



# **LXI Clock Synchronization Extended Function**

Revision 1.0

8 November 2016

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## ***Reference Documents***

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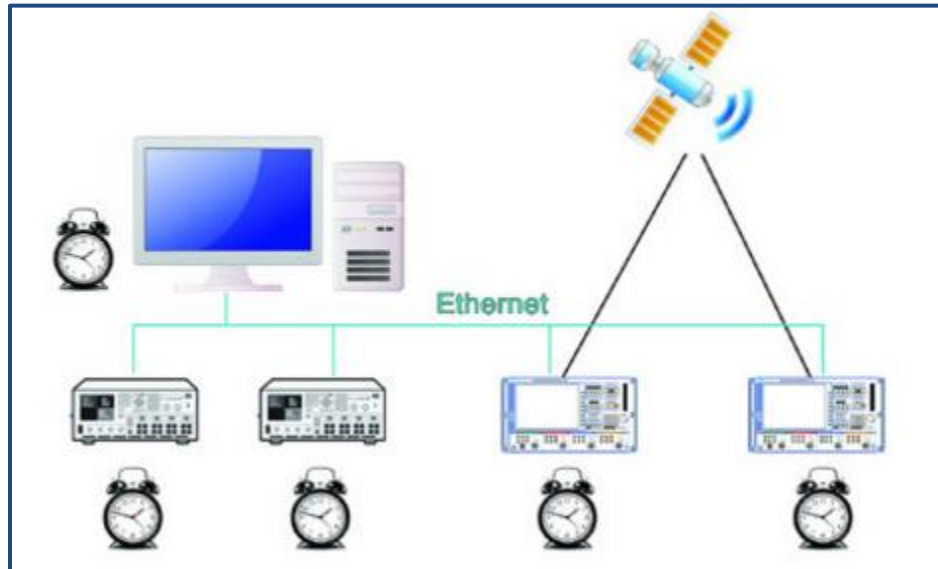
## *Revision history*

<i>Revision</i>	<i>Description</i>
1.0 Version	Initial Release November 8, 2016

# 1 Overview

## 1.1 Introduction

LXI Clock Synchronization inherits IEEE 1588- 2008, a protocol used to synchronize real-time clocks with sub microsecond accuracy in devices of a networked distributed system. This allows common timer events to be tied to absolute times for very precise triggering and synchronization. This also enables the correlation between instruments in order to aid monitoring and debugging.



IEEE 1588 specifies a Precision Time Protocol (PTP) that may be used to synchronize clocks in a Test and Measurement(T&M) system. When a T&M system implements PTP, each instrument, computer, or other controller in the system contains a clock. PTP allows synchronizing all these clocks and keeping them synchronized. PTP requires data communications between all devices; in T&M systems, this is typically implemented using Ethernet LAN. Other time synchronization methods have been used in T&M applications, including Network Time Protocol (NTP), Global Positioning Satellite (GPS) based systems, and hardwired distribution of reference oscillator signals. However, when compared with these alternatives, IEEE 1588-based systems provide more precise and accurate synchronization while offering the benefits of standard Ethernet LAN networking connections.

## 1.2 Purpose and Scope of this Document

### 1.2.1 Purpose

Each LXI Extended Function has its own document with unique section numbering that, if merged with the LXI Device Specification document, would produce a contiguous representation of the entire LXI Specification. Since all Extended Functions have some common requirements, this document will be the single reference to those requirements rather than repeating them in each separate document.

This document supplies the requirements for LXI conformance to the LXI Clock Synchronization Extended Function.

### 1.2.2 Scope

This document defines a common set of **RULES** and **RECOMMENDATIONS** for constructing a conformant LXI Device with one or more Extended Functions. Whenever possible these specifications use existing industry standards.

The original LXI Device Specification included both requirements for all LXI Devices and a number of Extended Functions in a single document. Common information remains in the LXI Device Specification and specific information related to the Extended Function moves to separate documents.

## 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.

**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 Additional LXI Conformance Requirements

### 1.4.1 Extended Functions

#### 1.4.1.1 General Description

The LXI Standard consists of the LXI Device Specification, required for all LXI Devices. In addition, it includes all optional Extended Functions.

#### **LXI Extended Functions**

Extended Functions come in the form of external documents. Each Extended Function document will have sections numbered as though they were part of the LXI Device Specification, but the documents are separate to simplify maintenance of the standard and to add new Extended Functions without altering the LXI Device Specification. The [Guide to LXI Documentation](#) identifies the Extended Function documents.

#### 1.4.1.2 Conformance Requirements

The rules in this document define the conformance requirements for this Extended Function. In addition to the requirements for all LXI Devices found in the *LXI Device Specification*, an Extended Function may require conformance to another Extended Function. All these requirements are detailed in the following Rule.

##### 1.4.1.2.5 RULE – LXI Clock Synchronization Conformance Requirements

The rules in this document define the conformance requirements for this Extended Function. In addition to the requirements for all LXI Devices found in the LXI Device Specification, there may be cases where an Extended Function requires conformance to another Extended Function. All requirements follow below:

#### **LXI Device Specification Document:**

- All LXI Devices shall conform to the rules found in Section 1.4 and all subsections
- Section 6.1.1 and 6.5 including all subsections
- Section 9.6 including all subsections
- Function element with the FunctionName attributes of “LXI Clock Synchronization” and version “1.0” in the LXIExtended Function element of the LXI identification document as described in section 10.2.5.

#### **LXI Clock Synchronization (this document):**

- Include all rules



## 2 Physical Specifications

The LXI Device Specification details the physical requirements for an LXI Device conformance. When adding the LXI Clock Synchronization, there are recommendations and observations added to the physical specification, as indicated below in Section 2.5.

### 2.5 Electrical Standards – Status Indicators

Section 2.5 of the LXI Device Specification contains the overall organization requirements and recommendations for positioning and labeling Status Indicators for an LXI Device. The first table in that section includes cases where the LXI Device supports LXI Clock Synchronization. Please refer to that Section for more information on the requirements. The sections below give more information on Recommendations and Observations when implementing the LXI Clock Synchronization Extended Function.

#### 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.

### 3 LXI Device Synchronization and Events

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 LXI Clock Synchronization Using IEEE 1588

##### 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.

##### ***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 UsingTimestamps

Note that LXI Devices generating timestamps based on an IEEE 1588 need to follow requirements in the *LXI Timestamped Data Extended Function*.

### 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).