 1588 Time-Based Triggers

LXI Devices containing triggerable functions or events and which implement IEEE 1588 shall include one or more time-based triggers. This is necessary for implementation of autonomous time-based event coordination in the LXI Device.

3.2.11 RULE – Generation of Timestamps

LXI Devices generating timestamps based on an IEEE 1588 clock shall provide information as to the accuracy of the timestamps that they supply. As a minimum, this information shall be available as part of the documentation that accompanies each LXI Device (whether printed or electronic).

3.2.11.1 Recommendation – Precision of Timestamps

Timestamps should be derived from the IEEE 1588 clock with a precision that is consistent with the event or data acquisition process and the resolution of the clock. For example if the measurement front-end bandwidth is 1 Hz then the timestamp precision should be better than 1 second. If the measurement front-end bandwidth is 1 GHz then the timestamp precision should be better than 1 nanosecond or whatever the local clock supports.

3.2.11.2 Recommendation – Timestamp Precision Available via Driver

The precision of the timestamp should be available via a driver call.

3.2.12 Rule – Pulse-per-Second Output

A pulse-per-second output shall be available on all LXI Devices implementing IEEE 1588. The mechanical and electrical specifications of this output shall be vendor-defined, but the output shall generate a rising edge synchronous with the second's transitions of the IEEE 1588 clock.

This pulse-per-second output is intended to be compared with corresponding outputs of the other clocks in the system to verify synchronization performance. The test point does not need to be available externally, although it can be brought to an external point if desired (for instance, by configuring the LXI Trigger Bus to carry the signal).

3.3 LXI Event Messages

This section defines the mechanism for communicating LXI Event Messages between modules in an LXI system. The rules of this section make it possible for LXI Devices to communicate timestamped information about asynchronous events to one another directly over the LAN, without the need for controller intervention.

Section 4 defines the data format for LXI Event Messages and the on-the-wire message format necessary to achieve overall instrument compatibility. Section 6.4 defines a programmatic use model for these LXI Event Messages.

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3.3.1 RULE – LXI Event Message Communication Transport Mechanism

All LXI Devices that transmit or receive LXI Event Messages shall be capable of the following:

- Using both multicast UDP and unicast TCP Stream transports for these transmissions.
- Listening for and responding to LXI Event Messages using both multicast UDP and unicast TCP Stream transports.

3.3.1.1 RULE – LXI Multicast Address and Port Numbers for LXI Event Messages

LXI Devices shall use the IANA registered multicast address 224.0.23.159 for LXI Event Message transmission using UDP multicast.

LXI Devices shall implement a UDP port listener (multicast capable) and a TCP socket listener for the purposes of receiving LXI Event Messages. The TCP listener shall be capable of at least 8 simultaneous connections. These listeners shall default to the IANA registered port number 5044 for LXI Event Messages—user configuration may override this default.

3.3.2 RULE – Require Specified Data Format for LXI Event Messages

LXI Event Message communication shall use the format specified in Section 4.

3.3.2.1 RULE – Use of LXI "Domain"

All modules receiving LXI Event Messages shall use the "domain" byte in the LXI Event Message to ensure that each received LXI Event Message is intended for receipt by the module. Each module shall be configurable as to the domain of which it is a member. Upon receipt of an LXI Event Message, the device shall ignore those whose "domain" byte does not match the locally configured value.

3.3.2.1.1 RULE – Other Uses of the "Domain" Byte Disallowed

The "domain" byte shall not be used other than as specified by Rule 3.3.2.1.

3.3.3 RULE – LXI Events to be Transmitted in an LXI Event Message

LXI Devices shall be configurable as to whether or not they transmit an LXI Event Message for any given LXI Event. Such events shall be the following:

- LXI Events specified in this standard
- LXI Device-specific events specified by the vendor
- Application-specific events specified by the user.

For these LXI Event Messages:

1. The Event ID shall be the following:
    a. A value specified in this document; e.g., LAN0
    b. A vendor-specific value documented by the vendor
    c. An application-specific value specified by the user.
2. The timestamp, T1, in the transmitted LXI Event Message shall be the time at which the LXI Event occurred or will occur with respect to the local clock of the transmitting module. Please refer to Section 3.3.7 for information on timestamps of zero. Note that it is permissible for a module to schedule a local or system-wide LXI Event in the future. For example, a controller can specify that “test-A” will start at

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some future time, or an instrument can specify that it will go out of calibration at some future time.

3. The data fields shall be null by default, but additionally may be:
    a. Specified in this document for standard-specified Event IDs
    b. A vendor-specific value documented by the vendor
    c. Application-specific as specified by the user.

Section 6 of this document contains details on the API that may be used for configuration.

3.3.4 RULE – Response to Received LXI Event Messages

It shall be possible for the user to program the LXI Device's response to an LXI Event as follows:

1. By default, the LXI Device shall not respond to the LXI Event Message.
2. The nature of the response shall be based on the Event ID and shall be specified or configured by the user. This does not preclude vendors from specifying a default response that can be overridden by the user.
3. The action time, T2, shall be computed as T2=T1+Dt. The time T2 may be in the past or the future and shall be interpreted in the context of the local clock of the receiver of the LXI Event Message. By default, Dt shall be zero.
4. The use of the data field shall be specified by the user. This does not preclude vendors from specifying a default interpretation for a specific Event ID.

For all events, the specified response shall occur when the action time T2 matches the local clock in the receiving LXI Device. Note that the accuracy and precision of this match depends on the implementation of IEEE 1588 and the design of the LXI Device.

When T2 is in the future, LXI Devices shall schedule an internal alarm or similar mechanism to cause the specified response to occur at the proper time.

When T2 is in the past, LXI Devices shall take immediate action by default. Additionally, vendors may provide user-selectable options for the behavior when T2 is in the past, including no response (ignore) as well as LXI Device-specific semantics (e.g., report data previously measured at time T2 and stored for future retrieval).

While many LXI Devices will likely provide a standard trigger/arm state machine model to respond to LXI Event Messages, the use LXI Event Message is not limited to such behavior models. For the trigger layer of the trigger/arm state machine (as seen in the figure accompanying Rule 6.4.4), T1 is the time at which the transition from "WaitingForTrigger" to "Wait: trigger delay" occurs. Dt is the time spent in the "Wait: trigger delay" state and T2 is the time at which the measure layer is entered.

Please refer to Section 6.4.4 for reserved Event IDs.

Section 6 of the LXI specification contains details on the API that may be used to configure these responses.

3.3.4.1 RULE – Interpretation of Times Associated with LXI Event Message Communications

The following definitions and figure shall be used to clarify the timing behavior of responses to LXI Event Messages:

Reception Time – Time when an LXI Event Message is received by a module. This time is normally logged in the LXI Event Log.

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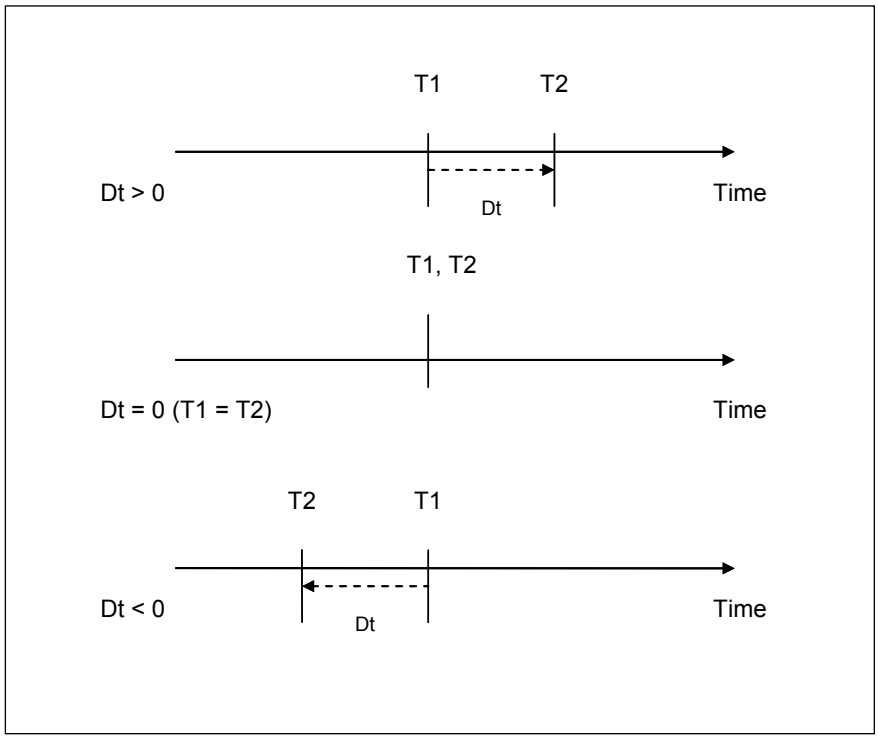
Trigger Time – The point in time at which the response to an event begins. This is the timestamp field of the LXI Event Message. In the classic SCPI trigger state machine (see example figure in section 6.4.4), the response to a trigger event causes the state machine to begin the optional offset (e.g., trigger delay or advance) and then the triggered action (e.g., take a measurement, enable source output, change switch configuration, etc.).

T1 = Trigger Time – Timestamp field of the LXI Event Message. If T1 is zero ("Now"), it is replaced with the current time of the receiving clock.

Dt = Offset – This may be zero, positive, or negative.

T2 = Action Time – Examples of this time are as follows: take a measurement, enable source output, change switch configuration, etc.



3.3.5 Recommendation – Support LXI Events with Arbitrary Event IDs

In addition to the Event IDs "LAN0" through "LAN7", LXI Devices should support LXI Events with arbitrary Event IDs.

3.3.6 RULE – Ignore LXI Event Message with Unknown Event ID

If an LXI Device receives an LXI Event Message with an Event ID not known by the LXI Device, the LXI Device shall ignore the message.

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3.3.6.1 Permission – Log Unknown LXI Event Messages

If an LXI Device receives an LXI Event Message with an Event ID not known by the LXI Device, the LXI Device may log this event in an LXI Event Log.

3.3.7 RULE – Timestamp of Zero

If a module receives an LXI Event Message with a Timestamp field of zero, the time indicated by the timestamp shall be interpreted as "now" by the receiving module, i.e., the current time as it is understood by the receiving module.

A module shall transmit an LXI Event Message with a value of zero for the Timestamp field only if one or more of the following apply:

- The module does not implement IEEE 1588
- The LXI Device is overloaded and cannot capture timestamps fast enough. This condition should be considered a serious or fatal error.
- The user-specified semantics required upon receipt is "now."

3.3.8 RULE – LXI Event Interpolation

When transmitting LXI Event Messages with a Stateless Event (Flags Bit 4) value of 0 (zero), devices shall behave as follows:

- when transmitting LXI Event Messages configured to be in Wired-OR mode the device shall transmit only a single sense of the event in Hardware Value (Flags Bit 2)
- otherwise, devices shall send both senses of the event in Hardware Value (Flags Bit 2)

When the value of Stateless Event (Flags Bit 4) is zero, recipients of events are required to compare the sense of incoming events with the current state of that event. If the received event sense (value of Hardware Value – Bit 2) is identical (true or false) to the current state of the event, recipients must interpolate an opposite sense event occurring immediately prior to the received event and behave accordingly.

Note: The Wired-OR mode of transmission for LXI Events does not implement true Wired-OR logic in the way that the LXI Trigger Bus does. Wired-OR mode has no mechanism for detecting the absence of all signals (the false state) because it is impractical to keep an infinite buffer of all packets received.

3.4 Recommendation – Programmable LXI Devices

The introduction, 3.1, implies that LXI Devices can respond to and generate LXI Events based on user configuration. There are a number of ways in which this feature can be implemented, the simplest of which is to pre-define all of the possible responses that an LXI Device might execute for each LXI Event. It is recommended that LXI Devices be programmable for this purpose and capable of downloading executable code.

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3.5 LXI Event Handling

3.5.1 RULE – Measurement-related Functions Initiated by LXI Events

Any measurement-related function executable via the controller-based driver (e.g., IVI) shall also be executable from within the LXI Device. These functions shall be executable by the local LXI Device based on any of the following LXI Event mechanisms implemented in the LXI Device:

- LXI Event Messages from other system modules, 3.3
- Internal time-based events, 3.2.10
- LXI Trigger Bus, 5.

(Note: The term "measurement-related" does not refer to basic LXI Device configuration. For instance, setting the frequency of a source is a "measurement-related function," while setting the IP address of an LXI Device is not.)

3.5.1.1 Recommendation – Include Conventional Triggers

Conventional hard-wired trigger inputs may be included in the acceptable LXI Events subject to rule 3.5.1.

3.5.1.2 Recommendation – Allow Multiple Actions from a Single Trigger

LXI Devices should provide for the execution of multiple events or configuration changes to be initiated by a single LXI Event, programmable by the user.

3.5.1.3 RULE – Specify Trigger Response Times

For each triggered function configurable under rule 3.5.1 that is implemented in an LXI Device, the published specification shall include the time that it takes to respond to each of the possible triggering methods. This information shall include the minimum, maximum, and typical response times (exclusive of LAN latencies and other timing effects that are external to the LXI Device itself). For response times that are probabilistic in nature, the minimum and maximum response times shall be specified with a 95% confidence. If the response time is unknown or cannot be determined, the manufacturers shall explicitly state that the time is unknown. This information shall be available as a part of the documentation that accompanies each LXI Device (whether printed or electronic).

3.5.1.3.1 Recommendation – Trigger Output Response Times Available via Driver

The information provided for in 3.5.1.3 should be available on the controller via the driver interface.

3.5.1.3.2 Recommendation – LXI Events Executable via Driver Call

Events under rule 3.5.1and recommendation 3.5.1.1 should also be accessible via the driver interface on the controller.

3.5.1.3.3 Permission – Exemption from Triggering Requirements

LXI Devices that have fewer triggering options are exempt from all requirements to enable triggering for types of triggers that do not exist on the device.

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3.5.2 Recommendation – Trigger Outputs Can Be Transmitted by Any Method

Any LXI Device capable of detecting an LXI Event that can be used as a trigger should be configurable to communicate this trigger event to other devices by LXI Event Message (using the LXI Event Message format defined in Section 4), LXI Trigger Bus, or optional vendor specific hardware.

3.5.2.1 RULE – Specify Trigger Output Response Times

If Recommendation 3.5.2 is implemented, for each LXI Event that can cause a trigger the published specification shall include the time it takes the LXI Device to respond to the event and transmit a trigger by each of the possible triggering methods. This information shall include the minimum, maximum, and typical response times. For response times that are probabilistic in nature, the minimum and maximum response times shall be specified with a 95% confidence. If the response time is unknown or cannot be determined, the manufacturers shall explicitly state that the time is unknown. This information shall be available as a part of the documentation that accompanies each LXI Device (whether printed or electronic).

3.5.2.2 Recommendation – Trigger Output Response Times Available via Driver

The information provided for in Rule 3.5.2.1 should be available on the controller via the driver interface.

3.5.2.3 Recommendation – Events Available via Driver Call

Events under Recommendation 3.5.2 should also be accessible via the driver interface on the controller.

3.5.2.4 Permission – Exemption from Triggering Requirements

LXI Devices that have fewer triggering options are exempt from all requirements to output triggers for types of triggers that do not exist on the device.

3.6 RULE – Data Timestamps

LXI Devices shall assign a timestamp to all measurement data. See section 6.5 concerning driver requirements associated with LXI Timestamped Data.

For all LXI Devices implementing IEEE 1588, all such timestamps shall be derived from the local IEEE 1588 synchronized real-time clock. LXI Devices implementing any part of the standard LXI API (see section 6) shall return a valid data timestamp value.

3.6.1.1.1 Permission – Circumstances Under Which Data Timestamps May Be Zero

Data timestamp values may be zero under the following circumstances:

- The LXI Device does not implement IEEE 1588, or
- The LXI Device is overloaded, and cannot capture timestamps fast enough. This condition should be considered a non-fatal error, or

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- Vendors may implement an option to disable the collection of timestamps in an LXI Device. In this case, the LXI Device shall collect timestamps by default, and users must explicitly disable the functionality.

Note: See section 3.2.11 for timestamp specifications based on IEEE 1588 clocks.

3.7 RULE– Internal Log File for Events

All LXI Devices capable of acting on or generating LXI Events shall be configurable to record a timestamp and event identifier for all transmitted and received LXI Event Messages (TCP unicast and UDP multicast) in an internal LXI Event Log. This LXI Event Log shall be accessible via a driver transaction from the controller. (See the Programmatic Interface section 6.7.)

Logging shall be enabled or disabled via a driver command. The timestamps in the LXI Event Log shall be:

- Based on the local IEEE 1588 clock if implemented, else
- Shall be either 0 or based on a time base consistent with the current IEEE 1588 time base of the system.

3.7.1 Recommendation – Events To Be Logged

In addition to the logging required by 3.7, devices should log any events that are significant to the instrument or application domain, including driver commands, triggers of any form, or significant internal state change.

Vendors are allowed and encouraged to log additional events that are appropriate and meaningful for the application domain and device functionality.

.

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4 Module-to-Module Data Communication of LXI Event Messages

4.1 Introduction

This section describes the data format for direct module-to-module messages. These messages are LXI Event Messages that are either multicast on the LAN via UDP or transmitted through a point-to-point TCP connection. Each message is timestamped and signals the occurrence of some LXI Event in the system. LXI Devices in the system can be programmed to broadcast messages (or not) as needed.

4.2 RULE – LXI Event Message Size

For UDP communications, the total size of the data used for module-to-module communications of LXI Event Messages shall not be larger than a single LAN data packet.

4.3 RULE – LXI Event Message Format

Module-to-module LXI Event Messages shall contain the following fields as specified. Please see Appendix B for examples.

HW Detect	Domain	Event ID	Sequence	Timestamp	Epoch	Flags	Data Fields…	0 (two bytes)

Each field is described below. It is assumed that one byte is the standard size, i.e. 8 bits (also referred to as an octet). Furthermore, *all multi-byte numeric fields are big-endian (most significant byte comes first). Within each byte (octet) of the fields described above the least significant bit is transmitted first. For octet array fields the most significant field is transmitted first. The most significant array field is the field with index 0.*

The above fields shall be marshaled into the on-the-wire format in the following order:

HW Detect: Octet array of length 3: Used as a "magic value" to identify valid packets, and also reserved for future hardware detection of LXI Event packets. This field should be set to the value "LXI." Note that the third octet, ASCII "I" is also used as a version identifier; future revisions to this spec may change this value.

Domain: UInteger8. The default value shall be zero.

Event ID: Octet array of length 16: Contains an LXI Event identifier. This field shall contain the first 16 octets of the LXI Event name (a sequence of ASCII characters) specified in the LXI API. Event names longer than 16 ASCII characters are truncated to the first 16 characters. All LXI Event names listed in the table of strings for triggering and synchronization in Rule 6.4.4 that refer to repeated capabilities are predefined by the LXI Consortium. All LXI Event names beginning with the 3 ASCII characters LXI are reserved by rule 6.4.5. All other names are available to users. The leading character shall be in the octet with index 0. For LXI Event names of less that 16 characters the unused octets shall be set to 0x00. This field is not NULL-terminated (0x00) but appears so if the LXI Event name happens to be less than 16 characters. All 16 octets of this field are significant.

Sequence: UInteger32: Contains a sequence number. Each transmitting instrument shall maintain the following independent sequence counter(s):

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- One for each combination of UDP multicast network interface and UDP multicast destination port that the instrument supports
- One for each TCP connection.

Upon transmitting an LXI Event message, an instrument shall increment the sequence counter associated with the transport for that message by one.

The initial value of a sequence counter is not defined by this standard and is left up to the vendor.

By specifying how sequence numbers are generated, modules and applications may implement various forms of duplicate packet detection; however, discussion of duplicate packet detection is beyond the scope of this standard.

(Note: If packets are re-transmitted to enhance reliability, re-transmitted packets shall contain the same sequence number as the original.)

Timestamp: 10 octets: A timestamp that identifies the time that the LXI Event occurred or will occur. This timestamp shall use the format specified here:

```
struct TimeRepresentation
{
   UInteger32 seconds:
   UInteger32 nanoseconds:
   UInteger16 fractional_nanoseconds:
}
Where:
The seconds field is the least significant 32 bits of the seconds
field of the IEEE 1588 data type Timestamp.
The nanoseconds field is the nanoseconds field of the IEEE 1588 data
type Timestamp. The nanoseconds field is always less than 10^+9.
The fractional nanoseconds field shall be any fraction of a
nanosecond provided by the timestamp mechanism of the IEEE 1588
clock. Note that in the IEEE 1588 on-the-wire communication used for
synchronizing clocks, this information will be contained in the
correctionField. The application interface to the local clock may or
may not present fractional nanosecond information. If none is
provided then this field shall be zero.



These fields shall be marshaled into their on-the-wire format in the
following order: seconds, nanoseconds, fractional_nanoseconds.



For example:
+2.0 seconds is represented by seconds = 0x00000002 and nanoseconds =
+0x00000000
-2.0 seconds is represented by seconds = 0x00000002 and nanoseconds =
0x80000000
+2.000000001 seconds        by seconds = 0x00000002 and nanoseconds =
0x00000001
```

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If no event timestamp is available, for example if the event is derived from a legacy device or an LXI Device incapable of assigning a timestamp, a time value of 0 (zero) shall be assigned to the timestamp. A value of 0 for a timestamp shall be interpreted as "now," i.e., the time when the recipient handles the message.

Epoch: A UInteger16 that contains the most significant 16 bits of the seconds field of the IEEE 1588 data type Timestamp. Devices incapable of assigning a timestamp shall assign a value of zero (0) to the epoch.

Flags: UInteger16 that contains data about the packet. Bits within the flag byte are defined as follows:

Bit 0 – Error Message: If set to 1, shall indicate that this packet is an error message.

Bit 1 – Reserved. This bit shall be set to zero.

Bit 2 – Hardware Value: A logical value that characterizes trigger events (particularly hardware events). Refer to the programmatic interface section of the LXI spec for further explanation.

Bit 3 – Acknowledgement: If set to 1, shall indicate that this packet is an acknowledgement that a prior packet was successfully received. This allows LXI systems to implement UDP-based handshaking protocols (for increased reliability), if desired. Modules are not required to implement this feature; however, those modules shall ignore packets it this bit is set.

Bit 4 - Stateless Event. If set to 0 (required in versions of this standard prior to 1.2), shall indicate that the contents of Hardware Value (Flags Bit 2) must be monitored by receiving modules. If set to 1, indicates that the LXI Event being transmitted is stateless and thus the contents of Hardware Value (Flags Bit 2) must be ignored by receivers.

Bit 5-15 – Reserved. All bits shall be set to zero.

Data Fields: Arbitrary number of bytes, up to the capacity of the LXI Event Message. Each data field shall be formatted as follows:

Data Length (UInteger16): Length of the User Data that follows the next Identifier field. This field shall contain a zero if no further data is contained in the packet. The value of this field does not include the 1-octet Identifier in the length.

Identifier (Integer8): A user-definable identifier that specifies the type of data to follow. Numbers from zero to 127 are available for user-defined identifiers. All negative values are reserved for specification by the LXI Consortium.

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The LXI Consortium has defined the following Identifier values:

Value	Data Type	Length (Octets)	Notes
-1 (0xFF)	ASCII Data	1	ASCII Character String; not null-terminated
-2 (0xFE)	int8	1	Two's-complement
-3 (0xFD)	uint8	1	
-4 (0XFC)	int16	2	Two's-complement; multi-octet fields are big-endian
-5 (0XFB)	uint16	2	Multi-octet fields are big-endian
-6 (0XFA)	int32	4	Two's-complement; multi-octet fields are big-endian
-7 (0xF9)	uint32	4	Multi-octet fields are big-endian
-8 (0xF8)	int64	8	Two's-complement; multi-octet fields are big-endian
-9 (0xF7)	uint64	8	Multi-octet fields are big-endian
-10 (0xF6)	float32	4	IEEE 754 Format; multi-octet fields are big-endian
-11 (0xF5)	float64	8	IEEE 754 Format; multi-octet fields are big-endian
-12 (0xF4)	float128	16	IEEE 754 Format; multi-octet fields are big-endian
-13 (0xF3)	UTF-8 Data	1	Unicode String Data encoded in UTF-8; not null-terminated
-14 (0xF2)	UTF-8 JSON	1	JSON encoded in UTF-8; not null-terminated
-15 (0xF1)	UTF-8 XML	1	XML encoded in UTF-8; not null-terminated
-16 (0xF0)	Octet	n	Uninterpreted octet

For any of the LXI Consortium-defined Identifier values, the Data Length field may be an integer multiple of the data type's length, indicating that a sequence of values of the indicated data type is stored in the User Data field. For example, for a sequence of 3 int16 values the Data Length value is 6. Note that the Data Length field is always a length in octets, regardless of the Identifier value.

User Data (succeeding bytes): Data as an octet-array whose length is given by the Data Length field.

There may be multiple data fields in an LXI Event packet. The packet ends when a zero (two bytes) is encountered as the length of the next field or when the maximum data payload limit is reached.

This variable-length data field is designed to satisfy two different needs. First, it allows the LXI Consortium to define new data fields that may become a part of the LXI specification. Second, it allows vendors to define proprietary data fields of their own. LXI Event Messages containing user data with identifiers not known by the module shall be ignored.

The specification of the data identifiers in the above table does not require implementers to be able to parse all possible values, e.g. it is not required to implement a XML parser because of this table.

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4.3.1 RULE – Use of HW Detect Field

LXI Devices shall ignore any received LXI Event Message if the value of the HW Detect field does not match the value pertinent to the version of the LXI specification to which the LXI Device conforms.

4.3.2 RULE – Use of Domain Byte

LXI Devices shall maintain an internal configuration option that allows users to specify the value of the Domain field. Upon transmitting an LXI Event Message, LXI Devices shall copy that value to the Domain field. Upon receiving an LXI Event Message, LXI Devices shall ignore all packets whose Domain field does not match the LXI Device's own.

4.3.3 RULE – NULL Events

If the Event ID field of an LXI Event Message contains only zeros, the event shall be considered a "null event." All LXI Devices shall ignore null events, except that unless LXI Event Logs are disabled they shall be recorded in log files for debugging purposes.

4.3.4 RULE – Acknowledgements

One possible way to improve the reliability of UDP data transmissions is to program the receiving module to return an acknowledgement upon receipt of an LXI Event Message. If this is implemented, the acknowledgment packet shall have set the Acknowledgement flag (bit 3 of the Flags byte) to 1. Modules that do not implement this feature shall ignore received LAN Event Messages if this flag is set to 1.

4.3.4.1 RULE – Handling Acknowledgement Packets

If a module receives an LXI Event Message with the Acknowledgement flag set to 1, and the module does not implement a handshaking protocol, then the module shall ignore the packet.

4.4 RULE – Pre-defined Error Messages

Some LXI Event Messages may contain error messages rather than LXI Event notifications. These messages are broadcast on the same address and port as normal LXI Event Messages, but the Error bit (bit zero) of the Flags field of the LXI Event Message is set to 1. This allows the creation of an "LXI Event monitor" tool that can be used for debugging and can quickly identify errors as they occur.

Errors can be further identified by the use of the data fields in the message. This allows specific errors to be identified by an ID number, a descriptive string, or both.

Certain error messages are predefined. For these messages, the Event ID field in the LXI Event Message shall be set to "LXIError." The Data Field shall consist of an Error Identifier and possibly error specific data. Error identifiers shall be an Integer8 with negative values reserved for definition by the LXI Consortium.

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The following table lists the LXI Consortium defined error message Error Identifier and error specific data definitions.

Error Identifier	Error definition	Error specific data
-1	Time reset. A time reset has occurred. The error message is broadcast once by the grandmaster clock whenever the grandmaster IEEE 1588 clock has drifted away from a traceable source of UTC and is being adjusted.	The time offset that is needed to bring the timescale into agreement with UTC. The data type shall be the TimeInterval of IEEE 1588 (Integer64 scaled nanoseconds)

For example, the contents of the Data Field of Rule 4.3 for the LXI defined error Time reset are:

Data Length (UInteger16)	Identifier (Integer8)	User Data (error identifier)	Data Length (UInteger16)	Identifier (Integer8)	User Data
Octet 0 – 1	Octet 2	Octet 3	Octet 4 – 5	Octet 6	Octets 7-14
0x0001	0xFE (Integer8)	0xFF (-1)	0x0008	0xF8 (Integer64)	IEEE 1588 TimeInterval

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5 LXI Hardware Triggering

5.1 Introduction

Hardware triggers can be used to initiate predefined actions in an LXI Device, such as generating a signal, making a measurement, or closing a switch. Hardware triggering provides an alternative to, or complements, LXI Event-based triggering in applications requiring higher precision or lower latency (see Section 6 and 3.3 for more information on LXI Event-based triggering). LXI Devices send or receive hardware trigger signals using either the LXI Trigger Bus or vendor-specific hardware interconnect lines. The LXI Trigger Bus consists of eight shielded twisted-pair wires that can be used to distribute M-LVDS signals between groups of devices connected in either a daisy-chain, star, or hybrid-star configuration (see Figure 5.1).

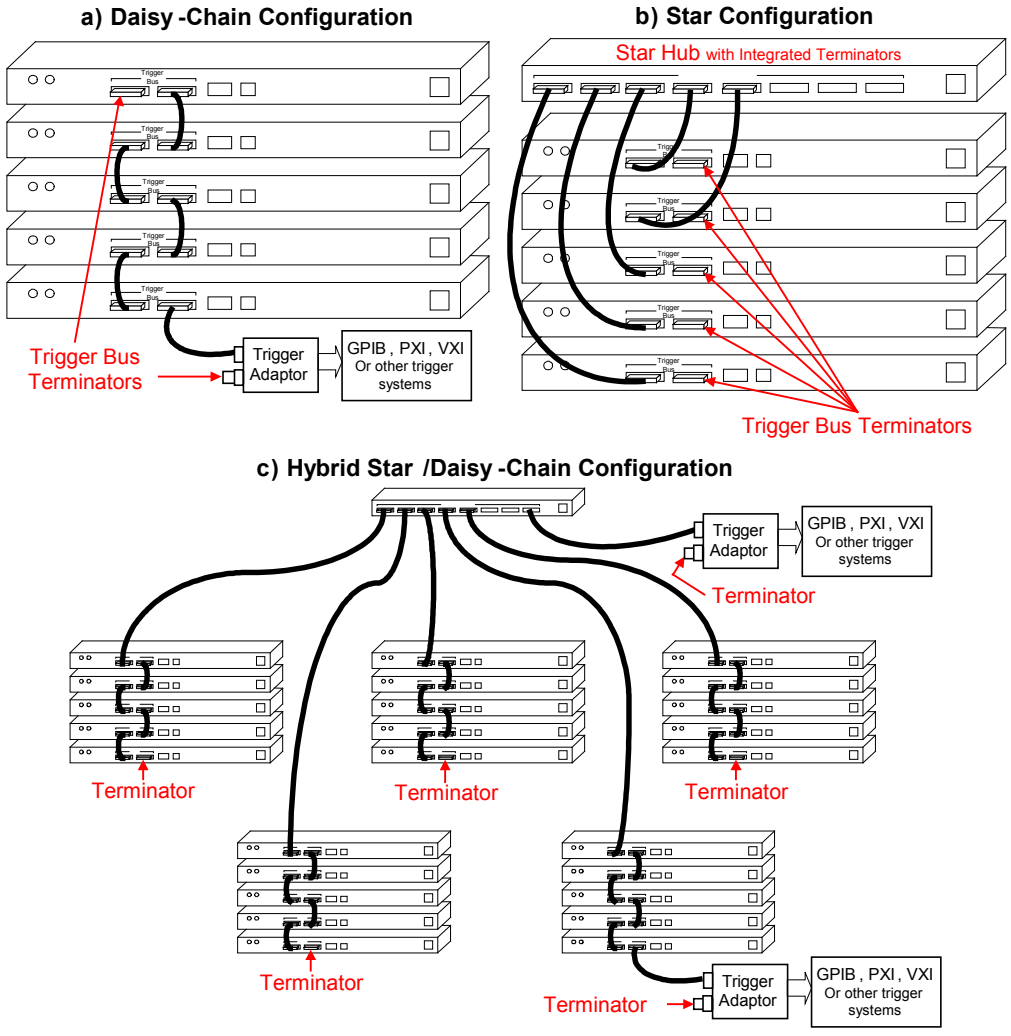

Figure 5.1 LXI Trigger Bus Configurations

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Several examples of possible hardware trigger scenarios are listed below:

- An external event generates a trigger signal that initiates an action in a device.
- A computer generates a trigger signal that initiates an action in a device.
- One device sends a trigger signal to one or more other devices that initiates simultaneous actions in those devices. (From the triggered device's perspective, this is the same as an external event.)
- A hardware trigger signal received by one device (either from another device or an external event) causes it to send any number of LXI Event-based triggers to one or more other devices, initiating preconfigured actions in those devices.
- LXI Event-based triggers received by one or more devices cause hardware triggers to be sent to one or more other devices, initiating actions in those devices.
- An external event generates a hardware trigger signal that is time-stamped by a device and used to capture data from a circular buffer prior to the trigger.
- A common reference clock, distributed using hardware trigger lines, is used to synchronize actions in multiple devices.

Each channel of the LXI Trigger Bus is capable of operating in one of two modes, the mode being set by programming the LXI Devices that are taking part in the trigger operation for that channel. LXI Devices that are not taking part in a trigger operation should have their drivers disabled.

The two modes of operation are:

- **Driven Mode**. This provides point-to-multipoint operation. One device initiates a trigger event to one or more receiving devices. This mode uses one driver per LXI Device for each LXI Trigger Bus channel.

- **Wired-OR Mode**. This is a multipoint-to-multipoint operation. One or more devices initiate a trigger event to one or more receiving devices. In this mode, the event can be initiated by the first device to trigger (first device to recognize an event starts others to perform tasks), or the last device to trigger (last device ready initiates others to perform tasks). The Wired-OR Mode requires one device to be configured as the Wired-OR Bias Device to provide a bias for the LXI Trigger Bus channel. Other driver devices participating in the wired trigger require the use of two drivers for each LXI Trigger Bus channel.

5.2 Permission – Vendor-Specific Hardware Trigger Interfaces

Optional, vendor-specific hardware trigger interfaces (e.g., BNC, SMB, etc.) are permitted on all functional classes of LXI Devices. Optional trigger ports may provide selectable inputs or outputs on either the front or rear of the device.

5.3 Electrical Requirements

5.3.1 RULE – Number of Channels

The LXI Trigger Bus shall consist of eight individual hardware channels.

5.3.2 RULE – Signaling Standard

Each LXI Trigger Bus channel shall use half-duplex, Multipoint-Low-Voltage-Differential Signaling (M-LVDS) with Type-1 receivers, compliant with TIA/EIA-899.

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5.3.3 RULE – Maximum Number of Nodes per Segment

The maximum number of nodes on any LXI Trigger Bus connection segment shall be 16.

5.3.4 RULE – LXI Trigger Bus Buffering

Each LXI Device connected to the LXI Trigger Bus shall provide half-duplex buffering on each channel, between the external M-LVDS pair and the internal signal routing of the LXI Device.

5.3.5 RULE – M-LVDS Transceiver Type

One of the following M-LVDS transceivers shall be used for the LXI Trigger Bus: Texas Instruments SN65MLVD080 (8 channel) or Texas Instruments SN65MLVD201 (single channel).

5.3.5.1 Permission – M-LVDS Transceiver Type

Vendors may use an equivalent device but must provide a technical justification for its use that demonstrates it has equivalent performance for LXI Trigger Bus application.

5.3.6 RULE – Input/Output Configurability

Each LXI Trigger Bus channel shall be individually configurable as an input or output (or both), and shall be capable of being individually enabled or disabled.

5.3.7 RULE – Driver Mode Configurability

Each LXI Trigger Bus driver shall be individually configurable to operate in either Driven or Wired-OR Mode.

5.3.8 RULE – Driver Topology

Each LXI Trigger Bus driver shall consist of two M-LVDS drivers with the outputs connected in parallel, as shown in Figure 5.2 b). In Driven Mode, only one driver shall be enabled, and the trigger signal shall be applied to the driver's input. In Wired-OR Mode, each driver shall be configured to drive current from the positive (A) output to the negative (B) output when enabled, and the trigger signal shall be applied to the enable inputs of both drivers.

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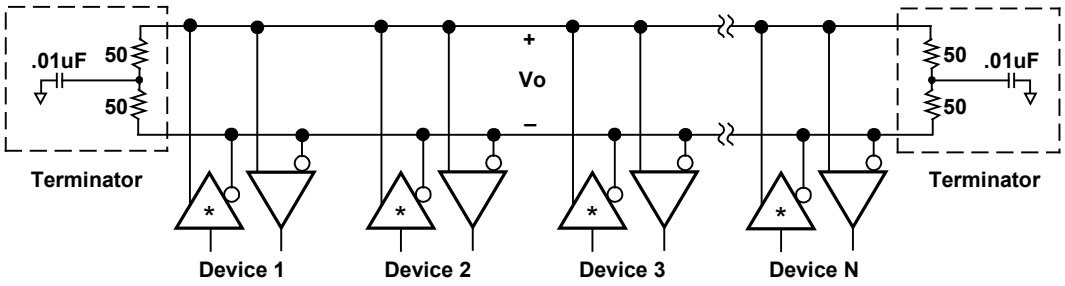

Figure 5.2 a) Single LXI Trigger Bus Channel with Bus Terminators (*See Fig 5.2 b)

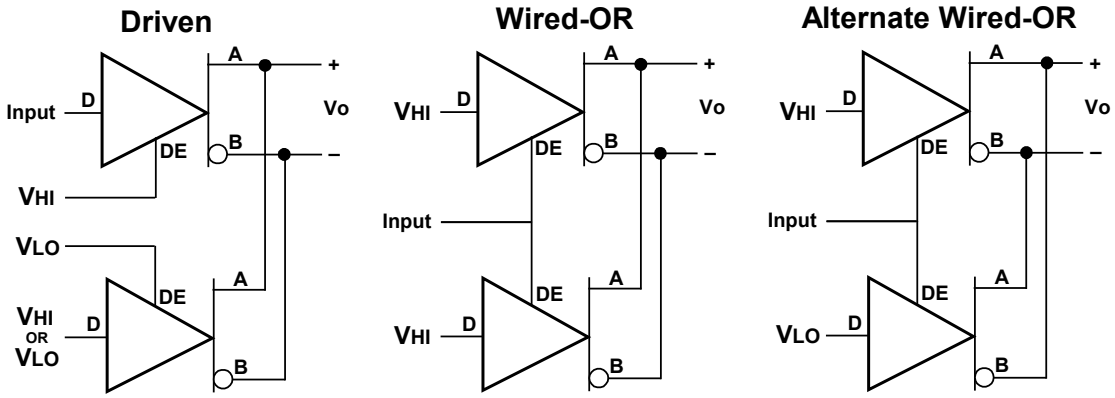

Figure 5.2 b) LXI Trigger Bus Drivers, Driven and Wired-OR Modes

5.3.9 RULE – Wired-OR Bias

Each LXI Trigger Bus channel configured for Wired-OR Mode operation shall be provided a Wired-OR Bias by any one of the LXI Devices connected to the bus.

5.3.10 RULE – Wired-OR Bias Device

Each LXI Device connected to the LXI Trigger Bus shall be capable of being configured to act as the Wired-OR Bias Device for any number of LXI Trigger Bus channels configured for Wired-OR operation, by providing the Wired-OR Bias for those channels. The Wired-OR Bias Device shall be capable of enabling and disabling the Wired-OR Bias under programmatic control, on a channel-by-channel basis.

5.3.11 RULE – Wired-OR Bias Device Functionality

The LXI Trigger Bus driver of an LXI Device that is configured to act as the Wired-OR Bias Device for a particular channel shall always operate in Driven Mode, and shall be continuously enabled to drive the LXI Trigger Bus channel low (negative), unless it is participating in the Wired-OR

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communication, in which case it shall actively drive the bus according to its input. (Refer to the Driven-Mode Driver schematic in Figure 5.2b).

5.3.12 RULE – Power-up Default Configuration

All LXI Trigger Bus channels shall default to the disabled configuration when power is applied to the device.

5.3.13 RULE – Configurable Edge or Level Detection of Signals

LXI Trigger Bus signals shall be programmable for positive or negative edge, or positive or negative level detection, on a channel-by-channel basis.

5.3.14 RULE - Signal Routing to All Eight Channels

Any LXI Device capable of transmitting or receiving signals on the LXI Trigger Bus shall be capable of doing so on any of the eight Trigger Bus channels.

5.3.15 RULE – Simultaneous Transmit and Receive

LXI Devices using the LXI Trigger Bus shall be capable of simultaneously transmitting and receiving signals on any of the eight LXI Trigger Bus channels.

5.3.16 Recommendation – Gating of Unwanted Receiver Outputs

In cases when it is not possible to disable individual receivers, unwanted receiver output signals should be gated-off inside the LXI Device, using additional logic.

5.3.17 RULE– Minimum Pulse Width in Driven Mode

The minimum pulse width of LXI Trigger Bus signals transmitted in Driven Mode on connection segments of 10 meters or less shall be 10 ns, and shall be 20 ns on connection segments of 20 meters or less.

5.3.18 RULE – Minimum Pulse Width in Wired-OR Mode

The minimum pulse width of LXI Trigger Bus signals transmitted in Wired-OR Mode on connection segments of 10 meters or less shall be 20 ns, and shall be 40 ns on connection segments of 20 meters or less.

5.3.19 RULE – Documentation of Minimum Trigger Pulse Width

Manufacturers shall provide documentation specifying the minimum pulse width required by an LXI Device to achieve reliable triggering when using edge detection.

5.3.20 Recommendation – Ready Signal

LXI Devices should provide an output signal indicating when the device is “ready.” For a measuring device, this means that it is in the “waiting for trigger” or “armed” condition. For a source type device, it indicates the output signal is stable and within specification. This signal, if available, should be accessible over the LXI Trigger Bus or via LAN.

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5.3.21 Recommendation – Measurement Complete Signal

LXI Devices should provide an output signal indicating when the device has completed a measurement. This signal, if available, should be accessible over the LXI Trigger Bus or via LAN.

5.4 Physical Requirements

5.4.1 RULE – LXI Trigger Bus Connector Type

25-pin Micro-D connectors shall be used to interconnect LXI Devices incorporating the LXI Trigger Bus.

5.4.2 Recommendation – LXI Trigger Bus Connector Type

The following connectors, or equivalents, are representative of the type recommended for LXI Trigger Bus connectivity: ITT Cannon MDSM-25PE-Z10-VR17 (single connector) or Molex 83619-9011 (dual connector). These connectors can be double-stacked in a 1U configuration for efficient space utilization.

5.4.3 RULE – Number of LXI Trigger Bus Ports

All LXI Devices implementing the LXI Trigger Bus (except devices conforming to all of the additional requirements of a Star Hub) shall have at least one LXI Trigger Bus port, consisting of a pair of LXI Trigger Bus connectors wired in parallel (like-numbered pins connected together). (See Section 2 for recommended connector locations).

5.4.4 Permission – Additional LXI Trigger Bus Ports

LXI Devices may have more than one LXI Trigger Bus port, provided that each port consists of a single pair of LXI Trigger Bus connectors wired in parallel (like-numbered pins connected together), and that each port provides the required buffering, as defined in Section 5.3.

5.4.5 RULE – Trace Characteristic Impedance

Traces interconnecting the LXI Trigger Bus connector pins shall be designed for 100-ohms (±10%) differential characteristic impedance.

5.4.6 RULE – Printed Circuit Trace Lengths

Traces interconnecting the LXI Trigger Bus connector pins shall be kept as short as possible, with a maximum trace length of 63.5 mm (2.5 inches) between connectors.

5.4.7 RULE – Channel-to-Channel Skew

Traces interconnecting the LXI Trigger Bus connectors shall be kept as equal in length as possible, with a trace length difference between channels (maximum-to-minimum) of less than 25 mm.

5.4.8 RULE – Maximum Stub Length

If a stub is created as a result of connecting the LXI Trigger Bus to a transceiver, the maximum stub length shall not exceed 12.7 mm (0.5 inches).

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5.4.9 RULE – LXI Trigger Bus Connector Pin Assignments

LXI Trigger Bus connectors and cables shall use the pin assignments shown in Table 5.1.

5.4.9.1 RULE – +3.3V Supply on LXI Trigger Bus Connectors

Each LXI Trigger Bus connector shall provide +3.3 V (± 0.2 V), capable of sourcing a total minimum current of 100 mA for both connectors (not 100 mA on each connector). The power supply shall be short circuit protected.

5.4.10 Recommendation – +3.3V Protection Using Self-Healing Fuse

The +3.3V power pin on each LXI Trigger Bus connector should be protected by a separate self-healing fuse.

5.4.11 RULE – Reserved Pins Not To Be Used For Other Purposes

Pins designated as "Reserved" shall not be used for any purpose that is not specifically authorized by the LXI Consortium.

Table 5.1 LXI Trigger Bus Pin Assignments

Pin	Signal
1	+3.3V
2	+3.3V_RETURN
3	LXI1p
4	LXI1n
5	GND
6	LXI3p
7	LXI3n
8	GND
9	LXI5p
10	LXI5n
11	Reserved
12	LXI7p
13	LXI7n
14	LXI0p
15	LXI0n
16	Reserved
17	LXI2p
18	LXI2n
19	GND
20	LXI4p
21	LXI4n
22	GND
23	LXI6p
24	LXI6n
25	Reserved
Connector Shell	CHASSIS

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Note: LXI Trigger Bus signals with a "p" suffix are the positive (A) half of the pair and those with an "n" suffix are the negative (B) half.

5.5 Specific Requirements for Star Hubs

5.5.1 RULE – Star Hub Number of Ports

A Star Hub shall have a minimum of three LXI Trigger Bus ports.

5.5.2 RULE – Star Hub Signal Buffering

Each channel of each Star Hub port shall provide half-duplex buffering between the external M-LVDS pair and the hub's internal signal routing.

5.5.3 RULE – Star Hub Internal Bus Termination, Single-Connector Ports

Star Hub ports implemented with a single connector shall provide internal, integrated termination resistors on all eight LXI Trigger Bus channels, identical to those defined in Rule 5.6.1.

5.5.4 RULE – Star Hub Minimum Signal Routing Capability

A Star Hub shall be capable, at a minimum, of receiving a LXI Trigger Bus signal on any channel of any port and simultaneously retransmitting that signal on the same channel of any number of other ports.

5.6 LXI Trigger Bus Cables and Terminators

5.6.1 RULE – LXI Trigger Bus Termination

The LXI Trigger Bus shall be terminated using termination connector blocks installed at both ends of a connection segment, as shown in Figure 5.1. Each individual channel shall be terminated at each end by two 50-ohm (±5 %) resistors connected in series between the positive (A) and negative (B) signal wires, and a 0.01µF capacitor to ground connected to the node between the resistors, as shown in Figure 5.2 a). The resistor values shall be matched to within ±2%.

5.6.2 RULE – LXI Trigger Bus Cable and Terminator Specifications

LXI Trigger Bus cables and terminators shall be constructed in conformance with the specification contained in the LXI Consortium document entitled "LXI Trigger Bus Cable and Terminator Specifications".

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6 LXI Programmatic Interface (Drivers)

The following rules will guide the software characteristics of LXI Devices. Software synergy is important to ensure LXI Devices are easy to integrate with each other and the test program.

Customers need a single standard driver to ensure interoperability.

6.1 RULE – IVI Driver Requirement

All LXI Devices shall provide an IVI Specific Driver. The details of this requirement are called out in Section 5 of IVI-3.1. If an LXI Device is a reasonable match to an existing IVI Class specification, its driver shall be compliant to that IVI Class[11].

6.1.1 RULE – Trigger and Event Required API

IVI drivers for LXI Devices shall conform to the IVI-3.15 IviLxiSync specification when required by a subsection of 1.9.1.2.

6.1.2 Recommendation – IVI-COM Recommendation

Although the LXI Foundation has chosen not to require a particular driver technology, there is a significant customer benefit in LXI Devices providing a consistent driver solution. Therefore, LXI Device vendors are encouraged to provide IVI-COM drivers with their devices. IVI-COM drivers provide excellent tools for customers that want to achieve interchangeability and are based on the Microsoft COM technology, which is supported by all major application development environments.

LXI vendors wishing to optimize the customers experience in National Instruments LabVIEW or National Instruments LabWindows should consider also providing G drivers[12] or IVI-C drivers respectively.

6.1.2.1 Permission – Provide Other Drivers as Needed

LXI Devices may optionally provide additional drivers. This is especially appropriate for operating environment other than Microsoft Windows (e.g., LINUX, VxWorks, UNIX, etc.). The LXI Consortium will not do explicit specification work to support these alternate drivers.

6.2 RULE – Syntax of the Device Address

LXI IVI Drivers shall accept VISA resource names.

The IVI driver provided with an LXI Device may use whatever underlying protocol is permitted by sections 8.1 and 8.1.1. However, the driver shall accept any valid VISA resource name as the network resource location as described in this section.

Specifically, valid VISA resource names for LXI Devices are:

```
TCPIP[board]::host address[::LAN device name][::INSTR]
TCPIP[board]::host address::port::SOCKET[13]
```

[11] For more information on IVI or to download the specifications, see www.ivifoundation.org
[12] Also known as VXI*plug&play* GWIN Framework drivers
[13] For additional information see vpp43.doc at http://www.ivifoundation.org/Downloads/Specifications.htm

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Where:

- *board* is an integer representing a physical network interface card in the computer
- *host address* is either a hostname or IP address (4 bytes in decimal separated by ".")
- "INSTR" is the *resource class*. It implies a protocol that supports read, write, trigger, status, and clear
- "SOCKET" is the *resource class*. It implies a protocol based on a raw tcp/ip connection that may only support read/write.

Although VISA does not specify that the data being read/written to the device is an ASCII instrument control language (such as SCPI), it is implied by the INSTR and SOCKET resource classes.

If the driver supports control of the device via either the SOCKET or INSTR protocols, the driver shall use the specified protocol, unless a subsequent driver call or initialization string alters that behavior.

The driver shall choose the most appropriate protocol for controlling that device. For the INSTR resource class the LXI Device name may be used to specify a port. If the IP port, the LXI Device name, or resource class is not relevant for that protocol, the driver shall ignore the irrelevant parameters.

Note that this resource descriptor may be passed directly by the customer to the open call or it may be extracted from the IVI Configuration Store.

6.3 RULE – IVI Property for Referencing a Signal Source

Any IVI interface referencing an LXI Trigger Bus signal or LXI Event Message as an input shall have a property of type BSTR named Source, or ending in Source, if there is a prefix. All actions within a device, which can be triggered by an LXI Trigger Bus line, IEEE 1588 alarm, or LXI Event Message, shall be configurable via an interface that has a source property as stated above.

6.4 RULE – Eight LXI Events for Arm/Trigger and Eight for LXI Event Messages

LXI Devices having an Arm-Trigger state machine shall provide a minimum of eight LXI Event inputs for arm and trigger purposes and eight LXI Event Message outputs for signaling other devices.

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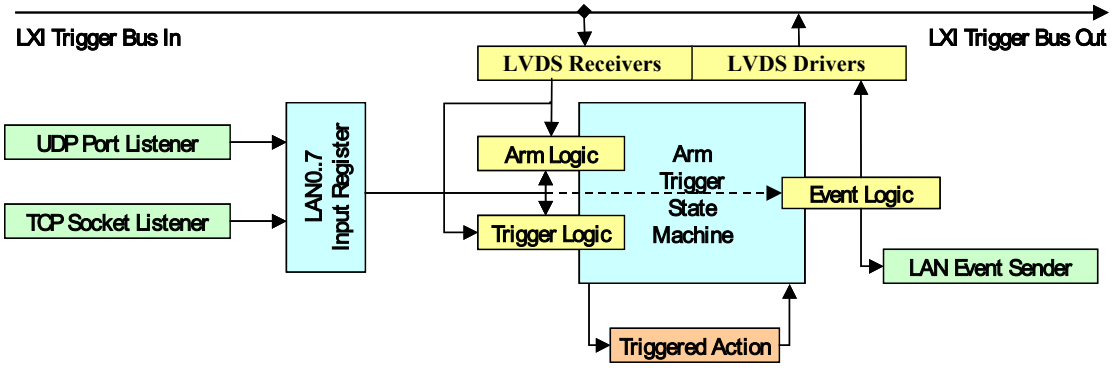
Note: This block diagram is not a part of Rule 6.4.

Example block diagram of LXI Sync Subsystem (for illustration purposes only).



6.4.1 Recommendation – Adding Additional Arm/Trigger Sources and Events

LXI Devices having an Arm-Trigger state machine should provide extensibility in their Arm, Trigger, and Event interfaces using Add() and Remove() methods.

6.4.2 RULE –IVI-3.15 IviLxiSync API Routes Events to LAN

All LXI Devices capable of routing a signal to the LXI Trigger Bus or to the LXI Event Sender shall be capable of doing so using the IVI-3.15 IviLxiSync API.

6.4.3 RULE – LXI Events Encode the Sense of the Event in Packet

All devices transmitting LXI Events whose signal source (the signal causing the event) is:

- one of the LXI Trigger Bus lines,
- one of the signals from an Arm-trigger state machine, or
- based on a logical signal within the device

shall encode the state of the source signal immediately following the transition that caused the event in Flag Bit 2 (Hardware Value)—which is reserved for the logical value of the event signal—and set Flag Bit 4 (Stateless Event) to 0. Hence, a rising edge transition records a logical one and a falling transition records a logical zero.

All devices transmitting LXI Events whose signal source is not based on logical signals as described in the previous paragraph (i.e., they are stateless or have some other semantics) shall have Flag Bit 4 (Stateless Event) set to 1. See also section 3.3.8.

6.4.4 RULE – Standard Strings Used to Designate Events

The strings listed in the following tables shall be used as indicated for triggering, synchronization, and LXI Event generation purposes. Devices are not required to implement all signals. Signal names are case sensitive.

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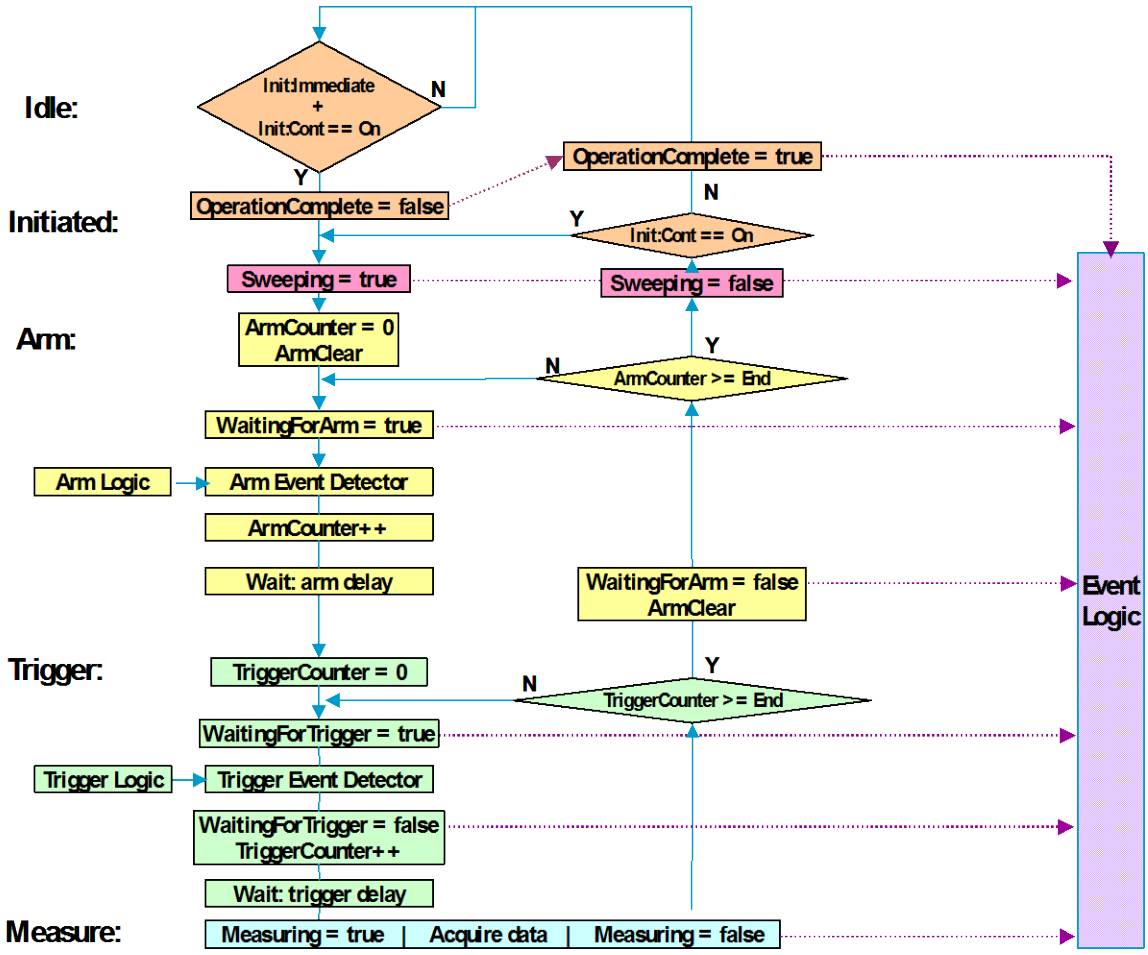
Note: This state machine example is not a part of Rule 6.4.4.

Example Arm-Trigger State Machine (for signal name reference purposes).



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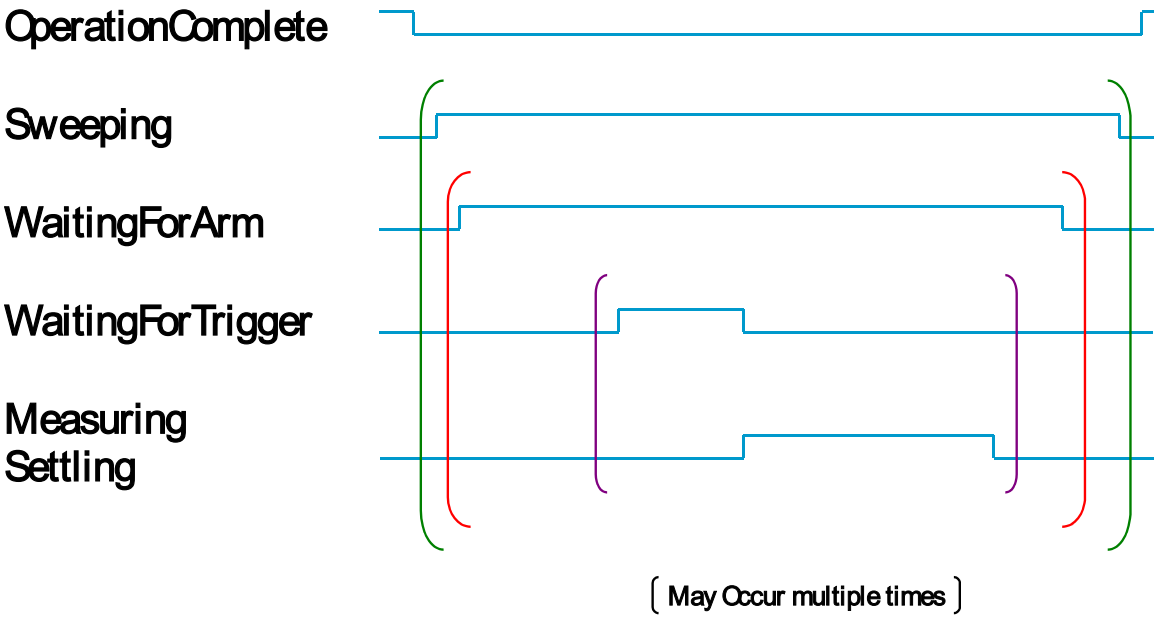
Arm-Trigger State Machine Signal Relationships:



Note: These strings are for Triggering and Synchronization. They are case sensitive.

String	Usage
LXI0	All repeated capability names referring to LXI Trigger Bus line 0. All Source properties needing to refer to LXI Trigger Bus line 0. As a signal Source in the IviEvents interface.
LAN0	All repeated capability names referring to LXI Event 0. All Source properties needing to refer to LXI Event 0. This is the LAN analog to LXI0. As a signal Source in the IviEvents interface. LXI Event Message shall have Stateless Event (Flags Bit 4) set to 0 (zero).
LXI1	All repeated capability names referring to LXI Trigger Bus line 1. All Source properties needing to refer to LXI Trigger Bus line 1. As a signal Source in the IviEvents interface.
LAN1	All repeated capability names referring to LXI Event 1. All Source properties needing to refer to LXI Event 1. This is the LAN analog to LXI1. As a signal Source in the IviEvents interface. LXI Event Message shall have Stateless Event (Flags Bit 4) set to 0 (zero).
LXI2	All repeated capability names referring to LXI Trigger Bus line 2. All Source properties needing to refer to LXI Trigger Bus line 2. As a signal Source in the IviEvents interface.
LAN2	All repeated capability names referring to LXI Event 2. All Source properties needing to refer to LXI Event 2. This is the LAN analog to LXI2. As a signal Source in the IviEvents interface. LXI Event Message shall have Stateless Event (Flags Bit 4) set to 0 (zero).
LXI3	All repeated capability names referring to LXI Trigger Bus line 3. All Source properties needing to refer to LXI Trigger Bus line 3. As a signal Source in the IviEvents interface.

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LAN3	All repeated capability names referring to LXI Event 3. All Source properties needing to refer to LXI Event 3. This is the LAN analog to LXI3. As a signal Source in the IviEvents interface. LXI Event Message shall have Stateless Event (Flags Bit 4) set to 0 (zero).
LXI4	All repeated capability names referring to LXI Trigger Bus line 4. All Source properties needing to refer to LXI Trigger Bus line 4. As a signal Source in the IviEvents interface.
LAN4	All repeated capability names referring to LXI Event 4. All Source properties needing to refer to LXI Event 4. This is the LAN analog to LXI4. As a signal Source in the IviEvents interface. LXI Event Message shall have Stateless Event (Flags Bit 4) set to 0 (zero).
LXI5	All repeated capability names referring to LXI Trigger Bus line 5. All Source properties needing to refer to LXI Trigger Bus line 5. As a signal Source in the IviEvents interface.
LAN5	All repeated capability names referring to LXI Event 5. All Source properties needing to refer to LXI Event 5. This is the LAN analog to LXI5. As a signal Source in the IviEvents interface. LXI Event Message shall have Stateless Event (Flags Bit 4) set to 0 (zero).
LXI6	All repeated capability names referring to LXI Trigger Bus line 6. All Source properties needing to refer to LXI Trigger Bus line 6. As a signal Source in the IviEvents interface.
LAN6	All repeated capability names referring to LXI Event 6. All Source properties needing to refer to LXI Event 6. This is the LAN analog to LXI6. As a signal Source in the IviEvents interface. LXI Event Message shall have Stateless Event (Flags Bit 4) set to 0 (zero).
LXI7	All repeated capability names referring to LXI Trigger Bus line 7. All Source properties needing to refer to LXI Trigger Bus line 7. As a signal Source in the IviEvents interface.
LAN7	All repeated capability names referring to LXI Event 7. All Source properties needing to refer to LXI Event 7. This is the LAN analog to LXI7. As a signal Source in the IviEvents interface. LXI Event Message shall have Stateless Event (Flags Bit 4) set to 0 (zero).
LXIERROR	Reserved for LXI defined error events. LXI Event Message shall have Stateless Event (Flags Bit 4) set to 1.

Note: These strings are for LXI Event Generation. They are case sensitive

String	Usage
OperationComplete	Used as a signal Source in the IviEvents interface. In the Arm-Trigger state machine: this signal is set false when transitioning from the Idle state to the Initiated state. It is set true when transitioning from the initiated state into the Idle state. LXI Event Message shall have Stateless Event (Flags Bit 4) set to 0 (zero).
Measuring	Used as a signal Source in the IviEvents interface. In the Arm-Trigger state machine of a measuring device: this signal is set true when transitioning out the bottom of the Trigger state. It is set false when transitioning into the Trigger state from below. LXI Event Message shall have Stateless Event (Flags Bit 4) set to 0 (zero).

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Settling	Used as a signal Source in the IviEvents interface. In the Arm-Trigger state machine of a source or signal conditioning device: this signal is set true when transitioning out the bottom of the Trigger state. It is set false when transitioning into the Trigger state from below. LXI Event Message shall have Stateless Event (Flags Bit 4) set to 0 (zero).
Sweeping	Used as a signal Source in the IviEvents interface. In the Arm-Trigger state machine: this signal is set true when transitioning from the Initiated state to the Arm state. It is set false when transitioning from the Arm state into the Initiated state. LXI Event Message shall have Stateless Event (Flags Bit 4) set to 0 (zero).
WaitingForArm	Used as a signal Source in the IviEvents interface. In the Arm-Trigger state machine: this signal is set true in the Arm state to enable the Arm logic. It is set false when transitioning from the Trigger state into the Arm state. LXI Event Message shall have Stateless Event (Flags Bit 4) set to 0 (zero).
WaitingForTrigger	Used as a signal Source in the IviEvents interface. In the Arm-Trigger state machine: this signal is set true in the Trigger state to enable the Trigger logic. It is set false after a trigger has been received. LXI Event Message shall have Stateless Event (Flags Bit 4) set to 0 (zero).
All	Used as a hostname in the Event destination. This implies the use of a UDP multicast packet to send the LXI Event.

6.4.4.1 RULE – Only Signals Corresponding to Implemented Capability Required

Devices which only implement a portion of the Arm-trigger state machine shall only be required to implement those signals relating to the implemented portion.

6.4.4.2 RULE – Devices Shall Document Supported Signals

Every device shall document which signals are supported.

6.4.5 RULE – LXI Event Names Beginning with LXI Reserved

The LXI Consortium reserves all strings used for LXI Event names beginning with LXI for future standardization. Such strings shall not be used for any LXI Event or trigger name that is not sanctioned by the consortium.

6.4.6 RULE – Destination Path Syntax

Destination path syntax for LXI Events shall be ([ ] denote optional items):

```
<Destination Path> ::= [host[:port]][/name][,<Destination Path>]
Defaults for the optional items are:
```

host	The local device (most appropriate for LXI Trigger Bus events). Host 'All' sends a UDP Multicast packet to all devices using the IANA registered host address for LXI Events. Any other explicit host entry sends events via a TCP stream connection.
port	The IANA registered port (5044) for LXI Events.
name	The Item string parameter used to select this LXI Event. This is the name associated with the event object.

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6.4.7 Recommendation – Create TCP Event Connections in Advance

LXI Events sent via TCP streams should build the TCP connection when the event enable is set true and should tear down the connection when the enable is set false. This minimizes the latency to transmit the event to the receiver at time of occurrence.

6.5 RULE – API Shall Represent Time as Two 64-bit Floats

All IVI interfaces shall represent IEEE 1588 time, time-stamps, or alarms as two 64-bit floating point numbers. One containing the seconds portion and one containing the fractional seconds.

6.5.1 RULE – Property Names for Real-Time Representation

All interfaces for setting or retrieving IEEE 1588 time or alarms derived from IEEE 1588 time shall have two properties of type DOUBLE named TimeSeconds and TimeFraction.

6.5.2 RULE – Property Names for Real-Time Timestamp

LXI Devices generating timestamps shall provide two properties of type DOUBLE named TimeStampSeconds and TimeStampFraction in all interfaces that are capable of querying measured data from the device for retrieving the timestamp associated with said data. These properties shall be read only.

6.5.2.1 Recommendation – Use a Single Timestamp for Data Sets

If the interface for returning measurement data provides a summary data set in which it is appropriate to include the timestamp, device designers are encouraged to use this means for associating the timestamp with the data, rather than adding two properties to the interface as it couples the data with the timestamp more securely.

6.6 RULE – Domain Property to Facilitate Multiple Systems on a Single LAN

All LXI Devices implementing LXI Events shall include a property named LXIDomain of type LONG for setting the LXI domain field transmitted and received in all LXI Events. The allowed range of this property is 0 – 255. The factory default value for this property shall be zero.

6.6.1 Recommendation – Domain Property Is Persistent

The value of the LXIDomain property should persist through power cycles of the device.

Recommendation – Location of Domain Property in API

The LXIDomain property should be placed in the same interface that contains the instrument I/O object (if present). This is commonly named System (often with a prefix).

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6.7 RULE – LXI Event Log

Access to the LXI Event Log, see 3.7, shall be provided by the API as an array of strings. The following capabilities shall be provided by the API:

- A Boolean property to enable or disable logging
- A method without parameters that clears the log
- A method that returns one or more log entries as a single string, with the instrument or driver deciding how many entries to return.

6.7.1 RULE – LXI Event Log Semantics

The LXI Event Log shall behave as a FIFO buffer, with new entries appended to the end of the buffer and the oldest entries removed from the beginning of the buffer when the buffer is read by a client.

The size of the LXI Event Log buffer is device dependent.

If the LXI Event Log overflows, the device shall include an entry in the log indicating that one or more entries were missed.

Devices may optionally require that logging be disabled before reading back the log.

Devices shall support both an overwriting and non-overwriting mode of operation when the LXI Event Log is full. When a new entry is added into a full log in overwriting mode, the oldest entry in the log is first discarded, thereby making room for the new entry, allowing the new entry to be appended. When a new entry is added into a full log in non-overwriting mode, the new entry is discarded, leaving the log untouched. Vendors shall expose some method (e.g., option strings, web interface, front panel, etc.) to provide the control for this feature, although no particular API is required. A future version of this specification may include such an API requirement.

Once a log entry is read, it shall be removed from the device's log.

6.7.2 RULE – Format of the LXI Event Log

The LXI Event Log shall return a string for each entry in the LXI Event Log.

A future version of this specification may include a format for the event entry.

6.8 Recommendation – Control Identification Light

Devices should include a programmatic interface to control the Device Identity indication (part of the LAN Status indicator). This should be implemented as a Boolean property. For details of the behavior of the Device Identity indication, see 8.10.

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7 LAN Specifications

7.1 RULE – Ethernet Required

LXI Devices shall implement Ethernet using the appropriate IEEE 802.x PHY/MAC specification. For a physical connection, this shall be 100 Mbits/second, IEEE 802.3 Type 100 BASE-TX.

7.1.1 Recommendation - Gigabit Ethernet

LXI Devices should support Gigabit (Type 1000BASE-T) Ethernet.

7.1.2 RULE – Proper Operation in Slower Networks

LXI Devices shall operate properly in Ethernet networks of equal or slower speed than themselves. For 10 Mbits/second this shall be IEEE 802.3 Type 10 BASE-T.

Highest Ethernet Speed	Required Network Speeds for the LXI Device
100 Mbits/second	10 or 100 Mbits/second
1000 Mbits/second	10, 100 or 1000 Mbits/second

7.2 RULE – MAC Address Display

LXI Devices shall display the MAC address of the LXI Device via a user-accessible display or label affixed to the LXI Device. The MAC address is not changeable.

7.2.1 Recommendation – MAC Address Visible While in Rack

The MAC address should be viewable while the LXI Device is in a rack.

7.3 RULE – Ethernet Connection Monitoring

LXI Devices shall incorporate Ethernet connection monitoring (one possible implementation of which is commonly known as Media Sense in Microsoft operating systems). Upon detecting a connection event, the current IP configuration shall be validated (including duplicate IP address detection) and, if necessary, updated.

7.4 Recommendation – Incorporate Auto-MDIX

LXI Devices should incorporate Auto-MDIX.

7.5 RULE – Label Required on LXI Devices Without Auto-MDIX

If Auto-MDIX is not used, the LXI Device shall be clearly labeled with a physical, human-readable label. A “soft” label, on an instrument display, for instance is insufficient.

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7.6 RULE – Enable Auto-Negotiation by Default

LXI Devices should support auto-negotiation by default to select the highest operating mode. In most cases, Auto-Negotiation eliminates the need for the user to explicitly set the operating modes at both ends of the cable. Most Ethernet products enable Auto-Negotiation by default.

7.6.1 Recommendation – Provide Override for Auto-Negotiation

LXI Devices should also provide a way for the user to override Auto-Negotiation for those (rare) situations when the results of Auto-Negotiation may not be what the user wants. Circumstances might include having 100BT capable nodes connected with CAT 3 (not capable of 100 Mbits/sec) cabling instead of CAT5. The auto-negotiate process in this case may select an operating mode that is too high for the installed cabling. For these reasons, it is recommended that LXI Devices allow the user to override Auto-Negotiation.

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8 LAN Configuration

8.1 RULE – TCP/IP, UDP, IPv4 Network Protocols

LXI Devices shall support TCP/IP networking, as outlined in a number of RFCs, including 791 (IP), 793 (TCP), and 768 (UDP). IPv4 shall be supported at a minimum.

LXI Devices can be controlled and communicated with using any higher-level protocol (such as RPC), as long as it is built on top of the TCP or UDP transport layers.

8.1.1 Recommendation – IPv6

LXI Devices should support IPv6 to ensure long-term network compatibility. See IETF RFCs 2874, 3364, 3484, 3513, 3596.

8.2 RULE – ICMP Ping Responder

LXI Devices shall support ICMP (Internet Control Message Protocol, used for a Ping Responder) for diagnostics.

The TCP/IP stack shall be able to respond to the ICMP echo message used by the ping command. The 'ping <hostname>' or 'ping <IP address>' command is the standard way to understand whether a user's connection to an Ethernet device is working.

8.3 RULE – ICMP Ping Responder Enabled by Default

ICMP Ping service ("Ping Responder") shall be enabled by default.

8.4 Recommendation – Provide Way to Disable ICMP Ping Responder

It is recommended that the user have a way to disable the ICMP Ping Responder.

8.5 Recommendation – Support ICMP Ping Client

LXI Devices should support ICMP Ping Client capability so that the user can ping other Ethernet devices.

8.6 RULE – IP Address Configuration Techniques

LXI Devices shall support three LAN configuration techniques: DHCP, Dynamically Configured Link Local Addressing (Auto-IP), and manual. LAN configuration refers to the mechanism that the device uses to obtain IP Address, Subnet Mask, Default Gateway IP Address, and DNS Server IP Address(es).
Collectively, DHCP and Dynamically Configured Link Local Addressing are considered automatic configuration methods. These automatic methods may provide additional or supplemental user entries for DNS servers as appropriate. The DHCP and Manual configuration methods provide configuration for: 1) module IP address, 2) Subnet Mask, 3) Default Gateway IP Address, 4) DNS server IP addresses.

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DHCP current specifications RFC 2131 and RFC 2132 are found at:

"RFC 2131 Dynamic Host Configuration Protocol," R. Droms, March 1997 (Obsoletes RFC1541) (Status: DRAFT STANDARD)

"RFC 2132 DHCP Options and BOOTP Vendor Extensions," S. Alexander, R. Droms, March 1997 (Obsoletes RFC1533) (Status: DRAFT STANDARD)

"RFC 3927 Dynamic Configuration of IPv4 Link-Local Addresses," S. Cheshire, B. Aboba, E. Guttman, May 2005 (Status: Proposed Standard)

8.6.1 RULE – Options for LAN configuration

LXI Devices shall support one of the following options for LAN configuration:

A single configuration setting of Automatic (implying DHCP and Dynamically Configured Link Local Addressing) or Manual.

Individual configuration settings for: DHCP, Dynamically Configured Link Local Addressing, and Manual. If more than one is enabled, the LXI Device's LAN configuration shall proceed in the following order: 1) DHCP, 2) Dynamically Configured Link Local Addressing, 3) manual.

8.6.2 Recommendation – 30-Second DHCP Timeout

LXI Devices should implement a 30-second DHCP time-out to control how long the DHCP client will wait for a response from a DHCP server before giving up.

8.6.3 RULE – Explicitly Request All Desired DHCP Parameters

LXI Devices shall explicitly request all desired DHCP parameters from the DHCP server. A DHCP client uses the "parameter request list" option to request specific parameter values from a server. The LXI Device DHCP implementation should ensure that parameters like default gateway and subnet mask are in the "parameter request list."

8.6.4 Recommendation – Accept the First DHCP Offer Received

LXI Devices should accept the first DHCP OFFER message received.

The DHCP protocol specifies that a DHCP client emit a DHCP discovery message to find a DHCP server, and then wait for DHCP offer messages from DHCP servers. The protocol allows, but does not require, the client to collect multiple offers prior to requesting an address from one of the responding servers. Some DHCP implementations accept multiple offers, but none allows the user to select which DHCP server is used. Accepting the first DHCP OFFER is the most common implementation and produces the fastest IP configuration via DHCP.

8.6.5 RULE – Do Not Require Additional DHCP Options for Normal Operations

LXI Devices shall not require any additional DHCP options for normal operations beyond what is needed for IP and DNS configuration. Other options may be requested, but the operation of the LXI Device shall not depend on receiving these parameters.

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8.6.5.1 Permission – Additional DHCP Options Allowed for LXI Device Updates

Network boot support, which requires an additional DHCP option, may be used to update LXI Devices.

8.6.6 RULE – Stop Using IP Address If DHCP Lease Not Renewed

If an LXI Device is unable to renew its DHCP lease it shall stop using the DHCP supplied IP configuration that failed to be renewed and, if so equipped, offer an alarm or error message.

8.6.7 RULE – Honor New DHCP Options at Lease Renewal

LXI Devices shall honor new DHCP options provided when renewing a lease.

8.6.8 Recommendation – Provide Manual DNS IP Address Entry

LXI Devices should allow the user to enter DNS server(s) IP addresses. The automatic IP configuration with manual DNS configuration enables the user to select a specific DNS configuration in addition to the DHCP configuration information. This is useful in network environments with a DNS server per department and a DHCP server per site.

8.6.9 Permission – User Configured Hosts File Allowed

LXI Devices may support a user configured hosts file.

Some LXI Devices that will have users running many network client applications (web browsing, etc) directly on the LXI Device may want to support the ability to set up a hosts file. A hosts file is a manual way for the user to set up specific mappings between hostnames and IP addresses.

8.7 RULE – Duplicate IP Address Detection

LXI Devices shall perform duplicate IP address detection to ensure an LXI Device does not start using an IP address that is already in use on that network.

LXI Devices shall disconnect from the network when a duplicate IP address is detected.

8.8 Recommendation – Check Network Configuration Values for Validity

The values entered by the module user should be checked to ensure they are in the valid range.

8.9 Recommendation – Single Hostname for All Naming Services

LXI Devices should have a single module default hostname used for all dynamic naming services. The single module hostname shall be a legal DNS name.

Default Hostname recommendations:

- Syntax requirements:
- Maximum length of 15 characters.
- First character must be a letter (RFC 1035).

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- Last character must be either a letter or a digit (RFC 1035).
- Intervening characters must be either a letter or a digit or a hyphen (RFC 1035).

Within a subnet, system, or DNS domain, this name needs to be unique. Therefore, a pattern constructed from the model name and last part of the serial number should normally meet this requirement, as in the following example from Agilent Technologies: A-E4440A-12345.

8.10 RULE – Provide an Error Indicator for LAN Configuration Faults

LXI Devices shall make use of the LXI LAN Status Indicator to inform the user of a LAN fault or error caused by:

- failure to acquire a valid IP address
- detection of a duplicate IP address
- failure to renew an already acquired DHCP lease (failure to obtain an initial DHCP lease is not a failure)
- LAN cable disconnected (as reported by Ethernet connection monitoring)

See 2.5.2 LAN Status Indicator for annunciation details.

The LXI LAN Status indicator indicates both the LAN error conditions above and provides an *identify* indication as described in section 2.5.2. This identifying indication is initiated by the user via the Web interface, 9.3, or by the API, 6.8. The LXI LAN Status indicator shall provide *LAN Fault*, *Normal Operation*, and *Device Identify* indications as shown in the state diagram below. Note that the state labeled "State Undefined" is transitory and the behavior of the indicator is not specified.

Regarding DHCP lease renewal failure and Auto-IP, there are two cases to consider. In both cases, the instrument is configured to automatically obtain an IP Address (with both DHCP and Auto-IP on). In the first case, when the device is connected to the network, it fails to obtain an IP Address through DHCP, and therefore claims an Auto-IP address. When this happens, the LAN Status Indicator should indicate no fault.

In the second case, when the device is connected to the network, it does successfully obtain a DHCP lease. However, at a later time the device fails to renew that lease through DHCP. Per rule 8.6.6 the device must stop using the IP Address it had obtained through DHCP at this point and the LAN Status Indicator must indicate a fault. Now, since Auto-IP is configured the device will then obtain an Auto-IP address. Despite the fact that the device now has an Auto-IP address, the LAN Status Indicator must remain in the fault state. This is to indicate to the user that a DHCP lease renewal has failed and that the device does not have the same IP Address that it did before.

At this point, the LAN Status Indicator must remain in the fault state until one of the following happens. 1) The device successfully acquires a new DHCP lease. (This can happen if it is configured to periodically attempt to obtain a new DHCP lease.). 2) The device is restarted. 3) The LAN Configuration is reinitialized for the device by the user. (This could be done through the LCI, unplugging and replugging the LAN cable, or another mechanism if the device is so equipped.) In scenarios 2 and 3, the behavior when the device again attempts to obtain an address is the same as in the first case, if DHCP fails but an Auto-IP address is obtained, the LAN Status is no fault.

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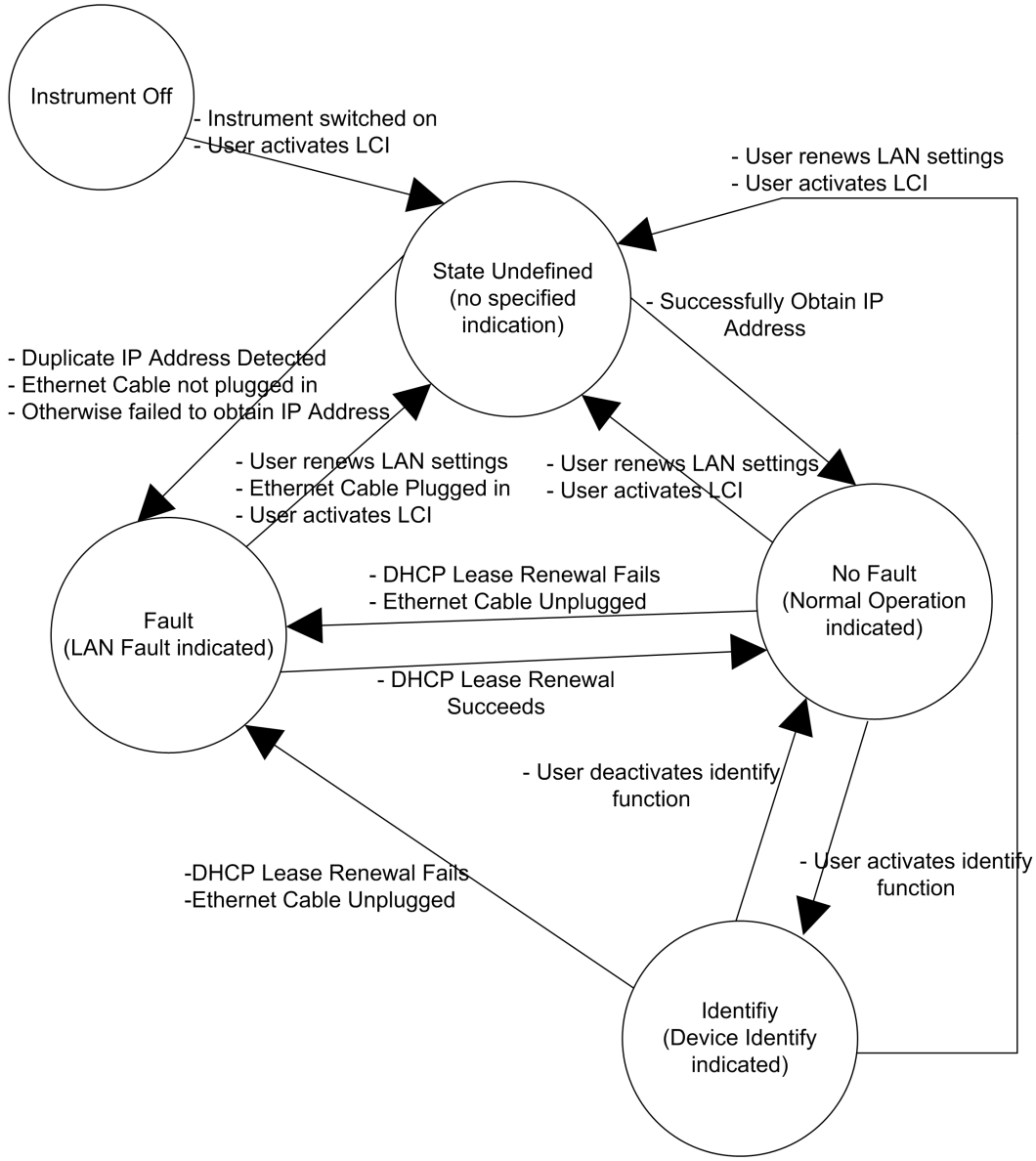

8.11 Recommendation – Support Dynamic DNS Hostname Registration

LXI Devices should support hostname registration through DHCP servers with cooperating Dynamic DNS servers.

8.11.1 Recommendation – Provide User Control of Dynamic DNS Registration

LXI Devices should allow the user to turn the Dynamic DNS capability on or off. On networks without Dynamic DNS support, the network ignores the hostname request sent out by the module.

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Some users may want to disable Dynamic DNS at the module to make use of a default hostname assigned by the network.

8.11.1.1 RULE – If Dynamic DNS Can Be Disabled, Its Default State Is Enabled

LXI Devices that allow Dynamic DNS to be turned off shall have the Dynamic DNS capability enabled by default

8.12 Recommendation - Provide DNS Client

LXI Devices should support a DNS client for resolving hostnames.

8.13 RULE – LAN Configuration Initialize (LCI)

LXI Devices shall provide a LCI reset mechanism, as defined in 2.4.5, that when activated places the LXI Device's network settings to a default state. These settings shall take effect when the LCI mechanism is activated, without requiring any further operator actions (e.g., if the LXI Device requires a reboot for the changes to take effect, the LXI Device shall reboot automatically). The LXI Device default state shall be fully documented and available in the manufacturer's supplied documentation.

Table of items affected by LAN Configuration Initialize Mechanism

Item	Value	Section
IP Address Configuration: o DHCP o AutoIP	 o Enabled o Enabled	8.6
ICMP Ping Responder	Enabled	8.3
Web Password for configuration	Factory Default	9.8
Dynamic DNS (if implemented)	Enabled	8.11.1.1
mDNS and DNS-SD	Enabled	10.3 , 10.4, 10.5.1, 10.7.1

If an LXI Device has a manual user interface (physical front panel) that allows the configuration of these items plus the network configuration, then that shall be sufficient to meet the needs addressed by this button, – as long as there is a single LAN Configuration Initialize key in the manual interface that sets the items in the above table as indicated.

8.13.1 Recommendation – LAN Configuration Initialize (LCI) Additional Settings

In addition to the settings listed in 8.12, The LCI mechanism should enable dynamically configured link local addressing, disable manual IP, and enable auto-negotiation.

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9 Web Interface

9.1 RULE – Web Pages Using W3C Compliant Browsers

LXI Devices shall serve a HTML web page that works correctly with all W3C compliant browsers. LXI Device web servers shall conform to HTTP (version 1.0 or greater). The HTML pages served shall conform to HTML (version 4.01 or greater) or XHTML (version 1.0 or greater).

9.1.1 RULE – Protocol and Port Number

LXI Devices shall accept HTTP connections on port 80 and serve the LXI required welcome page as a response to such connection requests. Navigation buttons or hyper links are allowed to access other ports as desired by the web page authors.

9.1.2 Recommendation – Web Server Root Document

The LXI Device should serve a web page from the root document set with file name *index.htm* or *index.html* so that the URL to access an LXI Device is http://<host>, where <host> is either a hostname or IP address. Also, the LXI Device web server should be configured to automatically return the file *index.htm* or *index.html* by default.

9.2 RULE – Welcome Web Page Display Items

The primary LXI welcome page shall display the following information in a read-only format.

- LXI Device Model
- Manufacturer
- Serial Number
- Description[14]
- LXI Class <A, B, or C>
- LXI version (initially 1.0, but it will grow)
- Hostname[15]
- MAC Address <XX-XX-XX-XX-XX-XX>
- TCP/IP Address <DDD.DDD.DDD.DDD>
- Firmware and/or Software Revision
- IEEE 1588 PTP Current time [If IEEE 1588 is implemented]
- LXI Device Address String

9.2.1 RULE – LXI Device Address String on Welcome Page

The primary LXI welcome page shall contain an IVI I/O Resource Descriptor, which is a string that specifies the address of the hardware asset that can be recognized by the I/O used by a software module that accesses the hardware. An example of such a Resource Descriptor is a VISA Resource.

[14] Refer to section 9.5.1.
[15] Refer to sections 8.9 and 9.2.3 purposes

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For VISA Resources of the form

```
TCPIP[board]::host address[::LAN device name]::INSTR
```

or

```
TCPIP[board]::host address::port::SOCKET
```

The value of "[board]" must be empty since the instrument cannot know which interface board a client may be using.

9.2.1.1 Recommendation – LXI Device Address String Label

This string should be labeled "Instrument Address String."

9.2.2 Recommendation – Web Page Title

An LXI Device web page title should follow the following format to align the bookmarks nicely:
LXI – Manufacturer-Model-<Optional Serial Number>-<Optional Description>

9.2.3 RULE – Actual Hostname Display

LXI Devices shall display the validated hostname(s) (DNS and/or mDNS) on the LXI Welcome Web page. The hostname(s) displayed on the LAN Configuration page need not be validated since they represent desired configuration values.

9.2.3.1 Recommendation – How To Determine Actual Hostname with Unicast DNS

LXI Devices should use the following algorithm to determine LXI Device hostname when using unicast DNS; it covers all the conditions described above, and allows the LXI Device to determine its hostname. The algorithm is:

1. If there is a unicast DNS server address configured in the LXI Device (either via DHCP or manually configured), do the following:
   a) Determine the LXI Device's IP address (DHCP/Manual/Dynamic Link-Local Addressing).
   b) Do a reverse unicast DNS look-up (IP address to hostname lookup) to determine the LXI Device's hostname on the network.
   c) If the lookup fails, then go to step 2.
   d) Do a forward unicast DNS look-up (hostname name to IP address lookup) to validate that the hostname can be resolved, and the same IP address is returned.
   e) If the lookup fails, then go to step 2.
   f) If the IP address from step 1a and 1c are different, then there is something wrong with the unicast DNS hostname configuration. Proceed to step 2.
   g) The hostname determined in step 1c is the correct hostname, and this hostname can be presented through the appropriate places in the LXI Device's user interface.

2. There is no hostname assigned to this LXI Device.
   a) Use the IP address in place of an actual hostname, and the IP address can be presented through the LXI Device user interface.

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9.2.3.2 Rule – Hostname Display

If an LXI Device does not support recommendation 9.2.3.1 or if mDNS is disabled then it shall show the assigned IP address or a blank field for the hostname.

9.2.3.3 Rule – mDNS hostname format

When displaying an mDNS hostname on the LXI Welcome Web page, the fully qualified mDNS hostname shall be displayed with its domain of .local.

9.2.3.4 Permission – If both DNS and mDNS are enabled

If both DNS and mDNS have qualified hostnames then the multiple hostnames maybe displayed in the one defined hostname field of the LXI Welcome Web page, separated by commas, or additional fields may be added on the LXI Welcome page for the additional hostnames

9.2.3.5 Rule – Description Field contains Resolved Service Name

The unique and resolved service name shall be shown in the description field of the Welcome page defined in section 9.2.

9.3 RULE – Device Identification Functionality on the Web Page

There shall be a device identification indicator functionality on the web page to control the LAN Status Indicator (see Sections 2.5.2 and 8.10).

9.3.1 Permission – No password protection for device identification indicator

The device's identification indicator functionality is not considered as an instrument setting. Therefore, the web page that exposes this functionality may not be password protected.

9.4 RULE – LAN and Sync Configuration Links on the Welcome Page

The Welcome page shall contain at least two hyperlinks/buttons to provide further information or to allow the user to configure LXI Device settings. The first linked web page shall contain the information as described in section 9.5 and the second linked webpage shall contain the information as described in section 9.6. The second link (Synchronization web page contents) is applicable for LXI Devices implementing any of IEEE 1588, LXI Event Messaging, or the LXI Trigger Bus.

9.4.1 Recommendation – Status Page Link on the Welcome Page

There should be an additional hyperlink/button – Status/Miscellaneous page on the LXI welcome page.

9.5 RULE – LAN Configuration Web Page Contents

The LAN configuration page shall contain the following parameters to configure the LAN settings:

- Hostname
- Description

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- TCP/IP Configuration Mode
- IP address [16]
- Subnet mask
- Default Gateway
- DNS Server(s)

The TCP/IP configuration field controls how the IP address for the instrument is assigned. For the manual configuration mode, the static IP address, subnet mask, and default gateway are used to configure the LAN. The automatic configuration mode uses DHCP server or Dynamic Link Local Addressing (Automatic IP), as described in Rule 8.6 to obtain the instrument IP address.

9.5.1 Recommendation – Default Description for LXI Device

The default description for the LXI Device should be manufacturer name, instrument type, model, and the serial number (e.g., Xyz Oscilloscope 54321D – 123456).

9.5.2 Recommendation – Auto-Negotiate Enable/Disable Through Web Page

If the LXI Device implements auto-negotiate enable/disable, then it should be exposed through the web page.

9.5.3 Recommendation – Ping Enable/Disable Through Web Page

If the LXI Device implements ping enable/disable, then it should be exposed through the web page.

9.5.4 Permission – Other Information on the LAN Configuration Page

Other additional information/IP configuration settings may be added to the IP configuration page (e.g., Domain Name).

9.5.5 Permission – Disable Switch for LAN Configuration Page

The IP configuration web interface may be disabled with a non-volatile switch or a key. For example, this switch may be a physical jumper setting or a front panel menu item in the LXI Device

9.5.6 Recommendation – mDNS Enable/Disable Through Web Page

If the LXI Device implements mDNS enable/disable, then it should be exposed through the web page.

9.5.7 Rule – Reverting Hostname to Factory Default

Setting the hostname field to the empty string (i.e., a string of length zero, or one consisting entirely of whitespace characters) shall revert the hostname to the factory default value.

9.5.8 Rule – Reverting Device Description to Factory Default

Setting the Device Description field to the empty string (i.e., a string of length zero, or one consisting entirely of whitespace characters) shall revert the Device Description to the factory default.

[16] Static IP address. Refer to section 8.6

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9.6 RULE – Sync Configuration Web Page Contents

The sync configuration web page for LXI Devices implementing IEEE 1588 shall include the "IEEE 1588 Parameters" listed in the following table.

The sync configuration web page for LXI Devices implementing LXI Event Messages shall include the "LXI Event Parameters" listed in the following table.

The sync configuration web page for LXI Devices implementing the LXI Trigger Bus shall include the "LXI Trigger Bus Parameters" listed in the following table.

Item	Value
IEEE 1588 Parameters:	
Current grandmaster clock	Hostname, IP address, or MAC address
Parent clock	Hostname, IP address, or MAC address
State	Master, Slave, Faulty, Disabled, Passive, Uncalibrated, Other (Initializing, Listening, Pre-master)
Current PTP time	Seconds since 0 hours, 1 January 1970 TAI (represented as a string of the form "seconds.fractional seconds")
Current local time (if available)	Date/time
Current grandmaster traceability to UTC	The string corresponding to the value of the timeSource field of the Announce message as defined in Table 7 of IEEE 1588, e.g. GPS, NTP, HAND_SET or ATOM…
Current observed variance of parent clock	In $(\text{nanoseconds})^2$
IEEE 1588 Domain	The integer, domainNumber, as defined by IEEE 1588.
IEEE 1588 Version	The integer, versionNumber, as defined by IEEE 1588, e.g. 2 for IEEE 1588-2008.
LXI Event Parameters:	
LXI Domain	As defined in Section 4
LXI Trigger Bus Parameters:	
Wired-Or Bias	Enabled or Disabled(default) for each of LXI0 to LXI7

Note: *Depending on the implementation, the value of the "Current PTP time" can be obtained by (1) directly reading the IEEE 1588 clock and translating into the display format or (2) using the timestamp received in an IEEE 1588 management message with managementID = Time, and translating into the display format.*

Note: *Devices that do not compute the "Current observed variance of parent" parameter shall display "Unavailable" (without quotes) as the parameter value.*

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9.7 Recommendation – Status Web Page Contents

The status/miscellaneous page should contain the following information:

- Status
- Errors/Warnings

The status field should contain busy status with any armed/trigger waiting status and any instrument-specific status information. Dynamic updates for this page should not be necessary.

9.7.1 Permission – Other Information on the Status Web Page

Any other additional information may be added to the status/miscellaneous page (e.g., the status of one of the LXI features defined in 1.9.1.2.2).

9.8 RULE – Web Page Security

Any page(s) that allows user to change the instrument's settings shall be password protected; user changeable default passwords are acceptable.

9.8.1 Permission – Blank password

The LXI Device's default password may be blank and the web interface may not need to put up a dialog box for a blank password.

9.9 RULE – LXI Logo

All the required web pages for an LXI Device shall contain an LXI compliance logo (See section 13.6).

9.10 Recommendation – LXI Web Interface Example

LXI Device web interfaces should follow the similar look and feel as the examples web pages in Appendix A.

9.11 Recommendation –LXI Device Control Using Web Page

LXI Devices should provide the ability to interact, control, setup and perform troubleshooting on the most common functions through a web interface, without writing a program.

9.12 Recommendation – Software/Firmware Upgrade Using Web Interface

As needed, LXI Devices should be able to update software/firmware utilizing the embedded Web interface. Updates should include minor file updates, major software updates, measurement application downloads, or OS changes.

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9.13 Recommendation – LXI Glossary

LXI Device web interface should support one of the following options to help explain the terminology used in this LXI specifications document:

- Copy of the glossary from the LXI specifications
- Link to a help file contains the glossary
- Link to a help file contains the glossary on the instrument vendor's home page

9.14 RULE – All URLs Beginning With "LXI" Are Reserved by the LXI Consortium

RFC 1738 defines the HTTP URL as the following:

http://<host>:<port>/<path>?<searchpart>

Any URL with a <path> that begins with the strings "lxi" or "LXI" or any combination of lowercase and uppercase letters combined to spell LXI are reserved for Consortium-defined uses. This includes the directory-like syntax in which the first part of <path> is any combination of lowercase and uppercase letters that spell LXI terminated with a "/":

http://<host>:<port>/lxi/<path>?<searchpart>

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10 LAN Discovery and Identification

10.1 RULE – Support VXI-11 Discovery Protocol

The VXI-11 protocol shall be supported by all LXI Devices for discovery purposes. Discovery shall be accomplished by issuing a broadcast RPC call on the host's subnet. The broadcast RPC shall be to either the portmapper itself on port 111 (querying for VXI-11 support) or the NULL procedure (procedure 0) on the Program Number assigned to the VXI-11 Core Service (0x0607AF).

Note: *At some point in the future, VXI-11 may no longer be required.*

10.1.1 RULE – VXI-11 Servers Respond Within One Second

All VXI-11 servers shall respond to a broadcast RPC to the NULL procedure within 1 second.

10.1.2 RULE – SCPI *IDN?

At a minimum an LXI Device shall be able to respond to the IEEE 488.2 "*IDN?" command. This is a simple query that returns four comma-separated fields, which indicate manufacturer, model, serial number, and firmware version[17].

10.1.2.1 Permission – Additional VXI-11 and SCPI Support Is Optional

LXI Devices may support additional VXI-11 functionality and SCPI commands beyond that required for discovery.

10.2 RULE – XML Identification Document URL

All LXI Devices shall provide an XML identification document that can be queried via a GET at "http://<hostname>:80/lxi/identification" that conforms to the LXI XSD Schema (available at http://www.lxistandard.org/InstrumentIdentification/1.0) and the W3C XML Schema Standards (http://www.w3.org/XML/Schema).

Please see Appendix C for example Identification Documents.

10.2.1 Permission – HTTP Redirection

LXI Devices may return an HTTP Status Code indicating Redirection – the 3xx range of values (e.g., 300, 301, 302, etc. of RFC 2616) – in response to a GET request on the URL defined in 10.2. Clients are expected to handle these redirections appropriately.

10.2.2 RULE – Content Type Header

The response to the GET request on the URL defined in 10.2 or to the URL that actually returns the XML document after possible redirection(s) shall include the "Content-Type" header with "text/xml" as the value.

[17] For more information, see IEEE 488.2 Section 10.14.

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10.2.3 RULE – Schema Location Attribute

The xsi:schemaLocation attribute of the root element of the identification document shall contain an entry for the LXI XSD namespace with an accompanying absolute URI on the instrument that shall return the actual XSD schema document from the instrument (http://www.w3.org/TR/xmlschema-0/#schemaLocation). The W3C XSD Schema itself (the "xsi" namespace of http://www.w3.org/2001/XMLSchema-instance) does not need to be available via a URI on the instrument.

Example:

```
<LXIDevice
  xmlns='http://www.lxistandard.org/InstrumentIdentification/1.0'
  xmlns:xsi='http://www.w3.org/2001/XMLSchema-instance'
  xsi:schemaLocation='http://www.lxistandard.org/InstrumentIdentification/1.0
  http://1.2.3.4/identification.xsd'>
<!-- other elements and attributes not shown here -->
</LXIDevice>
```

10.2.4 RULE – Connected Device URLs

Devices that support connected devices (e.g., bridges) shall provide base URLs for all connected devices in the ConnectedDevices element of the identification document. A base URL is defined as a URL with a "url-path" that clearly identifies the connected device and one onto which a suffix path may be added to access properties of that connected device. The base URL allows clients to enumerate devices connected to the bridge device.

For example, the base URL for a connected device might be "http://hostname/device0" while another connected device might have a base URL of "http://hostname/device5". The format and path naming conventions for these connected device base URLs are left up to the vendor.

The following is an example snippet from an identification document with connected device DeviceURI elements:

```
<ConnectedDevices>
  <DeviceURI>http://10.1.2.60/devices/LogicalAddress/0/</DeviceURI>
  <DeviceURI>http://10.1.2.60/devices/LogicalAddress/1/</DeviceURI>
</ConnectedDevices>
```

Future versions of this standard may implement additional web interfaces (e.g., resource management) that can be used on LXI Devices as well as on connected devices.

10.2.4.1 RULE – Connected Device XML Identification Document URLs

Devices that support connected devices shall provide identification documents that can be queried via a GET on <baseURL>/lxi/identification that conform to the LXI XSD Schema or one derived from that Schema according to the rules of XSD inheritance. The <baseURL> values may be found in DeviceURI elements of the ConnectedDevice element of the root element of the identification document of Rule 10.2. This rule coupled with Rule 10.2.4 allows clients to enumerate (discover) and identify all connected devices.

A future version of this standard may require that ConnectedDevices for common buses (e.g., VXI, PXI, GPIB, etc.) use particular derived schemas published by the LXI Consortium.

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10.2.4.2 RULE – Connected Device XML Identification Document Schema Location Attribute

The xsi:schemaLocation attribute of the root element of the identification document shall contain an entry for the LXI XSD namespace with an accompanying absolute URI on the instrument that shall return the actual XSD schema document from the instrument (http://www.w3.org/TR/xmlschema-0/#schemaLocation). The W3C XSD Schema itself (the "xsi" namespace of http://www.w3.org/2001/XMLSchema-instance) does not need to be available via a URI on the instrument.

10.3 RULE – Support mDNS

LXI Devices shall support Multicast DNS (mDNS) as defined by http://files.multicastdns.org/draft-cheshire-dnsext-multicastdns.txt.

10.3.1 RULE – Claiming Hostnames

Devices supporting mDNS shall assign themselves an mDNS hostname and shall automatically resolve mDNS hostname conflicts.

10.3.1.1 RULE – Hostname Conflicts

If an mDNS hostname conflict occurs, the LXI Device shall assign itself a new hostname and retry until the conflict is resolved. New hostnames shall be generated by appending a number to the end of the hostname. For example, a conflict on "Instr-ABC" would become "Instr-ABC-2" after the first collision, "Instr-ABC-3" on the second, and so on.

10.3.2 Recommendation – Default mDNS Hostname

The default hostname as defined in section 8.9 should be used as the default mDNS hostname.

10.3.3 RULE – Dynamic DNS Update and mDNS Hostname

LXI Devices that support Dynamic DNS Update shall use the user-configured hostname as the mDNS hostname.

10.3.4 RULE – DHCP "Host Name" Option and mDNS Hostname

Regardless of any value, a DHCP server may return as the DHCP "Host Name" option (option code 12); an LXI Device shall use the user configured or factory default hostname for mDNS hostname registration. (See Section 10.7.)

10.4 RULE – Support DNS-SD

LXI Devices shall support DNS Service Discovery (DNS-SD) as defined by http://files.dns-sd.org/draft-cheshire-dnsext-dns-sd.txt via mDNS.

10.4.1 RULE – Claiming Service Name

LXI Devices shall assign themselves a service name used to advertise services defined within this standard and shall automatically resolve service name conflicts.

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10.4.2 RULE – Single Service Instance Name for LXI Defined Services

LXI Devices shall assign themselves a single service name for use in advertising all required and recommended LXI services, as below, and shall resolve service name conflicts. The service instance name is the "instance" portion of a service name as follows:

<instance>. <service>. <domain>

Thus, an HTTP service with an instance name of "Instrument ABC" in the ".local" domain will have "Instrument ABC._http._tcp.local" as the service name.

10.4.2.1 RULE – User Configurable Service Name

LXI Devices shall allow a user to modify the non-volatile service name via the web interface, truncated to the first 63 bytes of UTF-8. When a user modifies a service name, the LXI Device shall unregister all services and then reregister using the new service name.

10.4.2.2 Recommendation – Default Service Name

LXI Devices should use the recommended default description of section 9.5.1 for their default service name truncated to the first 63 bytes of UTF-8.

10.4.2.3 RULE – Service Name Conflicts

If an mDNS service name conflict occurs, the LXI Device shall assign itself a new service name and retry until the conflict is resolved. New service names shall be generated by appending a number to the end of the service name. For example, a conflict on "Vendor Instrument" would become "Vendor Instrument (2)" after the first collision, "Vendor Instrument (3)" on the second, and so on.

10.4.3 Rule - Required Service Advertisements and TXT Record Keys

LXI Devices shall, at a minimum, advertise the following services via mDNS and shall provide the related keys in the TXT records for the service. Please refer to 10.4.3.5 for Permission on TXT Record Keys with default values.

Service Type	TXT Record Keys - Required	Description
http (_http._tcp)	txtvers=<version of TXT record">; default "txtvers=1"; current version is 1 path=<path to the root or index page of the server>; default "path=/"	All HTTP servers that a device supports that may be used with a typical web browser
lxi (_lxi._tcp)	txtvers=<version of TXT record">; default "txtvers=1"; current version is 1 Manufacturer=<first element of response to IEEE 488.2 *IDN?> Model=<second element of response to IEEE 488.2 *IDN?>	An LXI service that uses the HTTP protocol for identification and other operations as defined by this standard

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	SerialNumber=<third element of response to IEEE 488.2 *IDN?> FirmwareVersion=<fourth element of response to IEEE 488.2 *IDN?>	

10.4.3.1 RULE – TXT Records Are Required

The LXI Device shall provide a TXT record for every service instance being advertised. If there are no TXT record entries for a service (see Permission 10.4.3.5), an empty TXT record shall be provided.

10.4.3.2 RULE – TXT Records Consist of Key/Value Pairs

TXT records shall consist of key/value pairs of the form "name=value" (without quotes). The value begins after the first ASCII equal sign "=" and continues to the end of the string. The maximum length of a key/value pair is 255 bytes.

10.4.3.3 RULE – TXT Record Keys Are Case-Insensitive ASCII

All TXT record keys (names) shall be printable ASCII characters (0x20-0x7E), excluding "=" (0x3D), and shall be case-insensitive.

10.4.3.4 RULE – TXT Record Values

TXT record values (data beginning after the ASCII equal sign "=" [0x3D]) in general shall be opaque binary data, but may be ASCII or UTF-8 for particular keys.

10.4.3.5 Permission – TXT Record Key Default Values

If the value of a TXT record key is equal to the default value for that key, it may be omitted from the TXT record.

10.4.3.6 RULE – TXT Record Key Order

For any service that has a defined TXT record key of "txtvers" the "txtvers" key, if present, shall be the first key in the TXT record.

10.4.3.7 RULE – LXI Consortium TXT Record Keys

All TXT record keys beginning with "LXI" or "lxi" are reserved for Consortium-defined usage.

10.4.3.8 RULE – Vendor Defined TXT Record Keys

All TXT record keys (names) used with LXI Consortium required or recommended services shall be either keys (names) as defined by this standard or vendor-specific keys. Vendor-specific keys shall end with the vendor's domain name in accordance with section 6.4 of http://files.dns-sd.org/draft-cheshire-dnsext-dns-sd.txt. That is, vendor-defined keys shall be of the form "keyname.company.com=."

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10.4.3.9 Recommendation – Maximum Length of TXT Record

TXT records should be no longer than 512 bytes.

10.4.3.10 Recommendation – Additional Service Advertisements

If LXI Devices support the following services, they should advertise the services via mDNS:

Service Type	TXT Record Keys	Description
scpi-raw (_scpi-raw._tcp)	txtvers=<version of TXT record">; default "txtvers=1"; current version is 1 Manufacturer=<first element of response to IEEE 488.2 *IDN?> Model=<second element of response to IEEE 488.2 *IDN?> SerialNumber=<third element of response to IEEE 488.2 *IDN?> FirmwareVersion=<fourth element of response to IEEE 488.2 *IDN?>	Raw SCPI (IEEE 488.2) command interpreter
scpi-telnet (_scpi-telnet._tcp)	txtvers=<version of TXT record">; default "txtvers=1"; current version is 1 Manufacturer=<first element of response to IEEE 488.2 *IDN?> Model=<second element of response to IEEE 488.2 *IDN?> SerialNumber=<third element of response to IEEE 488.2 *IDN?> FirmwareVersion=<fourth element of response to IEEE 488.2 *IDN?>	Telnet server supporting SCPI (IEEE 488.2) commands
vxi-11 (_vxi-11._tcp)	txtvers=<version of TXT record">; default "txtvers=1"; current version is 1 Manufacturer=<first element of response to IEEE 488.2 *IDN?> Model=<second element of response to IEEE 488.2 *IDN?> SerialNumber=<third element of response to IEEE 488.2 *IDN?> FirmwareVersion=<fourth element of response to IEEE 488.2 *IDN?>	VXI-11 Server

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Note: Devices should advertise the VXI-11 service only if they support a complete and useful VXI-11 implementation (e.g., full command interpreter for the device). Devices with only minimally conformant VXI-11 services, as required in section 10.1 for discovery, are discouraged from advertising their VXI-11 service.

10.4.3.11 RULE – Service Advertisement Order

In order to minimize conflict resolution issues when advertising multiple services, services shall be advertised (and conflict resolved) in the following order:

1. _http._tcp.
2. _lxi._tcp.

10.4.3.12 Recommendation – Additional Service Advertisement Order

After advertising those services covered by Section 10.4.3.11, LXI Devices should advertise any of the following services they support in the following order.

a. _vxi-11._tcp.

b. _scpi-raw._tcp.

c. _scpi-telnet._tcp.

10.5 RULE – mDNS and DNS-SD Enabled by Default

Both mDNS and DNS-SD shall be enabled by default on LXI Devices.

10.5.1 RULE – mDNS and DNS-SD Enabled by LAN Configuration Initialize (LCI)

When the LCI reset mechanism is activated, it shall enable mDNS and DNS-SD.

10.6 RULE – mDNS Name Resolution

LXI Devices shall use mDNS for name resolution of hostnames in the ".local." domain. Reverse lookups of addresses in the 169.254/16 subnet (Dynamic Link-Local Addresses) shall be resolved via mDNS.

10.7 RULE – Nonvolatile Hostnames and Service Names

To promote stability, if a hostname conflict occurs and the LXI Device chooses a new hostname, the device shall save the new hostname in nonvolatile storage for use the next time the device is powered on. Similarly, if a service name conflict occurs and the LXI Device chooses a new service name, it shall save the new service name in nonvolatile storage for use the next time the device is powered on.

10.7.1 RULE – Hostname and Service Name Revert to Default

When the LCI mechanism is activated, the hostname and the service name shall revert to the last user-configured values, if available, or factory defaults otherwise.

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10.8 RULE – Link Changes

When a network "link change" occurs (e.g., an Ethernet cable is plugged in), the LXI Device shall verify that its hostname and service name are unique and shall re-register its services.

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11 Documentation

11.1 RULE – Full Documentation on IVI Interface

For each LXI Device, the manufacturer shall provide the documentation on the IVI driver, which is required in the IVI 3.1 Driver Architecture Specification, Section 5.21 Compliance Documentation.

11.2 RULE – Registration of the IVI Driver

The IVI driver shall be registered at the IVI Foundation website and be listed on the IVI Foundation driver registration database.

11.3 Recommendation – Documentation on LXI Device Web Page

The documentation should be provided through the LXI Device's webpage or accessible from the vendor website.

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12 LXI Licensing

LXI is a trademark of the LXI Consortium Inc., which reserves the right to allow or disallow use of the LXI label on products and published material based on conformance to the LXI Standards.

12.1 RULE – Trademark Only Available to Members in Good Standing

Only LXI Consortium members in good standing, as described in the LXI Consortium Bylaws, and its licensees may use the LXI Trademark.

12.2 RULE – Devices Must Comply with LXI Rules To Use Trademark

LXI Devices shall conform to one of the following specifications to qualify for using the LXI Trademark on the LXI Device or in describing an LXI Device:

1. Specification for Class C LXI Devices as defined in 1.9.1.2.1, or
2. Specification for Class B LXI Devices as defined in 1.9.1.2.8, or
3. Specification for Class A LXI Devices as defined in 1.9.1.2.9

12.2.1 RULE – Terms Using the LXI Trademark in Conjunction with Functional Classes of LXI Devices

The LXI Trademark or registered name, LXI, shall be used to indicate or describe the Functional Class of an LXI Device as specified in the following list:

1. As a logo on the LXI Device as specified in rule 12.2
2. Using the words “Class C LXI Device” or “LXI Class C Device” in descriptive material of any sort for devices meeting the specification for Class C LXI Devices as defined in 1.9.1.2.1, or
3. Using the words “Class B LXI Device” or “LXI Class B Device” in descriptive material of any sort for devices meeting the specification for Class B LXI Devices as defined in 1.9.1.2.8, or
4. Using the words “Class A LXI Device” or “LXI Class A Device” in descriptive material of any sort for devices meeting the specification for Class A LXI Devices as defined in 1.9.1.2.9.

12.2.2 RULE – Terms Using the LXI Trademark in Conjunction with the LXI Features of Section 1.9.1.2.2

The LXI Trademark or registered name, LXI, shall be used to describe the LXI Features specified in section 1.9.1.2.2 as specified in the following list:

1. Using the words “LXI Trigger Bus” in descriptive material of any sort for an LXI Device that both:

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a. Conforms to section 1.9.1.2.1 and

b. Implements the LXI Trigger Bus feature as defined in 1.9.1.2.3

2. Using the words "LXI Event Messaging" in descriptive material of any sort for an LXI Device that both:

   a. Conforms to 1.9.1.2.1 and

   b. Implements the LXI Event Messaging feature as defined in 1.9.1.2.4

3. Using the words "LXI Clock Synchronization" in descriptive material of any sort for an LXI Device that both:

   a. Conforms to 1.9.1.2.1 and

   b. Implements the LXI Clock Synchronization feature defined in 1.9.1.2.5

4. Using the words "LXI Timestamped Data" in descriptive material of any sort for an LXI Device that both:

   a. Conforms to 1.9.1.2.1 and

   b. Implements the LXI Timestamped Data feature defined in 1.9.1.2.6

5. Using the words "LXI Event Logs" in descriptive material of any sort for an LXI Device that both:

   a. Conforms to 1.9.1.2.1 and

   b. Implements the LXI Event Logs feature as defined in 1.9.1.2.7

12.3 RULE – Permitted Use of the Trademark

Use of the LXI Trademark shall comply with the following:

1. With regard to any logo version of the LXI Trademark, a member will use only artwork provided by the Consortium for the LXI Trademark and will not distort, modify, or animate the LXI Trademark.
2. Except as provided in rules 12.2.1 and 12.2.2, a member shall not use the LXI Trademark in combination with, nor include the LXI Trademark in, any other name, word, or Trademark, including the Company's corporate name, business name, or domain names.
3. Use of the LXI Trademark under the provision of rules 12.2.1 and 12.2.2 shall be contingent on demonstrating conformance based on the conformance procedures established by the LXI Consortium in section 13.
4. Upon request by the Consortium, a member shall submit to the Consortium samples of all marcom, packaging, and products bearing the LXI Trademark for approval, and shall make whatever changes to the display of the LXI Trademark that the Consortium requests. After samples have been approved pursuant to this paragraph, the Company shall not depart there from in any material respect without prior written consent by the Consortium. Approval by the Consortium does not constitute a waiver of any of Consortium rights, or of any of the Company's duties under this license agreement. Items shall not be deemed approved unless and until approved by the Consortium in writing.

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12.4 RULE – Logo Shall Conform To Design Guidelines

The LXI Logo shall conform to the design guidelines defined on the LXI Consortium Marketing website. (www.lxistandard.org)

12.5 RULE – Trademark Use

Member or licensee agrees that all Products offered in connection with the LXI Trademark will conform to the LXI Standard Specifications as set forth in this document.

Member or licensee agrees that the Products bearing or related to the LXI Trademark shall comply with all applicable laws and regulations in connection with such Products.

Member's or licensee's use of the LXI Trademark shall be in a manner consistent with the high standards, reputation, and prestige of the Consortium.

12.6 RULE – The License To Use

The license to use the LXI specification and logo shall expire 12 months from license grant, effective on the date of LXI Consortium dues expiration.

12.7 Trademark License

The Trademark License Agreement is publicly available at the LXI Consortium website.

12.8 RULE - Comply with IP Patent Policy

Any LXI Consortium member and Licensee shall comply with the LXI IP patent policy.

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13 Conformance Specifications

13.1 Introduction

The LXI Conformance Specifications define the general rules and agreements under which equipment manufacturers shall apply and be granted permission to label their equipment with the LXI Logo, use the LXI logo in marketing literature, and advertise their equipment as LXI conformant.

Regulatory requirements and governmental type approval requirements are outside the scope of the LXI Conformance specifications. It is the sole responsibility of the vendor of an LXI Device to fulfill the different national regulatory requirements before product launch and use.

Passing the LXI Conformance Process demonstrates a certain measure of conformance and interoperability, but products are not tested for every aspect of the LXI specifications. The vendor has the ultimate responsibility to ensure that the LXI Device complies with the LXI Specifications and interoperates with other devices.

13.2 General Intent of the Conformance Specifications

The Conformance Specifications are designed to ensure that the "Interoperability" goal of the LXI Consortium is met to the fullest extent possible while still allowing manufacturers to bring devices to market with the minimum of overhead in both time and cost. To this end, the specifications define, and manufacturers are encouraged to follow a "self regulation" policy to the greatest extent possible. The three methods under which a manufacturer can seek approval for a new LXI Device are:

- By testing it for interoperability against LXI Devices from other manufacturers in a controlled environment and using procedures approved by the Consortium.
- By applying for approval based on a written Technical Justification that it has a direct legacy from and traceability to an existing LXI Device that has already received approval.
- By certification from an independent Test Laboratory approved by the Consortium.

13.3 General Conformance Process

As with most standards, vendors are responsible for testing their devices against the LXI standard and documenting their conformance to the standard.

To gain certification and licensing, vendors must submit conformance documentation and a device application, available from the LXI website, to the Conformance Working Group for approval. If complete, the Conformance Working Group then recommends certification to the LXI Board of Directors for approval

Plug-fests are an important step toward improving interoperability across vendors by ensuring consistent spec interpretation and implementation. They also help identify problems that may be masked by a single vendor's consistent implementation errors. Plug-fests offer a collaborative, supportive environment to help vendors screen and improve their LXI implementations

The major steps in the conformance process are:

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13.3.1 Prior to Plug fest

13.3.1.1 Vendor performs in-house testing

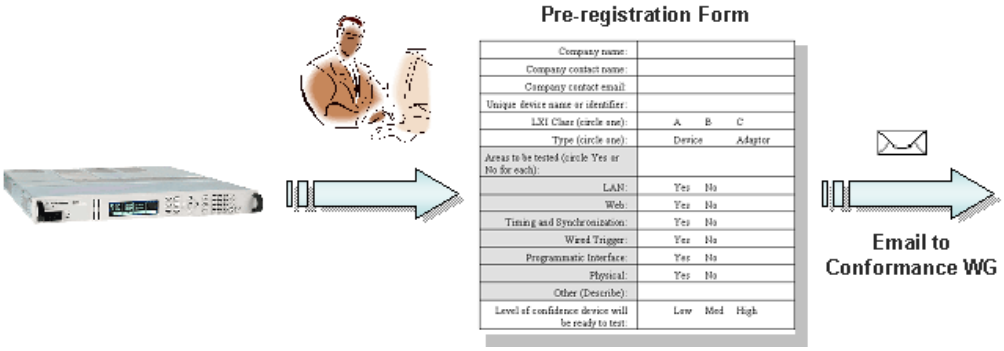
Vendor performs in-house testing to ensure conformance screening is likely to be successful.

Documents available from the LXI Consortium Technical Working Groups are test procedures to test the rules of the different sections (e.g. LAN, Web Interface, Hardware Trigger, etc.) of the LXI standard.

13.3.1.2 Vendor pre-registers device for screening at the plug fest.

This is not required, but devices that are not pre-registered are screened only after all pre-registered devices have been screened.

- Download Plug fest pre-registration form from LXI Consortium Web site
- Fill out form with vendor and device information and areas to be tested
- Email form to LXI Conformance WG prior to plug fest



13.3.2 At a Plug fest (public or privately arranged)

Vendor submits sample of device for screening. Also the vendor must provide a representative familiar with the operation of the device to assist consortium representatives with the screening.

The compiled test results are forwarded to the chair of the LXI Conformance WG at the conclusion of the plug fest.

13.3.3 After a Plug fest

Within one week of the conclusion of a plug fest, the Conformance WG will collate the results from each TWG for each device, and provide the vendor with an official record of the test results.

The record will include a summary statement identifying the device as “Fully Conformant”, “Conditionally Conformant”, or “Not Conformant” based on the requirements for the Class of Device for which the vendor requested testing. The record will also include the pass/fail status for each of the rules screened as part of the plug fest, and for any failures will provide details as to the nature of the failure. If the summary is “Conditionally Conformant”, the record will also include a statement explaining why conformance is conditional and what steps the vendor must take to achieve conformance.

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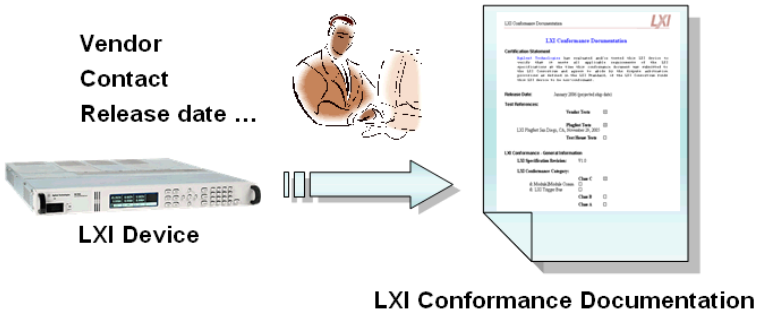
13.3.4 Application for LXI Conformance

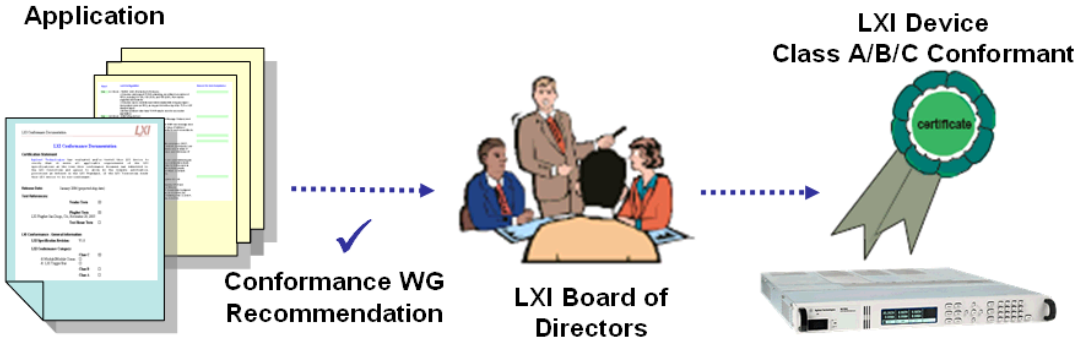
A vendor may submit to the LXI Consortium an "Application for LXI Conformance Certification". The application affirms the vendor's intent to comply with the LXI standard and to follow the rules of the consortium, include those for LXI copyright use and including those for the grievance resolution process. The application must be accompanied by:

- The LXI Conformance Documentation form including certification statement and general documentation about the LXI Device, vendor, contact and release date. The form is available from the LXI Conformance WG web site.



- The official screening test results from a plug fest where the device was tested showing the device as "Fully Conformant" or "Conditionally Conformant". For the latter, the application must also include a statement describing how/when the conditional requirement was satisfied.

The application should be sent to the Conformance WG. After successful inspection of the submitted information the Conformance WG chair will forward the application to the LXI Board of Directors with recommendation for approval as conformant to LXI Class C, LXI Class B, or LXI Class A, see 1.9.2.



The application must be accompanied by any applicable license fee (applicable to non-members seeking licensing)

Within two weeks, the LXI Consortium will notify the vendor that the application has either been approved or denied. I f approved, the notification will include an "Official Certification of Conformance" that will detail the vendors rights to use the LXI Trademark and advertise their device as LXI Conformant. If denied, the notification will explain why and detail what steps the

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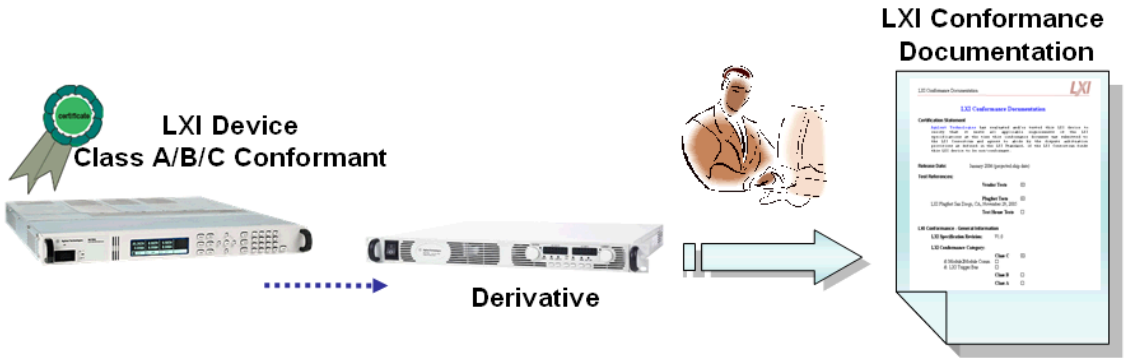
vendor can take to resolve the issue(s). If an application is denied, the LXI Consortium will, upon request, refund the vendor's license fee for that device.

13.3.5 Application for LXI Conformance on Technical Grounds

Manufacturers can use LXI legacy to claim compliance. If a family of devices uses a common LXI interface the passing of one device type can be used by the vendor to claim for the others, but the claim must still go to through the process.



In lieu of the process described above, the application may include an "Application for LXI Conformance Certification on Technical Grounds".

13.4 Conformance Grievance Process

The LXI Consortium has established a grievance process for resolving conformance, compatibility, and interoperability issues. This process

1. Provides a way for companies or individuals to raise concerns regarding illegitimate claims of LXI conformance,
2. Provides a way for the LXI Consortium to evaluate those complaints in a timely and equitable fashion, and
3. Establishes how the LXI Consortium responds to both legitimate and false complaints regarding conformance of LXI Devices.

13.4.1 Raising Concerns

To raise concerns about LXI conformance, a company, or individual should inform the LXI Consortium in writing of the complaint. The paper letter or email should be sent to the LXI Consortium business address. This letter must include:

- The LXI Device manufacturer name
- The LXI Device name (model, description, etc.)
- The software/firmware version of the LXI Device
- Any compliance claims made about the LXI Device
- Description of non-conforming behaviour

13.4.2 LXI Consortium Evaluation

When the LXI Consortium receives a complaint regarding conformance of an LXI Device, it will immediately notify the company that provides the LXI Device of the complaint. Within 30 days,

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the company must respond to the LXI Consortium. If the company does not respond, it is assumed to be claiming that there is no infraction and the arbitration process will be started.

If the company confirms the infraction, it will be given six months (in addition to the remainder of the 30 day response period) to either correct the specific flaws in the LXI Device or remove claims of LXI compliance. If the situation is not corrected within six months, the LXI Consortium will begin the censure process.

If the company claims the LXI Device is conformant, the arbitration process is initiated.

13.4.3 Arbitration

This process is invoked when there is a dispute regarding the validity of a complaint regarding the conformance of an LXI Device. It is presumed at the outset of this process that a written complaint as described above is available, as well as a written document from the provider of the LXI Device stating why it disputes the complaint.

To resolve the complaint, a Conformance Review Committee, chartered as a subcommittee of the LXI Technical Committee, will review and comment on claims. The Technical Committee chairman is responsible for creating the Conformance Review Committee and ensuring that all members of the Technical Committee have an opportunity to volunteer for the Conformance Review Committee. The Technical Committee chairman will initiate this process as soon as is convenient after being notified of the dispute. The membership will be made up of volunteer members from the Technical Committee; they shall elect an impartial chair from their membership. The committee may include both the LXI Device manufacturer and/or the person or company that initiated the complaint regarding the LXI Device in question.

The Conformance Review Committee will review the complaint. They will discuss the problem either in person or via phone meeting with the LXI Device manufacturer. The Conformance Review Committee will then formulate an authoritative opinion regarding the facts of the matter. The committee shall create a document either stating that the LXI Device appears to be conformant or stating the specific problems with the LXI Device, including references to the appropriate LXI specifications as to why the LXI Device in question does not comply. This will be sent to both the LXI Device manufacturer and the person or company that initiated the complaint.

If the flaw in the LXI Device is found to be based on a lack of clarity in the specification then the Conformance Review Committee will forward the matter to the Technical Committee and the Technical Committee shall initiate a request to update the specification using defined operating procedures for submitting specification changes.

If the LXI Device is found to be conformant, the matter is finished.

If the LXI Device is found to not be conformant, and if the LXI Device manufacturer agrees in writing to remedy the situation, the LXI driver manufacturer will be given three months from the time they are informed of the problem to remedy the situation (either update the LXI Device or remove claims of conformance).

If the LXI Device manufacturer is not satisfied with the written conclusions of the Conformance Review Committee, the LXI Device manufacturer may summarize the situation in writing to the LXI Board of Directors and request they take action on it. The Board of Directors shall review the findings of the Conformance Review Committee. If it does not agree, a new Conformance Review Committee will be formed to repeat the work of the previous committee. If the Board of Directors is in agreement with the Conformance Review Committee that the LXI Device is falsely claiming conformance to LXI, or falsely using the LXI Consortium logo, the company providing the LXI Device will be given one month to remedy the problem.

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13.4.4 Censure

If the company producing the LXI Device fails to remedy the problem in the prescribed period, the LXI Board of Directors shall take the following actions:

It shall pass a resolution indicating that the LXI Device is not in compliance and the LXI Device manufacturer has failed to correct it.

It shall send a letter based on a standard IVI Foundation form to the provider of the LXI Device stating that the provider is not allowed to use any LXI Consortium trademarks in reference to the LXI Device in question.

It shall remove the LXI Device's registration information from the publicly available LXI Consortium website.

At its discretion, the Board of Directors may also remove the LXI Device manufacturer from the LXI membership or issue a press release stating the situation with the LXI Device manufacturer and problems with the LXI Device in question.

13.4.5 Closure

All parties involved shall be notified of the results of the process.

If the LXI Device manufacturer subsequently corrects the problem, it may request that the LXI Consortium update its judgment on the LXI Device.

13.5 Specific Conformance Requirements

13.5.1 RULE – Conformance and Interoperability Testing

Interoperability testing shall be conducted either at Plug Fests arranged by the LXI Consortium, or at Interoperability Tests independently arranged by a manufacturer. In either case, the LXI Conformance and Interoperability Test Procedures defined by the Consortium shall be used, and the tests shall be witnessed by a designated representative of the Technical Committee of the Consortium. The specific requirements for Conformance and Interoperability Testing are defined below.

13.5.1.1 RULE – Scope of Conformance Testing

Conformance testing as specified in section 13.5 including all subsections shall be required for use of the LXI Trademark as specified in sections 12.2, 12.2.1, 12.2.2, and 12.3.

13.5.1.2 RULE – Conformance Demonstration at a Plug Fest

Manufacturers shall demonstrate conformance of an LXI Device at a Plug Fest arranged by the Consortium.

13.5.1.2.1 Permission – Conformance Demonstration at an Interoperability Test

Manufacturers can alternatively demonstrate conformance of an LXI Device at an Interoperability Test arranged by a member of the Consortium.

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13.5.1.3 RULE – Use of Approved Interoperability Test Procedures

Manufacturers shall use the LXI Conformance and Interoperability Test procedures defined by the Consortium when demonstrating conformance of an LXI Device at a Plug Fest or at an independently arranged Interoperability Test.

13.5.1.4 RULE – Witness of the Conformance Tests by a Designated Representative

The conformance tests must be witnessed by a designated representative of the LXI Technical Committee.

13.5.1.5 RULE – Test Documentation and Request for Certification

A Request for Certification for an LXI Device shall be submitted by the manufacturer requesting certification. It shall include the specifications of the LXI Device for which certification is being requested (LXI Conformance Documentation) and the conformance and interoperability test result documentation, including the date of the tests, the version of the LXI Specification which was used for the tests, the version of the Interoperability Test procedures used, the specifications of the other LXI Devices used in the tests, and the test results. Manufacturers will submit a separate Request for Certification request for each device for which certification is requested.

13.5.2 Technical Justification for Conformance

Conformance certification can be requested based on written Technical Justification that a new LXI Device has a direct legacy from and traceability to an existing LXI Device that has already received approval. Reasonable engineering judgment should be exercised when writing the justification document, and the main goal – that of building and selling LXI Devices that interoperate with other LXI Devices without problems – should be kept in mind when taking this course of action. The specific requirements for Interoperability Testing are defined below.

13.5.2.1 RULE – Technical Justification Procedure

The manufacturer requesting LXI Conformance Certification under this section shall submit a Technical Justification Document for the LXI Device for which certification is being requested. It shall include the LXI Conformance Documentation and the conformance and interoperability test result documentation, including the date of the tests, the version of the LXI Specification which was used for the tests of the original devices from which inheritance is claimed, the version of the Interoperability Test procedures used to test the original devices, the specifications of the other LXI Devices used in the tests, and the inheritance of the device or LXI interface of the device for which the certification is being requested. Manufacturers will submit a separate Request for Certification request for each device for which certification is requested.

13.5.3 Certification by an Independent Laboratory

Certification can be requested based on the results of conformance testing carried out by an Independent Laboratory approved by the Consortium.

13.5.3.1 RULE – Test Documentation and Request for Certification

A Request for Certification for an LXI Device shall be submitted by the manufacturer requesting certification. It shall include the specifications of the device for which certification is being requested (LXI Conformance Documentation) and the conformance and interoperability test result

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documentation,, including the name of the manufacturer, device type and serial number, date of the tests, the version of the LXI Specification which was used for the tests, the version of the Interoperability Test procedures used, the specifications of the other LXI Devices used in the tests, the test results, and the name of the independent laboratory, which carried out the tests. Manufacturers will submit a separate Request for Certification request for each device for which certification is requested.

13.6 LXI Device and Documentation Labeling Requirements

13.6.1 LXI Device Labeling

The general intent of these requirements is to ensure that LXI Devices are labeled in a clear manner that allows customers to readily identify the devices, without overly constraining manufacturers' use of corporate colors or technological advances in the use of electronic logos.

13.6.1.1 RULE – Front Panel Labeling Requirements

There shall be an LXI Label on the front of the device with no Class marking. The label shall conform to the specifications of the LXI Consortium in both design and size, and may be either color or monochrome.

13.6.1.2 Permission – Electronic Front Panel Labels

Electronic labels are acceptable instead of a painted or other label on the front of the device. The electronic labels shall be based on the bitmap provided by the LXI Consortium.

13.6.1.3 Recommendation – Device Specifications Label

The manufacturer should provide a label somewhere on the instrument defining the device characteristics and specifications including class, mechanical conformance, etc. The primary source of information on the device shall be provided through the web page in accordance with the specifications contained in Section 9, Web Interface.

13.7 LXI Cables and Terminators Conformance Requirements

13.7.1 RULE - LXI Cables and Terminators Conformance Requirements

LXI cables and terminators shall conform to the rules defined in the LXI Cables and Terminators specification

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14 Hybrid Systems

14.1 Introduction

A Hybrid System is a test system comprised of a mix of LXI Devices and other instruments (e.g. GPIB, PXI, VXI, etc.). Types of test systems to consider are:

- A System in which all devices are LXI conformant
- An Aggregate Hybrid System consisting of conformant LXI Devices and other instruments accessed through non-LXI conformant interfaces.
- A Conformant Hybrid System in which all devices are either LXI conformant or are accessed through an LXI conformant Adapter (for non-LXI conformant devices). In a Conformant Hybrid System, all adaptees have been successfully conformance tested with their respective adapters.

Three types of LXI Devices useful in assembling Hybrid Systems are **Bridges**, **Adapters**, and **Adapter Toolkits**:

- A Bridge presents a complete LXI interface on one side and a non-LXI interface on the other (such as GPIB, PCI, PXI, VXI, USB, IEEE 1394, etc.). As such, an LXI bridge is a fully conformant LXI Device (with its own discovery, IVI driver, and web pages—whose functions relate to the operation of the bridge), independent of the devices on the far side. All devices on the far side of the bridge are not LXI conformant. The intended use of a bridge is to help integrators of Aggregate Hybrid Systems incorporate non-LXI conformant devices in a manner similar or akin to LXI conformant devices. The Bridge is tested for conformance as a stand-alone device.

- An Adapter presents a complete LXI interface for one or more adaptees represented as an LXI Device or Devices in a Conformant Hybrid System. The intended use of an Adapter is to provide LXI conformance for its adaptees. Therefore, the Adapter and designated adaptees are conformance tested together as a set.

- An Adapter Toolkit is a hardware interface with a software development kit that, like an Adapter, presents a complete LXI interface for one or more adaptees represented as an LXI Device or Devices in a Conformant Hybrid System. However, unlike an Adapter, the Adapter Toolkit allows the integrator to select the adaptees and complete the customizations required to make the set LXI conformant. The intended use of an Adapter Toolkit is to help integrators of Conformant Hybrid Systems incorporate non-LXI conformant devices in a manner indistinguishable from conformant LXI Devices. The Adapter Toolkit is certified and carries the LXI logo. Although the Adapter Toolkit may be used to develop an LXI interface to another adaptee that is functionally complete and which can be used in a Hybrid System, the Adapter Toolkit and adaptee cannot be considered conformant until they have passed certification testing as a set.

Bridges, Adapters, and Adapter Toolkits are conformance tested like all other LXI Devices and are, therefore, eligible to carry the LXI logo. The associated devices (adaptees and downstream devices attached to a bridge) are not eligible to carry the LXI logo; the only case where this can occur is if the Adapter and the adaptee are in the same physical package (i.e., the Adapter is contained within the adaptee).

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14.2 RULE – Adapter and Adaptee(s) conformance tested together

An adapter shall be conformance tested with its adaptee(s). An adapter-adaptee combination is conformant provided the combination meets the requirements of section 1.9.1.2.

14.3 RULE – Adapter Toolkits and Adaptees conformance tested together

An Adapter Toolkit shall be conformance tested with at least one adaptee. The Adapter Toolkit is then considered LXI conformant provided the combination of the Adapter Toolkit and one adaptee meets the requirements of section 1.9.1.2.

14.3.1 Permission – A NULL device may be used as an adaptee

An Adapter Toolkit may be conformance tested using a NULL device as an adaptee. The NULL device allows the Adapter Toolkit to reflect itself at the LXI interface—thus the discovery response, IVI driver, and web page content are only pertinent to the Adapter Toolkit. Any Adapter Toolkit so tested cannot claim to offer LXI conformance on any particular adaptee until it is customized or configured for the adaptee.

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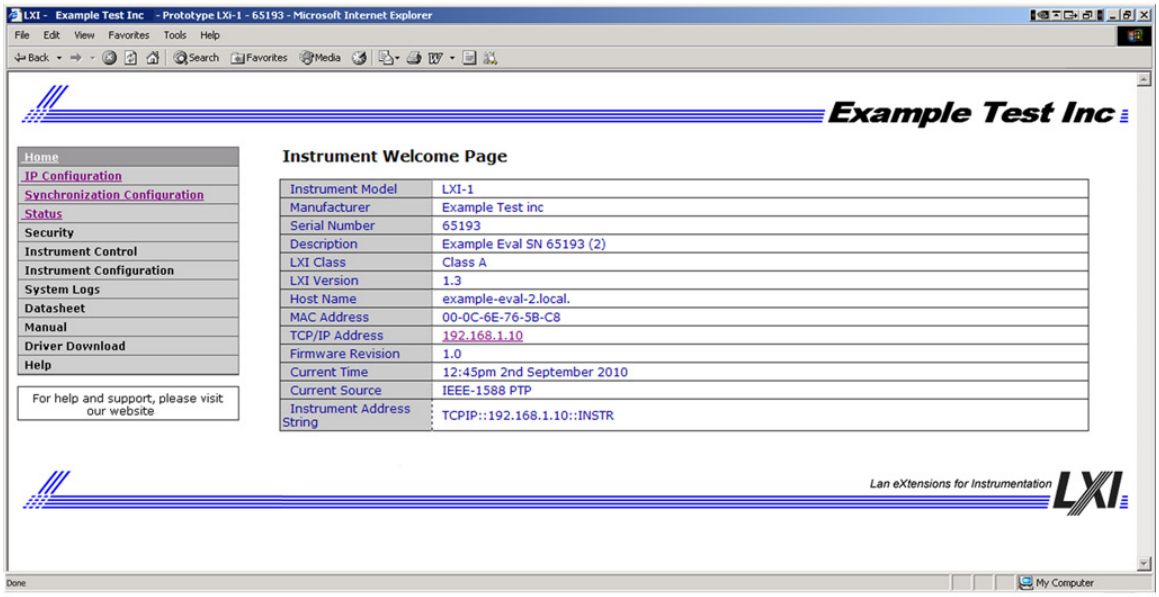
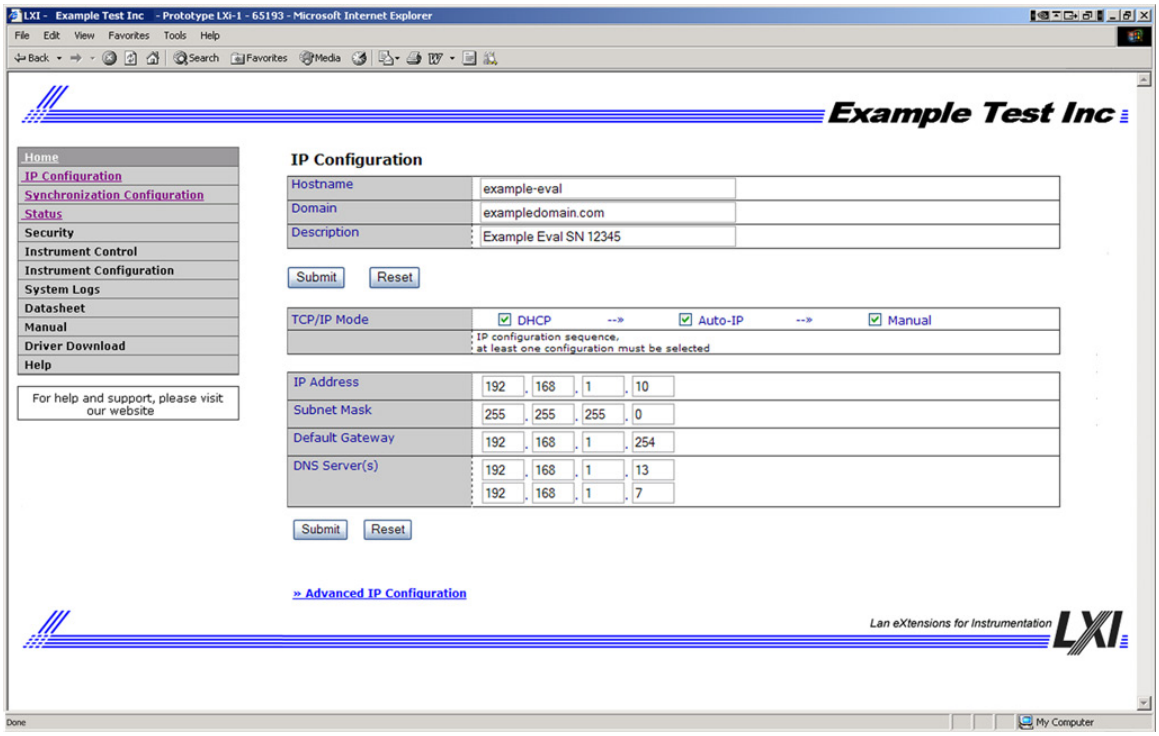
Appendix A Sample Web Pages





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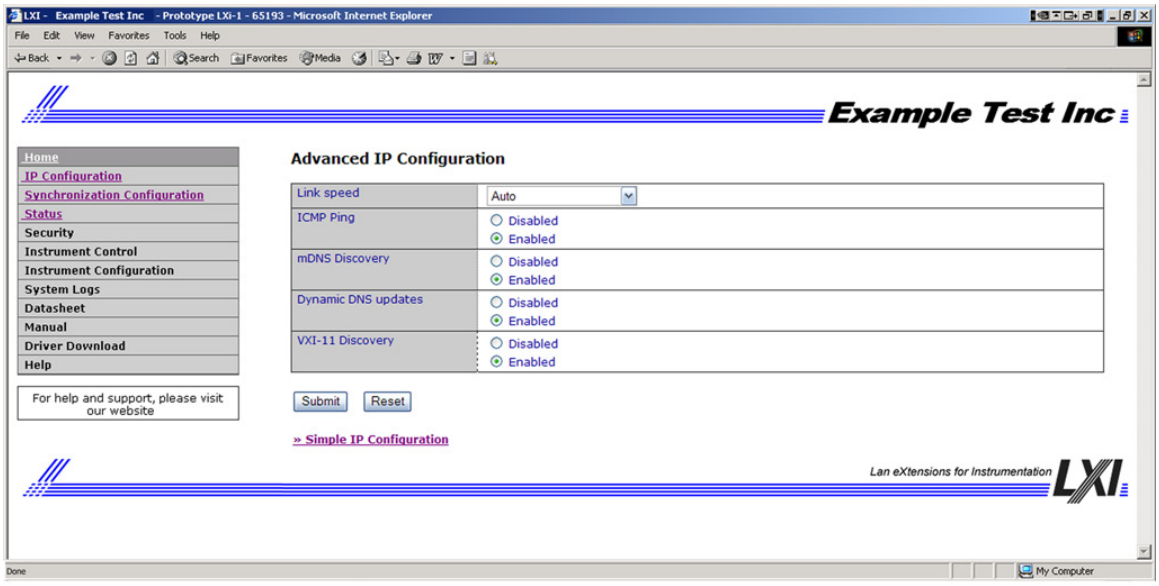

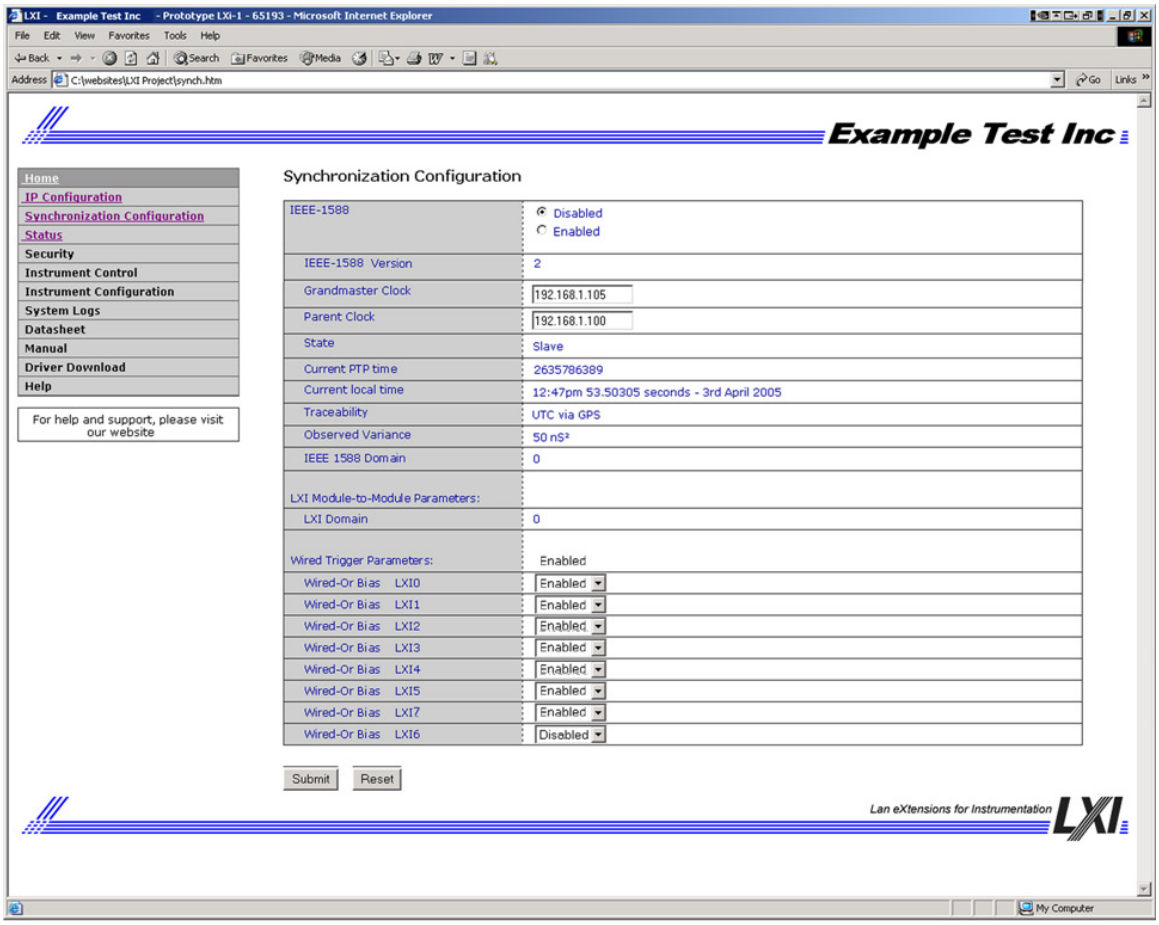

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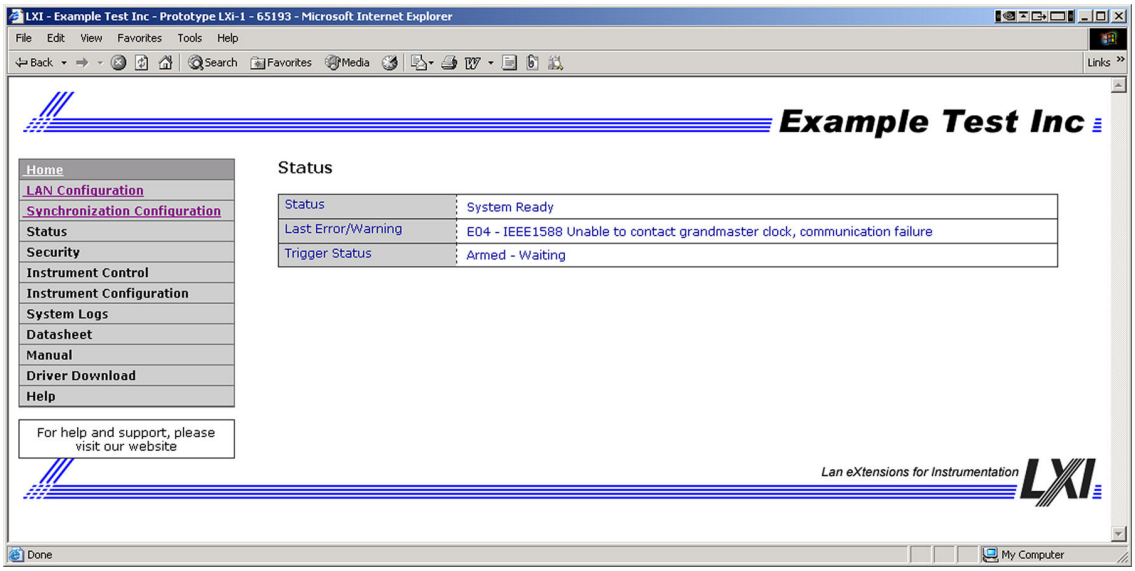

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Appendix B LXI Event Packet Examples

Table B.1 gives several examples of LXI Event packets.

Note: *The packet is terminated by a data length field with a value of zero (0x0000).*

Note: *All multi-octet fields are transmitted as big-endian.*

Table B.1 – LXI Event Packet Examples

Packet Header (ASCII) 3 Octets	**Domain** 1 Octet (uint8)	**Identifier** 16 Octets null padded	**Sequence Number** 4 Octets (uint32)	**Seconds** 4 Octets (uint32)	**Nanoseconds** 4 Octets (uint32)	**Fractional Nanoseconds** 2 Octets (uint16)	**Epoch** 2 Octets (uint16)	**Flags** 0: Error 1: 2:Signal Value 3: Ack 2 Octets (uint16)
LXI	0x00	LAN0	0x1357feff	0x00000002	0x00000111	0x0000	0x0000	0x0004 HDWR Value = TRUE
LXI	0x00	LAN5	0x12345678	0x00000002	0x80000000	0x0000	0x0000	0x0004 HDWR Value = TRUE
LXI	0x01	LAN3	0xff000539	0x463682c3	0x1dcd6500	0x0000	0x0000	0x0008 ACK & HDWR Value = FALSE

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Table B.2 illustrates usage of the data fields.

Note: *All LXI Event packets must be terminated by an empty data field – that is, one with a Data Length field with a value of zero and no Identifier or User Data field.*

Table B.2 – Usage

Data Length (2 octets)	**Identifier** (1 octet)	**User Data** (Data Length octets; encoded in hexadecimal)	**Notes**
0x0008	0x04	0102 0304 0506 0708	User-defined data type
0x0011	0xFF	5468 6973 2069 7320 6120 7374 7269 6E67 2E	The ASCII string, "This is a string."
0x0008	0xFC	0102 1112 2122 3132	Four int16's
0x0000			Packet Terminator

The octet stream for the LXI Event in the first row of Table B.1 containing all of the data fields of Table B.2 and encoded in hexadecimal would be the following:

```
4C58 4900 4C41 4E30 0000 0000 0000 0000 0000 0000 1357 FEFF 0000 0002
0000 0111 0000 0000 0004 0008 0401 0203 0405 0607 0800 11FF 5468 6973
2069 7320 6120 7374 7269 6E67 2E00 08FC 0102 1112 2122 3132 0000
```

That is:

Octets	**Notes**
4C58 49	LXI
00	Domain = 0
4C41 4E30 0000 0000 0000 0000 0000 0000	Event ID = "LAN0"
1357 FEFF	Sequence Number
0000 0002	Seconds
0000 0111	Nanoseconds
0000	Fractional Nanoseconds
0000	Epoch
0004	Flags (Hardware Value = True)
0008	Data Length = 8
04	Identifier (user-defined)
0102 0304 0506 0708	User Data
0011	Data Length = 17
FF	Identifier (0xFF – String)
5468 6973 2069 7320 6120 7374 7269 6E67 2E	User Data ("This is a string.")
0008	Data Length = 8
FC	Identifier (0xFC – int16)
0102 1112 2122 3132	User Data
0000	Data Length = 00 / Packet Terminator

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Appendix C Example Identification Documents

The following XML files are example instances of the LXI Identification and its extension (available at http://www.lxistandard.org/InstrumentIdentification/1.0).

Identification Document

Example Identification Document conforming to LXI InstrumentIdentification that illustrates ConnectedDevices, use of the Extension element for vendor-specific data, and the schemalocation attribute:

```
<?xml version="1.0" encoding="UTF-8"?><LXIDevice
xmlns="http://www.lxistandard.org/InstrumentIdentification/1.0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.lxistandard.org/InstrumentIdentification/1.0
http://sampledevice.local/static/LXIIdentification.xsd">
  <Manufacturer>My Company, Inc. </Manufacturer>
  <Model>EX1234</Model>
  <SerialNumber>543210</SerialNumber>
  <FirmwareRevision>1.2.3a</FirmwareRevision>
  <ManufacturerDescription>Sample Device</ManufacturerDescription>
  <HomepageURL>http://www.mycompany.com</HomepageURL>
  <DriverURL>http://www.mycompany.com</DriverURL>
  <ConnectedDevices>
    <DeviceURI>http://sampledevice.local/devices/device0/</DeviceURI>
    <DeviceURI>http://sampledevice.local/devices/device2/</DeviceURI>
  </ConnectedDevices>
  <UserDescription>Demo of Identification Schema</UserDescription>
  <IdentificationURL>http://sampledevice.local/lxi/identification</IdentificationURL>
  <Interface xsi:type="NetworkInformation" InterfaceType="LXI" IPType="IPv4"
InterfaceName="eth0">
    <InstrumentAddressString>TCPIP::10.1.2.32::INSTR</InstrumentAddressString>
<InstrumentAddressString>TCPIP::10.1.2.32::5000::SOCKET</InstrumentAddressString>
    <Hostname>10.1.2.32</Hostname>
    <IPAddress>10.1.2.32</IPAddress>
    <SubnetMask>255.255.255.0</SubnetMask>
    <MACAddress>00:3F:F8:6A:1A:3A</MACAddress>
    <Gateway>10.1.2.1</Gateway>
    <DHCPEnabled>True</DHCPEnabled>
    <AutoIPEnabled>True</AutoIPEnabled>
  </Interface>
  <Interface InterfaceType="MyCompanyCustomNetworkInterface"
InterfaceName="MyCompany1">
    <InstrumentAddressString>10.1.2.32:5025</InstrumentAddressString>
  </Interface>
```

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```
  <IVISoftwareModuleName>Thingamajig</IVISoftwareModuleName>
  <Extension>
    <SampleExtension>
    Arbitrary Vendor Extension Data can go here.
   </SampleExtension>
  </Extension>
  <LXIClass>A</LXIClass>
  <Domain>1</Domain>
  <LXIVersion>1.2</LXIVersion>
</LXIDevice>
```

Derived Schema

The following is an identification schema (XSD) that derives from the LXI InstrumentIdentification schema and is used for the two ConnectedDevices in the above sample Identification document. The schema creates a new element "MyDevice" that uses the "Device" element of the LXI InstrumentIdentification schema as a base to extend. The new element contains only one additional element beyond that defined by "lxi:Device": LogicalAddress, which is an unsigned byte.

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema targetNamespace="http://www.mycompany.com/MyIdentification/1.0"
           xmlns:xs="http://www.w3.org/2001/XMLSchema"
       xmlns:lxi="http://www.lxistandard.org/InstrumentIdentification/1.0"
       elementFormDefault="qualified"
       attributeFormDefault="unqualified">
  <xs:import namespace="http://www.lxistandard.org/InstrumentIdentification/1.0"
       schemaLocation="http://sampledevice.local/static/LXIIdentification.xsd"/>
  <xs:element name="MyDevice">
    <xs:annotation>
      <xs:documentation>An example identification of a device based on the generic
LXI Model
      </xs:documentation>
    </xs:annotation>
    <xs:complexType>
      <xs:complexContent>
    <xs:extension base="lxi:Device">
      <xs:sequence>
        <xs:element name="LogicalAddress" type="xs:unsignedByte"/>
      </xs:sequence>
    </xs:extension>
      </xs:complexContent>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

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Connected Devices

The sample Identification Document above contains two ConnectedDevice URIs. The identification documents for these two devices may be queried by appending "lxi/identification" to the URIs provided. These connected devices are instances of the sample MyIdentification Schema defined above. Note that they reference both the LXI InstrumentIdentification Schema as well as the derived MyIdentificationSchema in the schemalocation attribute.

The first device's identification document's URL is http://sampledevice.local/devices/device0/lxi/identification. The document's contents are:

```
<?xml version="1.0" encoding="UTF-8"?>
<MyDevice xmlns="http://www.mycompany.com/MyIdentification/1.0"
          xmlns:lxi="http://www.lxistandard.org/InstrumentIdentification/1.0"
          xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
         xsi:schemaLocation="http://www.lxistandard.org/InstrumentIdentification/1.0
                  http://sampledevice.local/static/LXIIdentification.xsd
                  http://www.mycompany.com/MyIdentification/1.0
                  http://sampledevice.local/static/MyIdentification.xsd" >
  <lxi:Manufacturer>My Company, Inc.</lxi:Manufacturer>
  <lxi:Model>1234</lxi:Model>
  <lxi:SerialNumber>123</lxi:SerialNumber>
  <lxi:FirmwareRevision>1.2.3a</lxi:FirmwareRevision>
<lxi:IdentificationURL>http://sampledevice.local/devices/device0/lxi/identification</
lxi:IdentificationURL>
<lxi:Interface InterfaceType="MyCompanyProprietary" InterfaceName="instr0">
<lxi:InstrumentAddressString>TCPIP::10.1.2.32::inst1::INSTR</lxi:InstrumentAddressStr
ing>
 </lxi:Interface>
  <lxi:Extension>
  <MySampleDeviceExtension>
   Arbitrary Vendor Extension Data can go here.
  </MySampleDeviceExtension>
  </lxi:Extension>
  <LogicalAddress>0</LogicalAddress>
</MyDevice>
```

The second device's identification document's URL is http://sampledevice.local/devices/device2/lxi/identification. The document's contents are:

```
<?xml version="1.0" encoding="UTF-8"?>
<MyDevice xmlns="http://www.mycompany.com/MyIdentification/1.0"
          xmlns:lxi="http://www.lxistandard.org/InstrumentIdentification/1.0"
          xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"

xsi:schemaLocation="http://www.lxistandard.org/InstrumentIdentification/1.0
                  http://sampledevice.local/static/LXIIdentification.xsd
                  http://www.mycompany.com/MyIdentification/1.0
                  http://sampledevice.local/static/MyIdentification.xsd" >
```

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```
  <lxi:Manufacturer>My Company, Inc.</lxi:Manufacturer>
  <lxi:Model>1234</lxi:Model>
  <lxi:SerialNumber>456</lxi:SerialNumber>
  <lxi:FirmwareRevision>1.2.3a</lxi:FirmwareRevision>
<lxi:IdentificationURL>http://sampledevice.local/devices/device2/lxi/identification</
lxi:IdentificationURL>
  <lxi:Interface InterfaceType="MyCompanyProprietary" InterfaceName="instr2">
<lxi:InstrumentAddressString>TCPIP::10.1.2.32::inst2::INSTR</lxi:InstrumentAddressStr
ing>
<lxi:InstrumentAddressString>TCPIP::10.1.2.32::3002::SOCKET</lxi:InstrumentAddressStr
ing>
  </lxi:Interface>
  <lxi:Extension>
  <MySampleDeviceExtension>
   Arbitrary Vendor Extension Data can go here.
  </MySampleDeviceExtension>
  </lxi:Extension>
  <LogicalAddress>2</LogicalAddress>
</MyDevice>
```

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Appendix D Glossary of Terms

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 with MDI-X or MDI connectors to connect without using a crossover cable. This feature is also known as Auto-crossover.

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)

DNS

See definition for: Domain Name System (DNS)

DNS-SD

DNS Service Discovery. A protocol to advertise instance service names to enable zero address configuration scenarios for networked devices.

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

The term domain is used in three contexts in this specification. See Domain name for the definition in the context of DNS. The term is also used in Rules 3.3.2.1 and 4.3.2 as LXI Domain to define a scoping mechanism for the processing of LXI Events. For devices implementing IEEE 1588 there is also the concept of an IEEE 1588 domain, which defines a set of IEEE 1588 clocks participating in the IEEE 1588 protocol.

Domain name

In the context of DNS, 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.

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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.

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

See definition for: Hypertext Markup Language (HTML)

HTTP

See definition for: Hypertext Transfer Protocol (HTTP)

Hypertext Markup Language (HTML)

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.

Hypertext Transfer Protocol (HTTP)

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.w3.org.

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 misoperation.

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).

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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.

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

See definition for: Internet Protocol (IP)

IP address

An address used to identify a node on an IP internetwork. Each node on the IP internetwork 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 interchangeability, provide better performance, and reduce the cost of program development and maintenance.

LAN

See definition for: local area network (LAN)

LCI

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

Local Area Network (LAN)

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.

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.

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LXI Device

A device that conforms to this specification, *See also: module*

LXI Event

An event is an abstraction of a change in the realization of a signal or condition. AN LXI Event is an event occurring in an LXI Device or communicated by means of an LXI Event Message.

LXI Event Message

A data packet used for module-to-module communication of LXI Events in an LXI system. The format and semantics of LXI Event Messages are defined in this standard.

LXI Identification XSD Schema

An XML Schema that conforms to XSD standards and is defined by the LXI Consortium to specify XML documents that provide identification information about LXI Devices.

M-LVDS

Multipoint Low-Voltage Differential Signaling 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 -50 mV are defined by the TIA/EIA-899 standard to be in the low state, and signals above +50 mV 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

See definition for: media access control

MAC Address

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

Media Access Control (MAC)

A sublayer of the IEEE 802 specifications that defines network access methods and framing.

mDNS

One of the discovery protocols specified for use in LXI Devices. mDNS stands for multicast Domain Name Service and is a protocol developed by the IETF Zeroconf Working Group.

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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.

Module

A device that communicates or interacts with an LXI Device. An LXI Device is a special case of a module, *See also: LXI Device.*

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 802.3af 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

See definition for IEEE 1588.

Schema

A document that describes a language or parameters of a language. Thus, XML Schemas provide a means of describing the structure, content, and semantics of XML documents.

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.

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.

SNMP

See definition for: Simple Network Management Protocol (SNMP)

Star Hub

An LXI Device that can be used to connect LXI 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 LXI Trigger Bus event by providing a mapping function between the LXI 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 an LXI Trigger Bus.

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Subnet

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

See definition for: Transmission Control Protocol/Internet Protocol (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.

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 fictitious URL *http://www.example.microsoft.com*.

URL

See definition for Uniform Resource Locator (URL)

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 utilize either VISA or another library.

W3C

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

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XSD

An XML Schema Definition, as defined by the W3C (http://www.w3.org/XML/Schema). It defines a type of XML document in terms of the constraints upon what elements and attributes may appear, their relationship to each other, what types of data may be in them, and so forth.

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Agilent Technologies
Keithley Instruments
Pickering Interfaces
Rohde & Schwarz
VXI Technology

Aeroflex
Ametek
Bruel & Kjaer S & V
C & H Technologies
EADS-NA Defense
Geotest-Marvin Test Systems
Intepro Systems
IPTE
Kepco
National Instruments
Tektronix
The MathWorks

Anritsu
GÖPEL electronic
Lambda America
Pacific Mindworks
ZTEC Instruments

AMREL
ARC Technology Solutions
Beijing Aerospace Measurement & Control
Beijing Control Industrial Computer
Beijing Institute of Radio Metrology & Measurement
Bustec
California Instruments
Circuit Assembly
Colby Instruments
COM DEV
Data Patterns
Data Physics
Data Translation
DowKey Microwave
Hitech Group International
Holding Informtest
JDS Uniphase
LeCroy
LXinstruments
NH Research
Pacific Power Source
Rigol Technologies
SofTec Microsystems
Symmetricom
Symtx
Tegam
Teradyne
TTI
Universal Switching
Wheelwright Enterprises
Yokogawa Electric