LXI Device Specification 2011

Revision 1.4

May 18, 2011 Publication Date

Reference Documents

Notice of Rights All rights reserved. This document is the property of the LXI Consortium. It may be reproduced, unaltered, in whole or in part, provided the LXI copyright notice is retained on every document page.

Notice of Liability The information contained in this document is subject to change without notice. "Preliminary" releases are for specification development and proof-of-concept testing and may not reflect the final "Released" specification.

The LXI Consortium, Inc. makes no warranty of any kind with regard to this material, including but not limited to, the implied warranties of merchantability and fitness for a particular purpose. The LXI Consortium, Inc. shall not be liable for errors or omissions contained herein or for incidental or consequential damages in connection with the furnishing, performance, or use of this material.

LXI Standards Documents are developed within the LXI Consortium and LXI Technical Working Groups sponsored by the LXI Consortium Board of Directors. The LXI Consortium develops its standards through a consensus development process modeled after the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Consortium and serve without compensation. While the LXI Consortium administers the process and establishes rules to promote fairness in the consensus development process, the LXI Consortium does not exhaustively evaluate, test, or verify the accuracy of any of the information contained in its standards.

Use of an LXI Consortium Standard is wholly voluntary. The LXI Consortium and its members disclaim liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon this, or any other LXI Consortium Standard document.

The LXI Consortium does not warrant or represent the accuracy or content of the material contained herein, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained herein is free from patent infringement. LXI Consortium Standards documents are supplied "as is". The existence of an LXI Consortium Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the LXI Consortium Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every LXI Consortium Standard is subjected to review at least every five years for revision or reaffirmation. When a document is more than five years old and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any LXI Consortium Standard.

In publishing and making this document available, the LXI Consortium is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is the LXI Consortium undertaking to perform any duty owed by any other person or entity to another. Any person utilizing this, and any other LXI Consortium Standards document, should rely upon the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

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

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. Requests for interpretations of this standard must be sent to interpretations@lxistandard.org using the form "*Request for Interpretation of an LXI Standard Document*". This document plus a list of interpretations to this standard are found on the LXI Consortium's Web site: http://www.lxistandard.org

Trademarks Product and company names listed are trademarks or trade names of their respective companies. No investigation has been made of common-law trademark rights in any work.

LXI is a registered trademark of the LXI Consortium

Patents: Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. A holder of such patent rights has filed a copy of the document "*Patent Statement and Licensing Declaration"* with the Consortium. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. Other patent rights may exist for which the LXI Consortium has not received a declaration in the form of the document "*Patent Statement and Licensing Declaration*". The LXI Consortium shall not be held responsible for identifying any or all such patent rights, for conducting inquiries into the legal validity or scope of patent rights, or determining whether any licensing terms or conditions are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Conformance The LXI Consortium draws attention to the document "*LXI Consortium Policy for Certifying Conformance to LXI Consortium Standards*", see 1.4.3. This document specifies the procedures that must be followed to claim conformance with this standard.

Legal Issues Attention is drawn to the document "*LXI Consortium Trademark and Patent Policies*" , see 1.4.3. This document specifies the requirements that must be met in order to use registered trademarks of the LXI Consortium.

Revision history

Revision	***Description***
May 18, 2011	Finalizing document after the vote to pass, which concluded on May 9, 2011: - Renaming file to *LXI Device Specifcation 2011* - Removing draft notes on title page - Removing "DRAFT" in background
Apr 11, 2011	Correcting formatting errors in TOC. Now is Word 2007 docx file
Apr 10, 2011	Corrected formatting errors introduced by Word 2007 when accepting changes – Sections 1.4.4.2. Also removed 6.8 from bullet 3 of 1.4.2.2.1. Removed 1.4.4.2 from bullet 1 in same section. Rule 1.4.5 had been reformatted to bullet 4 of 1.4.4.2.7. No rule numbers changed, since the new 1.4.5 is the same as a previous version of this draft and had been corrupted.
Feb 28, 2011	Corrected the XML example in Appendix to include InstrumentAddressString for HiSLIP device.
Feb 20, 2011	Corrections to spec after Feb 2011 LXI Meeting. Spec name changed to LXI Device Specification 2011. Broken links fixed in Section 1. XML Schema document was updated to add missing LXIExtendedFunctions header. Changes to wording above Rule 1.4.5. to permit additional Extended Functions as identified in the LXI Documentation Overview. Modifying publication date on this document as May 18, 2011. This specification will no longer use the LXI Cover sheets as in previous revisions.
Dec 16, 2010	Changes to Section 1 to accommodate LXI Identification of Extended Functions along with support in Section 10. Added Rule 10.2.5 LXI Extended Function Elements.
October 5, 2010	Removed permissions 3.5.1.3.3 and 3.5.2.4 related to exempting from implementing trigger functions that are not supported by Device. Modified 1.4.4.2.7 to break loop related to requirement of IEEE 1588 time synchronization for devices that implement Events and Event Log but use zero for time stamp. Corrected typo on reference to Section 8.1.
Aug 8, 2010	Changed version number to 1.4. Added commentary that makes it clear the Extended Function is not a closed list in Section 1.44. Updated the home web page example in the Appendix. Added Recommendation 8.1.1. Removed IVI.COM recommendation in 6.1.2
May 19, 2010	Changed Section 8 to IPv4 LAN Configuration in preparation for added IPv6 in the future.
May 17, 2010	Added changes to Home page example for LXI Device in Appendix A. This now includes new "1.31 LXI Device Specification 2010" for LXI version, and it includes the new "LXI Extended Functions" field including examples of each of the LXI Extended Functions detailed in Section 1. Previous example was Class A, but now that example is essentially the same as Class A, since it contains all of the LXI Extended Functions. Updated section 9.2 with new home page displayed requirements.
April 6, 2010	Removed all references to Class C and now focused on the LXI Core 2010 specification.
April 5, 2010	Revised Overview of Section 5 and replaced Figure 5.1 with version that does not emphasize LXI Trigger Bus Adapters or Star Hubs. Adapters and Star Hub information has been removed from the standards documents at this time. This involved removing Rules 5.5.1-5.5.4. Rules 5.6.1 and 5.6.2 were moved to ***LXI Wired Trigger Bus Cable and Terminator Specifications.*** Revised Observations on Recommendations that used Should or Must type language.

March 31, 2010	Another pass through standard. Intent to remove class structure from specification and rely upon the 5 key LXI extensions to the base Class C Device. The term Class C is retained, but now describes the Core or base functionality of an LXI Device. Terminology such as Functional Class has been replaced by Functional Declaration to describe the base class and its optional extensions. Added clarifying observation for Rule 8.7 on Duplicate IP Address Detection. Repositioned all Section 5 Rules to their original numbering. Permission 5.2 has been replaced by Rule 5.2 related to adhering to ***LXI Wired Trigger Bus Cable and Terminator Specifications*** document. Rule 5.3.13 has been removed due to redundancy with Configuration using driver. 5.3.17 and 5.3.18 have been removed as Rules and converted to Informative in the ***LXI Wired Trigger Bus Cable and Terminator Specifications*** document**.** Rule 5.4.9.1 was added for +3.3V Supply on LXI Trigger Bus Connectors.
January 25, 2010	Made pass through Section 5 to remove rules and documentation related to the interconnect between LXI Devices. These rules and documentation have been move to the new ***LXI Wired Trigger Bus Cable and Terminator Specifications*** document. Further notes on changes to rules will follow review.
August 19, 2009	Removed items related to conformance procedures, section 13, and licensing procedures, section 12 to separate documents. Revised front matter. Eliminated portions of section 1 including 1.1, 1.2, 1.6, 1.7, 1,8, 1.9.3-1.9.9. Removed to a separate document sections 1.10, 14. restored items from section 13 related to appearance of logo to section 2.
1.3 September 8, 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 1.4.4.2 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. Old 3.5, 3.6, and 3.7 consolidated in 3.5. Old 5.2 and 5.2.11 replaced by specifications in 1.4.4.2. Added **Error! Reference source not found.** and **Error! Reference source not found.** to clarify use of LXI Trademark with respect to LXI features. Augmented **Error! Reference source not found.** with respect to use of LXI Functional Class descriptions using the LXI Trademark. Minor modifications made to **Error! Reference source not found.** as a result. Removed all text and figures referencing the LXI Conformance spreadsheet, which no longer exists. Converted **Error! Reference source not found.** to a rule and added new rule

	Error! Reference source not found. clarifying role of conformance testing as a requirement for permission to use the LXI Trademark as specified in various parts of section **Error! Reference source not found.**.
1.2.01 Nov 2007	Fixed typographical error in Section 8.
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. • 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.
1.1 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
1.0 Sept 23, 2005	Initial version was adopted 9/23/2005.

1 Overview and Class Definition

1.1 Introduction

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. 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.

1.2 Purpose and Scope of this Document

1.2.1 Purpose

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

1. Unambiguous communication among 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

1.2.2 Scope

This document defines a set of **RULES** and **RECOMMENDATIONS** for constructing a conformant LXI Device. Whenever possible these specifications use existing standards.

The standard specifies:

1. LXI Device functional declarations,
2. Mechanical and electrical requirements,
3. Device synchronization and event messaging including the format of event messages,

4. A uniform triggering model that includes triggering based on hard wired triggers, event messaging, and timed events,

5. A programmatic interface to the event and uniform triggering models,

6. A hardware trigger bus as part of the uniform triggering model,

7. Requirements on LAN communication and configuration,

8. A web interface

9. Requirements on device identification and discovery mechanisms

10. Documentation requirements

1.3 Definition of Terms

This document contains both normative and informative material. Unless otherwise stated the material in this document shall be considered normative.

NORMATIVE: Normative material shall be considered in determining whether an LXI Device is conformant to this standard. Any section or subsection designated as a RULE or PERMISSION is normative.

INFORMATIVE: Informative material is explanatory and is not considered in determining the conformance of an LXI Device. Any section or subsection designated as RECOMMENDATION, SUGGESTION, or OBSERVATION is informative. Unless otherwise noted examples are informative.

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.

1.4 Applicable Standards and Documents

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

1.4.1 RULE – Applicable Version of Documents

For dated references, only the edition cited (including any amendments or corrigenda) shall be used in conjunction with this standard.

Unless otherwise stated, for undated references, the edition of the referenced document (including any amendments or corrigenda) applicable at the date of certification of the LXI Device to this standard shall be used in conjunction with this standard.

1.4.2 Standards and Specifications

1.4.2.1 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

---

[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

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

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

1.4.2.2 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)

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

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)

1.4.2.3 LXI Consortium Standards

"LXI IEEE 1588 Profile"

"LXI Wired Trigger Bus Cable and Terminator Specifications"

1.4.2.4 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

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

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

1.4.3 LXI Consortium Supplementary Documents[10]

"LXI Consortium Policy for Certifying Conformance to LXI Consortium Standards"

"LXI Consortium Trademark, Patent and Licensing Policies"

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

---

[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

"LXI Wired Trigger Bus Cable And Terminator Specifications"

1.4.4 LXI Functional Base Class and Extensions

1.4.4.1 General Description

The LXI Standard consists of a base class referred to as the LXI Core 2011 specification of an LXI Device. All LXI Devices must conform to the base class. The LXI Standard currently provides five Extended Functions to the LXI Core 2011 specification: LXI Wired Trigger Bus, LXI Event Messaging, LXI Clock Synchronization using IEEE 1588, LXI Timestamped Data, and LXI Event Logs.

LXI Core 2011 Device

The base class LXI Device provides a standardized LAN and web browser interface that is conformant with the LXI Standard. This base 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. These devices 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.

This standard does not require any physical size for an LXI Device. However, it specifies physical specifications for electrical standards, status indication, and environmental requirements.

LXI Extended Function

Any Extended Function not already in this document and approved by the LXI Consortium will come in the form of external documents. Each Extended Function document will have sections numbered as though they were part of the LXI Core 2011 specification. When the next major release occurs, those external documents will be integrated into the core specification. The "*Guide to LXI Documentation*" will identify such Extended Function documents.

An LXI Device can include one or all of the Extended Functions. Each extension has conformance requirements in addition to the base class.

1.4.4.2 RULE – Conformance Requirements

The rules in this section define the conformance requirements for the LXI Core 2011 Device and the current five Extensions. All LXI Devices shall conform to the rules in this section for the base class. All LXI Devices that add listed extensions shall conform to the rules in this section related to those extensions. Implementers of LXI Devices should also consider the recommendations, observations, and permissions included in the sections cited for the base class and each Extended Function.

1.4.4.2.1 RULE – LXI Core 2011 Device Conformance Requirements

All LXI Core 2011 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 1.4.5 and 1.4.6.
2. Section 2 including all subsections
3. Sections 6.1 and 6.2

4. Section 7 including all subsections

5. Section 8 including all subsections

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. Section 11 including all subsections

1.4.4.2.2 Permission – LXI Extended Functions

LXI Core 2011 Devices may include one or more of the following LXI Extended Functions. Each implementation of an LXI Extended Function shall conform to all rules in the sections cited in the following list. Further Extended Functions identified in the "*Guide to LXI Documentation*" will include similar rules and found in the "*LXI Consortium Policy for Certifying Conformance to LXI Consortium Standards*"

1. LXI Wired Trigger Bus, see 1.4.4.2.3

2. LXI Event Messaging, see 1.4.4.2.4

3. LXI Clock Synchronization, see 1.4.4.2.5

4. LXI Timestamped Data, see 1.4.4.2.6

5. LXI Event Logs, see 1.4.4.2.7

1.4.4.2.3 RULE – LXI Wired Trigger Bus Conformance Requirements

All LXI Devices implementing the LXI Wired Trigger Bus as permitted by 1.4.4.2.2 shall implement and conform to the requirements of section 1.4.4.2.1 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, and 6.4.4 through 6.4.6, including all subsections.

4. Section 9.6 including all subsections

5. A Function element with the FunctionName attributes of "LXI Wired Trigger Bus" and version "1.0" in the LXIExtendedFunction element of the LXI identification document as described by section 10.2.5

1.4.4.2.4 RULE – LXI Event Messaging Conformance Requirements

All LXI Devices implementing the LXI Event Messaging as permitted by 1.4.4.2.2 shall implement and conform to the requirements of section 1.4.4.2.1 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

4. A Function element with the FunctionName attributes of "LXI Event Messaging" and version "1.0" in the LXIExtendedFunction element of the LXI identification document as described by section 10.2.5

1.4.4.2.5 RULE – LXI Clock Synchronization Conformance Requirements

All LXI Devices implementing the LXI Clock Synchronization as permitted by 1.4.4.2.2 shall implement and conform to the requirements of section 1.4.4.2.1 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

4. A Function element with the FunctionName attributes of "LXI Clock Synchronization" and version "1.0" in the LXIExtendedFunction element of the LXI identification document as described by section 10.2.5.

1.4.4.2.6 RULE – LXI Timestamped Data Conformance Requirements

All LXI Devices implementing the LXI Timestamped Data as permitted by 1.4.4.2.2 shall implement and conform to the requirements of section 1.4.4.2.1 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 1.4.4.2.5

2. Section 3.6 including all subsections

3. A Function element with the FunctionName attributes of "LXI Timestamped Data" and version "1.0" in the LXIExtendedFunction element of the LXI identification document as described by section 10.2.5

1.4.4.2.7 RULE – LXI Event Log Conformance Requirements

All LXI Devices implementing the LXI Event Log permitted by 1.4.4.2.2 shall implement and conform to the requirements of section 1.4.4.2.1 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. If using non-zero time-stamped events, then include Section 1.4.4.2.5

2. Section 3.7 including all subsections.

3. Section 6.7 including all subsections

   A Function element with the FunctionName attributes of "LXI Event Log" and version "1.0" in the LXIExtendedFunction element of the LXI identification document as described by section 10.2.5

1.4.5 RULE – Functional Declaration

Manufacturers of LXI Devices shall clearly declare that a device is LXI Core 2011 conformant and shall declare any implemented LXI Extended Functions within the data sheet and supporting documentation. The Functional Declaration shall be declared as one of the following:

- LXI Core 2011 if the LXI Device is conformant to 1.4.4.2.1
- LXI Core 2011 Device with Extended Functions;
    - LXI Wired Trigger Bus is conformant to 1.4.4.2.3
    - LXI Event Messaging is conformant to 1.4.4.2.4
    - LXI Clock Synchronization is conformant to 1.4.3.2.5
    - LXI Timestamped Data is conformation to 1.4.4.2.6
    - LXI Event Log is conformant to 1.4.4.2.7

The only other declarations permitted are for other LXI Extended Functions approved by the LXI Consortium as defined in separate documents and described in the ***LXI documentation Overview***.

1.4.6 RULE – Web Indication of Functional Declaration

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

Observation

> If the Functional Declaration of an LXI Device is upgraded by a software download or hardware modification, the web interface must be updated to reflect the new class.

1.4.7 RULE – Terms Using the LXI Trademark

The LXI Trademark or registered name, LXI, shall be used to describe the LXI Extended Functions specified in section 1.4.4.2.2 only in descriptive material of any sort associated with an LXI Device or on the web page of an LXI Device as specified in the following list.

1. Use the words “LXI Wired Trigger Bus” for an LXI Device that both:
    a. Conforms to section 1.4.4.2.1 and
    b. Implements the LXI Wired Trigger Bus as defined in 1.4.4.2.3
2. Use the words “LXI Event Messaging” for an LXI Device that both:
    a. Conforms to 1.4.4.2.1 and
    b. Implements the LXI Event Messaging as defined in 1.4.4.2.4
3. Use the words “LXI Clock Synchronization” for an LXI Device that both:
    a. Conforms to 1.4.4.2.1 and

b. Implements the LXI Clock Synchronization defined in 1.4.4.2.5

4. Use the words “LXI Timestamped Data” for an LXI Device that both:

    a. Conforms to 1.4.4.2.1 and

    b. Implements the LXI Timestamped Data defined in 1.4.4.2.6

5. Use the words “LXI Event Logs” for an LXI Device that both:

    a. Conforms to 1.4.4.2.1 and

    b. Implements the LXI Event Logs as defined in 1.4.4.2.7

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 2.7 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 2.7 – 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 2.7 – 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

- Section 2.4 – Electrical Standards
- Section 2.5 – Electrical Standards – Status Indicators
- Section 2.7 – 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.

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.

Observation

> It is the system integrators' responsibility to provide the appropriate DC power and distribution facilities. Since there are permissions for a variety of Ethernet connectors and media as well as PoE, the system integrators should also consider the selection of the appropriate networking equipment when constructing systems that use DC or PoE hybrid power sources.

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.

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.

Observation

> It is possible to improperly configure the network settings of a device, potentially rendering it unable to communicate with any hosts. Additionally, the settings on a box could simply be forgotten. Due to the limited user interface of a typical LXI Device, there is no simple way to view or modify the network settings (e.g., via a web browser) without a working network connection; therefore, an LCI Mechanism is required.

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.

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.

2.4.9.4 Recommendation – M12 Style Connectors

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

Observation – M12 Style Connectors

M12 style connectors are commonly used for industrial Ethernet applications in both 4-pin and 8-pin configurations.

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.

Observation

Sealed RJ-45 jacks are fully compatible with standard RJ-45 plugs and are available, off-the-shelf, as a PCB mount, bulkhead, or cable end. The sealing interface meets a minimum of IP67 sealing performance as defined in IEC 60529 (dust free and watertight).

Observation – Optical Fiber Connections

The current state-of-the-art for optical fiber connections is in flux. This, along with a lack of any specific LXI Device proposal that incorporates optical fiber, has prompted the LXI technical committees to delay specifying any requirements in this area.

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 Wired Trigger Bus Connectors

2.4.10.1 RULE – LXI Wired Trigger Bus Connectors

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

2.4.10.2 Recommendation – Connector Location

Location of the LXI Wired 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 Wired 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 Wired 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.

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:

	PowerIndicator	**LAN StatusIndicator**	**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 sequence: First, enable power.	1588 LAN Power (Middle LED) LXI Device turn-on sequence: Second, acquire LAN IP Configuration.	1588 LAN Power (Top LED) LXI Device turn-on sequence: Third, 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:

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.

Observation

> The status indicators are ordered in the LXI Device turn-on sequence: first, enable power; second, acquire LAN IP Configuration; and third, acquire the IEEE 1588 clock. This orientation allows the user to observe the turn-on sequence and to easily determine which stage may have failed.

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.

Observation

> While some form of LAN Status Indicator is required to achieve LXI compliance, the recommended implementation is only expected on new designs. Legacy instruments should attempt to follow the spirit of the recommendations as closely as possible within the constraints imposed by their existing front panel layout and display technology.

2.5.2.1 RULE – LAN Status Indicator

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

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

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.

Observation

> The status indicators are ordered in the LXI Device turn-on sequence: first, enable power; second, acquire LAN IP Configuration; and third, acquire the IEEE 1588 clock. This orientation allows the user to observe the turn-on sequence and to easily determine which stage may have failed.

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.

Observation

> This status indicator is specifically defined as a recommendation to enable easier device upgrades from a non-IEEE 1588 capable to an IEEE 1588 capable LXI Device without physical modifications to the front panel.

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

Observation

> The Red LED color is only utilized for fault states as defined in the IEEE 1588 specification. While a single green LED could be utilized, it becomes more difficult to easily differentiate between an Unsynchronized and a Fault state.

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.

Observation

> The status indicators are ordered in the LXI Device turn-on sequence: first, enable power; second, acquire LAN IP Configuration; and third, acquire the IEEE 1588 clock. This orientation allows the user to observe the turn-on sequence and to easily determine which stage may have failed.

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.

Observation

> The status indicators are ordered in the LXI Device turn-on sequence: first, enable power; second, acquire LAN IP Configuration; and third, acquire the IEEE 1588 clock. This orientation allows the user to observe the turn-on sequence and to easily determine which stage may have failed.

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 LXI Device and Documentation Labeling Requirements

2.6.1.1 RULE – Front Panel Labeling Requirements

There shall be an LXI Logo on the front of the device with no Class marking. The logo shall conform to the specifications in the document *LXI Consortium Trademark, Patent and Licensing Policies*.

2.6.1.2 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 conform to the specifications in the document *LXI Consortium Trademark, Patent and Licensing Policies*.

2.7 Environmental Standards

2.7.1 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

IEC 60068-1 Environmental testing Observation – Default Standards

The procedures described in IEC Publication 60068-1 are a useful default standard for this testing. For areas outlined below, LXI Devices should conform to standards appropriate to the intended market.

- Shock and Vibration
- Operating Temperature
- Storage Temperature
- Humidity
- Acoustic Noise

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 Wired Trigger Bus-based: AN LXI Device function is triggered via a voltage on the LXI Wired 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 standard IEEE 1588 and the LXI 1588 Profile, see 1.4.1.

Observation – Older versions of IEEE 1588

LXI Standard Versions 1.3 and later of the specification require LXI Devices to support the IEEE 1588-2008 or later versions of the IEEE 1588 standard. LXI 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".

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.

Observation – Software Implementations Have Less Precision

It is possible to implement IEEE 1588 functionality using only software. However, hardware implementations are preferred and will be necessary to achieve a time precision of 40 nanoseconds.

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.

Observation – All LXI Devices in a System Should Have Appropriate Precision

System integrators making use of time-based control of an entire system must coordinate the time behavior of each LXI Device. The ability to fine-tune this coordination depends directly on the overall precision of the time base. The inclusion of a single LXI Device with poor precision, say 10 ms, will severely limit system integrators.

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.

Observation – Use of Low-Latency Switch

If a boundary or transparent clock is not available, the use of a LAN switch that offers low latency for UDP packets may yield acceptable timing precision.

3.2.4 Recommendation – Traceability to UTC

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

Observation – PTP Timescale

Traceability to UTC is achieved by implementing the timescale PTP defined in IEEE 1588.

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.

Observation – Setting time to UTC

Rule 3.2.5 may be implemented by designing the device to be an IEEE 1588 clockClass 6 device, by virtue of rule 3.2.6, or by having the time and time properties settable from the device sync web page.

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.

Observation – Unsafe to Make Large Time Corrections During Operation

Making large changes to the LXI time base during system operation may result in unintended failures. It may take some time (up to a minute or so) for clocks to re-synchronize. (This is especially true if the IEEE 1588 system is shut down or reset.) It is expected that time base updates will have to be manually initiated by the operator during a "safe" period. However, some applications may be able to recover dynamically.

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.

Observation – Ability To Identify Grand Master Clock

> Recommendation 3.2.7 allows system integrators to explicitly control the identity of the grandmaster and therefore better implement the requirements listed above.

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.

Observation – Absolute Oscillator Accuracy

> The IEEE 1588 standard requires an absolute accuracy of 0.01% for the oscillator driving the IEEE 1588 clock. This type of specification is necessary to limit the maximum frequency adjustment range of a clock to ensure that it can be synchronized to any master.
>
> Implementers may wish to use oscillators with better accuracy specifications but less tracking range. If they do so, they should ensure that the rest of the implementation is also of sufficiently high accuracy that the IEEE 1588 clock characterization parameters will ensure that (1) it will be selected as the master clock, or (2) any other system device that can be selected as a master clock (based on clock characterization) also has the same or better accuracy specifications.

Observation – Handling Leap Seconds

> The IEEE 1588 protocol provides the leap second information needed to convert between the IEEE 1588 epoch and UTC, so any node with an IEEE 1588 clock will have the data needed to translate between the two systems, PROVIDED the IEEE 1588 grandmaster inserts the information into the Announce packets. This is easy, if the ultimate time source is GPS (since leap second information is available from GPS), but not so easy (but still possible) for NTP, and even less so if the system time is set by hand.

Observation – Translating Between Different Time Bases

> There are a number of different representations of time (e.g. the IEEE 1588 time base and UTC) that are widely used in the industry. These systems have different references for time=0, and they treat leap seconds with greater or lesser rigor. Because of this, translating between different time bases is not necessarily a straightforward calculation.

The IEEE 1588 time base does not exhibit discontinuous behavior during leap second corrections, but this is not true of all other systems. As a result, computing a time interval by subtracting two IEEE 1588-based time values will always be correct (even if the time interval includes a leap second,) but the same cannot be said if, for example, NTP is used.

While this issue will be unimportant for many test system applications, some systems will be synchronized to outside time sources such as GPS. In those cases, care must be taken to account for leap seconds properly.

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.

Observation – Implement Time-Based Triggers in Hardware

While time-based triggers can be implemented in software, hardware-based time triggers based on the IEEE 1588 clock are necessary for high-precision timing. Implementers should carefully consider the applications in which their LXI Devices will be used to ensure that time-based triggers are sufficiently accurate.

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 Wired 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.

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.

Observation – Clarification of Intent of RULE 3.3.2.1

> Rule 3.3.2.1 allows multiple test systems to coexist on the same LAN. In this scenario, every test system will receive UDP multicast packets from every other system. This rule makes it possible for the various modules to be sure that they can distinguish the LXI Event Messages properly. Every module in a test system should be configured to be a member of the same domain; other test systems should be in different domains.

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 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.

Observation – Publish/Subscribe Architecture

Rules 3.3.1, 3.3.2, 3.3.3, and 3.3.4 implement a common publish-and-subscribe architectural design pattern for LXI Event Messages.

Observation – UDP Reliability

UDP is sometimes referred to as an "unreliable" protocol. It is possible for UDP data packets to be lost in transit. Most test systems, which are expected to be configured into small private subnets with modern LAN switches, will never experience UDP packet losses. More complicated network installations may encounter situations in which data can be lost. In these cases, TCP links may be utilized at the cost of higher latency. In addition, it is possible to enhance the reliability of UDP transmissions by any of several means, including automatic re-transmission of packets and custom handshaking protocols. The LXI specification does not mandate any of these methods. However, the LXI Event Message format specified in Section 4 includes some support for them to ensure that LXI Devices from different manufacturers can work together even if some of them attempt to enhance UDP reliability and others do not. Refer to that section for further details. Vendors may choose to implement some method of enhancing UDP reliability optionally, but such features must be carefully documented to ensure interoperability with other manufacturers' instruments.

In addition, it is possible for UDP packets to arrive out of sequence. Although this will only be seen on rare occasions in complex networks, LXI Devices should be

designed to account for the possibility. The LXI Event Message format in Section 4 includes a sequence number that can be used to detect out-of-order packets.

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:

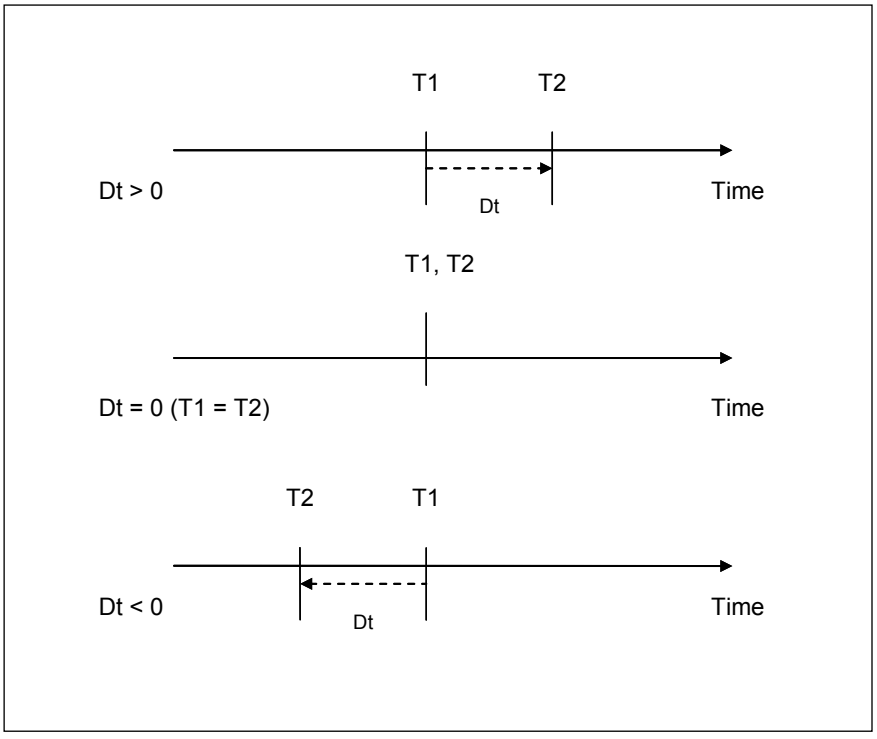
Reception Time – Time when an LXI Event Message is received by a module. This time is normally logged in the LXI Event Log.

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.

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 Wired 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.

Observation – Rule Replacement

> This rule replaces Rule 6.7.1 (LXI Events Mimic Hardware Wired-OR Capability) in LXI Standard 1.0 and 1.1. The original rule included event interpolation capability but implied a more complex implementation that has been deprecated.

Observation – Transmission by Multiple Event Sources

> This rule adds more robust behavior for the case in which multiple event sources are transmitting to one or more receivers. For example, normal operation of an LXI Event is to send an event packet on any logical signal transition (both rising and falling edges). Such operation is essential for anyone who desires to use the event system to link two hardware signals over the LAN in a point-to-point connection or who needs to take some action on both sides of the signal. However, when multiple sources actively transmit triggers to one or more receivers, it is possible for leading and trailing edges to overlap and cause triggers to be lost in the trigger logic. This happens in part because there is no guarantee that all of the packets will arrive in the same order in which they were transmitted. Therefore, when the Wired-OR mode of transmission is selected for LXI Events, only one edge (user-selectable) of the signal actually causes an LXI Event packet to be transmitted. Wired-OR mode works in conjunction with Rule 3.3.8 to provide a signal edge for each packet sent. The receivers are expected to take appropriate action each time a packet is received. This scenario is expected to be a common use model for some systems. One side benefit of this particular scenario is that the LXI Event traffic is cut in half, which may be an important throughput consideration for very large or dispersed systems.

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.

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 Wired 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.

Observation – Clarification of Intent of RULE 3.5.1

Rule 3.5.1 is intended to allow time-scheduled execution and inter-module coordination of execution without involving the controller. However, the term "executable by the local LXI Device" does not imply that an instrument command (e.g., a SCPI command) must be embedded in the LXI Event Message that is sent from one module to another. As described in Section 4, these messages contain an Event ID and a timestamp. Prior to receipt of these messages, the controller must program the instrument's response. Rule 3.5.1 is intended to ensure that all of the relevant functions of an instrument are available for responding to direct LXI Event Messages and other LXI Event mechanisms.

Likewise, Rule 3.5.1 does not require that the LXI Device's firmware must have an API that is identical to the driver's. It is required that trigger-related functionality be available in both the driver and the firmware, but there is no requirement that this functionality be presented to the user in the same format.

Nothing in this observation prohibits an LXI Device designer from implementing the LXI Devices' response to an LXI Event using hardware rather than firmware.

Furthermore, the term "trigger-related functions" refers to those actions that the controller has configured or set up in advance to be accomplished upon receipt of a trigger. It does not refer to the configuration or setup activity itself. However, see the following Recommendation.

Observation – Clarification of Intent of Recommendation 3.5.1.1

The intent of Recommendation 3.5.1.1 is to supply system integrators with the greatest possible flexibility in implementation of triggering. It is recognized that certain applications may require triggering in hardware that is not feasible in software (e.g., a hardware trigger that repeats at a 10 MHz rate may be impractical to handle in software). However, implementation of Recommendation 3.5.1.1 is important to achieve interoperability between instruments from various vendors. Although there are situations where it is not possible, designers should consider Recommendation 3.5.1.1 to be a rule unless serious technical obstacles exist.

Observation – Controller Need Not Implement IEEE 1588

> The controlling computer does not have to implement IEEE 1588. If a controller needs the current IEEE 1588 time in order to generate an LXI Event Message or for other purposes, it can always request the current time from any device participating in IEEE 1588 provided that the controller recognizes that the accuracy of this time will be severely degraded (perhaps by many milliseconds) by message and processing latencies.

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.

Observation – Downloading Executable Code to LXI Devices

> Recommendation 3.4 infers the preloading of time-based or procedural programs of actions to be taken based on a single LXI Event. This allows system-wide tradeoff between LXI Device configurations prior to the start of a test and run-time configuration involving the controller during a test. However, the LXI specification does not mandate any particular method for downloading such programs into an LXI Device, whether these programs are pre-installed in the LXI Device or whether they are implemented in software or hardware. This is left to the vendor's discretion.

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.

Observation – Likely Implementation for Trigger Functionality

> Triggering based on driver commands is usually implemented in firmware. Module-to-module LXI Event Message-based triggers will likely be implemented by a local event manager but may also use hardware techniques (e.g., LAN "packet sniffers") to reduce latency. Time-based triggers will usually use hardware techniques configurable by the event manager in the LXI Device. LXI Wired Trigger Bus and vendor-specific hardware trigger will naturally be based in hardware.

Observation – Trigger Schemes Can Be Mixed

> Rule 3.5.1 and recommendation 3.5.1.1 allow system integrators to select or combine trigger schemes to meet the overall coordination requirements of the system.

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 Wired Trigger Bus, or optional vendor specific hardware.

Observation – Clarification of Intent of Recommendation 3.5.2

> The intent of Recommendation 3.5.2 is to supply system integrators with the greatest possible flexibility in implementation of triggering. It is recognized that certain applications may require triggering in hardware that is not feasible in software (e.g., a hardware trigger that repeats at a 10 MHz rate may be impractical to handle in software). However, implementation of Recommendation 3.5.2 is important to achieve interoperability between instruments from various vendors. Although there are situations in which it is not possible, designers should consider Recommendation 3.5.2 to be a rule unless serious technical obstacles exist.

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.

Observation – Possible Trigger Output Implementations

Recommendation 3.5.2 implies that internal events in an LXI Device must interrupt the LXI Device's processor so that the processor can transmit LXI Event Messages to other modules if the LXI Device has been programmed to do so. It is also possible and permissible for a device to implement generation and communication of a trigger LXI Event at much lower levels in the protocol stack than at the application or interrupt level to reduce time delays and latency.

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
- 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.

Observation – Access to Timestamps

The timestamps associated with data are included with the transmission of that data to other devices.

Observation – Timestamps for Captured Data

The reporting of data and timestamps logically can either be by data-timestamp pairs, or (if the data is a time series) by a starting timestamp and a time increment.

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.

Observation – Clarification of Intent of Rule 3.7

The existence of such a log is invaluable in debugging a distributed LXI system.

Observation – Size of Log File

There is a trade-off between memory space/cost in the LXI Device and the frequency of logged events and the desired history time. Experience gives us a minimum recommended log size that is large enough to hold the most recent 256 event records. Even larger log files will make debugging easier.

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.

.

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.

Observation – Clarification of Intent of RULE 4.2

LXI Event Messages must be encoded into single packets on the LAN to achieve minimum latency and avoid unacceptable complications to the use of UDP multicasting.

LAN data packets will be fragmented if they are too big. However, "too big" is a user-definable parameter. A common value is 1400 bytes, but users may set this parameter to a larger or smaller value. Fortunately, LAN devices must always be able to accept packets of at least 512 bytes without fragmenting the packet. If all the devices in the system are suitably configured, packet size may be larger. It is the responsibility of the system integrator to ensure that systems are properly configured.

The available space in a packet depends on the LAN options that are being used and whether IPv6 is implemented. Overall, it is reasonable to expect that at least 450 bytes will be available for data packets. Some of this space is allocated for required data fields such as a timestamp (see the following paragraphs for details). The rest of the space is available for user-defined purposes, subject to the formatting constraints described below.

For TCP-based communications, any fragmented packets will automatically be reassembled by the receiving module's protocol stack. In this case, module-to-module communication of LXI Events may include data of any size. However, the larger the data, the longer it takes to get to the receiver. Time-critical communications will generally use small packet sizes.

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):

- 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

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.

Observation – Rational for Changes in the Definition of Timestamp and Epoch

> In IEEE 1588-2008 two significant changes were made in the representation of timestamps: the former IEEE 1588-2002 epoch and seconds fields were combined into a single UInteger48, and negative timestamps are no longer allowed. Eliminating negative timestamps has no practical effect on LXI since negative timestamps do not occur in an LXI system. The change in datatype required the revision of the relationship between LXI and IEEE 1588-2008 timestamp datatypes.

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.

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 **t**he 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.

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.

Observation – LXI Event Message Version

> The 'HW Detect' field is currently specified as "LXI". This value may change in the future as new versions of the LXI specification become available. Every effort will be made to ensure that later versions of the LXI Event Message format are compatible with earlier versions, but this cannot be guaranteed.

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.

Observation – Clarification of the Intent of RULE 4.3.2

> The Domain value is designed to allow multiple test systems to coexist on the same subnet. The instruments in each test system should be configured to have the same 'Domain' setting. Each test system would then ignore any messages that were transmitted by the other. This allows identical software to run on multiple test systems that are on a single subnet.

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.

Observation – Re-transmission/Acknowledgement Not Needed with TCP

If point-to-point TCP data transmission is utilized, re-transmission or handshaking protocols need not be implemented. TCP will automatically attempt up to five re-transmission and acknowledgement cycles to increase the reliability of packet delivery. Note that if the LXI Event is time critical, latency of TCP will be much greater (about five times greater, even if the connection is already established) than for UDP.

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.

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

5 LXI Device Wired Trigger Bus

5.1 Introduction

The LXI Device Wired Trigger Bus implements a cabling system to interconnect multiple LXI Devices. The physical interface builds upon the TIA/EIA-889 Multipoint Low Voltage Differential Signaling (M-LVDS) standard. This standard uses differential current driven signals to exchange data between semiconductor devices. Each LXI Device supporting the LXI Wired Trigger Bus has a minimum of two Trigger Bus connectors. This provides a pass-through connection of the bus by routing signals through each participating instrument. A termination device is required at the end of each LXI Wired Trigger Bus connection segment, provided by the LXI Wired Trigger Bus Terminator. The terminator attaches to the second connector at each segment end, as seen in Figure 5.1.

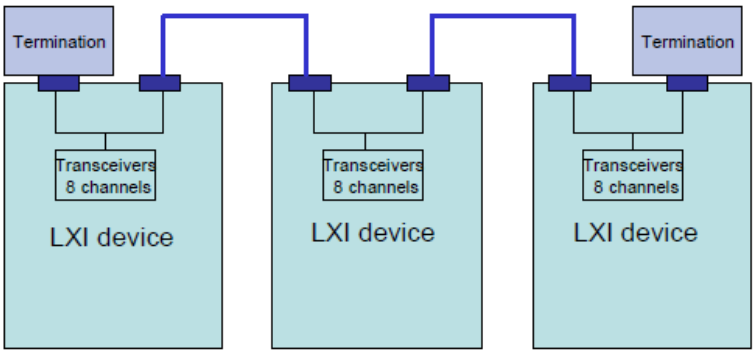


Figure 5.1 Configuration of LXI Devices using the LXI Wired Trigger Bus

The LXI Wired Trigger Bus provides eight physically independent trigger channels, matching the number of logical channels provided by the LXI Event Message mechanism in the LXI standard. The LXI Wired Trigger Bus designates LXI0 to LXI7, while the LXI Event Message designates identifiers LAN0 to LAN7.

Trigger events made through the LXI Wired Trigger Bus or the LXI Event Message trigger system are interchangeable, since the trigger model is consistent in each mode of operation.

Triggering within and between LXI devices varies widely between applications, and several examples of possible trigger scenarios are as follows:

- Internal or external events generate a trigger signal to initiate an action in a device.
- A computer sends a trigger signal event that initiates an action in a device.
- One device sends an LXI Event-based trigger signal to one or more other devices.
- LXI Event-based triggers received by one or more devices cause hardware triggers to be sent to one or more other devices
- A hardware trigger signal is time-stamped by a device and synchronizes other actions
- A common reference clock, distributed using hardware trigger lines, synchronizes actions in multiple devices.

There are important differences in performance between the LXI Wired Trigger Bus and LXI Event Messages. LXI Event Messages are LAN-based and depend upon the LAN driver, LAN speed,

software interrupts, and processor speed. The LXI Wired Trigger Bus is a dedicated bus interface with the following characteristics:

- Hardware delays on the bus cables and associated routing logic dominate the trigger delay between an event and the initiation of an action at another node
- LXI Devices connect the trigger bus signals as directly as possible from the interface to the hardware performing the task.
- Once set up there is virtually no software or firmware related delays in reaction times.

The LXI Wired Trigger Bus exhibits both low trigger delay and low trigger jitter and performance levels not achievable through the LAN based trigger mechanisms. In addition to supporting high performance trigger operations, the trigger bus can also exchange clock signals or other data signals between LXI Devices.

Each channel of the LXI Wired Trigger Bus is capable of operating in one of two modes and 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 would have their LXI Wired Trigger Bus 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 Wired 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. The Wired-OR Mode requires one device to be the Wired-OR Bias Device, and its driver provides a bias for the LXI Wired Trigger Bus channel. Other devices participating in the wired trigger require the use of two drivers for each LXI Wired Trigger Bus channel, so they can both transmit and receive their own signals.

The remainder of this section will focus on the required operation of LXI Devices that implement the LXI Wired Trigger Bus. Requirements related to the construction of cables, proper termination, electrical adapter components, trigger distribution hubs, and physical device-to-device electrical performance is located in the document "***LXI Wired Trigger Bus Cable and Terminator Specifications***"

5.2 RULE - LXI Wired Trigger Bus Cable and Termination Specification.

Each LXI Device implementing the LXI Wired Trigger Bus shall meet the interconnect requirements in the document "***LXI Wired Trigger Bus Cable and Terminator Specifications"*** in order to assure proper device operation within a system consisting of other LXI Devices implementing the LXI Wired Trigger Bus.

5.3 Electrical Requirements

5.3.1 RULE – Number of Channels

LXI Devices implementing the LXI Wired Trigger Bus shall support all eight hardware channels.

5.3.2 RULE – Signaling Standard

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

5.3.4 RULE – LXI Wired Trigger Bus Buffering

Each LXI Device connected to the LXI Wired 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 Wired Trigger Bus: Texas Instruments SN65MLVD080 (8 channel) or Texas Instruments SN65MLVD201 (single channel).

5.3.6 RULE – Input / Output Configurability

Each LXI Wired 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 – Drive Mode Configurability

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

5.3.8 RULE – Driver Topology

Each LXI Wired Trigger Bus driver shall consist of two M-LVDS drivers with the outputs connected in parallel, as shown in Figure 5.2b. 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.

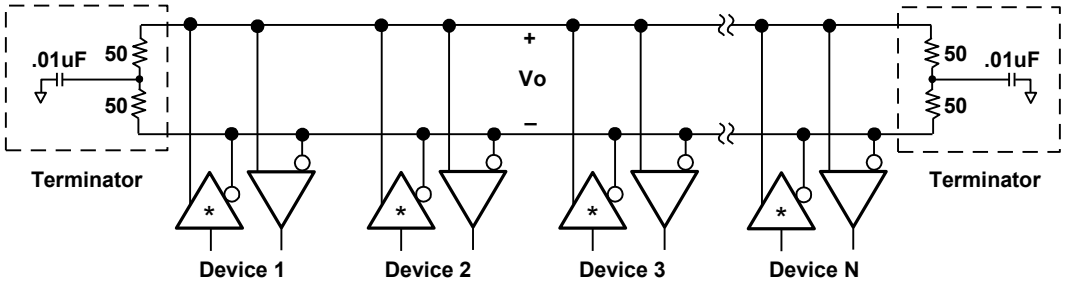
Observation – Wired-OR Signaling

In Driven Mode, only one of the two parallel drivers is enabled, and the trigger signal is applied to the input pin of the enabled driver (the input to the disabled driver can be either high or low). The differential trigger lines are driven to the high or low state by sourcing (positive) or sinking (negative) current through the termination resistors.

In Wired-OR Mode, both parallel drivers are used with their input pins held high, and the trigger signal is applied to the enable pins of both drivers. The differential trigger lines are driven to the high or low state by sourcing (positive) or turning off current to the termination resistors (see Figure 5.2a). To improve the noise margin, a single driver in one of the connected LXI Devices (referred to as the Wired-OR Bias Device) can be programmatically configured to drive a constant negative current through the termination resistors, thus forcing the trigger lines low when all of the other drivers on the bus are disabled. The parallel driver topology used in this mode is required to overcome the negative bias current, resulting in a net positive current through the termination. Note that the Wired-OR Bias Device may still participate in Wired-OR signaling, but unlike all of the other devices on the bus, it operates its driver in Driven Mode, rather than Wired-OR Mode.

Caution should be exercised when using a channel operating in Wired-OR Mode which has a Bias Device that participates in the Wired-OR signaling, particularly in applications requiring edge detection. Under some conditions, it is possible, due to non-linear properties in the drivers and the distributed nature of the bus, for false pulses on the order of 10-20 ns to be generated when the Bias Device changes state. In such situations, depending on the application, additional steps may be required to prevent undesired behavior, such as deglitching the received signal using additional logic, re-sampling the bus 50-100 ns after an edge transition, or by using reflected-wave switching. Note that this effect does not occur in the more typical situation where the Bias Device is not participating in the Wired-OR signaling, and thus should only be of concern in situations where all of the devices on the bus are required to participate.

The alternate Wired-OR topology shown in Figure 5.2b may be advantageous when designing a printed circuit board layout. In that topology, the inputs to the drivers have opposite levels, and the positive output (A) of one driver is connected to the negative output (B) of the other driver, and vice versa. This alternative topology is particularly advantageous if the driver IC's are placed on opposite sides of the printed circuit board, and each LXI Wired Trigger Bus channel uses one driver from each IC.



(*See Fig 5.2b for driver configuration)

Figure 5.2 a) Single LXI Wired Trigger Bus Channel with Bus Terminators

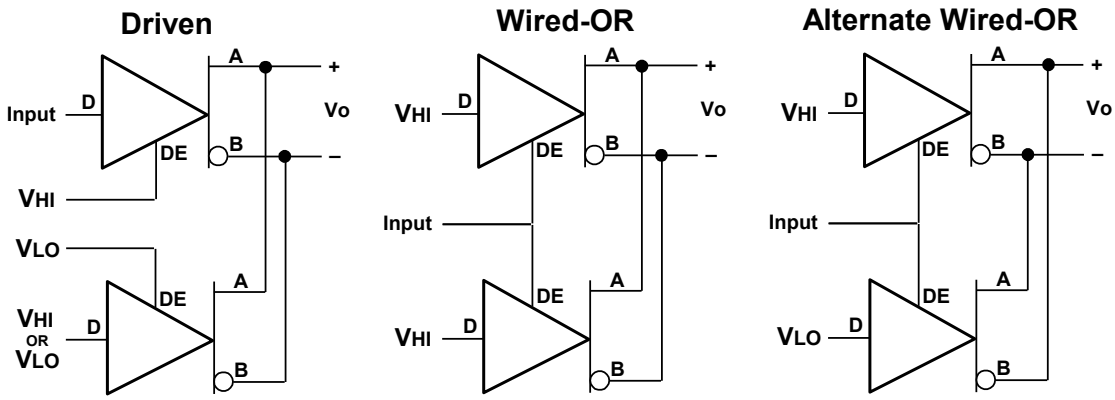


Figure 5.2 b) LXI Wired Trigger Bus Drivers, Driven and Wired-OR Modes

5.3.9 RULE – Wired-OR Bias

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

Observation – Wired-OR Bias Device

> In the case where there are multiple channels configured for Wired-OR operation, a single LXI Device can provide the Wired-OR Bias for all necessary channels, or the bias for different channels can be provided by different LXI Devices. In either case, the LXI Device providing the bias for a given channel is the Wired-OR Bias Device for that channel.

5.3.11 RULE – Wired-OR Bias Device Functionality

The LXI Wired Trigger Bus driver of an LXI Device configured to act as the Wired-OR Bias Device for a particular channel shall always operate in Driven Mode. It shall drive the LXI Wired Trigger Bus channel low (negative), unless it is participating in the Wired-OR 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 Wired Trigger Bus channels shall default to the disabled configuration when power is applied to the LXI device.

5.3.14 **RULE - Signal Routing to All Eight Channels**

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

Observation – Signal Routing to All Eight Channels

> This rule requires that any LXI Device using the LXI Wired Trigger Bus must be capable of routing trigger signals to or from any of the eight channels. This eliminates the possibility of conflicting channel use restrictions by different vendors.

5.3.15 **RULE – Simultaneous Transmit and Receive**

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

Observation – Transmitting and Receiving the Same Signal

> The ability of a device to receive its own transmitted LXI Wired Trigger Bus signal is useful for such purposes as diagnostics or trigger delay management.

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 inside the LXI Device, using additional logic, to stop the input signal from affecting internal trigger circuitry.

Observation – Receiver Output Gating Function

> When there is intentional activity on an LXI Wired Trigger Bus channel that an LXI Device is not currently using, the gating function in the device is used to prevent that activity from causing undesired device behavior. Furthermore, if no LXI Devices on the bus are actively driving a particular channel, the input signal levels of any receivers connected to it will lie very close to their threshold levels. This condition can result in unintended receiver output activity that should be gated inside the device.

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.

Observation – Waiting for Trigger and Measurement Complete

> The Arm-Trigger State Machine discussed in Section 6 The LXI Programmatic Interface outlines the need to support Waiting for Trigger and Measurement Complete, which are necessary to provide synchronization of this LXI Device with other LXI Devices in the system.

5.4 Physical Requirements

5.4.1 RULE – LXI Wired Trigger Bus Connector Type

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

5.4.2 Recommendation – LXI Wired Trigger Bus Connector Type

The following connectors, or equivalents, are representative of the type recommended for LXI Wired 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.

Observation – Connector Performance

While both single and double-stacked connectors are acceptable, better performance is achievable using double-stacked connectors, due to their compact size.

5.4.3 RULE – Number of LXI Wired Trigger Bus Ports

All LXI Devices implementing the LXI Wired Trigger Bus shall have at least one LXI Wired Trigger Bus port, consisting of a pair of LXI Wired Trigger Bus connectors wired in parallel (like-numbered pins connected together). (See Section 2 for recommended connector locations).

5.4.4 Permission – Additional LXI Wired Trigger Bus Ports

LXI Devices may have more than one LXI Wired Trigger Bus port, provided that each port consists of a single pair of LXI Wired Trigger Bus connectors wired in parallel (like-numbered pins connected together), and that each port provides the required buffering, as defined in Section 5.32.

Observation – Additional LXI Wired Trigger Bus Ports

While it is permissible to have more than one LXI Wired Trigger Bus port on an LXI Device, it is not recommended. Implement with caution. Consider the following points for additional ports.

a) Count each port (connector pair) on an LXI Device as a separate node. This helps in determining the number of LXI Wired Trigger Bus nodes on a connection point.

b) Do not assume the LXI Programmatic Interface supports more than one LXI Wired Trigger Bus port on an LXI Device. Consult the most current versions of the following LXI Consortium documents before implementing additional ports: see Sections 6 and 9 of this document and the "IVI-3.15: IviLxiSync Specification."

c) Perform tests on each port individually to verify compliance with all of the requirements in Section 5 of the LXI Specification.

d) Clearly identify the pairing of LXI Wired Trigger Bus connectors to avoid user confusion.

5.4.5 RULE – Trace Characteristic Impedance

Traces interconnecting the LXI Wired 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 Wired 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

Inside the LXI Device, Traces interconnecting the LXI Wired 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.

Observation – Channel-to-Channel Skew

This rule is included to ensure that the channel-to-channel timing skew introduced by the LXI Device is less than 200 ps.

5.4.8 RULE – Maximum Stub Length

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

5.4.9 RULE – LXI Wired Trigger Bus Connector Pin Assignments

LXI Wired 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 Wired Trigger Bus Connectors

Each LXI Wired 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.

Observation – +3.3V Supply Usage

> The +3.3V supply on LXI Wired Trigger Bus connectors is useful for such purposes as powering vendor-specific adaptors or other similar devices. Note that the +3.3V and +3.3V_RETURN pins are not connected in LXI Wired Trigger Bus cables and are thus only available directly from the connectors.

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

It is recommended the +3.3V power pin on each LXI Wired Trigger Bus connector be protected by a separate self-healing fuse.

5.4.11 **RULE – Reserved Pins Shall Not 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 Wired 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

Note: LXI Wired 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.

.

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].

Observation – Reference to IVI Specifications

> Note that the above reference to IVI 3.1 also requires conformance to certain portions of:
> IVI 3.2: Inherent Capabilities Specification
> IVI 3.3: Standard Cross Class Capabilities Specification
> IVI 3.4: API Style Guide.
> IVI Class Specifications

Observation – Device-to-Device Communication

> Device-to-device communication may use different interfaces. User may aggregate devices into measurement capabilities not possible by individual devices. The resulting package of devices may be controlled by a single IVI interface.

Observation – Protocol Between the Driver and the Device

> With IVI drivers, the vendor may select any IVI-to-device communication protocol they choose, as long as an IVI driver encapsulates it.

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 1.4.4.2.

6.1.1.1 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.

[11] For more information on IVI or to download the specifications, see www.ivifoundation.org

The IVI driver provided with an LXI Device may use whatever underlying protocol is permitted by sections 8.1. 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[12]
```

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.

Observation – Different Protocols May Be Supported by Additional Drivers

> If vendors wish to support multiple protocols for controlling their instrument, drivers for each protocol may be provided.

Observation – SCPI Is Not Required

> The LXI spec does not require an underlying SCPI interface to the device. LXI presumes the primary control interface is IVI.
> The actual communication between the driver and the device is at the discretion of the device designer to optimize the performance and price of the device.

6.3 RULE – IVI Property for Referencing a Signal Source

Any IVI interface referencing an LXI Wired 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 Wired Trigger Bus line, IEEE 1588 alarm, or LXI Event Message, shall be configurable via an interface that has a source property as stated above.

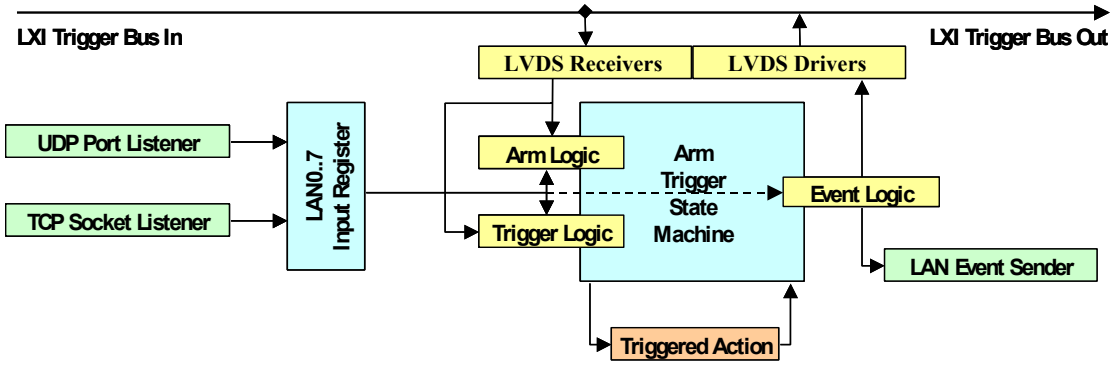
[12] For additional information see vpp43.doc at http://www.ivifoundation.org/Downloads/Specifications.htm

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.

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 Wired 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 Wired 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

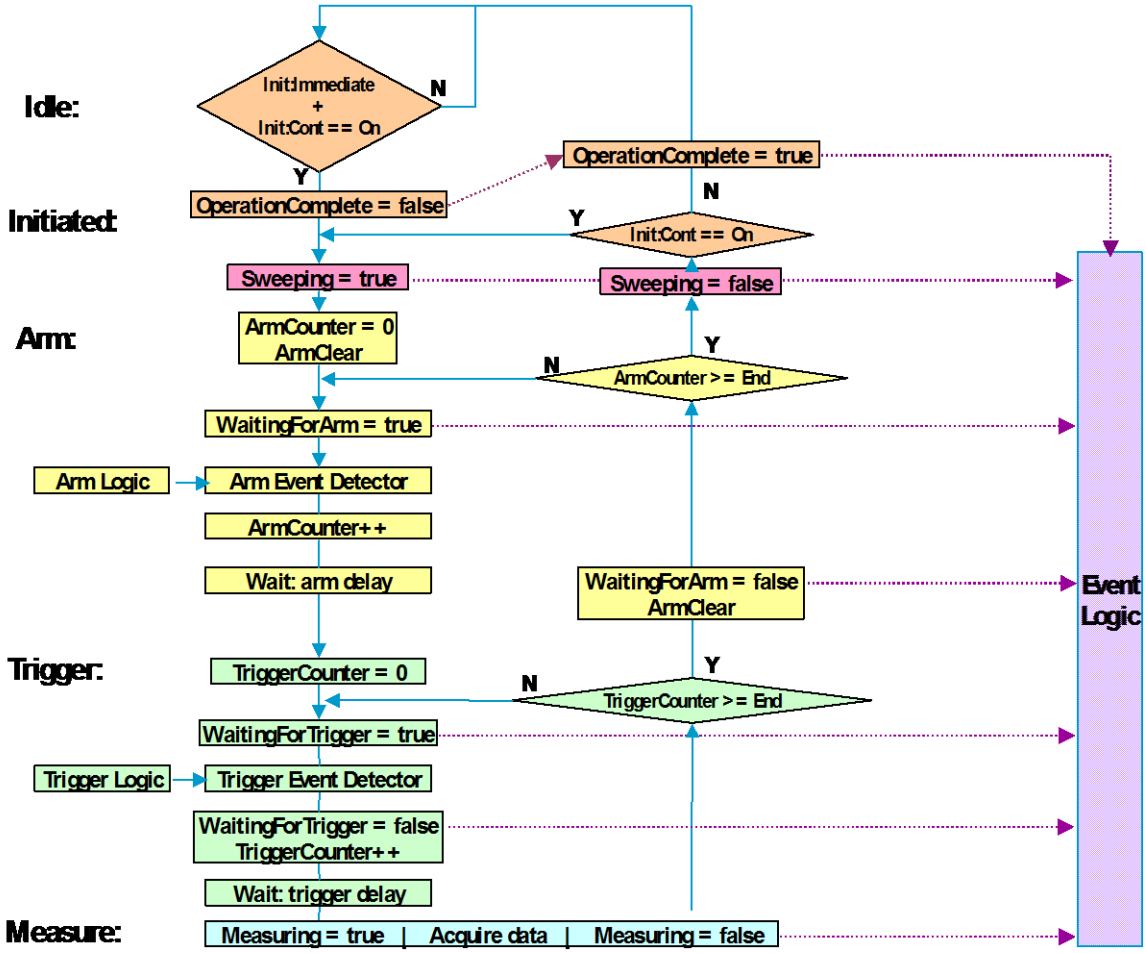
The strings listed in the following tables shall be used as indicated for triggering, synchronization, and LXI Event generation purposes. Devices are not required to implement all signals. Signal names are case sensitive.

Observation – User Defined Strings of EventIDs

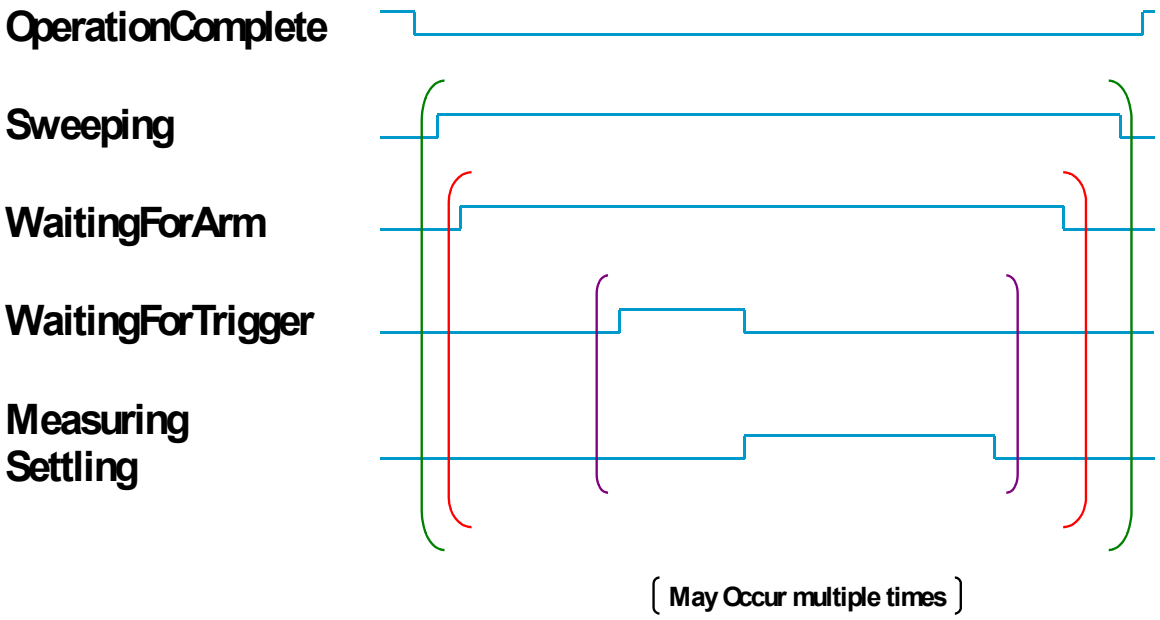
> Section 4.3 permits users to generate application specific EventID strings. Rule 6.4.4 only defines the use of LXI defined EventID strings. This rule does not preclude the use of user defined EventIDs for triggering, synchronization, LXI Event generation or any other purpose.

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

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



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 Wired Trigger Bus line 0. All Source properties needing to refer to LXI Wired 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 Wired Trigger Bus line 1. All Source properties needing to refer to LXI Wired 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 Wired Trigger Bus line 2. All Source properties needing to refer to LXI Wired 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 Wired Trigger Bus line 3. All Source properties needing to refer to LXI Wired Trigger Bus line 3. As a signal Source in the IviEvents interface.

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 Wired Trigger Bus line 4. All Source properties needing to refer to LXI Wired 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 Wired Trigger Bus line 5. All Source properties needing to refer to LXI Wired 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 Wired Trigger Bus line 6. All Source properties needing to refer to LXI Wired 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 Wired Trigger Bus line 7. All Source properties needing to refer to LXI Wired 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).

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 Wired 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.

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.

Observation – Explanation of Selected Time Representation

> IEEE 1588 time needs to have sufficient resolution to represent nanosecond differences across time spans of multiple decades.

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.

6.6.2 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).

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.

7 LAN Specifications

7.1 RULE – Ethernet Required

LXI Devices shall implement Ethernet using the appropriate IEEE 802.x PHY/MAC specification, see 1.4.1. 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.

Observation – Ethernet Networks and Backwards Compatibility

Ethernet networks are almost always backward compatible such that Ethernet devices with different maximum speeds can interoperate together. LXI Devices must have this same capability - a 100 Mbits/sec Ethernet LXI Device must be able to operate on a 10 Mbits/sec only network. This capability is usually directly supported by the Ethernet silicon and normally does not require any additional development work. The interoperability matrix is as follows:

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.

Observation – Advantages of Connection Monitoring

> Ethernet connection monitoring (e.g. Media Sense) allows a network host's operating system and applications to respond to the network media being connected and disconnected. Responses to link detection (media connected) might include network configuration.

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.

Observation – Purpose of Auto-MDIX

> Auto-MDIX functionality, built into Ethernet PHY devices, allows network equipment to be connected without the need for special "crossover" cables, simplifying installation, troubleshooting, and maintenance. Currently, 1GB or higher LAN devices incorporate Auto-MDIX. This industry trend is expected to continue. The requirement for a physical label is to remove confusion when connecting LXI Devices to networks, or diagnosing connectivity issues.

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.

Observation - Use CAT5 or Better Cable for LXI Systems

> Network infrastructure (e.g., cabling, switches, routers, etc.) intended for use with LXI Devices has to support 100BT LAN and CAT5 cable at a minimum.

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.

Observation – Purpose of Auto-Negotiation

> Auto-Negotiation is the Ethernet capability to automatically determine the proper Ethernet link speed and duplex mode. The Auto-Negotiate process works by having each Ethernet device exchanging its speed/duplex capabilities with the other end of the cable, and then the highest operating mode available on both ends is selected.
>
> The implementation of Auto-Negotiation has both hardware and software components. The software parts of Auto-Negotiation are documented below. With respect to the entire network software set, Auto-Negotiation is part of the Ethernet driver. For reference, these are the modes supported by Ethernet (note that Gigabit Ethernet is always full duplex):

Ethernet Speed	Ethernet Duplex Mode
10 Mbits/sec	Half
10 Mbits/sec	Full
100 Mbits/sec	Half
100 Mbits/sec	Full
1000 Mbits/sec	Full

7.7 RULE – Multiple LAN Interfaces

If multiple LAN interfaces (NIC's) are present in an LXI Device, at least one of them shall be fully conformant with the LXI Base Cass (Rule 1.4.4.2.1). The other NIC's don't have to provide any LXI capabilities.

If a vendor decides that all the NIC's are LXI capable, then they shall be fully conformant with the LXI Base Class (web server, mDNS, XML identification schema etc.) as a minimum. All NIC's claiming to be LXI conformant will be tested when submitted for LXI Compliance Testing.

Observation - Use separate NIC for LXI Extended Functions

> It may be a good idea to have one NIC fully conformant with the LXI Base Class and use another NIC(s) for the extended functions: Event Messaging, Clock Synchronization, IPv6 (future), etc.

All LAN interfaces that provide any LXI extended functions only, as in the above observation, shall advertise the functionality of that interface. To "Advertise and Display" Multiple LAN Interfaces, either of the following two alternatives listed are acceptable methods:

1. The web pages, xml identification schema, mDNS, etc., contain or advertise the information for ALL LXI conformant NIC's on all NIC's.
2. The web pages, xml identification schema, mDNS, etc., contain or advertise the information pertinent to the NIC through which the query was received

8 IPv4 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 – LXI Devices should also 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.

Observation – Disabling ICMP Ping Responder

> Disabling the ICMP Ping Responder minimizes the risk that unauthorized people would find, connect to, and alter the configuration of the LXI Device.

8.5 Recommendation – Support ICMP Ping Client

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

Observation – Ping Client Usage

> An ICMP Ping Client available in a module may be useful in debugging communication problems with a TCP/IP configuration on a module.

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.

Observation – Dynamic Link-Local Addressing

Dynamically Configured Link-Local Addressing allows automatic IP address setup on small ad-hoc networks without DHCP servers. Networks without DHCP servers are common on small private networks without network administrators. An LXI Device hooked directly up to a laptop with an Ethernet crossover cable is very likely to use Dynamic Configured Link-Local Addressing.

Observation – Default Route with Dynamic Link-Local Addressing

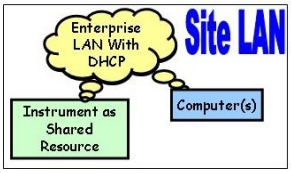
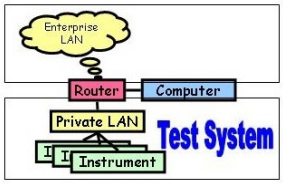
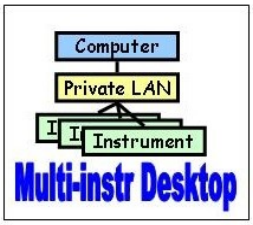
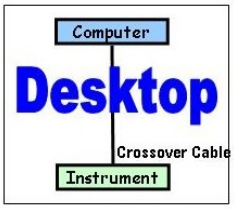
Implementers should take particular note of section 2.6.2 of RFC 3927 "Dynamic Configuration of IPv4 Link-Local Addresses", which addresses forwarding rules for devices operating with Dynamic Link-Local Addresses. Proper implementation of this (e.g., configuring a default route of the Dynamic Link-Local Address or network interface) supports communication between devices with routable addresses and devices with link-local addresses on the same network segment.

Observation – Manually Configured Networks

Manually configured networks might be used on small test systems in which a user desires complete control of module IP configuration. Also, some users do not permit Dynamic Configured Link-Local Addressing on their networks.

The table below compares the applicability of these three methods to the network topologies.

Applicability of Configuration Methods to Network Topologies

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

Observation – DHCP Used for Automatic IP Assignment

Dynamic Host Configuration Protocol (DHCP) is widely used to centrally manage networks and automate IP address assignments. DHCP involves a DHCP server and several DHCP clients.

A DHCP server may be set up for large public networks or for local private subnet networks. Many corporate networks will have a DHCP server maintained by a network administrator that is a network-wide resource. A private subnet may have a DHCP server that is either software or hardware. A DSL/Cable router usually has a built-in DHCP server, for example. A DHCP client is supported in most operating systems, including Windows, VxWorks, and Linux.

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.

Observation – Length of Timeout Important

> A time-out that is too short will result in failing to contact a server, if the DHCP server is busy or the LAN is congested. On the other hand, a time-out that is too long will cause the module to appear to hang (or the network configuration to hang) while booting, if it is on a LAN with no DHCP server.

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.

Observation – DHCP Option Uses

> When generating a discover or request packet, the DHCP client (LXI Device) is permitted to send a list of DHCP options for which it requires answers before it can properly boot. The options may also be used to provide additional information to the server. This information can be used to generate a specialized reply just for that client. For example, some clients (LXI Devices) may require that a boot file name be provided, and each LXI Device may require a unique boot file for update purposes. This also implies LXI Devices have local storage.

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.

Observation – DHCP Lease Renewal

> When a DHCP client renews a lease or validates a current lease via a request transaction, it is possible for the DHCP server to send a reply with different option values than it sent when first sending the lease. For example, the DHCP server may specify a new DNS server to use. The implication is that the server wants the client to use the new values; however, this is not explicitly stated in the DHCP protocol. The DHCP client should 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.

Observation – Manual Network Configuration

> Some TCP/IP networks require each device to be manually configured with an IP address, subnet mask, default gateway, and optionally DNS server(s) IP addresses. On manually configured networks, the network administrator will provide the network configuration values to the module user.

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.

Observation – Duplicate IP Address Detected

> The intension and spirit of Rule 8.7 is to prevent improperly configured LXI devices from interfering with other devices on a network. An LXI device will always check to see if an IP address it has been assigned is in use before using it. This is true for DHCP assigned addresses, Link-Local addresses or static IP addresses. This is also true for which ever method is used to change the IP configuration: front panel, Web page, Power on or pressing the LAN Configuration Initialization mechanism.
>
> What the device does when it has detected a duplicate address can be one of the following options. Whichever method is used, the device must not use the duplicate IP address:
>
> When the duplicate address has been detected the device should show an assigned IP address of 0.0.0.0, in the case of IPv4, and show a LAN fault on the LXI LAN Status Indicator.
>
> When the duplicate address has been detected, the device can also fall back to the currently valid IP address and not show a fault on the LXI LAN Status Indicator.

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).
- 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)

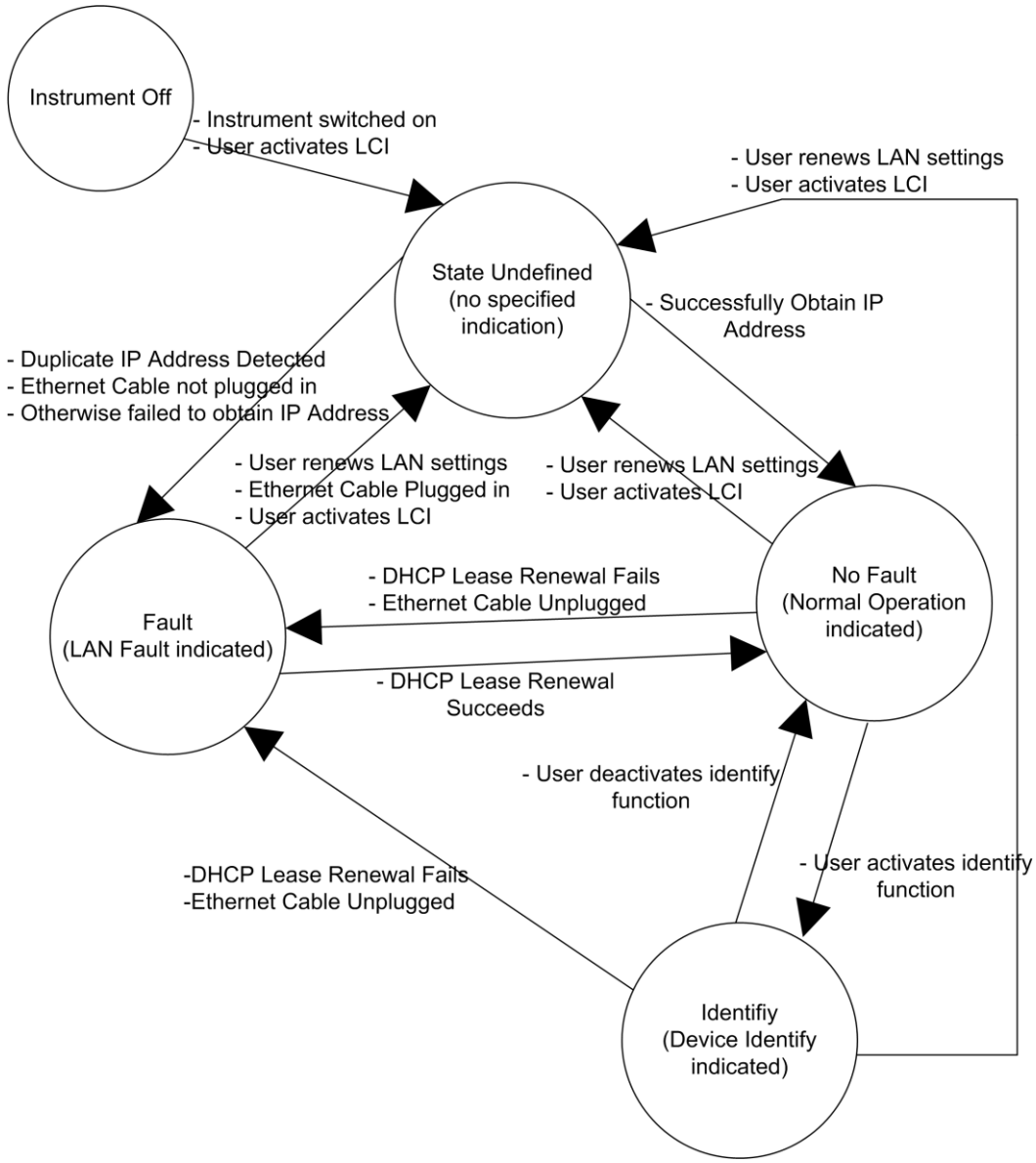
See 2.5.2 LAN Status Indicator for annunciation details.

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 re-plugging 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.



8.11 Recommendation – Support Dynamic DNS Hostname Registration

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

Observation – Convenience of Dynamic DNS

Dynamic DNS (Domain Name System) Servers allow a network device (LXI Device) to set up a hostname without a network administrator doing anything. Many networks have been adding support for Dynamic DNS because it lowers the support costs of administering the network.

Dynamic DNS hostname registration happens with the DHCP server talking to the Dynamic DNS server (these two software components may be hosted in the same physical server computer). Figure 2-1 depicts how the DCHP client (module) communicates with the DHCP server, which, in turn, updates the Dynamic DNS Server. The module is directly involved in steps 1 and 2 in this figure as the DHCP client.

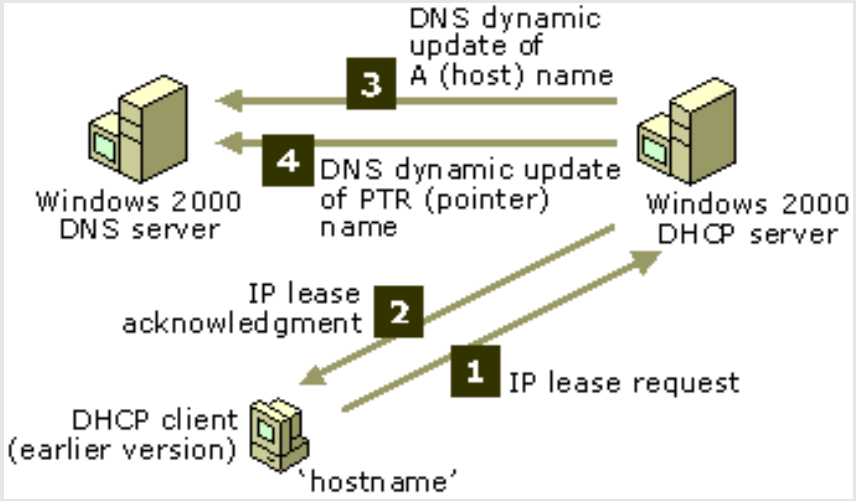


Figure 7 1 Dynamic DNS Update via DHCP

It is useful to describe what happens to an LXI Device on a network like this. A module would start without any IP address configuration information, and only have a hostname that it desires to register. By default, the desired hostname to be registered would be the factory assigned hostname from the manufacturer. If the user is on a "managed" network, they will most likely want to change the hostname to match a name that meets their company standards. The module sends out DHCP requests with its desired hostname in the request to the DHCP server (step 1). The DHCP server responds with an IP address and other TCP/IP configuration information in the response to the module (step 2). The DHCP server then attempts to register the newly allocated IP address and the desired hostname with the Dynamic DNS server (step 3 & 4).

Note: The registration process may fail and the desired hostname may NOT be assigned to the module.

If the user wants to change the hostname after the registration process initiated by the DHCP server, it is likely to require the module to be re-booted to reinitiate a DHCP request and hostname registration attempt.

When the module user changes the module's dynamic hostname, the user is likely to have to reboot the module to have the name change take effect in the dynamic DNS servers. To eliminate the need for a reboot after a hostname change, module implementations can give their user a way to release the DHCP lease and then to get a new DHCP lease. In most cases, this should enable the hostname change to take effect without requiring a reboot.

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

Observation – DNS Client Usage

Hostname Lookup Support

The previous section discussed how to make a module reachable as a server via a hostname. This section discusses the ability of the module to become a client in the network running things like a Web browser. This capability may not be used on all modules because they have little need to become a client on the network. In order to be a client on the network the module needs to be able to do hostname look-ups just like any other computer in 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.

Observation – DNS Client Advantages

DNS client capability allows an LXI Device to translate a hostname into an IP address. This capability may be used for the following applications:
Running client applications (like a web browser) on the LXI Device to connect to other resources and/or servers on the network. This would be used, for example, to do firmware updates from a supplier's website.
Doing reverse look-ups of IP addresses that have a connection to the LXI Device to get the hostname of the user connected, which is more recognizable than an IP address.

Enabling a connection by hostname to nodes on the organization's LAN, such as servers or printers.
Validating the DNS hostname that the LXI Device has by doing a reverse IP-to-hostname look-up on the LXI Device's IP address and then doing a forward hostname-to-IP address look-up to verify that it returns the LXI Device's IP address.

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.

Observation – It Is Possible To Improperly Configure Network Settings

It is possible to improperly configure the network settings of an LXI Device, potentially rendering it unable to communicate with any hosts. Additionally, the settings on a box could simply be forgotten. Due to the limited user interface of a typical LXI Device, there is no simple way to view or modify the network settings (e.g., via a web browser) without a working network connection. Therefore, a simple mechanism, such as pressing the recessed rear panel LCI mechanism to force the LXI Device's network settings to a known default state, is a very desirable feature.

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.

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[13]
- LXI Extended Functions
- LXI version
- Hostname[14]
- 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]
- Current source of time
- LXI Device Address String [VISA]

[13] Refer to section 9.5.1, 10.4.1, and 10.7
[14] Refer to sections 8.9 , 9.2.3 , 10.3.1, and 10.7

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.

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.

Observation – How a Hostname May Be Assigned on the Network

The actual hostname that a module gets on a network is not necessarily the dynamic hostname that the module requested. Generally, the hostname is going to be different if the network does not support Dynamic DNS naming. The possibility of a module hostname that is different than expected makes it important for the module to determine what hostname it has really been assigned and display this in the appropriate places in the LXI Device user interface. There are also some cases in which the module will not have a hostname at all and in those cases, the IP address will have to be used in place of the hostname.

The following network configurations can create a situation when the desired module hostname may be different from the real hostname:
Module has Dynamic DNS Naming disabled
A network without any DNS server
A network with a non-dynamic (static) DNS server
A module that requests a hostname already in use on the network

The cases that may be confusing for the user are the ones where the dynamic hostnames in the modules are different from the real hostnames on the network. Most of these cases will involve networks with static DNS servers. On those networks, the user will have to set up the hostname they wanted with their network administrator.

Attempting to register a dynamic DNS hostname with a static DNS server will just fail, and the dynamic module hostname will be ignored.

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.

Observation – mDNS Hostnames Require No Validation

Given the nature of mDNS and its conflict resolution mechanism, when a module has successfully registered an mDNS hostname, the hostname requires no further validation since it is implicitly validated as part of the registration process.

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.

Observation – Hostname Display

When displaying its hostname an LXI Devices may show a unicast DNS hostname, an mDNS hostname, an IP address, or some combination of these.

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.

Observation – Using Fully Qualified Domain Names with mDNS

> To reduce potential problems with name resolution, users should specify the Fully Qualified Domain Name (FQDN) when working with mDNS hostnames. So, for example, a device with an mDNS hostname of "dev-123" should be addressed as "dev-123.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 Wired 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
- TCP/IP Configuration Mode
- IP address [15]
- 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.

[15] Static IP address. Refer to section 8.6

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.

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 Wired Trigger Bus shall include the "LXI Wired 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 Wired 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.*

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 1.4.4.2.2).

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 the LXI Logo (See section 1.4.6).

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.

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>

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.

*Observation – SCPI *IDN? Usage*

A host may establish a VXI-11 connection to each discovered LXI Device and perform a SCPI *IDN? command to determine the LXI Device's manufacturer and model.

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[16].

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.

Observation – Other Discovery Mechanisms Will Be Investigated

The LAN Working group intends to investigate other discovery technologies beyond VXI-11 for later versions of the LXI Standard. The Rendezvous and Universal Plug and Play (UPnP) suites will be the focus of this work.

10.2 RULE – XML Identification Document

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.

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

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.

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.

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.

10.2.5 RULE – LXI Extended Function Elements

Devices that support LXI Extended Functions shall provide Function elements within the LXIExtendedFunctions element, and a string containing the version number specifying the implementation of that extended function. In addition, some extended functions may provide additional information within their Function element. This allows clients to enumerate the set of extended functions associated with the device.

10.3 RULE – Support mDNS

Observation

> LXI Devices, which implement Dynamic Configuration of Link Local Addresses (AutoIP), are useful on a LAN with no central administration (e.g., DHCP server or manual static IP assignment authority). Similarly, Multicast DNS allows devices to perform DNS operations on a local link, even without the presence of an administered DNS server. This is useful for setting up simple LANs, allowing devices and controllers to use meaningful hostnames in a cooperative manner. With the addition of DNS Service Discovery (DNS-SD), it becomes straightforward for clients and servers to advertise, browse, and discover service products (e.g., HTTP servers) on the LAN.

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.)

.

Observation

> This rule helps ensure stability since the mDNS hostname should remain unchanged when the device is moved between different networks

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.

Observation

> Service names are meant to be browse-able and should be as descriptive as possible. Spaces are encouraged to promote readability.

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?> SerialNumber=<third element of response to IEEE 488.2 *IDN?> FirmwareVersion=<fourth element of response to IEEE 488.2	An LXI service that uses the HTTP protocol for identification and other operations as defined by this standard

	*IDN?>	

Observation

> The “lxi” service is expected to run on port 80.

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.

Observation

> The “txtvers” key is recommended by the DNS-SD maintainers for all new protocols to promote compatibility across versions of the protocol. This key must be provided if it has a value other than 1 and, if present, it must be the first key in the TXT record so that clients can easily parse 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=."

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?>	VXI-11 Server

	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?>	

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.

Observation

> The DNS-SD standard refers to "flagship" protocols. The HTTP Service (_http._tcp.) can be considered the flagship service for LXI Devices.

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.

Observation

> Devices may allow mDNS to be disabled (e.g., via a web interface), but mDNS shall be re-enabled when the LCI is activated, as mDNS and DNS-SD are useful in locating instruments on the LAN. The principle reason for disabling mDNS and DSN-SD is to suppress service announcement traffic.

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.

Observation

> In addition to claiming and responding to queries for its hostname via mDNS, a device must also resolve hostnames for outgoing connections (e.g., LXI Event communication) via mDNS. mDNS hostnames should always be specified as Fully Qualified Domain Names (FQDNs) that is with the ".local." domain.

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.

Observation

> The device should save the original (desired) hostname or service name along with any new hostname or service name acquired through conflict resolution. If, subsequently, the new hostname or service name conflict at startup, the device should revert to use of the desired hostname or service name. Otherwise, a "Device-1-2" or "Device-1-3" could occur.

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.

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.

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 Compliance Documentations section of the IVI 3.1 Driver Architecture Specification.

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.

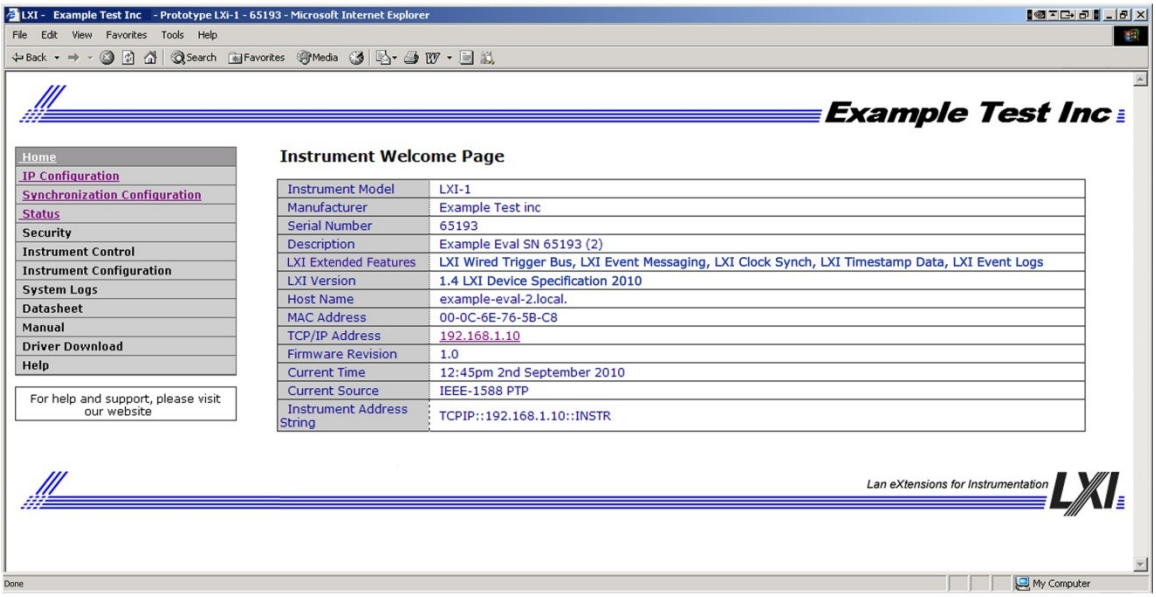
11.3 Recommendation – Documentation on LXI Device Web Page

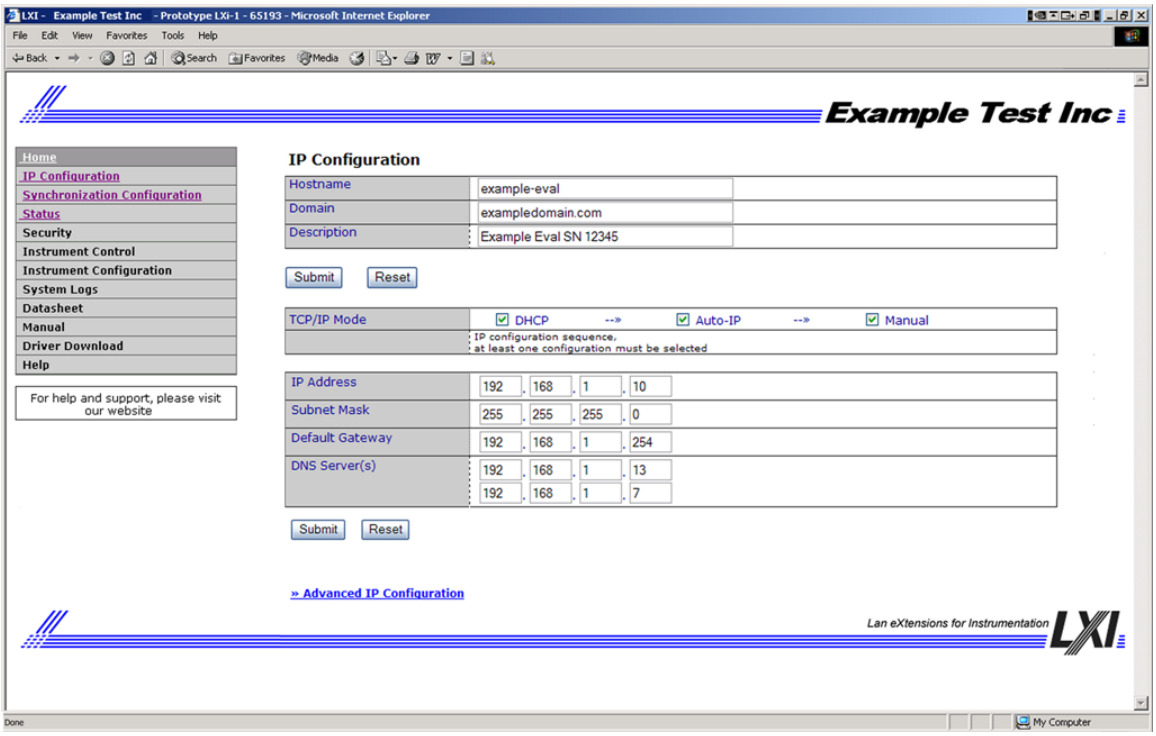
The documentation should be provided through the LXI Device's webpage or accessible from the vendor website.

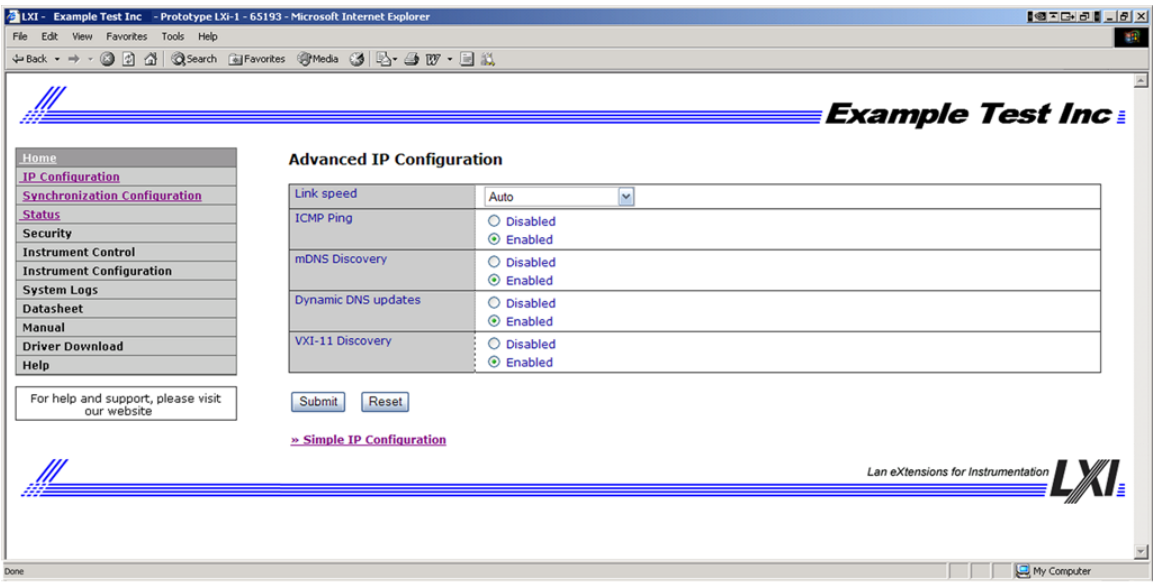
Observation

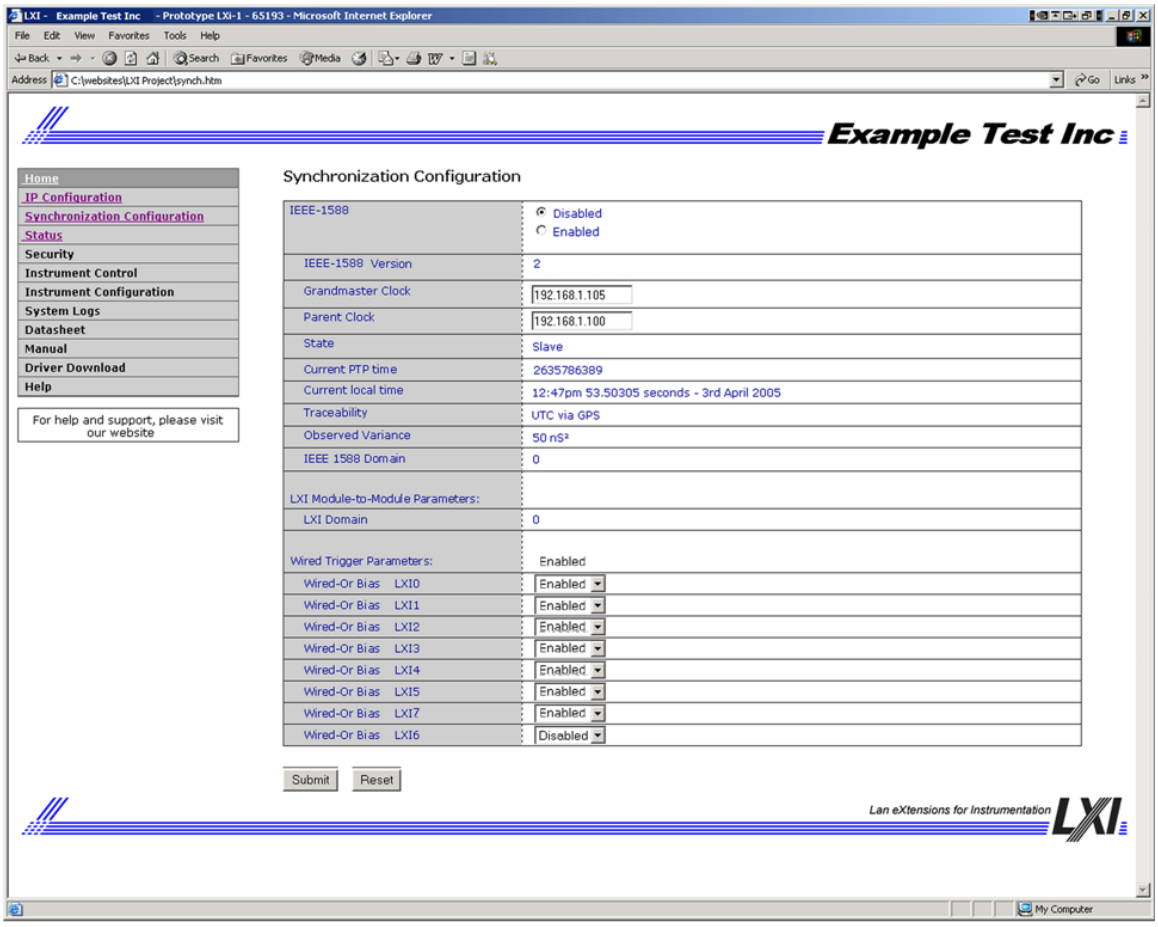
> A sufficiently powerful device could provide an html version of the documentation through its own web interface.

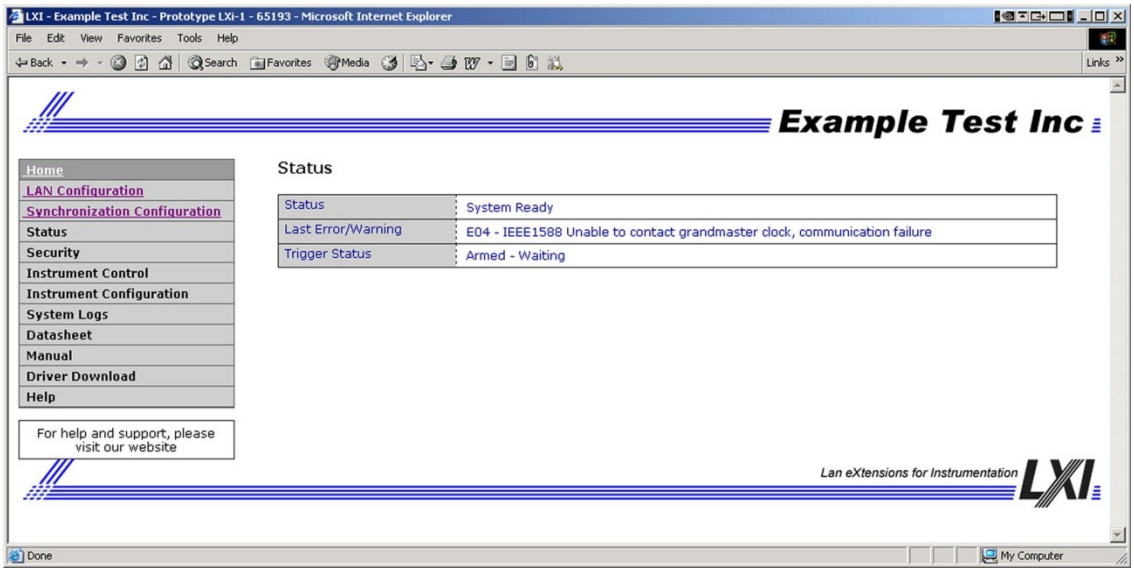
Appendix A Sample Web Pages (INFORMATIVE)











Appendix B LXI Event Packet Examples (INFORMATIVE)

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

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

Appendix C Example Identification Documents (INFORMATIVE)

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 schema location 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
    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>
  <InstrumentAddressString>TCPIP::10.1.2.32::hislip0::INSTR</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>
  <IVISoftwareModuleName>Thingamajig</IVISoftwareModuleName>
- <Extension>
  <SampleExtension>Arbitrary Vendor Extension Data can go here.</SampleExtension>
    </Extension>
  <Domain>1</Domain>
  <LXIVersion>1.4</LXIVersion>
- <LXIExtendedFunctions>
  <Function FunctionName="LXI Wired Trigger Bus" Version="1.0" />
  <Function FunctionName="LXI Event Messaging" Version="1.0" />
  <Function FunctionName="LXI Clock Synchronization" Version="1.0" />
```

```
  <Function FunctionName="LXI Timestamped Data" Version="1.0" />
  <Function FunctionName="LXI Event Logs" Version="1.0" />
- <Function FunctionName="LXI HiSLIP" Version="1.0">
  <Port>4880</Port>
    </Function>
    </LXIExtendedFunctions>
    </LXIDevice>
```

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" >
  <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>
```

Appendix D Glossary of Terms (Normative)

Use of Technical Terms

The definitions of technical terms and acronyms in this appendix shall be used in interpreting the defined term or acronym in the context of this standard.

API

API stands for Application Programming Interface.

Auto-MDIX

Auto-MDIX is a protocol, which allows two Ethernet devices to negotiate their use of the Ethernet TX and RX cable pairs. This allows two Ethernet devices 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.

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 improper operation.

IEEE

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

IEEE 1588 (PTP)

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

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.

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.

LXI Logo

The LXI Consortium licenses a registered name and logo for use in association with products that are conformant with the standard.

Details of the logo design and the Trademark License Agreement are found in the document(s) "*LXI Consortium Trademark and Patent Policies*"

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.

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)

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.

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.