

# Automotive Ethernet Transmitter Test Application

10 Mbps to 10 Gbps

The Keysight AE6000T Automotive Ethernet Transmitter Test solution provides you with an easy and accurate way to verify and debug the physical layer of your Automotive Ethernet designs.



# Table of Contents

Compliance Testing of Transmitters ..... 3

Outlining the Transmitter Specifications ..... 5

Applying Configurability and Guided Connections..... 8

Generating Pass/Fail Reports ..... 9

Minimum Requirements: Instruments and Accessories..... 11

Ordering Information Accessories..... 12

Configuration Guidelines..... 13

Example Order ..... 14

# Compliance Testing of Transmitters

Advanced Driver Assistance Systems (ADAS) connected cars and Autonomous Vehicles (AVs) are transforming commercial and passenger transportation. Every leap in performance demands more and faster data, and this is driving a transition to Automotive Ethernet for in-vehicle networks.

Unlike CAN, LIN, Automotive Ethernet demands rigorous compliance verification using test cases that cover transmitters (Tx), receivers (Rx), and harness/connector assemblies. The requirements include complex measurements that, until recently, have been uncommon in the auto industry: vector network analysis with S-parameters, bit error rate (BER) testing, and electrical compliance of high-speed digital signals.

To help you save time and effort, Keysight offers solutions that automate the testing and validation across Transmitter (Tx), Receiver (Rx), and the connections between Automotive Ethernet devices. Our engineers have invested thousands of hours in learning the standards and creating automated, repeatable compliance tests. These proven applications help you ensure proper test configuration and valid measurement results. Ultimately, you'll have greater confidence that your device is compliant.

The Keysight AE6910T/AE6920T Automotive Ethernet Transmitter Test Application lets you automatically execute physical-layer (PHY) electrical tests for transmitter compliance using IEEE and/or Open Alliance (OABR) specifications. In addition to the measurement data, the report provides a margin analysis that shows how closely your device passed or failed each test.

The AE6910T/AE6920T software performs various electrical tests required to meet the current Automotive Ethernet specifications in one installation. The application helps you execute a broad subset of the conformance tests performed with various Keysight equipment.

The AE6910T/AE6920T Automotive Ethernet Transmitter Test Application allows you to select the reference specification and the test plan depending on that specification. Currently, it supports the following data rates and standards:

- 10BASE-T1S, IEEE 802.3cg and OPEN Alliance TC14<sup>1</sup>
- 100BASE-T1<sup>2</sup>, IEEE 802.3bw and OPEN Alliance TC1<sup>1</sup>
- 100BASE-T1, OPEN Alliance TC8 ECU Layer 1
- 1000BASE-T1, IEEE 802.3bp and OPEN Alliance TC12<sup>1</sup>
- 1000BASE-T1, OPEN Alliance TC8 ECU layer 1
- 2.5/5/10GBASE-T1, IEEE 802.3ch and OPEN Alliance TC15<sup>1</sup>

Note: The software is installed and runs on a Keysight Infiniium oscilloscope and is available with a node-locked, transportable, floating, and USB dongle license type. Each license can be purchased with 6-, 12-, 24-, or 36-months of support. Please see the ordering information for additional details on software license types.

---

<sup>1</sup> The software does not have dropdown selection for all of the OA standards however the cross reference is very close between IEEE and OA.

<sup>2</sup> Also supports BroadR-Reach

## Overview of benefits

Using the AE6910T/AE6920T software greatly simplifies testing. The Automotive Ethernet electrical performance validation and conformance software offers several features to simplify the validation of Automotive Ethernet designs:

- Automatic configuration of all the required test equipment, reducing overall test time
- Wide range of tests for standards conformance of IEEE and OPEN Alliance test cases, saving the hassle of multiple installations and licenses while reducing cost.
- Trust the results, accurate and repeatable results with Keysight oscilloscopes.
- Be confident in the test setup, with setup instructions and calibration cues for all required test equipment.
- Detailed information on each test that ran in case you need to follow up and debug.
- Automated reporting in a comprehensive pass/fail HTML format with margin analysis

# Outlining the Transmitter Specifications

The AE6910T/AE6920T Automotive Ethernet Tx test software saves you time by setting the stage for automatic execution of electrical tests. Some of the difficulties of performing electrical tests for Automotive Ethernet are properly connecting to the oscilloscope, loading the proper setup files, and then analyzing the measured results by comparing them to limits published in the specification. The AE6910T/AE6920T software does much of this work for you.

The AE6910T/AE6920T software automatically configures the oscilloscope for each test. It provides an informative report with results that include margin analysis, indicating how close your product is to passing or failing the specification.

There are two governing standards bodies, IEEE and OPEN Alliance, and different data rates for conformance tests set by those bodies.

An oscilloscope is used as the primary testing tool for the above tests. Additional instruments are needed for distortion, MDI return loss, MDI mode conversion loss, and power spectral density (PSD) tests. The following tables identify those differences and provide an equipment recommendation. All tests require an oscilloscope, though a network analyzer will also be needed for the MDI return loss test and the MDI mode conversion loss test. An arbitrary waveform generator (or function generator) is required for transmitter distortion for 100 Mbps and 1 Gbps tests.

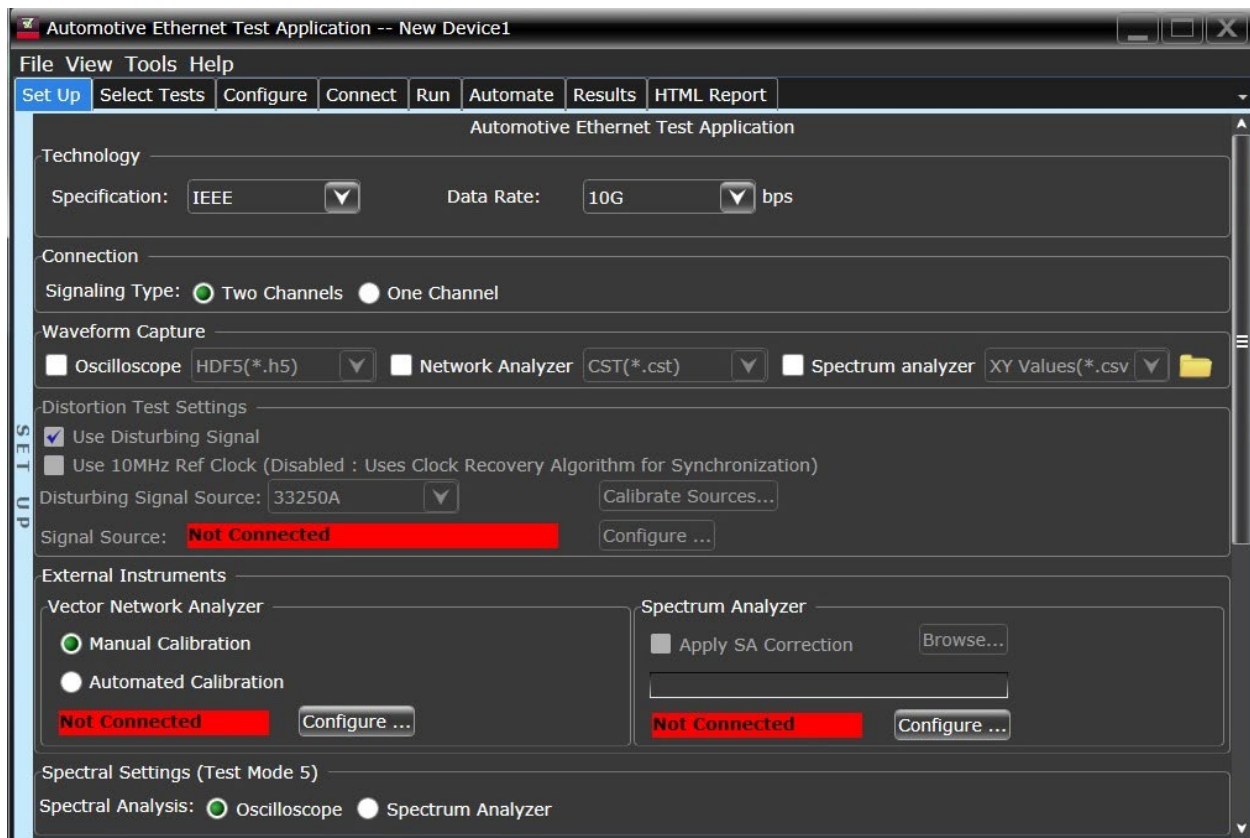
Data rate	Oscilloscope minimum bandwidth	Additional equipment required
10BASE-T1S	500 MHz	NA
100BASE-T1	1 GHz	VNA, AWG
1000BASE-T1	2 GHz	VNA, AWG
2.5GBASE-T1	4 GHz	VNA
5GBASE-T1	6 GHz	VNA
10GBASE-T1	13 GHz	VNA

There are some variations in test description naming across the different standards. To see a complete list of the measurements made by the test software, please look in the [MOI of the software](#). All these standards are accessible from one software application in the AE6910T/AE6920T.

## Saving time with the AE6910T/AE6920T software

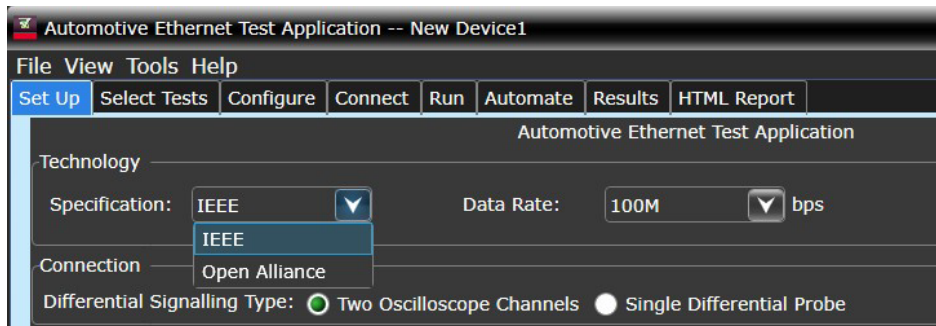
The AE6910T/AE6920T Automotive Ethernet Tx test application extends the ease-of-use advantages of Keysight's Infiniium oscilloscopes to testing Automotive Ethernet designs. The Keysight automated test engine quickly walks you through the steps required to select, set up, and perform the tests. You can then easily view the results.

The test selections available in the following steps are then filtered according to the choices made in the setup page. You can select a category of tests all at once or specify individual tests. You can save tests and configurations as project files and recall them later for quick testing or review of previous test results. Straightforward menus let you perform tests with a minimum number of mouse clicks.

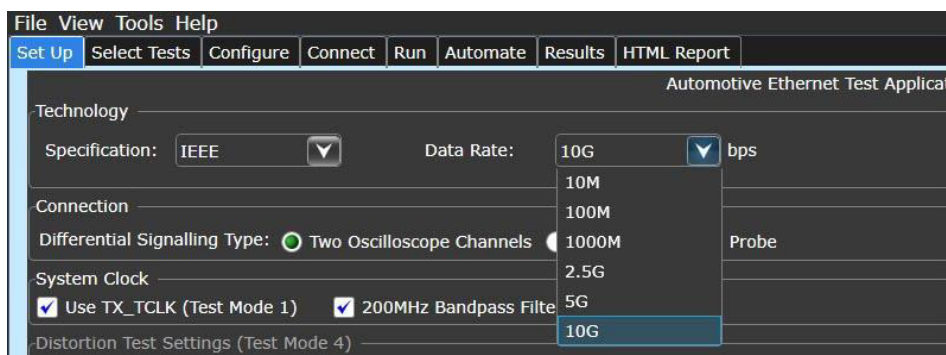


**Figure 1.** The clean interface allows you to select tests and create a test plan according to the selected specification.

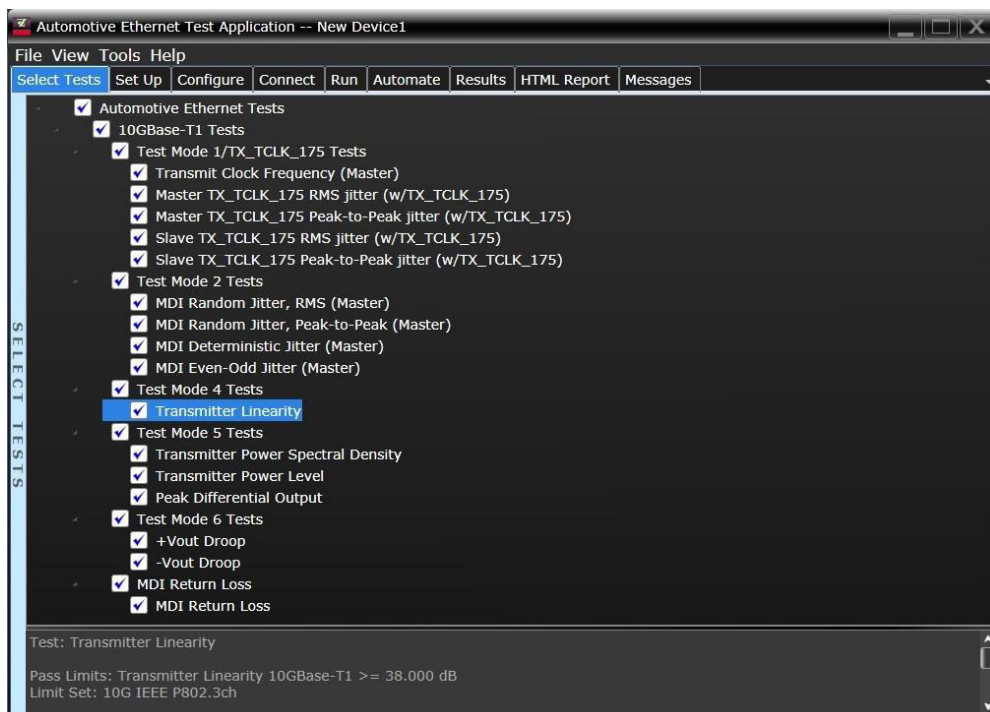
To select between the specifications and data rates, there are drop-down menus on the first two selections as shown below.



**Figure 2.** A drop-down menu to select which standard specification you want to test against.



**Figure 3.** A second drop-down menu allows you to select the data rate you are interested in testing.

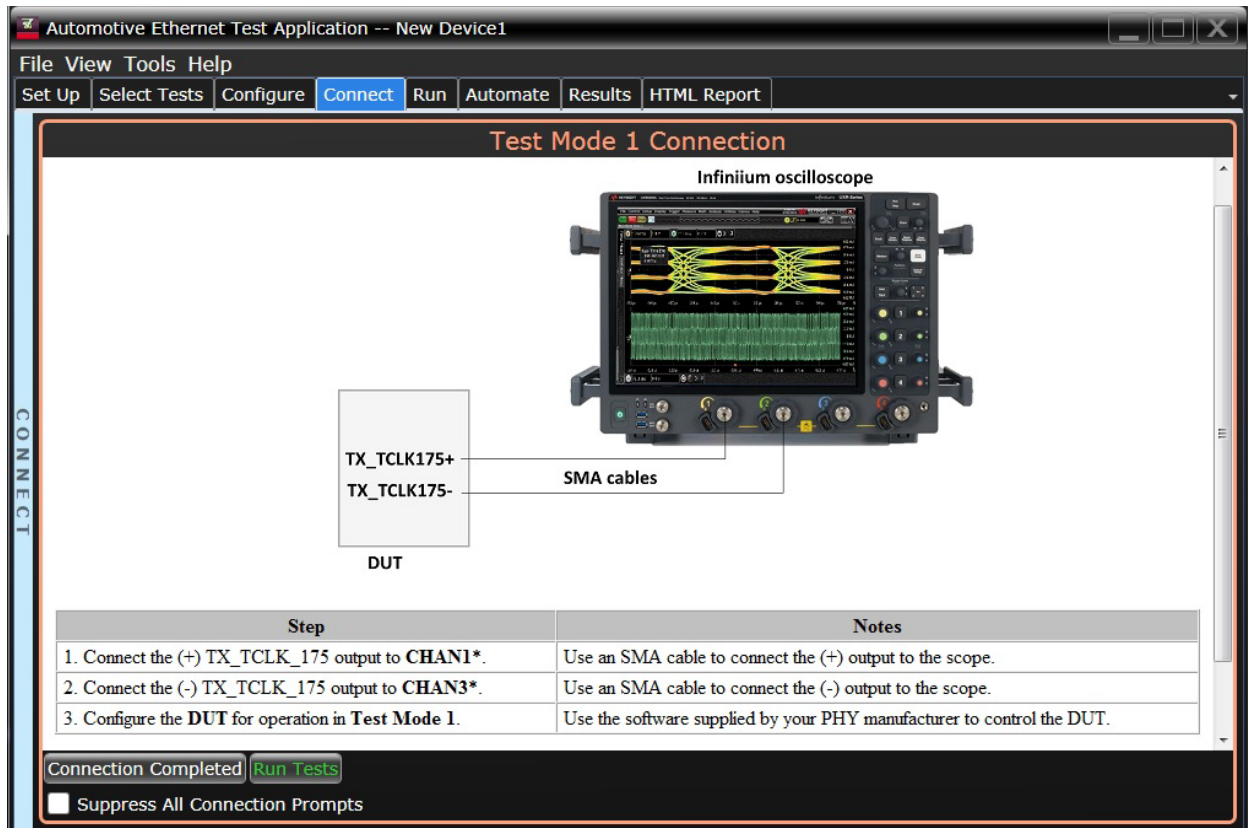


**Figure 4.** You can easily select individual tests or groups of tests with just a mouse-click.



# Applying Configurability and Guided Connections

The AE6910T/AE6920T software provides flexibility in your test setup. It guides you to make connection changes with hook-up diagrams when the specific tests require it. Test connections are clearly identified including additional hardware and cables. When you select multiple tests where the connections must be changed, the software prompts you with a message and appropriate connection diagrams. In addition, the connection setup provides step-by-step instructions along with example signals to help make sure you are getting the intended readings.

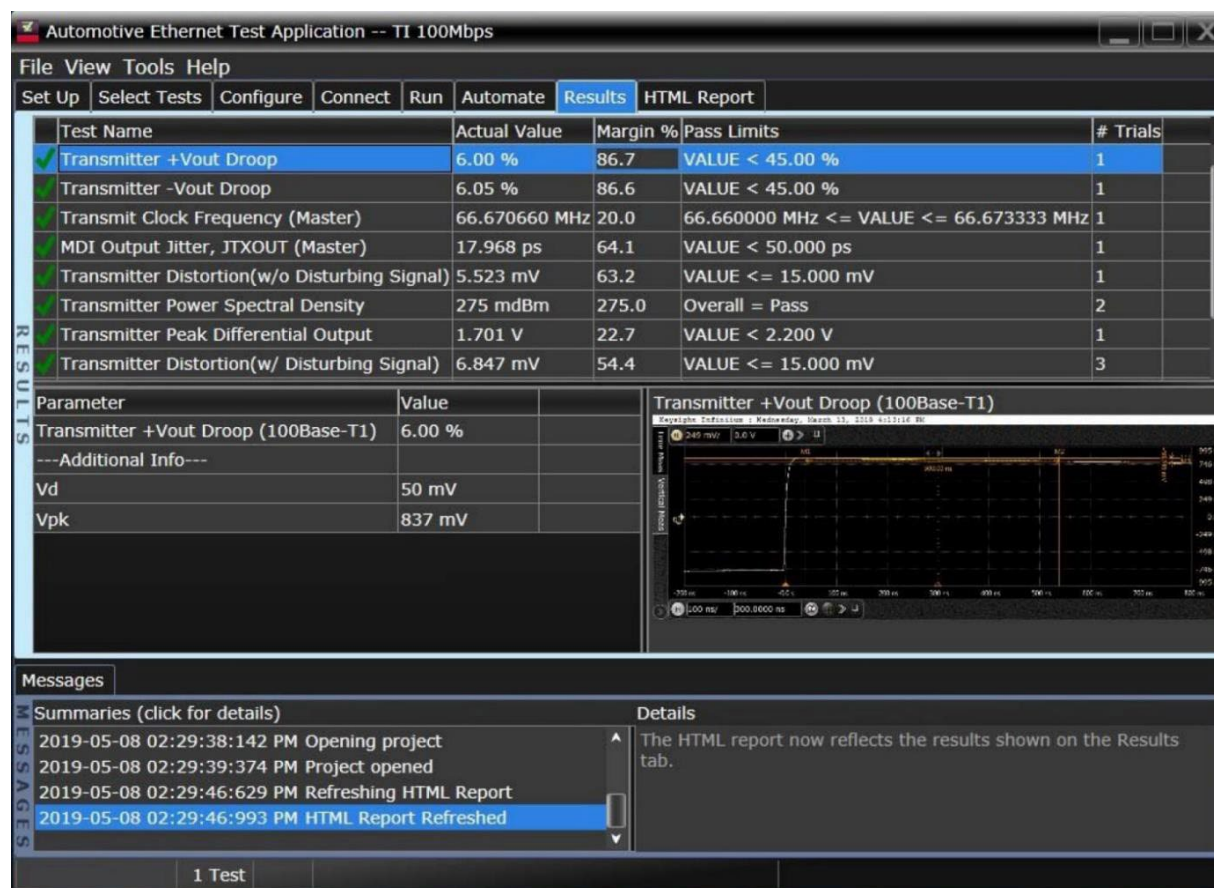


**Figure 5.** The software will guide you through setting up each test, including oscilloscope configuration and probing.



# Generating Pass/Fail Reports

In addition to giving you measurement results, the AE6910T/AE6920T software also provides a report format that shows you not only where your product passes or fails but also reports how close you are to the limits specified for a particular test. You can select the margin test report parameter, which means you can specify the level at which warnings are issued to alert you to electrical tests where your product is operating close to the official test limit defined by the specification. How close your device comes to passing or failing a test is indicated as a percentage in the margin field. A result highlighted in yellow or red indicates that your device has tripped the margin threshold level for a warning or failure.



**Figure 7.** The test software results screen shows a summary of the tests performed, pass/fail status, and the margin that it passed or failed at. Clicking on a specific test also shows the test specification and a measurement waveform, if appropriate.

# Test Report

## Summary of Results

Pass

Test Statistics		Margin Thresholds	
Failed	0	Warning	< 5 %
Passed	15	Conform	< 0 %
Total	15		

Pass	# Failed	# Trials	Test Name (click to jump)	Actual Value	Margin	Pass Limits
✓	0	1	MDI Random Jitter, RMS (Master)	830 fs	17.0 %	VALUE < 1.000 ps
✓	0	1	MDI Random Jitter, Peak-to-Peak (Master)	7.189 ps	28.9 %	VALUE < 10.000 ps
✓	0	1	MDI Deterministic Jitter (Master)	750 fs	91.7 %	VALUE < 9.000 ps
✓	0	1	MDI Even-Odd Jitter (Master)	730 fs	82.3 %	VALUE < 4.000 ps
✓	0	1	Transmitter Linearity	42.693 dB	12.4 %	VALUE ≥ 30.000 dB
✓	0	1	Transmitter Power Spectral Density	2.258 dBm/Hz	22.5 %	Overall = Pass
✓	0	1	Transmitter Power Level	45.9 mW	54.9 %	-1.0000 dBm ≤ VALUE ≤ 2.0000 dBm
✓	0	1	Transmitter Peak Differential Output	1.872 V	17.6 %	VALUE < 3.300 V
✓	0	1	Transmitter Output Swing	-20 mV	100.1 %	VALUE < 15.00 %
✓	0	1	Transmitter Output Swing	-440 mV	102.9 %	VALUE < 15.00 %
✓	0	1	Transmit Clock Frequency (Master)	175.770453 MHz	35.2 %	175.772461 MHz ≤ VALUE ≤ 175.790039 MHz
✓	0	1	Master TX_TCLK_175 RMS Jitter (w/TX_TCLK_175)	854 fs	14.6 %	VALUE < 1.000 ps
✓	0	1	Master TX_TCLK_175 Peak-to-Peak Jitter (w/TX_TCLK_175)	6.828 ps	31.7 %	VALUE < 10.000 ps
✓	0	1	Slave TX_TCLK_175 RMS Jitter (w/TX_TCLK_175)	846 fs	37.7 %	VALUE < 2.000 ps
✓	0	1	Slave TX_TCLK_175 Peak-to-Peak Jitter (w/TX_TCLK_175)	7.243 ps	63.8 %	VALUE < 20.000 ps

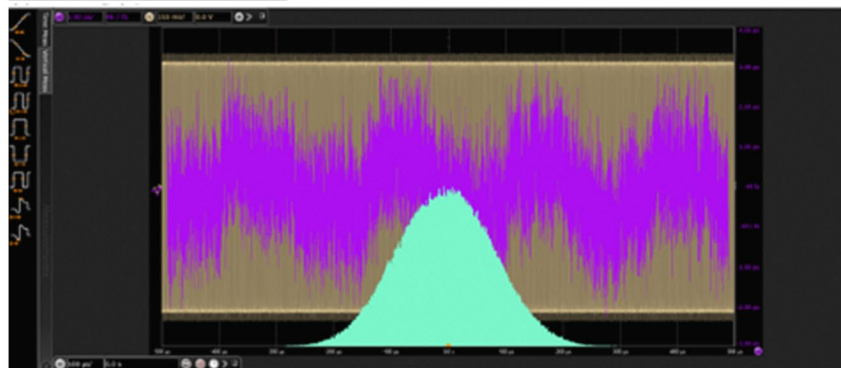
## Report Detail

✓ MDI Random Jitter, RMS (Master) Summary Next

IEEE Std 802.3ah™-2020 (Section 140.5.2.3.1)

The RMS (Root Mean Square) value of the MDI random jitter, relative to an unjittered reference shall be less than 1ps.  
Actual Value Measurement Name: MDI Random Jitter, RMS (Master) 100Base-T1  
Pass Limits: VALUE < 1.000 ps

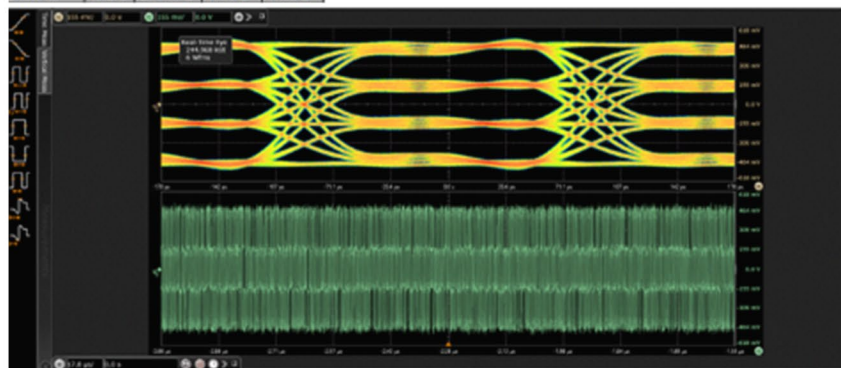
Actual Value	Margin	200MHz Bandpass Filter:
830 fs	17.0 %	ON



✓ Transmitter Linearity IEEE Std 802.3ah™-2020 (Section 140.5.2.2)

The transmitter SNOR distortion, shall exceed 30dB  
Actual Value Measurement Name: Transmitter Linearity 100Base-T1  
Pass Limits: VALUE ≥ 30.000 dB

Actual Value	Margin	Peak	Signs e	Signs n
42.693 dB	12.4 %	482.782 m	2.922 m	2.000 m



✓ Transmitter Power Spectral Density IEEE Std 802.3ah™-2020 (Section 140.5.2.4)

Test mode 5 (normal operation), the power spectral density (PSD) of the transmitter, shall be between the upper and lower masks specified in Equation (140-14) and Equation (140-15)  
f the IEEE802.3ah standard:  
Actual Value Measurement Name: Power Spectral Density (100Base-T1)  
Pass Limits: Overall = Pass

**Figure 8.** The test software HTML report documents your tests and indicates the pass/fail status, test specification range, measured values, and margin. If appropriate, additional details are available for each test, including the test limits, test description, and test results, including waveforms.

# Minimum Requirements: Instruments and Accessories

The AE6910T/AE6920T is software installed directly onto a Keysight Infiniium class oscilloscope. Additional hardware is required depending on the specification. The table below captures the specifications' minimum requirements and lists the equipment Keysight offers for that measurement type.

Test requirement	Min Instrument requirement	Supported Keysight models
Basic compliance tests	500 MHz oscilloscope, 2 channels (10BASE-T1S)	Infiniium EXR-series, MXR-series
	1 GHz oscilloscope, 2 channels (100BASE-T1)	
	2 GHz oscilloscope, 2 channels (1000BASE-T1)	
	4 GHz oscilloscope, 2 channels (2.5GBASE-T1)	
	6 GHz oscilloscope, 2 channels (5GBASE-T1)	
	13 GHz oscilloscope, 2 channels (10GBASE-T1)	Infiniium UXR
Transmitter distortion test	2-channel function generator with a minimum bandwidth of 11 MHz (100BASE-T1)	33512A/B, 33522A/B
	2-channel function generator with a minimum bandwidth of 125 MHz (1000BASE-T1)	33622A, 81150/60A
MDI return loss and mode conversion loss tests	Network analyzer (VNA) 2-port configuration and a calibration kit with the start and stop frequency range. <ul style="list-style-type: none"> <li>• 1 MHz - 66 MHz (100BASE-T1)</li> <li>• 2 MHz - 600 MHz (1000BASE-T1)</li> <li>• 1 MHz – 1 GHz (2.5GBASE-T1)</li> <li>• 1 MHz – 2 GHz (5GBASE-T1)</li> <li>• 1 MHz – 4 GHz (10GBASE-T1)</li> </ul>	P5000A/B <sup>3</sup> , P9382B <sup>4</sup> , E5071C <sup>4</sup> , E5080B <sup>4</sup> , PXI M9804A

## Notes:

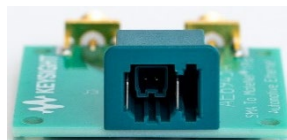
- 802.3cg for 10BASE-T1S does not require transmitter distortion tests, MDI return loss, or mode conversion loss tests.
- 802.3ch for 2.5/5/10GBASE-T1 does not require transmitter distortion tests

<sup>3</sup> The P5000B/ P9382B Series VNA supports host PCs with Thunderbolt 3 interface only. Check out the Streamline series VNA configuration guide with Keysight literature number 3121-1254EN for more details.

<sup>4</sup> Both E5071C & E5080B support differential measurement simulation (Sdd11 & Sdc11) with a fixture simulator option.

# Ordering Information Accessories

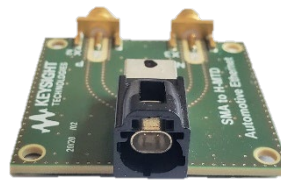
Model number	Description	Used for what purpose
AE6804A	SMA cable: SMA (m) -SMA (m) x 2	
AE6802A	Adapter: BNC (m) to SMA (f) x 2 <sup>5</sup>	
AE6941A	Automotive Ethernet test fixture AE6941A	
AE6942A <sup>6</sup>	SMA to Molex/Mini-50 adapter board AE6942A	Basic compliance setup
AE6943A <sup>7</sup>	SMA to MATEnet adapter board AE6943A	
AE6960A <sup>7</sup>	SMA to H-MTD adapter board AE6960A	
AE6965A <sup>7</sup>	H-MTD to 2.92 Y adapter AE6965A (jack to jack)	
AE6950A <sup>7</sup>	Frequency Divider Board AE6950A	Transmitter distortion test
AE6809A	BNC cable: BNC(m) to BNC(m) cable x 2	Connect to a function generator for distortion test (100/1000BASE-T1)
N7550A	RF Electronic calibration module, N7550A (ECal), DC-4 GHz, 2-Port	Calibration of a network analyzer for MDI return and mode conversion loss tests
85052B or 85052D	Mechanical calibration kit	
N4417AK20	Cable: N-type-N (m) to 3.5 mm (m) x2	Connect to a network analyzer E5080B for MDI return and mode conversion loss tests.
Y1740A-100	Cable 3.5 mm (m) to 3.5 mm (m)	Connect to network analyzer P5000A/B
AE6805A	SMA semi-rigid cable: 2.92mm (m) – 2.92mm (m) x2	In place of SMA cables for 2.5/5/10GBASE-T1 tests,
AE6808A	Filter for distortion test x 2	Required with 33622A for 1000BASE-T1 transmitter distortion test
AE6809A	Cable BNC (m) to BNC (m)	Transmitter distortion test



AE6943A SMA to MATEnet



AE6942A SMA to Molex/Mini-50



AE6960A SMA to H-MTD



AE6965A-HMK H-MTD to 2.92, jack to jack

<sup>5</sup> Two BNC to SMA adapters come with each oscilloscope, 2 additional are required for decode capability.

<sup>6</sup> IEEE 802.3bw does not specify a connector, users may have different means to connect D+ and D- signals to the oscilloscope. For DUTs that use Molex/Mini50, MATEnet or H-MTD connections, Keysight's adapter boards can be used with the automotive Ethernet test fixture AE6941A and/or directly with SMA cables. For MultiGbase-T1 Tx testing, AE6965A H-MTD Y adapter and a pair of SMA cable can be used instead of using the AE6960A with a H-MTD cable and a SMA cable pair.

<sup>7</sup> The frequency divider board is required for the IEEE standard but there is a software algorithm available in the AE6910T/AE6920T if your Tx CLK is either not pinned out or you want a minimum configuration.

# Configuration Guidelines

Notes	Description	Part number	Test data rate			
			10BASE-T1S	100BASE-T1	1000BASE-T1	2.5, 5, 10 GBASE-T1
Required Choose 1	Automotive Ethernet Transmitter Application 10M-5G	AE6910T	x	x	x	Up to 5 Gbps
	Automotive Ethernet Transmitter Application 10M-10G	AE6920T	x	x	x	x
Optional	Automotive Ethernet Protocol Trigger & Decode 100/1000M	D9020AUTP		x	x	
Optional <sup>8</sup>	Frequency divider board	AE6950A		x	x	
Required <sup>9</sup>	Pulse Amplitude Modulation PAM-N Analysis Software for Infiniium MXR	D9010PAMA				x
Required <sup>10</sup>	Pulse Amplitude Modulation PAM-N Analysis Software for Infiniium UXR, V-series	D9020PAMA				x
Required	Automotive Ethernet compliance test fixture	AE6941A		x	x	
Adapter of choice, Qty 2 <sup>10</sup>	SMA to Molex/Mini-50 adapter board	AE6942A	x	x	x	
	SMA to MATEnet adapter board	AE6943A	x	x	x	
	SMA to H-MTD adapter board	AE6960A		x	x	x
	SMA to H-MTD	AE6965A				x
Qty 2 <sup>11</sup> , choose 1	SMA cable SMA (m) – SMA (m)	AE6804A		x	x	x
	SMA semi-rigid cable (use for multigig tests)	AE6805A				x
Qty 2 <sup>12</sup>	BNC to SMA adapter	AE6802A		x	x	x
Qty 2 depending on VNA	Cable, type-N (m) to 3.5 mm (m) <sup>13</sup> for use with E5080B	N4417AK20		x	x	x
	Cable 3.5 mm (m) to 3.5 mm (m) for use with USB VNA	Y1740A-100		x	x	x
Qty 2	Low Pass Filter, use with 33622A 1000BASE-T1 distortion test	AE6808A			x	
Qty 2	Cable BNC (m) to BNC (m) cable	AE6809A		x	x	x
Required, choose 1	ECal 2 ports and connectors used to calibrate VNA	N7550A		x	x	x
	Mechanical calibration kit for VNA	85052B or 85052D		x	x	x
Required <sup>14</sup>	MXR-Series oscilloscope 2 GHz, 4 analog, 16 digital channels	MXR204B	x	x	x	
	UXR-Series oscilloscope 13 GHz, 4 Channels	UXR0134B		x	x	x
	MXR-Series oscilloscope 6 GHz, 4 analog, 16 digital channels	MXR604B	x	x	x	Up to 5Gbps
	UXR-Series oscilloscope 33 GHz, 4 Channels	UXR0334B		x	x	x
Distortion test, choose 1	33622A Waveform/ Function Generator, 2-channel, 120 Hz <sup>15</sup>	33622A		x	x	
	81160A Pulse Function Arbitrary Noise Generator, 2 channels, 500 MHz sine waveform output	81160A		x	x	
MDI return loss/mode conversion loss Choose 1	E5080B Vector network analyzer, 2-port test set, 9 kHz to 4.5 GHz without bias tees	E5080B opt 240,181,182		x	x	x
	Vector Network analyzer Thunderbolt 2-port 9 kHz to 4.5 GHz	P9370B		x	x	x

<sup>8</sup> A frequency divider board is still required for the IEEE standard however there is a software algorithm available in the AE6910T/AE6920T if Tx CLK is either not pinned out or are looking for a minimum configuration.

<sup>9</sup> PAM-n analysis option is required to run the linearity SNDR test.

<sup>10</sup> Order 2 available adapter boards of your choice for compliance, order 2 additional for protocol decoding.

<sup>11</sup> 2 SMA cables for compliance are required and 2 additional are required for decode capability.

<sup>12</sup> Two BNC to SMA adapters come with each oscilloscope, 2 additional are required for decode capability.

<sup>13</sup> Alternatively, an SMA to N-type adapter could be used such as the 1250 -1250.

<sup>14</sup> An oscilloscope is required minimum bandwidth is recommended on page 14. Those listed here are examples and suggested bandwidth for each covered data rates.

<sup>15</sup> Order AE6900T-108 filter for distortion test on 1000BASE-T1 DUTs.

# Example Order

## Full compliance of 1000BASE-T1

Quantity	Part number to order	Description
1	AE6910T	Automotive Ethernet Tx compliance test software 10M – 5G
1	AE6941A	Automotive Ethernet test fixture
2	AE6942A AE6943A AE6960A	Adapter board of choice
2	AE6804A	SMA cable
2	AE6809A	BNC (m) to BNC (m) cable, used for disturbing test
1	MXR204B	MXR 2 GHz oscilloscope
1	33622A	Function generator used for transmitter distortion tests
2	AE6808A	Filter used with 33622A for 1GBASE-T1 distortion test
1	P5000B VNA with opt 200	Used for MDI return loss measurements
1	85052B	Mechanical calibration kit, used to calibrate VNA
2	Y1740-100	3.5 mm (m) to 3.5 mm (m) cable to connect to VNA

## Full compliance of 10GBASE-T1

Quantity	Stand alone	Description
1	AE6920T	Automotive Ethernet Tx compliance test software 10M – 10G
1	D9020PAMA	Pulse Amplitude Modulation PAM-N Analysis Software for UXR-Series Oscilloscopes
2	AE6960A or AE6965A-HMK	H-MTD Adapter
2	AE6805A	SMA semi-rigid cable
1	UXR0134B	UXR 13 GHz oscilloscope
1	E5080B opt 240,181,182	Vector network analyzer with option TDR, 4-port test set, 9 kHz to 4.5 GHz without bias tees
1	N7550A Ecal	Used to calibrate ENA
2	N4417AK20	Cable: N-type-N (m) to 3.5 mm (m) connects to ENA

## Download the latest hardware instrument firmware versions

---

Keysight Infiniium Series oscilloscopes

- [MXR-Series](#)
- [UXR-Series](#)

Other [www.keysight.com/find/scope-apps-sw](http://www.keysight.com/find/scope-apps-sw)

---

Keysight E5080B ENA analyzer [E5080B Firmware](#)

---

Keysight P5000 ENA [P5000 Firmware](#)

For additional information, please go to: <http://www.keysight.com/find/AE6000T>



Keysight enables innovators to push the boundaries of engineering by quickly solving design, emulation, and test challenges to create the best product experiences. Start your innovation journey at [www.keysight.com](http://www.keysight.com).

This information is subject to change without notice. © Keysight Technologies, 2020 - 2024, Published in USA, February 13, 2024, 5992-2672EN