

# IxNetwork Industrial, Automotive, and Carrier Ethernet Test Solution

Validate Enhanced-Ethernet, Time-Sensitive Networks

## Problem: Uncertainty About How Ethernet Can Replace Legacy Connectivity

The popularity of Ethernet in IT has propelled new adoption in other industries such as Ethernet virtual connections (EVCs) for metro Ethernet access, professional Audio-Video installations, automotive electronic control unit (ECU) connectivity, industrial automation and control, and time/clock distribution. But the successful replacement of these existing purpose-built Ethernet networks requires significant enhancements that include new signaling protocols and traffic control mechanisms. How can you ensure the enhanced Ethernet achieves the same level of performance and quality of the legacy connectivity for a converged IT/OT network?

## Solution: Leading Ethernet Test System Extended for Industrial Ethernet

Keysight's IxNetwork is the leader in Ethernet test solutions for network equipment manufacturers (NEMs) and service providers. Leveraging our rich Ethernet expertise, the IxNetwork Industrial, Automotive, and Carrier Ethernet test solution provides unparalleled test coverage. Each IxNetwork test port can emulate hundreds of Ethernet endpoints with realistic behavior. Various test scenarios can be executed with our graphical user interface (GUI) or application programming interface (API) scripting to characterize performance bottlenecks and resiliency.

With this test solution, you can validate that your Ethernet implementation:

- Provides the carrier-grade scale and performance needed for metro EVC access
- Supplies the low latency/jitter and dedicated bandwidth needed for professional audio/video
- Provides the scheduling and reliability for mission-critical applications in industrial networks
- Achieves the scale and precision needed for timing and clock synchronization between networking devices

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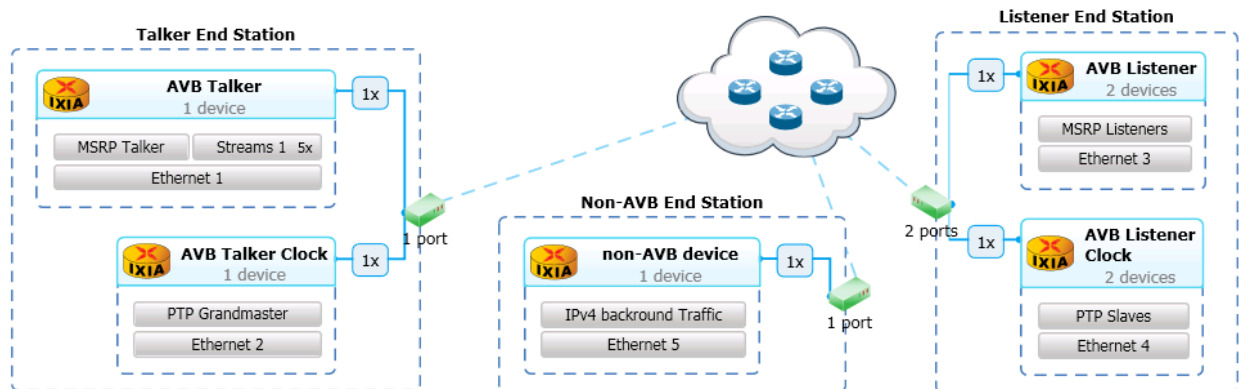
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## Highlights

- Validate industrial time-sensitive networking (TSN) scheduled traffic (IEEE 802.1Qbv) on multiple redundant time synchronization domains (IEEE 802.1AS-2020)
- Verify Frame Preemption (IEEE 802.1Qbu) with accurate emulation of fragments, preemptable and express frames
- Verify TSN standards for IEEE 802.1CB, IEEE 802.1Qci, and IEEE802.1Qcc
- Ensure professional quality AV that relies on stringent latency/jitter and resource reservation by emulating large volume of audio-video bridging (AVB) Talker-Listener instances and traffic
- Ensure high performing and scaling Carrier Ethernet services (E-Line, E-LAN, E-Tree) by emulating maintenance intermediate points (MIP) and maintenance end points (MEP)
- Verify functionality, quality, and scaling of PTP implementations to IEEE 1588v2 and G8265.1/G8275.1 telecom profiles and SMPTE ST-2059-2 Broadcast Media profiles by emulating Leader and Follower clocks
- Validate conformance with respect to Avnu Alliance Automotive Profile, TSN Conformance Test package
- Validate conformance with Avnu industrial test plan for IEEE 802.1Qbv
- Validate conformance with Avnu base TSN test plan for IEEE 802.1AS-2020 and IEEE 802.1Qbv

# Key Features

- TSN emulation — Scheduled traffic (IEEE 802.1Qbv) based on gPTP time (IEEE 802.1AS-2020), Frame Preemption (IEEE 802.1Qbu / IEEE 802.13br), Frame Replication (IEEE 802.1CB), Filtering & Policing (IEEE 802.1Qci)
- Configuration of TSN devices through Netconf/Yang (IEEE 802.1Qcc)
- AVB emulation — Stream reservation protocol IEEE 802.1Q Clause 35, forwarding and queuing of time-sensitive applications IEEE 802.1Qav, AV stream transport IEEE 1722
- Conformance test packages for new TSN standards and Avnu automotive profile and Avnu industrial test plan
- Automatic generation of fragments through TSN wizard from the preemptable stream configuration in a frame preemption (IEEE 802.1Qbu) scenario
- Automatic generation of MACsec encrypted express streams and preempted fragments through TSN wizard in a frame preemption (IEEE 802.1Qbu) scenario
- IEEE 1588v2 precision time protocol (PTP) emulation
- Support for telecom PTP profiles ITU-T G.8265.1/G.8275.1/G.8275.2
- Support for SMPTE ST-2059-2 PTP profile for Professional Broadcast Application
- Ethernet service OAM emulation, IEEE 802.1ag and ITU-T Y.1731
- Synchronous Ethernet (ESMC) emulation
- Provider backbone bridges with traffic engineering (PBB-TE) emulation
- Ethernet link OAM emulation, defined in IEEE 802.3ah Clause 57
- Ethernet local management interface (ELMI), MEF 16



**Figure 1.** IxNetwork visual interfaces enable intuitive and comprehensive emulation of AVB/TSN Talkers and Listeners and gPTP Leaders and Followers

# Conformance Coverage

Conformance Packages include the following:

- Scenario-based custom test case generation
- Graphical representation of test results
- Detailed logging
- Failure debugging at packet capture levels

## Avnu base TSN test plan for IEEE 802.1AS-2020 and IEEE 802.1Qbv

As the adoption of TSN is increasing across different ecosystems, every device manufacturer must ensure a proper implementation of the IEEE 802.1 standards. Avnu has come up with TSN test specifications for IEEE 802.1AS-2020 — Timing & Synchronization for Time-Sensitive Applications and IEEE 802.1Qbv — Enhancements for Scheduled Traffic. Device manufacturers use the IxNetwork TSN test package to check compliance with the Avnu base TSN Test Plan.

## Avnu industrial test plan for IEEE 802.1Qbv

As the adoption of TSN is increasing in the industrial ecosystem, every device manufacturer must ensure a proper implementation of the IEEE 802.1 standards. Avnu has designed test cases to determine if a product conforms to specifications originally defined in IEEE 802.1Qbv-2015 Enhancements for Scheduled Traffic. Device manufacturers use the IxNetwork TSN test package to check compliance with the Avnu Industrial Test Plan.

## Avnu automotive profile test plan

Avnu has released a specification and test plan to guide vendors in automotive AVB product development. The Avnu test plans can be used for the certification process by Avnu or certified test houses. The IxNetwork Avnu Automotive Test Package helps to validate implementations and prepare for the certification process. The test package contains the following:

- gPTP
- FQTSS
- Media Formats and SR Classes
- Exception Handling
- Diagnostics Counters
- Network and Device Startup



## IxNetwork TSN conformance package

This package contains test cases for testing and benchmarking scenarios that span across these TSN standards:

- 802.1AS
- 802.1AS-2020
- 802.1Qbv
- 802.1Qbu
- 802.1CB
- 802.1Qci
- 802.1Qcc

# Specifications

## Ethernet Service OAM

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### Supported Standards

- IEEE 802.1ag
- ITU-T Y.1731

### Emulations

- Emulation of Entities in a CFM Network, including:
  - Maintenance End Point (MEP)
  - Maintenance Intermediate Point (MIP)

### Configuration

- Full Configuration of Maintenance Point Parameters, including:
- Maintenance Association (MA) Name (all standard formats)
  - Maintenance Domain (MD) Name (all standard formats)
  - Maintenance Domain Level (0–7)

### IEEE 802.1ag Protocols

- Continuity Check Protocol
- Continuity Check Message (CCM)
  - Full Range of Continuity Check Intervals (CCIs) supported 3.33 ms–10 minutes
- Loopback Protocol
  - Loopback Message (LBM) and Loopback Reply (LBR)
- Linktrace Protocol
  - Linktrace Message (LTM) and Linktrace Reply (LTR)

### ITU-T Y.1731 Protocols

- OAM Functions for Fault Management
  - Ethernet Continuity Check (ETH-CC)
  - Ethernet Loopback (ETH-LB)
  - Ethernet Link Trace (ETH-LT)
  - Ethernet Alarm Indication Signal (ETH-AIS)
  - Ethernet Remote Defect Indication (ETH-RDI)
  - Ethernet Locked Signal (ETH-LCK)
  - Ethernet Test Signal (ETH-Test)

## Ethernet Service OAM

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- OAM Functions for Performance Monitoring
  - Frame Loss Measurement (ETH-LM)
  - Frame Delay Measurement (ETH-DM)
  - Frame Delay Variation Measurement (ETH-DVM)
  - Support for One-Way DM and DVM

## Statistics

<b>Bridge/MEP</b>	Bridges Configured MEPs Configured MAs Configured Remote MEPs MEP FNG Defect MEP FNG Defect	Bridges Running MEPs Running MAs Running MEP FNG Reset MEP FNG Defects Reported Clearing Session Flap Count
<b>Continuity Check</b>	CCM Tx/Rx CCM Received Equal Invalid CCM Received, Defective RMEPS CCM Cross Connect Defects, CCM Unexpected Periods CCM Unexpected Level, Out of Sequence CCM Received RMEP Ok, RMEP Failed RMEP Error NoDefect, RMEP Error Defect RMEP XConn Defect, RMEP XConn NoDefect AIS Tx/Rx LCK Tx/Rx TST Tx/Rx TST Out of Sequence Tx/Rx TST PRBS Bit Error Rx	RDI Tx/Rx CCM Received Low
<b>Performance Measurements</b>	LMM Tx/Rx LMR Tx/Rx DMM Tx/Rx DMR Tx/Rx 1DM Tx/Rx	
<b>Linktrace</b>	LTM Sent LTR Sent Invalid LTR Received LTR Received State	LTM Received LTR Received LTM Received State
<b>Loopback</b>	LBM Tx/Rx LBR Tx/Rx Invalid LBM Received LBI Idle LBI Waiting LR Respond	Invalid LBR Received LBI Transmitting LBR Respond

## Ethernet Link OAM

<b>Standards</b>	<ul style="list-style-type: none"><li>• IEEE 802.3ah-2004 Clause 57</li></ul>
<b>Statistics</b>	<p>Local Discovery State</p> <ul style="list-style-type: none"><li>• Information PDU Tx/Rx</li><li>• Unique Information PDU Tx/Rx</li><li>• Event Notification PDU Tx/Rx</li><li>• Unique Event Notification PDU Tx/Rx</li><li>• Variable Request PDU Tx/Rx</li><li>• Variable Response PDU Tx/Rx</li><li>• Loopback Enable Control PDU Tx/Rx</li><li>• Loopback Disable Control PDU Tx/Rx</li><li>• Unsupported PDU Rx</li><li>• Errored Symbol Period Event Running Total Tx/Rx</li><li>• Errored Frame Event Running Total Tx/Rx</li><li>• Errored Frame Period Event Running Total Tx/Rx</li><li>• Errored Frame SS Event Running Total Tx/Rx</li><li>• Organization Specific PDU Tx/Rx</li><li>• Link Fault Tx/Rx</li><li>• Dying Gasp Tx/Rx</li><li>• Critical Event Tx/Rx</li><li>• Remote Revision</li><li>• Local Revision</li></ul>
<b>Provider Backbone Bridges with Traffic Engineering (PBB-TE)</b>	
<b>Standards</b>	<ul style="list-style-type: none"><li>• IEEE 802.1Qay PBB-TE</li><li>• Nortel-led Carrier Ethernet Ecosystem Certified Interoperable</li><li>• PBT Implementation</li><li>• IEEE 802.1ah Provider Backbone Bridges</li></ul>
<b>PBB-TE Specific Per Port Statistics</b>	<ul style="list-style-type: none"><li>• Trunks Configured</li><li>• Trunks Running</li></ul>
<b>Standard and pre-standard B-VLAN TPID values</b>	<ul style="list-style-type: none"><li>• 0x8100, 0x9100, 0x9200 and 0x88A8</li></ul>
<b>Configuration</b>	<ul style="list-style-type: none"><li>• Enable/Disable Individual Trunks</li><li>• Enable/Disable Optional TLV Validation</li><li>• Enable/Disable Out of Sequence CCM Detection</li></ul>
<b>Per Trunk Configuration</b>	<ul style="list-style-type: none"><li>• MEP ID</li><li>• Source MAC Address / Destination MAC Address</li><li>• Short MA Name Format (supporting all standard formats)</li><li>• Short MA Name</li><li>• MD Level</li><li>• MD Name Format (supporting all standard formats)</li><li>• MD Name</li></ul>



## Ethernet Link OAM

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- CCI Interval (supporting all standard intervals)
  - B-VLAN ID
  - B-VLAN Priority
  - B-VLAN TPID
- 

## Ethernet Local Management Interface (ELMI)

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Protocol	Ethernet Local Management Interface (E-LMI)
Standard	MEF 16
Statistics	<ul style="list-style-type: none"><li>• Learned Info:<ul style="list-style-type: none"><li>◦ LMI Status</li><li>◦ LMI Status</li><li>◦ Protocol Version</li><li>◦ Send Sequence Num</li><li>◦ Receive Sequence Num</li><li>◦ Data Instance</li><li>◦ Invalid Protocol Version</li><li>◦ Invalid EVC Reference Id</li><li>◦ Invalid Message Type</li><li>◦ Out of Sequence IE</li><li>◦ Duplicated IE</li><li>◦ Mandatory IE Missing</li><li>◦ Invalid Mandatory IE</li><li>◦ Invalid Non-Mandatory IE</li><li>◦ Unrecognized IE</li><li>◦ Unexpected IE</li><li>◦ Short Message</li></ul></li><li>• UNI Status<ul style="list-style-type: none"><li>◦ EVC MAP type</li><li>◦ UNI Id Length</li><li>◦ UNI Id</li><li>◦ CM</li><li>◦ CF</li><li>◦ Per CoS</li><li>◦ CIR Magnitude</li><li>◦ CIR Multiplier</li><li>◦ CBS Magnitude</li><li>◦ CBS Multiplier</li><li>◦ EIR Magnitude</li></ul></li></ul>

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## Ethernet Local Management Interface (ELMI)

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- EIR Multiplier
  - EBS Magnitude
  - EBS Multiplier
  - UPB 000
  - UPB 001
  - UPB 010
  - UPB 011
  - UPB 100
  - UPB 101
  - UPB 110
  - UPB 111
  - EVC Status
    - Reference Id
    - Status Type
    - EVC Type
    - Untagged/Priority Tag
    - Default EVC
    - EVC Id Length
    - EVC Id
    - Vlan Id
    - CM
    - CF
    - Per CoS
    - CIR Magnitude
    - CIR Multiplier
    - CBS Magnitude
    - CBS Multiplier
    - EIR Magnitude
    - EIR Multiplier
    - EBS Magnitude
    - EBS Multiplier
    - UPB 000
    - UPB 001
    - UPB 010
    - UPB 011
    - UPB 100
    - UPB 101
    - UPB 110
    - UPB 111
    - Global Statistics
  - E-LMI Aggregated Statistics
    - UNI-C configured
    - UNI-C Running
-

## Ethernet Local Management Interface (ELMI)

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- UNI-N configured
  - UNI-N Running
  - Session Operational
  - Session Flap
  - Check Tx
  - Check Rx
  - Full Status Enquiry Tx
  - Full Status Enquiry Rx
  - Full Status Tx
  - Full Status Rx
  - Full Status Continued Enquiry Tx
  - Full Status Continued Enquiry Rx
  - Full Status Continued Tx
  - Full Status Continued Rx
  - Single EVC Asynchronous Status Tx
  - Single EVC Asynchronous Status Rx
  - UNI Status Tx
  - UNI Status Rx
  - EVC Status Tx
  - EVC Status Rx
  - CE-VLAN ID/EVC MAP Tx
  - CE-VLAN ID/EVC MAP Rx
  - Remote Protocol Version
  - Invalid Protocol Version
  - Invalid Message Type
  - Out of Sequence IE Rx
  - Duplicated IE Rx
  - Mandatory IE Missing Rx
  - Invalid Mandatory IE Rx
  - Unrecognized IE Rx
  - Unexpected IE Rx
  - Short Message Rx
  - Unsolicited Status Rx
  - Invalid Status Rx
-

## IEEE 1588 Precision Time Protocol (PTP)

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### Standards

- IEEE 1588v2 (2008)
- G.8265.1 Telecom Profile
- G.8275.1 Telecom Profile
- G.8275.2 Telecom Profile
- IEEE 802.1AS gPTP Profile and parts of gPTP-rev for multiple domain support (requires separate 930-2113 AVB license)
- SMPTE ST-2059-2
- PTP Power Profile IEEE C37.238-2017

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### Protocol Options

- PTP over various encapsulations: IEEE 802.3/Ethernet (with optional VLANs), UDP/IPv4, UDP/IPv6
- PTP Mode: Multicast, Unicast and Mixed
- Delay-Request Mechanisms: Delay Request/Response, Peer Delay, or One-Way mode (disabling the delay requests)
- Timestamping mode: One-step, Two-step
- Setting of IP ToS or DiffServ value
- VLAN 802.3 priority (with support for multiple nested VLANs)
- Lock emulated Follower time to emulated Grandmaster time to compute raw time error introduced by switches/bridges (Transparent or Boundary clocks) by disabling Update Time
- Frequency and time offset adjustment for each emulated session (Timestamp offset and Nanoseconds per Second)

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### Key Configuration Parameters

- Clock parameters: Clock Identity, Port Number, Domain
  - Messages rates:
    - Announce Interval Log -9 (512/s) to Log 9 (1 per 512s)
    - Sync Interval Log -9 (512/s) to Log 9 (1 per 512s)
    - (P)Delay Request Interval Log -9 (512/s) to Log 9 (1 per 512s)
    - Management interval Log -9 (512/s) to Log 9 (1 per 512s)
  - Announce and Sync Receipt Timeout intervals
  - Correction fields values for Sync, Follow-Up, (P)DelayReq, (P)DelayResp and PdelayResp Follow-up (when emulating Transparent Clock port)
  - Grandmaster Identity, Steps Removed, and Path Trace TLV (when emulating a Boundary Clock port)
  - BMCA related parameters: Priority 1, Clock Class, Clock Accuracy, Offset Scaled Log Variance, Priority 2
  - Strict Grant, Signal Interval and Grant Unicast Duration (configurable separately for Announce, Sync and DelayReq messages)
  - Edit bits in Announce message including PTP Timescale, Time Source, Alternate Master Flag, Time Traceable, Frequency Traceable, Leap59, Leap61, Current UTC Offset Valid and Value
  - Unicast parameters: Handle Announce TLV, Send Multicast Announce, Handle Cancel TLV, Renewal Invited, Learn Port ID, Signal Interval, Grant Unicast Duration, Grant Delay Response Duration
  - G.8265.1 parameters: Request Interval, Request Interval Attempts, Request Hold-down Timer, Sync Receipt Timeout, Delay Response Receipt Timeout
-

## IEEE 1588 Precision Time Protocol (PTP)

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- G.8275.1 parameters: Multicast Address (Non-forwardable or Forwardable), Not Follower and Drop Malformed (accept non-standard values in messages)
  - gPTP parameters: Sync Receipt Timeout, FollowUp TLV fields (Cumulative Scaled Rate Offset, GM Time Base Indicator, Last GM Phase Change, Scaled Last GM Freq Change)
  - Follower recovered clock quality measurement: enable Reverse Sync, Reverse Sync Interval
  - SMPTE Data parameters: Default System Frame Rate Numerator, Default System Frame Rate Denominator, Master Locking Status, Time Address Flags, Current Local Offset, Jump Seconds, Time of Next Jump, Time of Next Jam, Time of Previous Jam, Previous Jam Local Offset, Daylight Saving, Leap Second Jump
  - Debug parameters: Enable Offset Trigger, Offset Trigger (ns), Number of Records to Be Logged, Log Future Packet info, Log File Location, Log Clean Up, Log File Lifetime (days)
- 

### Impair Timing Messages (negative testing)

- Announce Drop Rate (%)
  - Sync Drop Rate (%)
  - Follow Up delay with insertion rate (%)
  - Follow-Up Drop Rate (%)
  - Follow-Up Bad CRC Rate (%)
  - (P)Delay Request Drop Rate (%)
  - (P)Delay Request Timing Offset and Spread
  - (P)Delay Response delay with insertion rate (%)
  - (P)Delay Response Drop Rate (%)
  - PDelay Response Follow-Up delay with insertion rate (%)
  - PDelay Response Follow-Up Drop Rate (%)
  - Drop Signal Request with Announce TLV
  - Drop Signal Request with Sync TLV
  - Drop Signal Request with Delay Response TLV
- 

### PDU Builder Support for PTP Messages for Negative Testing

#### Statistics

- PTP Total, Per Range or Device Group and Per Session
  - Interface Identifier
  - Range Identifier
  - Session Status
  - PTP Status (Listening/Uncalibrated/Leader/Follower)
  - Offset (Time Error)
  - Path Delay
  - Time Slope
  - Port Identity
  - Master Port Identity
  - Grandmaster Port Identity
  - Min/Max/Avg Offset (Time Error)
  - Min/Max/Avg Path Delay
  - Announce Messages Tx/Rx
-

- Sync Messages Tx/Rx
- FollowUp Messages Tx/Rx
- DelayReq Messages Tx/Rx
- DelayResp Messages Tx/Rx
- PdelayReq Messages Tx/Rx
- PdelayResp Messages Tx/Rx
- PdelayResp FollowUp Messages Tx/Rx
- Signaling Messages Tx/Rx
- Sync Messages Received Rate
- FollowUp Messages Received Rate
- DelayReq Messages Received Rate
- DelayResp Messages Received Rate
- PdelayReq Messages Received Rate
- PDelayResp Messages Received Rate
- PdelayRespFollowUp Messages Received Rate
- Local Clock Class
- Master Clock Class
- Local Clock Accuracy
- Master Clock Accuracy
- Current UTC Offset
- Steps Removed
- Leap59
- Leap61
- Frequency Traceable
- Time Traceable
- Correction Field Sync Min/Max/Ave
- Correction Field Follow-up Min/Max/Ave
- Correction Field DelayReq Min/Max/Ave
- Correction Field PDelayReq Min/Max/Ave
- Correction Field DelayResp Min/Max/Ave
- Correction Field PDelayResp Min/Max/Ave
- Foreign Master 0–4
  - Identity
  - Port Number
- Timestamp: T1, T2, T3, T4
- Timestamps in UTC format
- Inter-Arrival Time of Announce (real-time/min/max)
- Inter-Arrival Time of Sync (real-time/min/max)
- Inter-Arrival Time of FollowUp (real-time/min/max)
- Inter-Arrival Time of DelayReq (real-time/min/max)
- Inter-Arrival Time of DelayResp (real-time/min/max)
- Inter-Arrival Time of PDelayReq (real-time/min/max)
- Inter-Arrival Time of PDelayResp (real-time/min/max)
- Inter-Arrival Time of PdelayResp Follow-up (real-time/min/max)

## IEEE 1588 Precision Time Protocol (PTP)

### Analyzer Support for Protocol Decode

- |   |   |
|---|---|
| <b>Test Composer PTP Events (Classic)</b> | <ul style="list-style-type: none"><li>• Change BMC Parameters<ul style="list-style-type: none"><li>◦ Priority 1, Priority 2</li><li>◦ Clock Class</li><li>◦ Clock Accuracy</li></ul></li><li>• Change Log Message Intervals<ul style="list-style-type: none"><li>◦ Announce Interval</li><li>◦ Sync Interval</li><li>◦ Delay Request Interval</li></ul></li><li>• Change Misc. Parameters<ul style="list-style-type: none"><li>◦ Domain</li><li>◦ Announce Receipt Timeout</li></ul></li><li>• Change Negative Testing Parameters<ul style="list-style-type: none"><li>◦ Delay Response with insertion rate</li><li>◦ Delay Response drop rate</li><li>◦ Follow Up delay with insertion rate</li><li>◦ Follow Up drop rate</li><li>◦ Follow Up Bad CRC rate</li></ul></li><li>• PTP Clear Stats</li><li>• PTP Pause</li><li>• PTP Resume</li><li>• PTP Start</li><li>• PTP Stop</li></ul> |
|---|---|

- |  |  |
|--|--|
| <b>Test Composer PTP Events (NGPF)</b> | <ul style="list-style-type: none"><li>• Change all GUI configuration parameters</li><li>• Start and Stop sessions</li><li>• Clear Statistics</li><li>• Send IEEE 802.1AS Signaling Message</li></ul> |
|--|--|

## Ethernet Synchronization Messaging Channel Protocol (ESMC)

- |                               |   |
|-------------------------------|---|
| <b>Standards</b>              | <ul style="list-style-type: none"><li>• ITU-T G.8264</li></ul>  |
| <b>ESMC Protocol Features</b> | <ul style="list-style-type: none"><li>• SSM Quality Level and extended Quality Level</li><li>• Rate 1/s to 100/s (beyond legal limit of 10/s)</li><li>• Flag Mode (Auto, On or Off)</li></ul> |

### PDU Builder Support for ESMC Messages for Negative Testing

- |                   |   |
|-------------------|---|
| <b>Statistics</b> | <ul style="list-style-type: none"><li>• Last change (timestamp)</li><li>• Last quality (Quality Level)</li><li>• Total messages Tx/Rx</li></ul> |
|-------------------|---|

## Ethernet Synchronization Messaging Channel Protocol (ESMC)

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- Even messages Tx/Rx
- STU/UNK Tx/Rx
- PRS Tx/Rx
- PRC Tx/Rx
- INV3 Tx/Rx
- SSU-A/TNC Tx/Rx
- INV5 Tx/Rx
- INV6 Tx/Rx
- ST2 Tx/Rx
- SSU-B Tx/Rx
- INV9 Tx/Rx
- EEC2/ST3 Tx/Rx
- EEC1/SEC Tx/Rx
- SMC Tx/Rx
- ST3E Tx/Rx
- PROV Tx/Rx
- DNU/DUS Tx/Rx
- Extended TLV Tx/Rx
- ePRTC Tx/Rx
- ePRC Tx/Rx
- eEEC Tx/Rx
- Minimum inter-arrival time
- Average inter-arrival time
- Maximum inter-arrival time
- Average message rate
- Maximum message rate

### Analyzer (Optional) Support for Protocol Analysis and Decode

#### Test Composer ESMC Events

- Change ESMC
    - Rate
    - Quality Level
    - Flag Mode
  - ESMC Clear Stats
  - ESMC Start
  - ESMC Stop
-



## Two-Way Active Measurement Protocol (TWAMP)

<b>Standards</b>	IETF RFC 5357
<b>Statistics</b>	<ul style="list-style-type: none"><li>• TWAMP Control: Initiated Sessions, Successful Sessions, Failed Sessions, Active Sessions, Initiated Session Rate, Successful Session Rate, Failed Session Rate</li><li>• TWAMP Data: Datagram TX, Datagram RX, Datagram Lost, Datagram Unexpected, Data Streams Initiated, Data Streams Successful, Data Streams Failed</li><li>• TWAMP Test: Initiated Sessions, Successful Sessions, Failed Sessions, Active Sessions, Initiated Session Rate, Successful Session Rate, Failed Session Rate</li><li>• TWAMP Server Control: Initiated Sessions, Successful Sessions, Failed Sessions, Active Sessions, Initiated Session Rate, Successful Session Rate, Failed Session Rate</li><li>• TWAMP Server Data: Datagram TX, Datagram RX, Datagram Lost, Datagram Unexpected, Data Streams Initiated, Data Streams Successful, Data Streams Failed</li><li>• TWAMP Server Test: Initiated Sessions, Successful Sessions, Failed Sessions, Active Sessions, Initiated Session Rate, Successful Session Rate, Failed Session Rate</li></ul>

## Audio Video Bridging (AVB) / Time Sensitive Networking (TSN) Protocols

<b>Standard</b>	IEEE 802.1Qat IEEE 802.1Qav IEEE 802.1Qbv IEEE 802.1AS IEEE 1722
<b>MSRP Talker Configuration</b>	<ul style="list-style-type: none"><li>• Protocol Version</li><li>• Join Timer (ms)</li><li>• Leave Timer (ms)</li><li>• Leave All Timer (ms)</li><li>• Stream Count</li><li>• Domain Count</li><li>• Domains<ul style="list-style-type: none"><li>◦ SR Class ID</li><li>◦ SR Class Priority</li><li>◦ SR Class VID</li></ul></li></ul>
<b>AVB Stream Configuration</b>	<ul style="list-style-type: none"><li>• Stream ID</li><li>• Destination MAC</li><li>• VLAN ID</li><li>• Max Frame Size</li><li>• Max Interval Frames</li><li>• Data Frame Priority</li></ul>

## Audio Video Bridging (AVB) / Time Sensitive Networking (TSN) Protocols

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	<ul style="list-style-type: none"><li>• Rank</li><li>• Port Tc Max Latency (ns)</li></ul>
<b>MSRP Talker Statistics</b>	<ul style="list-style-type: none"><li>• Per packet statistics</li><li>• MSRP Packet Tx</li><li>• MSRP Packet Rx</li><li>• Per attribute type statistics</li><li>• MSRP Listener Advertise Rx</li><li>• MSRP Talker Advertise Tx</li><li>• MSRP Talker Advertise Rx</li><li>• MSRP Listener Ready Rx</li><li>• MSRP Listener Ready Failed Rx</li><li>• MSRP Listener Asking Failed Rx</li><li>• MSRP Domain Packet Rx</li><li>• MSRP Domain Advertise Tx</li><li>• MSRP Domain Advertise Rx</li><li>• MVRP Packet Tx</li><li>• MVRP Packet Rx</li><li>• MSRP Talker New Tx</li><li>• MSRP Listener New Rx</li><li>• MSRP Talker Mt Tx</li><li>• MSRP Listener Mt Rx</li><li>• MSRP Talker JoinMt Tx</li><li>• MSRP Listener JoinMt Rx</li><li>• MSRP Talker JoinIn Tx</li><li>• MSRP Listener JoinIn Rx</li><li>• MSRP Talker Lv Tx</li><li>• MSRP Listener Lv Rx</li><li>• MSRP Talker In Tx</li><li>• MSRP Listener In Rx</li><li>• Per Port statistics</li><li>• MSRP Packet Tx</li><li>• MSRP Packet Rx</li><li>• MSRP Listener Advertise Rx</li><li>• MSRP Talker Advertise Tx</li><li>• MSRP Talker Advertise Rx</li><li>• MSRP Listener Ready Rx</li><li>• MSRP Listener Ready Failed Rx</li><li>• MSRP Listener Asking Failed Rx</li><li>• MSRP Domain Packet Rx</li><li>• MSRP Domain Advertise Tx</li><li>• MSRP Domain Advertise Rx</li><li>• MVRP Packet Tx</li><li>• MVRP Packet Rx</li></ul>

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## Audio Video Bridging (AVB) / Time Sensitive Networking (TSN) Protocols

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- MSRP Talker New Tx
- MSRP Listener New Rx
- MSRP Talker Mt Tx
- MSRP Listener Mt Rx
- MSRP Talker JoinMt Tx
- MSRP Listener JoinMt Rx
- MSRP Talker JoinIn Tx
- MSRP Listener JoinIn Rx
- MSRP Talker Lv Tx
- MSRP Listener Lv Rx
- MSRP Talker In Tx
- MSRP Listener In Rx

---

### MSRP Talker Actions

- Stop
- Start
- Advertise New

---

### SRP Talker Database

- Talker Specific
- Attribute First Value
  - Stream ID
  - Data Frame Parameters
  - TSpec
  - PriorityAndRank
  - Latency
  - Applicant State
  - Registrar State
  - Source MAC Address
  - Talker Advertise Tx
  - Talker JoinMt Tx
  - Talker JoinIn Tx
  - Talker In Tx
  - Talker New Tx
  - Talker Mt Tx
  - Talker Lv Tx
  - Listener Advertise Rx
  - Listener Ready Rx
  - Listener Ready Failed Rx
  - Listener Asking Failed Rx
  - Listener New Rx
  - Listener JoinMt Rx
  - Listener JoinIn Rx
  - Listener In Rx
  - Listener Lv Rx
  - Listener Mt Rx
-

## Audio Video Bridging (AVB) / Time Sensitive Networking (TSN) Protocols

---

### Domain Specific

- SR Class ID
- SR Class Priority
- SR Class VID
- Source MAC Address

### VLAN Specific

- VLAN ID
  - Registrar State
  - Source MAC Address
- 

### MSRP Listener Configuration

#### MSRP Listener

- Protocol Version
- Join Timer (ms)
- Leave Timer (ms)
- Leave All Timer(ms)
- Start VLAN ID
- VLAN Count
- Advertise As New
- Subscribed Stream Count
- Domain Count

#### Subscribed Streams

- Stream ID
  - Domains
  - SR Class ID
  - SR Class Priority
  - SR Class VID
- 

### MSRP Listener Statistics

- Per packet statistics
  - MSRP Packet Tx
  - MSRP Packet Rx
  - Per Listener statistics
  - MSRP Listener Advertise Tx
  - MSRP Listener Tx
  - MSRP Listener Rx
  - MSRP Talker Advertise Rx
  - MSRP Talker Failed Rx
  - MSRP Listener Ready Tx
  - MSRP Listener Ready Failed Tx
  - MSRP Listener Asking Failed Tx
  - MSRP Domain Advertise Tx
  - MSRP Domain Advertise Rx
-

## Audio Video Bridging (AVB) / Time Sensitive Networking (TSN) Protocols

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- MVRP Packet Tx
- MVRP Packet Rx
- MSRP Listener New Tx
- MSRP Talker New Rx
- MSRP Listener Mt Tx
- MSRP Talker Mt Rx
- MSRP Listener JoinMt Tx
- MSRP Talker JoinMt Rx
- MSRP Listener JoinIn Tx
- MSRP Talker JoinIn Rx
- MSRP Listener Lv Tx
- MSRP Talker Lv Rx
- MSRP Listener In Tx
- MSRP Talker In Rx
- Per Port Stats
- MSRP Packet Tx
- MSRP Packet Rx
- Per attribute type statistics
- MSRP Listener Advertise Tx
- MSRP Talker Advertise Rx
- MSRP Talker Fail Rx
- MSRP Ready Tx
- MSRP Ready Failed Tx
- MSRP Asking Failed Tx
- MSRP Domain Packet Rx
- MVRP Packet Tx

---

### MSRP Listener Actions

- Leave Stream
- Join Stream
- Stop
- Start

---

### MSRP Listener Database

- Listener Specific
- First Value
    - SRP Stream ID
    - Data Frame Parameters
    - TSpec
    - PriorityAndRank
    - Accumulated Latency
  - Attribute Type
  - Attribute Sub Type
  - Applicant State
  - Registrar State
  - Source MAC Address
-

## Audio Video Bridging (AVB) / Time Sensitive Networking (TSN) Protocols

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- Error Code
- Bridge ID
- Talker Failed Rx
- Talker New Rx
- Talker JoinMt Rx
- Talker JoinIn Rx
- Talker In Rx
- Talker Lv Rx
- Talker Mt Rx
- Listener Advertise Tx
- Listener Ready Tx
- Listener Ready Failed Tx
- Listener Asking Failed Tx
- Listener JoinMt Tx
- Listener JoinIn Tx
- Listener In Tx
- Listener New Tx
- Listener Mt Tx
- Listener Lv Tx
- Accumulated Latency
- Received VLAN
- Max Frame Size
- Max Interval Frames
- Data Frame Priority
- Rank
- Domain Specific
- SR Class ID
- SR Class Priority
- SR Class VID
- Source MAC Address
- VLAN Specific
- VLAN ID
- Applicant State

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### gPTP Protocol Configuration

- See the preceding 1588 PTP configuration parameters
- Automotive Ethernet AVB Functional and Interoperability Specification 1.4 — disable use of BMCA / Announce message

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### gPTP Actions

Send gPTP Specific Signaling Messages

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### gPTP Statistics

See the preceding 1588 PTP statistics

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# Platform Options

Visit [www.keysight.com](http://www.keysight.com) for More Information on IxNetwork Platform Options

Virtual Platform	IxNetwork Virtual Edition (VE)
<b>Chassis</b>	<ul style="list-style-type: none"> <li>• XGS12-HSL/SDL/SD Chassis</li> <li>• XGS2-HSL/SDL/SD Chassis</li> </ul>
<b>Fixed Chassis</b>	<ul style="list-style-type: none"> <li>• AresONE 800GE QSFP-DD800 800/400/200/100GE</li> <li>• AresONE-S 400G 16PHW QSFP-DD 400/200/100/50GE</li> <li>• AresONE-S 400G 8PHW QSFP-DD 400/200/100/50GE</li> <li>• AresONE-400G QSFP-DD 400/200/100/50GE</li> <li>• AresONE-400G OSFP 400/200/100/50GE</li> <li>• AresONE-400G High Performance QSFP-DD 400/200/100/50GE</li> <li>• NOVUS ONE PLUS 10GE/5GE/2.5GE/1GE/100M</li> </ul>
<b>Appliances</b>	<ul style="list-style-type: none"> <li>• NOVUS ONE 10GE/1GE/100M</li> </ul>
<b>Load Modules</b>	<ul style="list-style-type: none"> <li>• K400 QSFP-DD 400/200/100/50GE</li> <li>• K400 CFP8 400GE</li> <li>• NOVUS High Density QSPF28 100/50/40/25/10GE</li> <li>• NOVUS High Density SFP28/QSPF28 100/50/25/10GE</li> <li>• NOVUS 10GE/1GE/100M</li> <li>• NOVUS 10GE/5GE/2.5GE/1GE/100M</li> <li>• Xcellon-Multis QSFP28 100/50/25GE</li> <li>• Xcellon-Multis CFP4 100GE</li> <li>• Xcellon-Multis CXP 100/40/10GE</li> <li>• Xcellon-Multis QSFP 40/10GE</li> <li>• Xcellon-Lava CFP 100/40GE</li> <li>• Xcellon-Flex QSFP/SFP+ 40/10GE</li> </ul> <p><b>Note:</b> AVB/TSN protocols are supported on:</p> <ul style="list-style-type: none"> <li>• NOVUS 10GE/1GE/100M</li> <li>• NOVUS 10GE/5GE/2.5GE/1GE/100M</li> <li>• NOVUS ONE PLUS</li> </ul> <p>Only AVB is supported on: Xcellon-AVB 40/10GE (944-1132)</p> <p>100BASE-T1 and 1000BASE-T1 interface speeds are supported through additional SFP transceiver modules (948-0062)</p> <p>TSN capability requires the following upgrade to the load modules: TSN OPTION ENABLEMENT (Factory Installed) — 905-1020 OR TSN FIELD UPGRADE OPTION 905-1021</p>

# IxNetwork Technology Solutions

Visit [www.keysight.com](http://www.keysight.com) for More Information on IxNetwork Technology Solutions

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- IxNetwork Overview — L2/3 Network Infrastructure Performance Testing
  - IxNetwork Software Defined Networking (SDN) Test Solution
  - IxNetwork Routing and Switching Test Solution
  - IxNetwork MPLS Test Solution
  - IxNetwork Industrial, Automotive, and Carrier Ethernet Test Solution
  - IxNetwork Broadband and Authentication Test Solution
  - IxNetwork Data Center Ethernet Test Solution
  - IxNetwork MACsec Test Solution
-



# Ordering Information

## Ethernet Service OAM and PBB-TE

### 930-2032

IxNetwork, Optional Software, Ethernet CFM IEEE 802.1ag and ITU-T Y.1731 Protocol Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

### 930-2033

IxNetwork, Optional Software, PBB-TE Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

### 930-2034

IxNetwork, Software Bundle, Carrier Ethernet; includes 930-2032 and 930-2033; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

## Ethernet Link OAM

### 930-2040

IxNetwork, Software Option, Ethernet Link OAM (IEEE 802.3ah Clause 57) Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

## IEEE 1588 Precision Time Protocol (PTP) & SYNC-E ESMC

### 930-2070

IxNetwork, Optional Software, IEEE 1588v2 (PTP) Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

### 930-2073

IxNetwork, Optional Software, ITU-T SyncE (ESMC) Protocol Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

## 930-2132

Ixia IxNetwork, Optional Software, Media Profiles for IEEE 1588v2 (PTP) Protocol Emulation; Enable IEEE 1588v2 (PTP) Protocol with SMPTE Profile and AES67 Profile for Professional Broadcast Application; REQUIRES: 930-2070 IEEE 1588v2 (PTP) Protocol Emulation; REQUIRES: pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

## 930-2137

IxNetwork, Optional Software, Power Profile for IEEE 1588v2 (PTP) Protocol Emulation; Enable IEEE 1588v2 (PTP) Protocol with IEEE C37.238-2017 Power Profile; REQUIRES: 930-2070 IEEE 1588v2 (PTP) Protocol Emulation; REQUIRES: pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

## 930-2501

IxNetwork, Optional Software Bundle, Timing Protocols Bundle; INCLUDES: 930-2070 IxNetwork, Optional Software, IEEE 1588v2 (PTP) Emulation; 930-2073 IxNetwork, Optional Software, ITU-T SyncE (ESMC) Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

## Ethernet Local Management Interface (ELMI)

### 930-2075

IxNetwork, Optional Software, ELMI (MEF 16) Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

## Two-Way Active Measurement Protocol (TWAMP)

### 930-2041

IxNetwork, Software Option, Two Way Active Measurement Protocol (TWAMP) RFC 5357 Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

## Audio Video Bridging (AVB)/Time Sensitive Networks (TSN)

### 905-1020

TSN Option Enablement for FACTORY INSTALLED CAPABILITY on NOVUS 10GE/1GE/100M Modules OR Novus One 10GE/1GE/100M Appliances (905-1020)

## **905-1021**

TSN Option Enablement for FIELD UPGRADE CAPABILITY on NOVUS 10GE/1GE/100M Modules OR Novus One 10GE/1GE/100M Appliances (905-1021)

## **905-1065**

TSN FACTORY INSTALLED OPTION for enabling TSN capability for the new purchase of the NOVUS-10GE/25GE8SFP28 (944-1164), 8-port, SFP28 10GE/25GE load modules

## **905-1066**

IXIA TSN FIELD UPGRADE OPTION for enabling TSN capability on the NOVUS-10GE/25GE8SFP28 (944-1164), 8-port, SFP28 10GE/25GE load modules

## **930-2120**

IXIA IxNetwork AVB/TSN for NOVUS 10GE/1GE/100M Modules OR NOVUS-S 10/25GE8SFP28 Modules includes 802.1AS-2011, 802.1AS 2020, Qbv Scheduled Traffic, Qbu Frame preemption ,1CB Redundancy, Qav CBS, MSRP, 1722 and 1733 protocol emulation , REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

## **930-2530**

Ixia IxNetwork perpetual, Bundle - basic package (930-2221) and AVB/TSN for Novus ONE PLUS Fixed Chassis, includes IxNetwork Basic, 802.1AS-2011, 802.1AS 2020, Qbv Scheduled Traffic, Qbu Frame preemption ,1CB Redundancy, Qav CBS, MSRP, 1722 and 1733 protocol emulation

## **930-9530**

Ixia IxNetwork, node-locked 12-month subscription Bundle - basic package (930-2221) and AVB/TSN for Novus ONE PLUS Fixed Chassis, includes IxNetwork Basic, 802.1AS-2011, 802.1AS 2020, Qbv Scheduled Traffic, Qbu Frame preemption ,1CB Redundancy, Qav CBS, MSRP, 1722 and 1733 protocol emulation

## **930-2423**

Ixia IxNetwork AVNU conformance and interoperability tests for Automotive (930-2423)

## **930-2425**

IXIA IxNetwork Optional Scripts, IxNetwork TSN conformance and interoperability tests (930-2425)

## **930-2426**

IXIA IxNetwork AVNU conformance and interoperability tests for Industrial TSN - 802.1Qbv (930-2426)

## **930-2427**

IXIA IxNetwork AVNU conformance and interoperability tests for TSN – 802.1AS-2020 & 802.1Qbv (930-2427)

## **930-2531**

IXIA IxNetwork AVNU bundle conformance and interoperability tests for TSN (930-2531). Includes: 930-2423, 930-2426, 930-2427

## **930-2532**

IXIA IxNetwork TSN/AVNU wireline bundle conformance and interoperability tests for TSN. INCLUDES: TSN conformance (930-2425) and AVNU conformance (930-2531)

## **948-0062**

IXIA SFP TRANSCEIVER, AUTOMOTIVE ETHERNET, 1000BASE-T1, 100BASE-T1, 1GBPS/100MBPS - IEEE Compliant (948-0062)

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