# D9010EBZC 10GBASE-T Ethernet Test Application

KEYSIGHT

METHODS OF IMPLEMENTATION

# Notices



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**WARNING**

A WARNING notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

# Contents

# 1 Overview



KEYSIGHT TECHNOLOGIES

## 10GBASE-T Ethernet Automated Testing—At a Glance

The Keysight D9010EBZC 10GBASE-T Ethernet Test Application helps you verify that the transmitter device under test (DUT) conforms to the specifications with the Keysight Infiniium digital storage oscilloscopes. The Keysight D9010EBZC 10GBASE-T Ethernet Test Application:

- Lets you select individual or multiple tests to run.
- Lets you identify the device being tested and its configuration.
- Shows you how to make oscilloscope, spectrum analyzer and vector network analyzer connections to the device under test.
- Automatically checks for proper oscilloscope configuration.
- Automatically sets up the oscilloscope for each test.
- Provides detailed information for each test that has been run and lets you specify the thresholds at which marginal or critical warnings appear.
- Creates a printable HTML report of the tests that have been run.

**NOTE**

**The tests performed by the Keysight D9010EBZC 10GBASE-T Ethernet Test Application are intended to provide a quick check of the electrical health of the DUT, which is designed based on the 10GBase-T or MGBase-T technology. This testing is not a replacement for an exhaustive test validation plan.**

Compliance testing measurements for devices using the 10GBase-T and NBase-T technologies are described in the *IEEE 802.3-2018 Standard.* For devices using the MGBase-T technology, the compliance testing measurements are described in the Broadcom MGBase-T Ethernet Specification. For more information on 10GBase-T and NBase-T technology, see the IEEE 802 Standards web site at www.ieee802.org and for the MGBase-T technology at Broadcom website at www.broadcom.com.

## Required Equipment and Software

In order to run the 10GBASE-T Ethernet automated tests, you need the following equipment and software:

### Hardware

- Use one of the following Oscilloscope models. Refer to www.keysight.com for the respective bandwidth ranges.
  - 90000 Series Infiniium Digital Storage Oscilloscope (DSO). Keysight recommends using Oscilloscopes with bandwidth of 4 GHz or higher.
  - Keysight UXR Oscilloscopes
  - Keysight MXR Oscilloscopes
- Spectrum Analyzer with the minimum frequency range upper limit of 3 GHz (MXA, EXA, PSA or ESA series).
- Vector Network Analyzer with usable frequency range of 1 MHz to 500 MHz (875x, 439x, E506x/7x and N5230A series).
- Balun with 3 GHz bandwidth.
- U7237A 10GBase-T Transmitter test fixture.
- SMA cable (24" or shorter).
- SMP to SMA cables (provided with U7237A 10GBase-T Transmitter test fixture).
- Keyboard, qty = 1, (provided with the Keysight Infiniium oscilloscope)
- Mouse, qty = 1, (provided with the Keysight Infiniium oscilloscope)
- Keysight also recommends using a second monitor to view the test application.

### Software

- The minimum version of Infiniium Oscilloscope Software (see the Keysight D9010EBZC 10GBASE-T Ethernet Test Application Release Notes)
- Keysight D9010EBZC 10GBASE-T Ethernet Test Application software

### Licensing information

Refer to the *Data Sheet* pertaining to 10GBASE-T Ethernet Test Application to know about the licenses you must install along with other optional licenses. Visit "http://www.keysight.com/find/D9010EBZC" and in the web page's **Document Library** tab, you may view the associated Data Sheet.

To procure a license, you require the Host ID information that is displayed in the Keysight License Manager application installed on the same machine where you wish to install the license.

The licensing format for Keysight License Manager 6 differs from its predecessors. See "Installing the License Key" on page 13 to see the difference in installing a license key using either of the applications on your machine.

## In This Book

This manual describes the tests that are performed by the Keysight D9010EBZC 10GBASE-T Ethernet Test Application in more detail; it contains information from (and refers to) the *IEEE 802.3-2018 Standard* for the 10GBase-T and NBase-T tests and also information from (and refers to) the Broadcom MGBase-T Ethernet Specifications for MGBase-T tests.

- Chapter 2, "Installing the Test Application and Licenses" shows how to install the automated test application software and licenses (if it was purchased separately).
- Chapter 3, "Preparing to Take Measurements" shows how to start the 10GBase-T Compliance Test Application and gives a brief overview of the required preparation and how the application is used.
- Chapter 4, "U7237A 10GBase-T Transmitter Test Fixtures" describes the U7237A 10GBase-T transmitter test fixture in detail.
- Chapter 5, "Transmitter Timing Jitter (MASTER) Test" contains information on the transmitter timing jitter MASTER test as specified in clause 55.5.3.3 of the *IEEE 802.3-2018 Standard*.
- Chapter 6, "Transmit Clock Frequency Test" contains information on the transmit clock frequency test as specified in clause 55.5.3.5 of the *IEEE 802.3-2018 Standard* and the *Transmit Clock Frequency* section of the *MGBase-T Ethernet Specification*.
- Chapter 7, "Maximum Output Droop Test" contains information on the positive and negative droop test as specified in clause 55.5.3.1 of the *IEEE 802.3-2018 Standard*.
- Chapter 8, "Transmitter Power Spectral Density Test" contains information on the power spectral density test as specified in clause 55.5.3.4 of the *IEEE 802.3-2018 Standard* and the *Transmitter Power Spectral Density* section of the *MGBase-T Ethernet Specification*.
- Chapter 9, "Power Level Test" contains information on the power level test as specified in clause 55.5.3.4 of the *IEEE 802.3-2018 Standard*.
- Chapter 10, "Transmitter Linearity Tests" contains information on the transmitter linearity tests as specified in clause 55.5.3.2 of the *IEEE 802.3-2018 Standard*.
- Chapter 11, "Transmitter Nonlinear Distortion Tests" contains information on the Transmitter Nonlinear Distortion tests as specified in clause 126.5.3.3 of the *IEEE P802.3bz/D2.1 Standard*.
- Chapter 12, "MDI Return Loss Test" contains information on the MDI return loss test as specified in clauses 55.8.2.1 and 126.8.2.2 of the *IEEE 802.3-2018 Standard*.
- Chapter 13, "Transmitter Timing Jitter (SLAVE) Test" contains information on the transmitter timing jitter SLAVE test as specified in clause 55.5.3.3 of the *IEEE 802.3-2018 Standard*.

### See Also

The Keysight D9010EBZC 10GBASE-T Ethernet Test Application's Online Help, which describes:

- Starting the 10GBASE-T Ethernet Test Application
- Creating or Opening a Test Project
- Setting Up the Test Environment
- Selecting Tests
- Configuring Tests
- Verifying Physical Connections
- Running Tests
- Configuring Automation in the Test Application
- Viewing Results
- Viewing HTML Test Report
- Exiting the Test Application
- Additional Settings in the Test App

# 2 Installing the Test Application and Licenses



If you purchased the D9010EBZC 10GBASE-T Ethernet Test Application separate from your Infiniium oscilloscope, you must install the software and license key.

## Installing the Test Application

1 Make sure you have the minimum version of Infiniium Oscilloscope software (see the D9010EBZC release notes). To ensure that you have the minimum version, select **Help > About Infiniium...** from the main menu.

2 To obtain the 10GBASE-T Ethernet Test Application, go to Keysight website: "http://www.keysight.com/find/D9010EBZC".

3 In the web page's **Free Trials** tab, click the **Details and Download** button to view instructions for downloading and installing the application software.

# Installing the License Key

To procure a license, you require the Host ID information that is displayed in the Keysight License Manager application installed on the same machine where you wish to install the license.

## Using Keysight License Manager 5

To view and copy the Host ID from Keysight License Manager 5:

1 Launch Keysight License Manager on your machine, where you wish to run the Test Application and its features.

2 Copy the Host ID that appears on the top pane of the application. Note that x indicates numeric values.

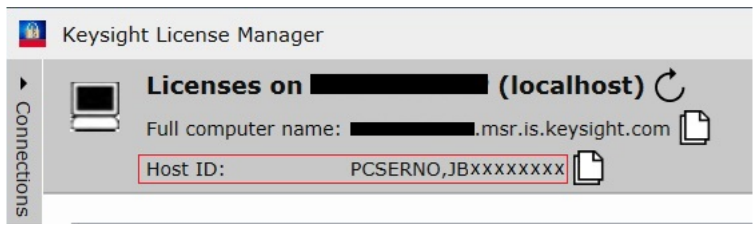


Figure 1 Viewing the Host ID information in Keysight License Manager 5

To install one of the procured licenses using Keysight License Manager 5 application,

1 Save the license files on the machine, where you wish to run the Test Application and its features.

2 Launch Keysight License Manager.

3 From the configuration menu, use one of the options to install each license file.

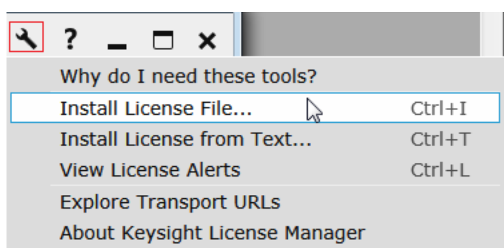


Figure 2 Configuration menu options to install licenses on Keysight License Manager 5

For more information regarding installation of procured licenses on Keysight License Manager 5, refer to Keysight License Manager 5 Supporting Documentation.

## Using Keysight License Manager 6

To view and copy the Host ID from Keysight License Manager 6:

1 Launch Keysight License Manager 6 on your machine, where you wish to run the Test Application and its features.

2 Copy the Host ID, which is the first set of alphanumeric value (as highlighted in Figure 3) that appears in the Environment tab of the application. Note that x indicates numeric values.

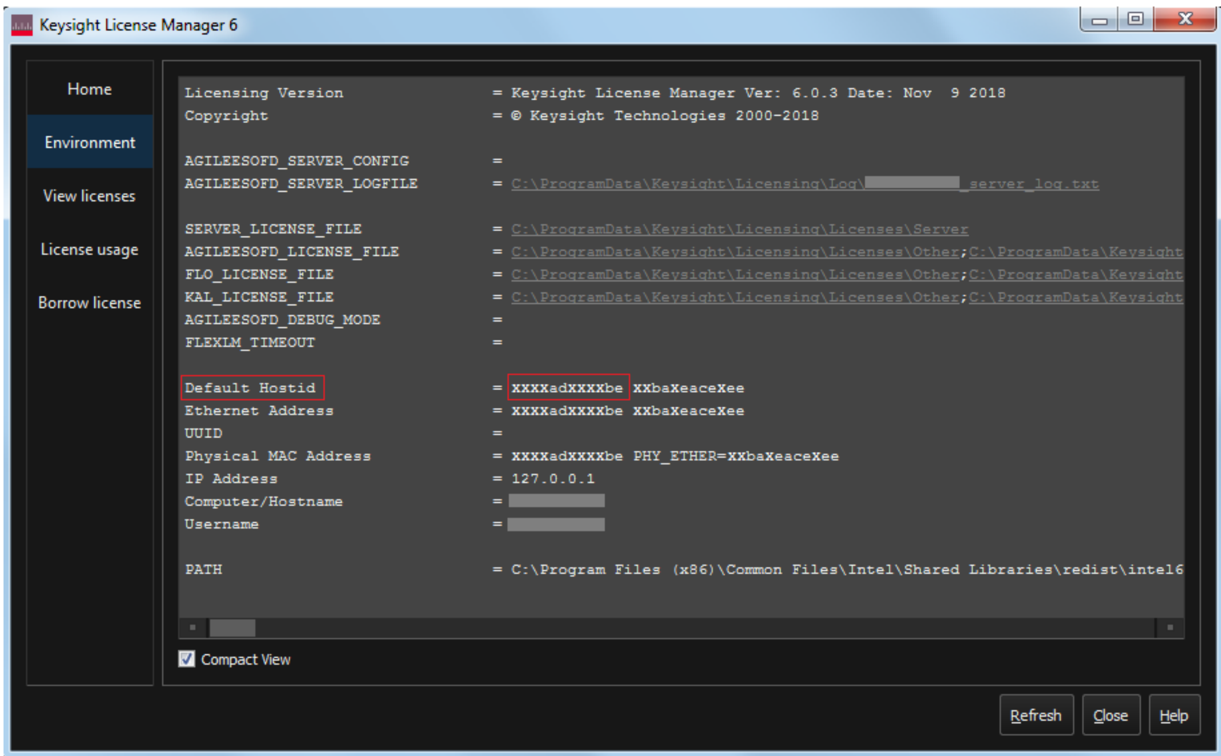


Figure 3 Viewing the Host ID information in Keysight License Manager 6

To install one of the procured licenses using Keysight License Manager 6 application,

1 Save the license files on the machine, where you wish to run the Test Application and its features.
2 Launch Keysight License Manager 6.
3 From the Home tab, use one of the options to install each license file.

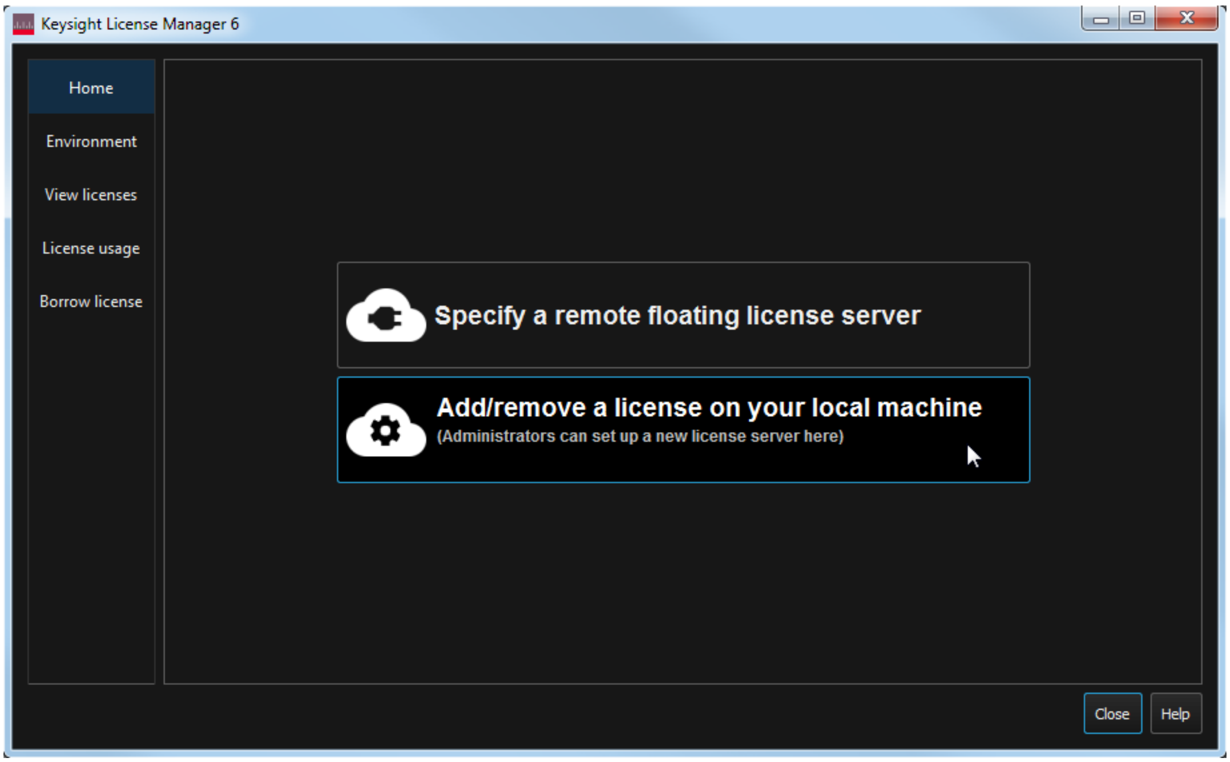


Figure 4 Home menu options to install licenses on Keysight License Manager 6

For more information regarding installation of procured licenses on Keysight License Manager 6, refer to Keysight License Manager 6 Supporting Documentation.

# 3 Preparing to Take Measurements



Before running the automated tests, you should calibrate the oscilloscope and probe. No test fixture is required for this application. After the oscilloscope and probe have been calibrated, you are ready to start the 10GBASE-T Ethernet Test Application and perform the measurements.

## Calibrating the Oscilloscope

If you have not already calibrated the oscilloscope, refer to the *User Guide* for the respective Oscilloscope you are using.

**NOTE** If the ambient temperature changes more than 5 degrees Celsius from the calibration temperature, internal calibration should be performed again. The delta between the calibration temperature and the present operating temperature is shown in the **Utilities > Calibration** menu.

**NOTE** If you switch cables between channels or other Oscilloscopes, it is necessary to perform cable and probe calibration again. Keysight recommends that, once calibration is performed, you label the cables with the channel on which they were calibrated.

## Starting the 10GBASE-T Ethernet Test Application

1 Ensure that the 10GBASE-T Ethernet Device Under Test (DUT) is operating and set to desired test modes. To start the 10GBASE-T Ethernet Test Application: From the Infiniium Oscilloscope's main menu, select **Analyze > Automated Test Apps > D9010EBZC 10GBASE-T Ethernet Test App**.

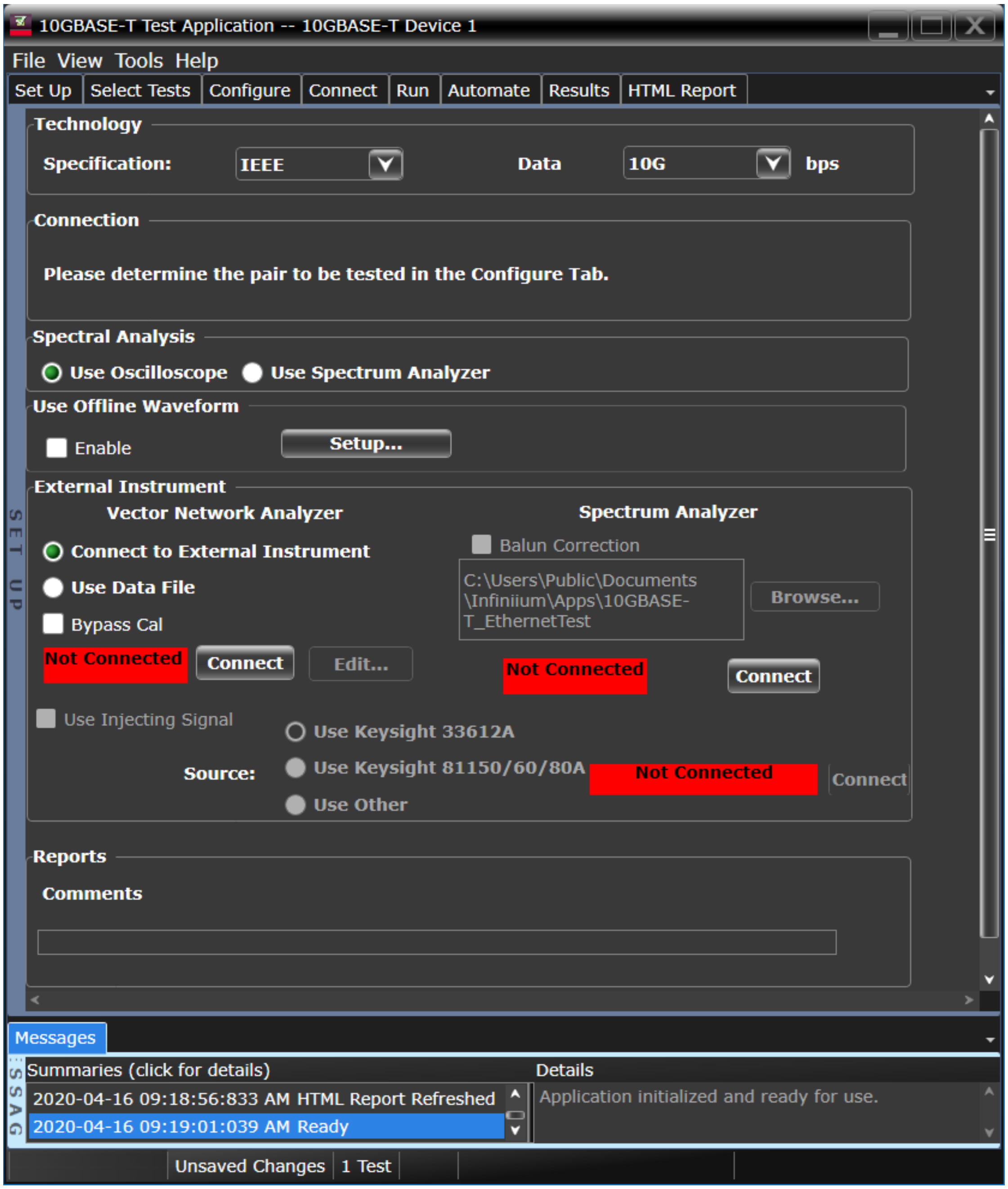


Figure 5 10GBASE-T Ethernet Test Application Main Window

To understand the functionality of the various features in the user interface of the Test Application, refer to the *Keysight D9010EBZC 10GBASE-T Ethernet Test Application Online Help* available in the Help menu.

The task flow pane and the tabs in the main pane show the steps you take in running the automated tests:

| | |
|---|---|
| **Set Up** | Lets you identify and set up the test environment, including information about the device under test. The Test App includes relevant information in the final HTML report. |
| **Select Tests** | Lets you select the tests you want to run. The tests are organized hierarchically so you can select all tests in a group. After tests are run, status indicators show which tests have passed, failed, or not been run, and there are indicators for the test groups. |
| **Configure** | Lets you configure test parameters (for example, channels used in test, voltage levels, etc.). |
| **Connect** | Shows you how to connect the oscilloscope to the device under test for the tests that are to be run. |
| **Run** | Starts the automated tests. If the connections to the device under test need to be changed while multiple tests are running, the tests pause, show you how to change the connection, and wait for you to confirm that the connections have been changed before continuing. |
| **Automate** | Lets you construct scripts of commands that drive execution of the application. |
| **Results** | Contains more detailed information about the tests that have been run. You can change the thresholds at which marginal or critical warnings appear. |
| **HTML Report** | Shows a compliance test report that can be printed. |

**NOTE** In the **Configure** tab, the values for all such Configuration parameters that are Oscilloscope-dependent, will correspond to the Oscilloscope Model (DSOs, MXRs, or UXRs), where you are running the Test Application.

## Connections for Compliance Tests

To run tests using the 10GBASE-T Ethernet Test Application, you must make proper connections between the Oscilloscope, DUT and if needed, any external device (such as Vector Network Analyzer or Spectrum Analyzer). Once you select the tests that you want to run, refer to the **Connect** tab in the 10GBASE-T Ethernet Test Application for connection instructions and the connection diagram, similar to the one shown in Figure 6.

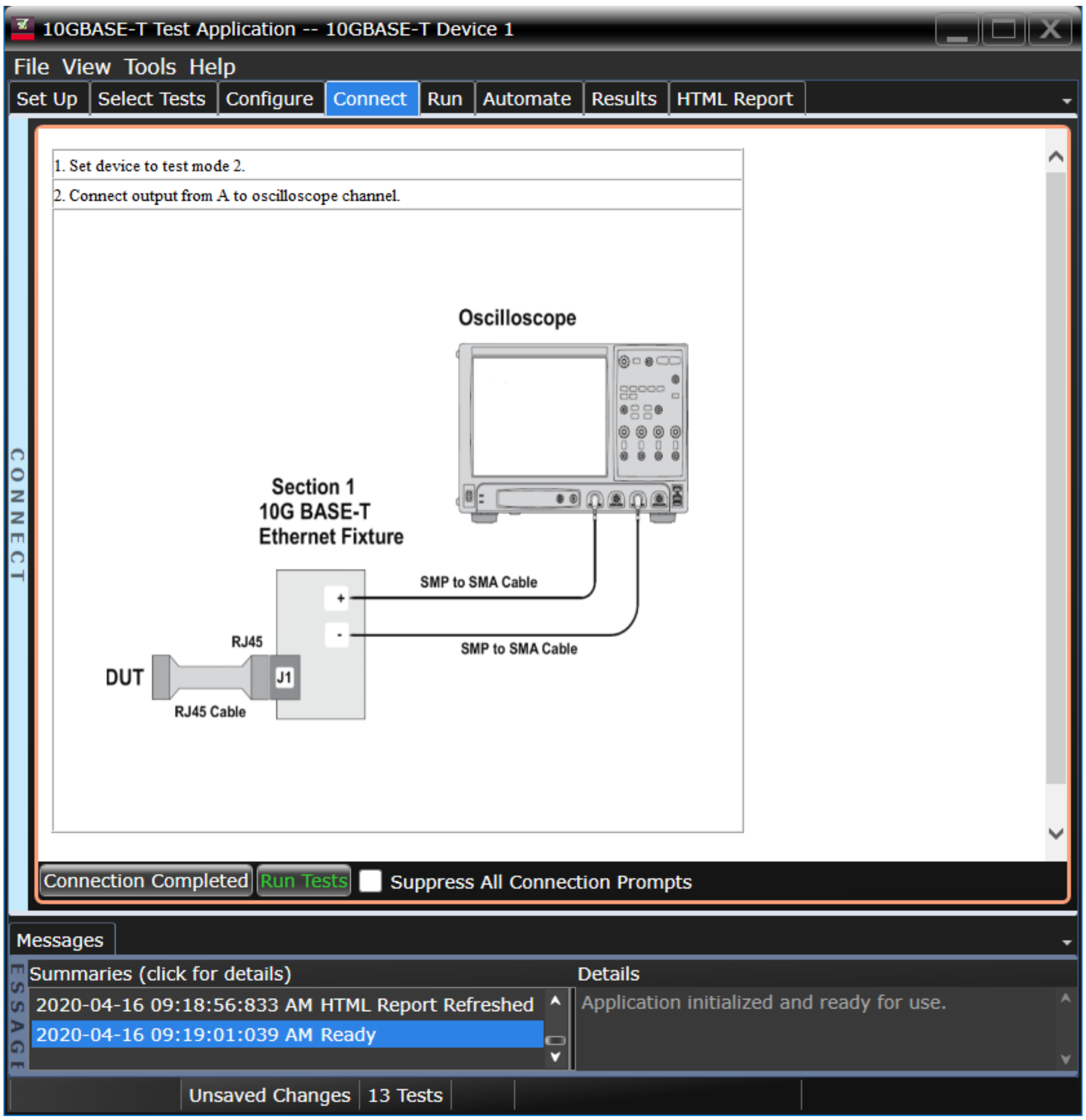


Figure 6 Physical connection diagram and instructions for compliance tests

# 4 U7237A 10GBase-T Transmitter Test Fixtures



The U7237A 10GBase-T transmitter test fixtures are required to perform the 10GBase-T Compliance test measurements.

## U7237A 10GBase-T Transmitter Test Fixture Description

The U7237A 10GBase-T Transmitter Test Fixture is required to perform the measurement with the Keysight D9010EBZC 10GBASE-T Ethernet Test Application. The fixture helps you to easily access the 10GBase-T test signals or MGBase-T test signals.

The fixture has three sections: Section 1, Section 2 and Section 3.

Section 1 of the U7237A 10GBase-T transmitter test fixture is required for the following tests:

- Transmitter Timing Jitter (MASTER) Test
- Transmit Clock Frequency Test
- Maximum Output Droop Test
- Transmitter Power Spectral Density Test
- Power Level Test
- Transmitter Linearity Tests
- MDI Return Loss Test

Section 2 of the fixture is required for the following test:

- Transmitter Timing Jitter (SLAVE) Test

Section 3 of the fixture is required for calibration during the MDI Return Loss Test.

Figure 7, Figure 8 and Figure 9 shows the U7237A 10GBase-T Transmitter Test Fixtures. The U7237A 10GBase-T transmitter test fixture is shipped to you as one piece of board with 3 sections, as shown in Figure 7. The board has a V-cut break-out tab that allows you to easily separate the board into two pieces.

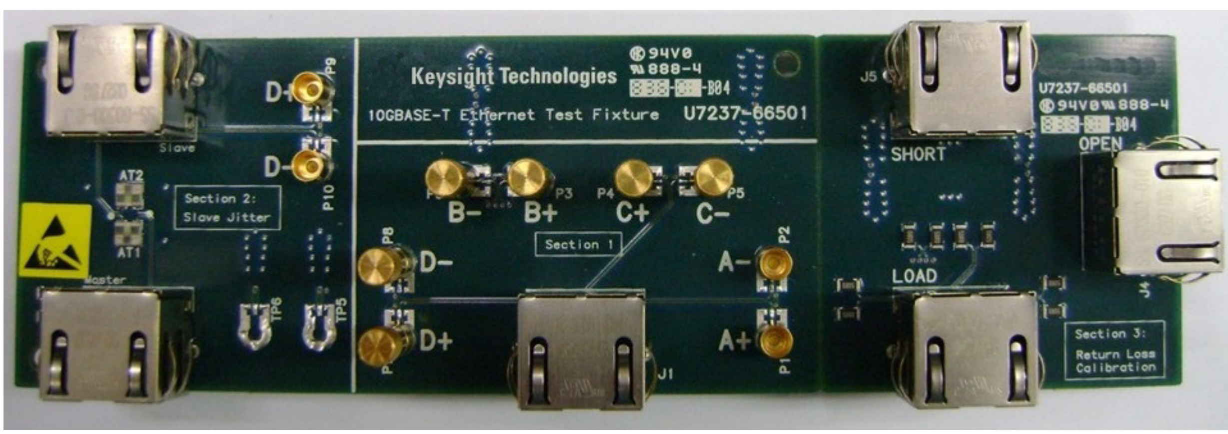


Figure 7 Complete U7237A 10GBase-T Transmitter Test Fixture Board

The bigger piece of board, as shown in Figure 8 has Section 1 and Section 2. This sections are required to perform the conformance tests. Whereas, the smaller board which has Section 3, as shown in Figure 9 is required to calibrate the Vector Network Analyzer.

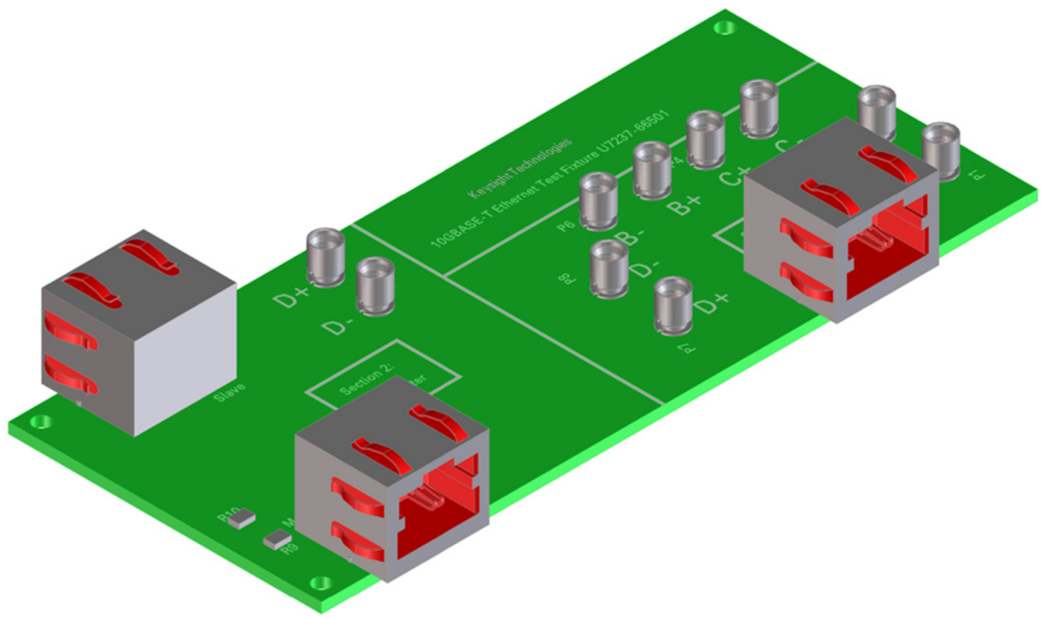


Figure 8 Section 1 and Section 2 of the U7237A 10GBase-T Transmitter Test Fixture

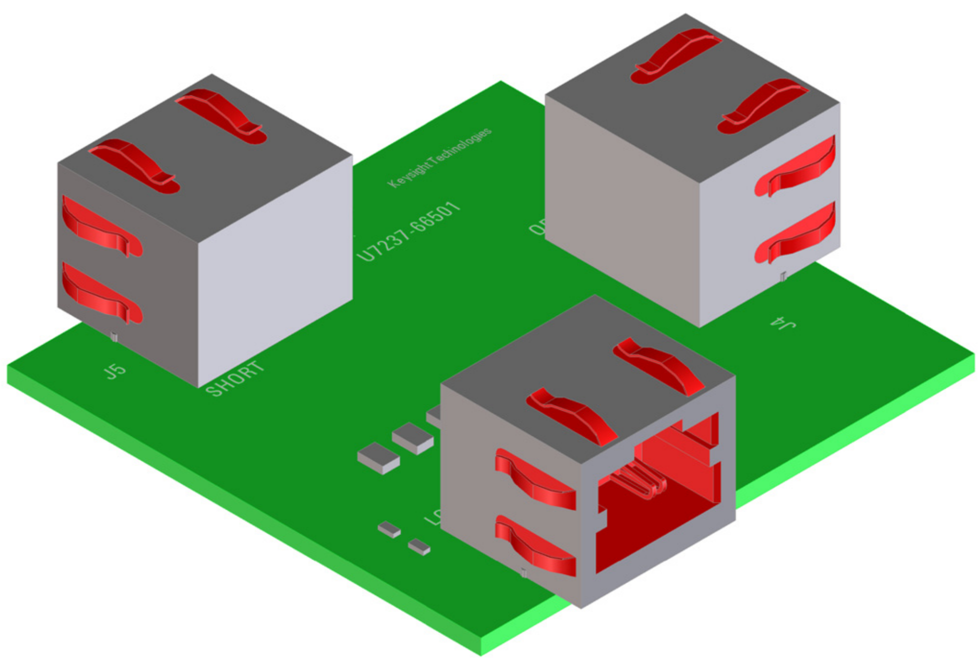


Figure 9 Section 3 of the U7237A 10GBase-T Transmitter Test Fixture

## Fixture and Accessories

The complete set of 10GBase-T transmitter test fixture contains the following items:

| Part Number | Description | Quantity |
| --- | --- | --- |
| U7237-66501 | 10GBase-T Test Fixture | 1 unit |
| 1250-3553* | 50 ohm RF SMP female straight connector | 6 units |
| N4235-61602 | 16 inches phase matched SMP female/SMA male cable pair | 2 units |
| U7237-61601 | 8 inches 10GBase-T shielded patch cord | 2 units |
| 0955-2095 | Precision instrumentation Balun 300 KHz to 3 GHz | 1 unit |

* It is always recommended to mate and de-mate connectors straight up. However, this connector is capable of mating at a +/- 0.020" radial tolerance. In handling this connector, one should not hold or squeeze it on the interface side. Always hold it on the knurled end.

## Dimension

The dimension of the U7237A test fixture board is as follows:

PCB board height = 1.89 inches

PCB board width = 6.30 inches

PCB board thickness = 0.063 inches

## Test Modes

The test modes are required for testing the transmitter waveform, transmitter distortion, transmitter jitter, transmitter droop and BER testing:

- Test Mode 1 is a mode provided to enable the timing jitter testing on a SLAVE transmitter.
- Test Mode 2 is for transmitter jitter testing when the transmitter is in the MASTER timing mode and for transmit clock frequency testing.
- Test Mode 3 is for transmitter jitter testing in the SLAVE mode if the loop timing is supported.
- Test Mode 4 is for the transmitter linearity testing.
- Test Mode 5 is used to verify whether the transmitter is compliant with the transmit PSD mask, the power level test and MDI return loss test.
- Test Mode 6 is for testing the transmitter droop.
- Test Mode 7 is used to enable the measurement of the bit error rate of the link.

# Characteristics, Regulatory and Safety Information

## Electrical Characteristics

The following electrical characteristics are the specification of the U7237A 10GBase-T Transmitter Test Fixture:

| Description | Specification | |
|---|---|---|
| Bandwidth | 3 GHz | |
| Attenuation between the master & slave in Section 2 (3 GHz bandwidth) | 15 dB + 1 dB (including transmission line) | |
| Isolation (between transmitter & Pair D) | > 30 dB | |
| Insertion loss | **Frequency Range** | **Max Insertion Loss** |
| | 0- 500 MHz | < 0.5 dB |
| | 500 MHz - 1 GHz | < 1.5 dB |
| | 1 GHz - 2 GHz | < 3.2 dB |
| | 2 GHz - 3 GHz | < 4.5 dB |
| Ethernet shielded patch cord | CAT6A | |
| Balun bandwidth | 300 KHz to 3 GHz | |

## Operating and Non-operating Environmental Characteristics

The following are the environmental characteristics of the U7237A 10GBase-T Transmitter Test Fixture:

| Description | Minimum Requirement |
|---|---|
| Ambient temperature | Operating = 0°C to 40°C<br>Non-operating = - 51°C) to 71°C |
| Humidity | Operating = 95% RH at 40°C for 24 hours |
| Altitude | Operating = 4,570m (15,000 ft)<br>Non-operating = 15,244m (50,000 ft) |
| Indoor use | This fixture is rated for indoor use only |
| Random vibration | HP/Keysight class B1 and MIL-PRF-2880 OF Class 3 random |
| Mechanical shock | HP/Keysight class B1 and MIL-PRF-2880 OF (operating 30g, 1/2 sine, 11-ms duration, 3 shocks/axis along major axis. Total of 18 shocks) |

## Safety Information

The U7237A 10GBase-T Transmitter Test Fixture herewith complies with the essential requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC and carries the CE-marking accordingly. The product was tested in a typical configuration with HP/Keysight test systems.

The following are the safety regulatory information of the U7237A 10GBase-T Transmitter Test Fixture:

Minimum Requirement:

IEC 61010-1: Second edition 2001-2

EN 61010-1:2001

UL3111-1 or UL 6101B-1:2003 (must be a Keysight ID)

Canada: CSA-C22.2 No. 1010.1:1992

# 5 Transmitter Timing Jitter (MASTER) Test



This section provides the Methods of Implementation (MOIs) for Transmitter Timing Jitter (MASTER) test using a Keysight Infiniium 90000-Series DSO Oscilloscope, Keysight Infiniium MXR Oscilloscope, or a Keysight Infiniium UXR Oscilloscope; 10GBase-T Transmitter Test Fixture and the Keysight D9010EBZC 10GBASE-T Ethernet Test Application.

# Procedure for Transmitter Timing Jitter (MASTER) Test

Running the Transmitter Timing Jitter (MASTER) Test using the 10GBase-T Test Application

1 Start the 10GBase-T Compliance Test Application as described in "Starting the 10GBASE-T Ethernet Test Application" on page 19.
2 To make connections for the Transmitter Timing Jitter (MASTER) test, refer to "Connections for Compliance Tests" on page 21.
3 Connect one end of the RJ45 cable to the DUT and another end to J1 connector on the Section 1 of the 10GBase-T Transmitter Test Fixture.
4 Connect the SMP connector pairs, for example A+ and A- SMP connectors to the any two of the Oscilloscope Channels by using the SMP to SMA cables.
5 In the 10GBASE-T Ethernet Test Application, click the **Set Up** tab.
6 Select one of the following options under **Technology** to run tests on the DUT based on the respective technology standards. The **Select Tests** tab lists tests based on the technology you select.
   - **Specification: IEEE** and **Data Rate: 10G**,
   - **Specification: MGBASE-T** and **Data Rate: 5.0G** or **2.5G**,
   - **Specification: NBASE-T** and **Data Rate: 5.0G** or **2.5G**
7 Based on the test requirements, select the appropriate options and perform connections in the **Spectral Analysis** and **External Instruments** areas.
8 Enter your comments in the **Comments** text box.
9 Click the **Select Tests** tab and check the tests you want to run. Check the parent node or group to check all the available tests within the group.

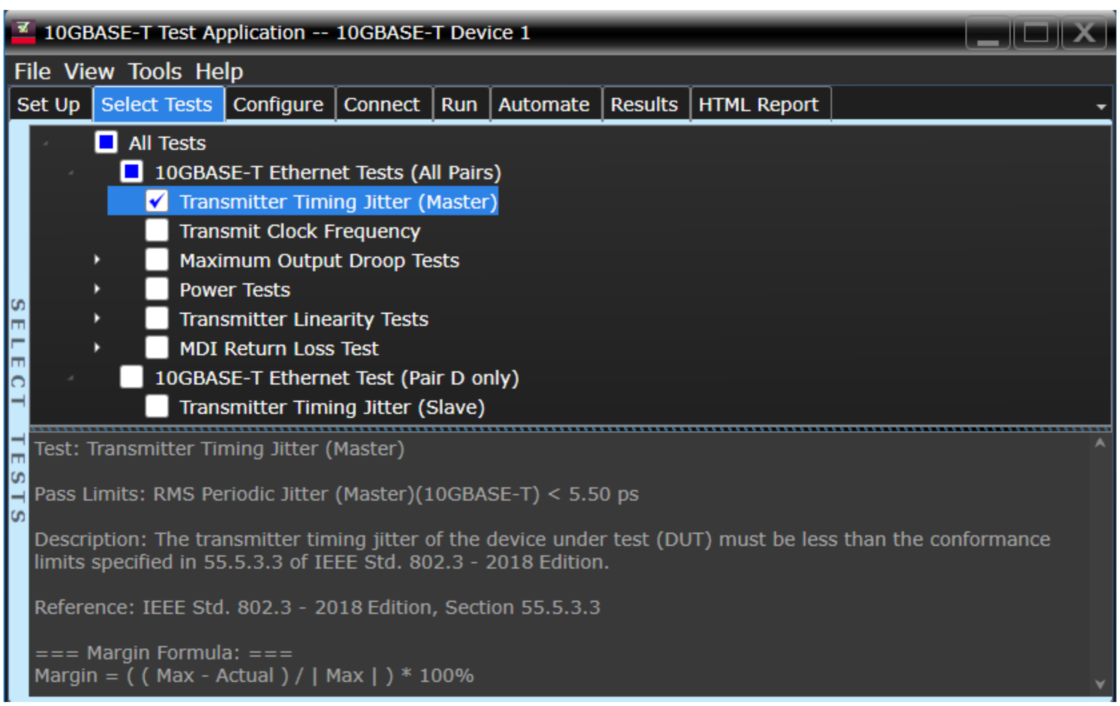


Figure 10 Selecting Transmitter Timing Jitter (MASTER) Test

10 Follow the 10GBASE-T Ethernet Test Application's task flow to set up the configuration options (see Table 1), run the test, and view the test results.

**Table 1 Test Configuration Options**

| Configuration Option | Description |
|---|---|
| Connection Pair (Positive) | The channel number for connection pair positive. |
| Connection Pair (Negative) | The channel number for connection pair negative. |
| Signal Type | Type of signal generated on the Oscilloscope. |
| Sampling Rate [Debug mode] | Sampling Rate configured on the Oscilloscope. |
| Apply Band Pass Filter for Jitter Tests | Apply a a bandpass filter at the input for jitter tests. |
| Band Pass Filter Center Frequency [Debug mode] | Center Frequency of the Band Pass Filter. |
| Band Pass Filter Bandwidth [Debug mode] | Bandwidth of the Band Pass Filter. |

Note: The **Configure** tab of the 10GBASE-T Ethernet Test Application displays the default values for the options listed in the table. Refer to the 10GBASE-T Ethernet Test Application's Online Help to see how to change the values, if required.

# Transmitter Timing Jitter (MASTER) Test—Implementation Methodology

The purpose of the Transmitter Timing Jitter (MASTER) test is to verify that the MASTER transmitter timing jitter of the device under test (DUT) is within the conformance limits specified in clause 55.5.3.3 of *IEEE 802.3-2018*.

For this test, the obtained timing jitter must be less than 5.5ps over a sample size of 200000 ± 20000. This jitter value is to be verified for each of the four pairs of the 10G test mode 2 signaling for a particular DUT. These pairs are identified as Pair A, Pair B, Pair C and Pair D.

## Test Definition Notes from the Specification

### IEEE 802.3—2018 Clause 55.5.3.3 Transmitter Timing Jitter

RMS period jitter over an integration time interval of 1 ms ± 10% is defined as the root mean square period difference from the average period *(T - $T_{avg}$)* accumulated over a sample size of 200000 ± 20000.

$$RMS\ \ period\ \ jitter < \sqrt{\frac{(\sum [(T - Tavg)^2])}{Sample\ \ Size}}$$

### NBASE-T PHY Spec V1.1, Section 2.9, Test Mode 2: Transmit jitter test in MASTER mode

The RMS period jitter is measured over an integration time interval of 2ms ± 10% for 5G and 4ms ± 10% for 2.5G

## Pass Condition

The RMS period jitter measured at the MDI must be less than 5.5ps for all the pairs.

## Measurement Algorithm

1 Configure the MASTER DUT to produce Test Mode 2 signal.

2 On the Infiniium Oscilloscope,

*a* Convert the single ended signal to differential signal:

FUNC2 = Positive Connection Pair (default Channel1) subtract Negative Connection Pair (default Channel3) to get the differential signal.

*b* Trigger on the rising edge of Positive Connection Pair. Set the trigger level to offset voltage of Positive Connection Pair.

*c* In the **Configure** tab of the Compliance Test Application, set the sampling rate:

- On the 90000-series DSO Oscilloscopes, set the value either as 20 Gsa/s or as 40 Gsa/s.
- On the UXR Oscilloscopes, set the value either as 32 Gsa/s or as 64 Gsa/s.
- On the MXR Oscilloscopes, set the value either as 8 Gsa/s or as 16 Gsa/s.

3 On the 10GBASE-T Ethernet Test Application, apply a Bandpass filter of 2 MHz bandwidth in the following manner:

- 200 MHz center frequency for **Specification: IEEE** and **Data Rate: 10G**,
- 100 MHz for **Specification: MGBASE-T** or **NBASE-T** and **Data Rate: 5.0G**,
- 50 MHz for **Specification: MGBASE-T** or **NBASE-T** and **Data Rate: 2.5G**.

4 On the Infiniium Oscilloscope,

  a The number of acquisitions to be taken depends on the time range and the memory depth selected by the user:

  Number of Acq = Time Range / (Memory Depth * 1/Sampling Rate)

  b Enable the histogram and measure the period to the acquired waveform.

  c Take the standard deviation from the histogram statistics.

  d Compare the test result with the compliance test limit.

## Test References

See Clause 55.5.3.3 Transmitter Timing Jitter in the *IEEE 802.3-2018 Standard*.

Also See Section 2.9, Test Mode 2: Transmit jitter test in MASTER mode in the *NBASE-T PHY Specification, V1.1 Standard*.

# 6 Transmit Clock Frequency Test



This section provides the Methods of Implementation (MOIs) for Transmit Clock Frequency test using a Keysight Infiniium 90000-Series DSO Oscilloscope, a Keysight Infiniium MXR Oscilloscope, or a Keysight Infiniium UXR Oscilloscope; 10GBase-T Transmitter Test Fixture and the Keysight D9010EBZC 10GBASE-T Ethernet Test Application.

## Procedure for Transmit Clock Frequency Test

Running the Transmit Clock Frequency Test using the 10GBase-T Test Application

1. Start the 10GBASE-T Ethernet Test Application as described in "Starting the 10GBASE-T Ethernet Test Application" on page 19.
2. To make connections for the Transmit Clock Frequency test, refer to "Connections for Compliance Tests" on page 21.
3. Connect one end of the RJ45 cable to the DUT and another end to J1 connector on the Section 1 of the 10GBase-T Transmitter Test Fixture.
4. Connect the SMP connector pairs, for example A+ and A- SMP connectors to the any two of the Oscilloscope Channels by using the SMP to SMA cables.
5. In the 10GBASE-T Ethernet Test Application, click the **Set Up** tab.
6. Select one of the following options under **Technology** to run tests on the DUT based on the respective technology standards. The **Select Tests** tab lists tests based on the technology you select.
   - **Specification: IEEE** and **Data Rate: 10G**,
   - **Specification: MGBASE-T** and **Data Rate: 5.0G** or **2.5G**,
   - **Specification: NBASE-T** and **Data Rate: 5.0G** or **2.5G**
7. Based on the test requirements, select the appropriate options and perform connections in the **Spectral Analysis** and **External Instruments** areas.
8. Enter your comments in the **Comments** text box.
9. Click the **Select Tests** tab and check the tests you want to run. Check the parent node or group to check all the available tests within the group.

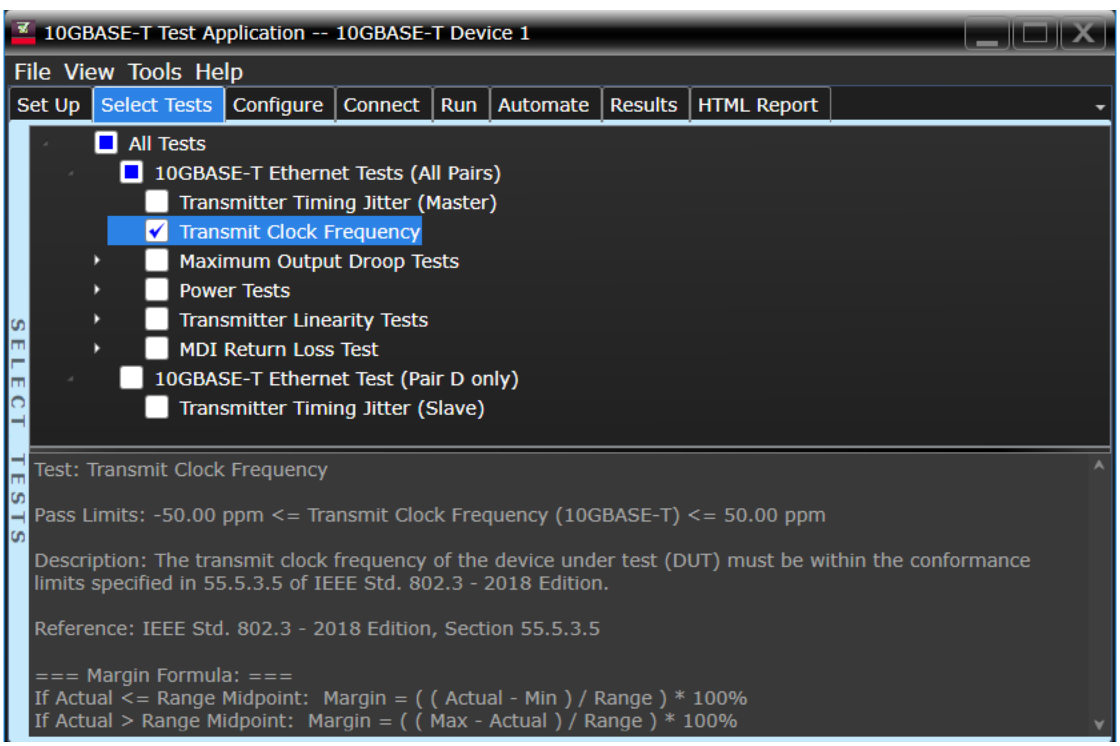


Figure 11 Selecting Transmitter Clock Frequency Test

10 Follow the 10GBASE-T Ethernet Test Application's task flow to set up the configuration options (see Table 2), run the test, and view the test results.

**Table 2 Test Configuration Options**

| Configuration Option | Description |
|---|---|
| Connection Pair (Positive) | The channel number for connection pair positive. |
| Connection Pair (Negative) | The channel number for connection pair negative. |
| Signal Type | Type of signal generated on the Oscilloscope. |
| Sampling Rate [Debug Mode] | Sampling Rate configured on the Oscilloscope. |

Note: The **Configure** tab of the 10GBASE-T Ethernet Test Application displays the default values for the options listed in the table. Refer to the 10GBASE-T Ethernet Test Application's Online Help to see how to change the values, if required.

# Transmit Clock Frequency Test—Implementation Methodology

The purpose of the Transmit Clock Frequency test is to verify that the device under test (DUT) meets the requirements as specified in clause 55.5.3.5 of IEEE 802.3-2018 for the 10GBase-T DUT and Broadcom MGBase-T Ethernet Specification for an MGBase-T DUT. For this test, the Transmit Clock, which is recovered from the transmitted Quinary symbol sequence, must have a symbol rate of 800MHz ± 50ppm for the 10GBase-T DUT, 400MHz ± 50ppm for the 5G MGBase-T DUT and 200MHz ± 50ppm for the 2.5G MGBase-T DUT. This is verified for each of the four pairs of the Test Mode 2 signaling for a particular DUT. These pairs are identified as Pair A, Pair B, Pair C and Pair D.

## Test Definition Notes from the Specification

### IEEE 802.3—2018 Clause 55.5.3.5 Transmit Clock Frequency

The symbol transmission rate on each pair of the MASTER PHY shall be within the range 800MHz ± 50ppm.

### MGBase-T Ethernet Specification, Transmit Clock Frequency section

The symbol transmission rate on each pair of the MASTER PHY shall be within the range 400MHz ± 50ppm and 200MHz ± 50ppm for the 5G and 2.5G modes, respectively.

## Pass Condition

The Transmit Clock, which is recovered from the transmitted Quinary symbol sequence, must have a symbol rate of 800MHz ± 50ppm for the 10GBase-T DUT, 400MHz ± 50ppm for the 5G MGBase-T DUT or 200MHz ± 50ppm for the 2.5G MGBase-T DUT; depending on the data.

## Measurement Algorithm

1. Configure the DUT to produce Test Mode 2 signal.
2. On the Infiniium Oscilloscope,
   *a* Convert the single ended signal to differential signal:
   FUNC2 = Positive Connection Pair (default Channel1) subtract Negative Connection Pair (default Channel3) to get the differential signal.
   *b* Trigger on the rising edge of Positive Connection Pair. Set the trigger level to offset voltage of Positive Connection Pair.
   *c* In the **Configure** tab of the 10GBASE-T Ethernet Test Application, set the sampling rate:
   - On the 90000-series DSO Oscilloscopes, set the value either as 20 Gsa/s or as 40 Gsa/s.
   - On the UXR Oscilloscopes, set the value either as 32 Gsa/s or as 64 Gsa/s.
   - On the MXR Oscilloscopes, set the value either as 8 Gsa/s or as 16 Gsa/s.

   *d* Measure the clock data rate of the FUNC2 signal with the clock recovery option as Semi-Automatic.
   *e* Compare the test result with the compliance test limit.

## Test References

See Clause 55.5.3.5 Transmit Clock Frequency in the *IEEE 802.3-2018 Standard* for the 10GBase-T DUT and Transmit Clock Frequency section in the MGBase-T Ethernet Specification for an MGBase-T DUT.

# 7 Maximum Output Droop Test



This section provides the Methods of Implementation (MOIs) for Maximum Output Droop test using a Keysight Infiniium 90000-Series DSO Oscilloscope, a Keysight Infiniium MXR Oscilloscope, or a Keysight Infiniium UXR Oscilloscope; 10GBase-T Transmitter Test Fixture and the 10GBASE-T Ethernet Test Application.

# Procedure for Maximum Output Droop Test

Running the Maximum Output Droop Test using the 10GBase-T Test Application

1. Start the 10GBASE-T Ethernet Test Application as described in "Starting the 10GBASE-T Ethernet Test Application" on page 19.
2. To make connections for the Maximum Output Droop test, refer to "Connections for Compliance Tests" on page 21.
3. Connect one end of the RJ45 cable to the DUT and another end to J1 connector on the Section 1 of the 10GBase-T Transmitter Test Fixture.
4. Connect the SMP connector pairs, for example A+ and A- SMP connectors to the any two of the Oscilloscope Channels by using the SMP to SMA cables.
5. In the 10GBASE-T Ethernet Test Application, click the **Set Up** tab.
6. Select one of the following options under **Technology** to run tests on the DUT based on the respective technology standards. The **Select Tests** tab lists tests based on the technology you select.
   - **Specification: IEEE** and **Data Rate: 10G**,
   - **Specification: MGBASE-T** and **Data Rate: 5.0G** or **2.5G**,
   - **Specification: NBASE-T** and **Data Rate: 5.0G** or **2.5G**
7. Based on the test requirements, select the appropriate options and perform connections in the **Spectral Analysis** and **External Instruments** areas.
8. Enter your comments in the **Comments** text box.
9. Click the **Select Tests** tab and check the tests you want to run. Check the parent node or group to check all the available tests within the group.

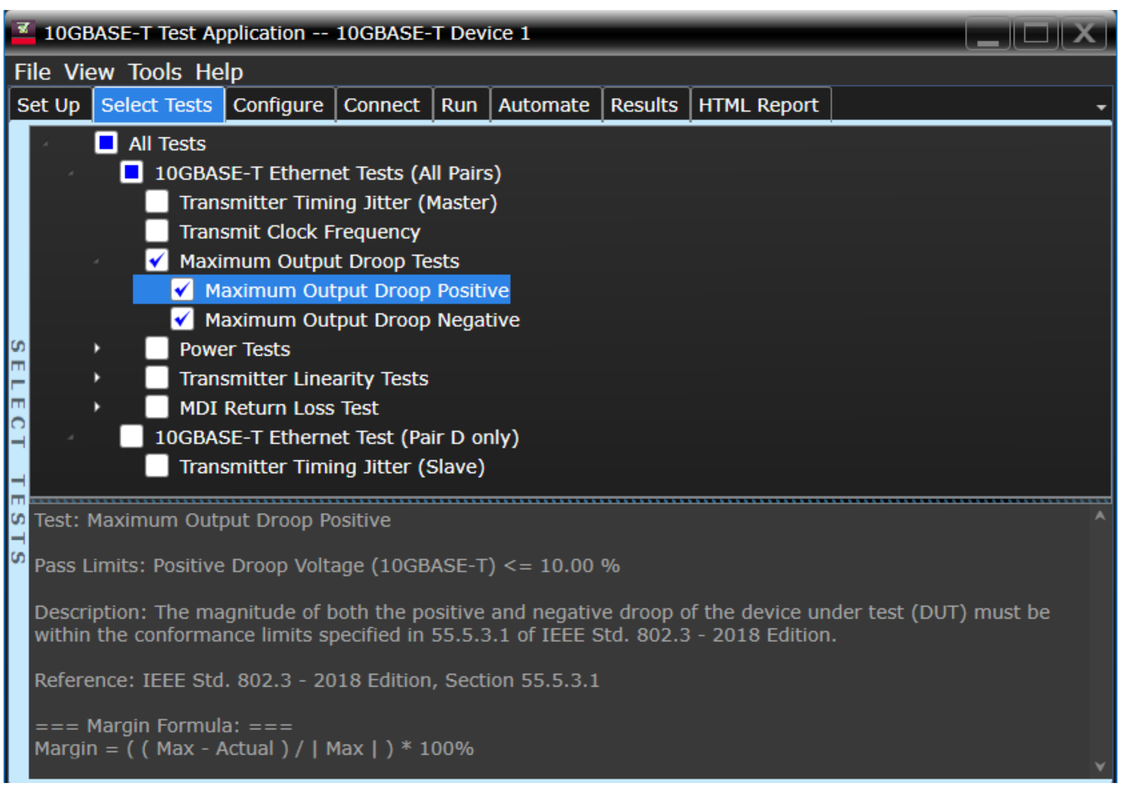


Figure 12 Selecting Maximum Output Droop Test

10 Follow the 10GBASE-T Ethernet Test Application's task flow to set up the configuration options (see Table 3), run the test, and view the test results.

**Table 3 Test Configuration Options**

| Configuration Option | Description |
|---|---|
| Connection Pair (Positive) | The channel number for connection pair positive. |
| Connection Pair (Negative) | The channel number for connection pair negative. |
| Signal Type | Type of signal generated on the Oscilloscope. |
| Sampling Rate [Debug Mode] | Sampling Rate configured on the Oscilloscope. |

Note: The **Configure** tab of the 10GBASE-T Ethernet Test Application displays the default values for the options listed in the table. Refer to the 10GBASE-T Ethernet Test Application's Online Help to see how to change the values, if required.

# Maximum Output Droop Test—Implementation Methodology

The purpose of the Maximum Output Droop test is to verify that the positive and negative droop of the device under test (DUT) is within the conformance limits specified in the clause 55.5.3.1 of IEEE 802.3-2018. For this test, the amplitude of both the positive and negative droop must be less than 10%, measured at initial value of 10ns after the zero cross point and final value at 90ns after the zero cross point. This droop will be verified for each of the four pairs of the 10G Test Mode 6 signaling for a particular DUT. These pairs are identified as Pair A, Pair B, Pair C and Pair D.

For an NBASE-T 5G DUT, the amplitude of both the positive and negative droop must be less than 12.5%, measured at initial value of 10ns after the zero crossing and a final value at 170ns after the zero crossing.

For an NBASE-T 2.5G DUT, the amplitude of both the positive and negative droop must be less than 17.5%, measured at initial value of 10ns after the zero crossing and a final value at 330ns after the zero crossing.

## Test Definition Notes from the Specification

### IEEE 802.3—2018 Clause 55.5.3.1 Maximum Output Droop

With the transmitter in Test Mode 6 and using the transmitter test fixture 1, the magnitude of both the positive and negative droop shall be less than 10%, measured with respect to an initial value at 10ns after the zero crossing and final value at 90ns after the zero crossing.

### NBASE-T PHY Spec V1.1, Section 2.9, Test Mode 6: Droop test

With the transmitter in test mode 6 and using the transmitter test fixture 1, the magnitude of both the positive and negative droop shall be less than (7.5+2.5/S)%, measured with respect to an initial value at 10ns after the zero crossing and a final value at (10+80/S)ns after the zero crossing.

## Pass Condition

The average droop over all acquisitions in a given lane must be less than 10% for a 10GBASE-T and MGBASE-T DUT. It should be less than 12.5% for a 5G NBASE-T DUT and 17.5% for a 2.5G NBASE-T DUT.

## Measurement Algorithm

1 Configure the DUT to produce Test Mode 6 signal.
2 On the Infiniium Oscilloscope,
   *a* Convert the single ended signal to differential signal:
   FUNC2 = Positive Connection Pair (default Channel1) subtract Negative Connection Pair (default Channel3) to get the differential signal.
   *b* Trigger on the rising edge of Positive Connection Pair. Set the trigger level to offset voltage of Positive Connection Pair.
   *c* In the **Configure** tab of the Compliance Test Application, set the sampling rate:
   - On the 90000-series DSO Oscilloscopes, set the value either as 20 Gsa/s or as 40 Gsa/s.
   - On the UXR Oscilloscopes, set the value either as 32 Gsa/s or as 64 Gsa/s.
   - On the MXR Oscilloscopes, set the value either as 8 Gsa/s or as 16 Gsa/s.
   
   *d* Measure the amplitude at 10ns reference from the trigger point.
   *e* Measure the amplitude at 90ns reference from the trigger point for 10GBASE-T and MGBASE-T, 170ns for 5G NBASE-T, 330ns for 2.5G NBASE-T.

*f* Calculate the droop:

%droop = (10ns amplitude) - (90/170/330 ns amplitude)/(10ns amplitude)

*g* Compare the test result with the compliance test limits.

## Test References

See Clause 55.5.3.1 Maximum Output Droop in the *IEEE 802.3-2018 Standard*.

Also See Section 2.9, Test Mode 6: Droop test in the *NBASE-T PHY Specification, V1.1 Standard*.

# 8 Transmitter Power Spectral Density Test



This section provides the Methods of Implementation (MOIs) for Transmitter Power Spectral Density test using a Keysight Infiniium 90000-Series DSO Oscilloscope, a Keysight Infiniium MXR Oscilloscope, or a Keysight Infiniium UXR Oscilloscope; Spectrum Analyzer, 10GBase-T Transmitter Test Fixture and the 10GBASE-T Ethernet Test Application.

There are two methods of running the Transmitter Power Spectral Density test:

- Using an External Spectrum Analyzer.
- Using the Oscilloscope.

## Procedure for Transmitter Power Spectral Density Test Using an External Spectrum Analyzer

### Running the Transmitter Power Spectral Density Test using the 10GBASE-T Ethernet Test Application

1. Start the 10GBASE-T Ethernet Test Application as described in "Starting the 10GBASE-T Ethernet Test Application" on page 19.
2. To make connections for the Transmitter Power Spectral Density test, refer to "Connections for Compliance Tests" on page 21.
3. Connect one end of the RJ45 cable to the DUT and another end to J1 connector on the Section 1 of the 10GBase-T Transmitter Test Fixture.
4. Connect the SMP connector pairs, for example A+ and A- SMP connectors to the Balun by using the SMP to SMA cables.
5. Connect the Balun to the Spectrum Analyzer by using the SMA cable.
6. Use a LAN or GPIB to USB cable to connect the Spectrum Analyzer to the Oscilloscope.
7. In the 10GBASE-T Ethernet Test Application, click the **Set Up** tab.
8. Select one of the following options under **Technology** to run tests on the DUT based on the respective technology standards. The **Select Tests** tab lists tests based on the technology you select.
   - **Specification: IEEE** and **Data Rate: 10G**,
   - **Specification: MGBASE-T** and **Data Rate: 5.0G** or **2.5G**,
   - **Specification: NBASE-T** and **Data Rate: 5.0G** or **2.5G**
9. In the **Spectral Analysis** area, select **Use Spectrum Analyzer**.
10. Ensure that the application detects the Spectrum Analyzer connection to the Oscilloscope. If the status indicates **Not Connected**, click the **Connect...** button in the **Spectrum Analyzer** area of the **External Instruments** section of the 10GBASE-T Ethernet Test Application.

11 A pop-up box appears where you can enter either the VISA/SICL address or the IP address. Enter the information and click the **Verify** button, followed by the **Done** button to close this box. The VISA/SICL address or the IP address can be obtained from the Keysight Connection Expert application, as shown in Figure 13.

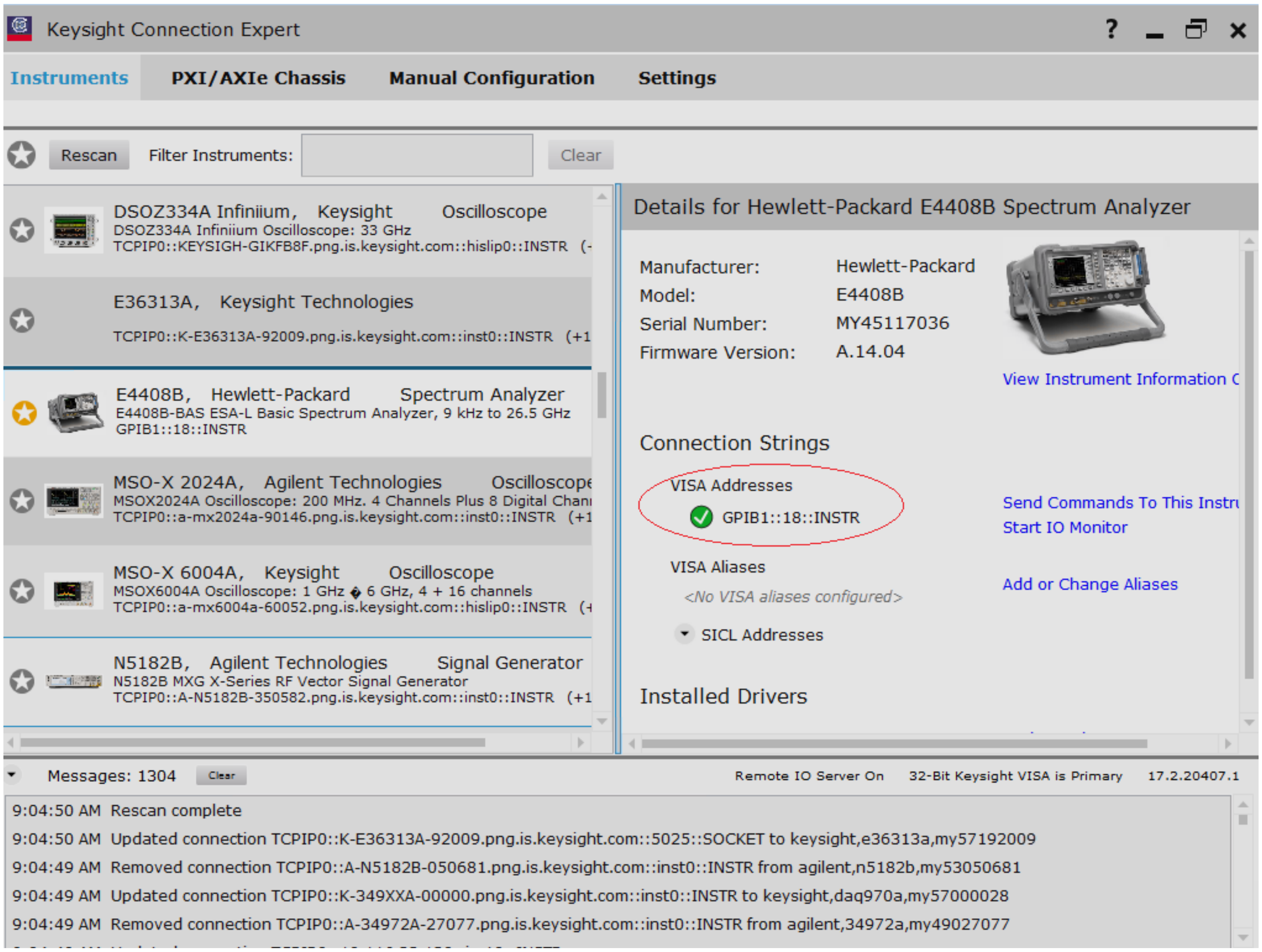


Figure 13 Checking VISA/SICL Address for Spectrum Analyzer in the Keysight Connection Expert

12 Once the 10GBASE-T Ethernet Test Application detects the Spectrum Analyzer, it is indicated on the **Set Up** tab as shown in Figure 14.

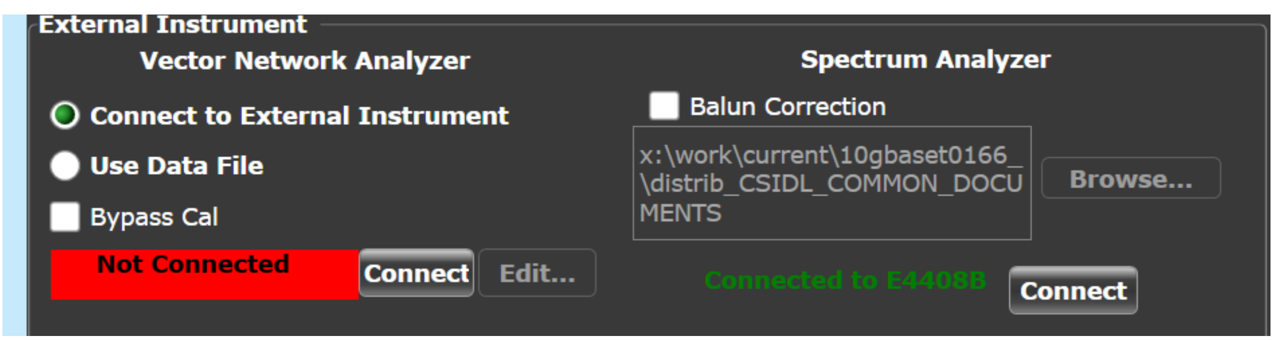


Figure 14 Connection status after the Test App detects the Spectrum Analyzer

13 Enter your comments in the **Comments** text box.
14 Click the **Select Tests** tab and check the tests you want to run. Check the parent node or group to check all the available tests within the group.
15 Follow the 10GBASE-T Ethernet Test Application's task flow to set up the configuration options (see Table 4), run the test, and view the test results.

**Table 4** Test Configuration Options Using Spectrum Analyzer

| Configuration Option | Description |
| --- | --- |
| **Power Test** | |
| Start Frequency | The start frequency for the Spectrum Analyzer. |
| Stop Frequency | The stop frequency for the Spectrum Analyzer. |
| Resolution Bandwidth | The resolution bandwidth for the Spectrum Analyzer. |
| Test Type | The test type for the Power Spectral Density test. |
| Command File [Debug Mode] | The command file for the Spectrum Analyzer. |
| Reference Level | The reference level for the Spectrum Analyzer. |
| Frequency Resolution Step | The frequency resolution step configured on the Oscilloscope. |
| #Averages | The number of averages for Power Spectral Density test using the Spectrum Analyzer. |

Note: The **Configure** tab of the 10GBASE-T Ethernet Test Application displays the default values for the options listed in the table. Refer to the 10GBASE-T Ethernet Test Application's Online Help to see how to change the values, if required.

# Procedure for Transmitter Power Spectral Density Test Using the Oscilloscope

## Running the Transmitter Power Spectral Density Test using the 10GBASE-T Ethernet Test Application

1. Start the 10GBASE-T Ethernet Test Application as described in "Starting the 10GBASE-T Ethernet Test Application" on page 19.
2. To make connections for the Transmitter Power Spectral Density test, refer to "Connections for Compliance Tests" on page 21.
3. Connect one end of the RJ45 cable to the DUT and another end to J1 connector on the Section 1 of the 10GBase-T Transmitter test fixture.
4. Connect the SMP connector pairs, for example A+ and A- SMP connectors to the Oscilloscope.
5. In the 10GBASE-T Ethernet Test Application, click the **Set Up** tab.
6. Select one of the following options under **Technology** to run tests on the DUT based on the respective technology standards. The **Select Tests** tab lists tests based on the technology you select.
   - **Specification: IEEE** and **Data Rate: 10G**,
   - **Specification: MGBASE-T** and **Data Rate: 5.0G** or **2.5G**,
   - **Specification: NBASE-T** and **Data Rate: 5.0G** or **2.5G**
7. In the **Spectral Analysis** area, select **Use Oscilloscope**.
8. Enter your comments in the **Comments** text box.
9. Click the **Select Tests** tab and check the tests you want to run. Check the parent node or group to check all the available tests within the group.
10. Follow the 10GBASE-T Ethernet Test Application's task flow to set up the configuration options (see Table 5), run the test, and view the results.

**Table 5 Test Configuration Options Using Oscilloscope**

| Configuration Option | Description |
|---|---|
| Connection Pair (Positive) | The channel number for connection pair positive. |
| Connection Pair (Negative) | The channel number for connection pair negative. |
| **Power Test** | |
| Start Frequency | The start frequency for the Spectrum Analyzer. |
| Stop Frequency | The stop frequency for the Spectrum Analyzer. |
| Resolution Bandwidth | The resolution bandwidth for the Spectrum Analyzer. |
| Memory Depth | Memory Depth configured on the Oscilloscope. |
| Signal Type | Type of signal generated on the Oscilloscope. |
| Sampling Rate [Debug Mode] | Sampling Rate configured on the Oscilloscope. |
| Spectral Windowing | Windowing function applied to the input data segment before implement FFT using Oscilloscope. |

Note: The **Configure** tab of the 10GBASE-T Ethernet Test Application displays the default values for the options listed in the table. Refer to the 10GBASE-T Ethernet Test Application's Online Help to see how to change the values, if required.

### Selecting Transmitter Power Spectral Density Test

Figure 15 shows the tests available under the **Power Tests** group of the **Select Tests** tab.

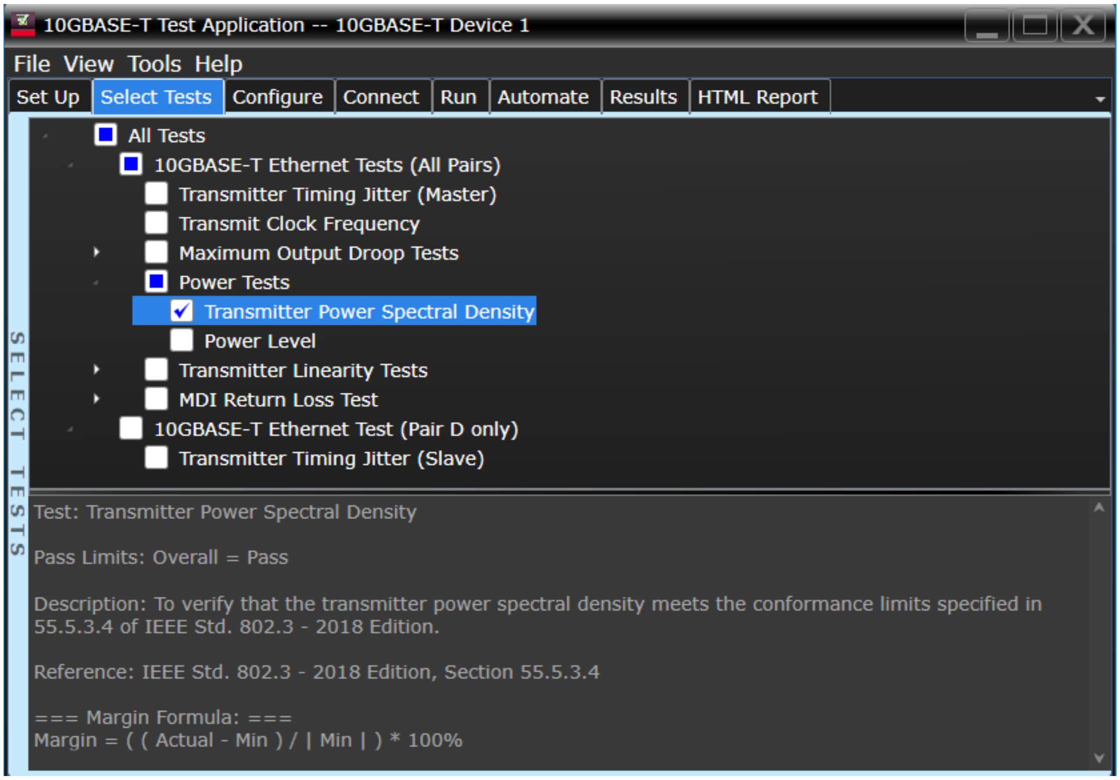


Figure 15 Selecting Power Spectral Density Test

## Transmitter Power Spectral Density Test—Implementation Methodology

The purpose of the Transmitter Power Density test is to verify that the power spectral density (PSD) of the device under test (DUT) is within the conformance limits specified in clause 55.5.3.4 of *IEEE 802.3-2018* for the 10GBase-T DUT and in the MGBase-T Ethernet Specification for an MGBase-T DUT.

The PSD of the 10GBase-T DUT, MGBase-T (2.5G) and MGBase-T (5.0G) and NBase-T (2.5G) and NBase-T (5.0G) must be within the upper and lower masks as shown in Figure 16, Figure 17, Figure 18 and Figure 19 respectively below. PSD of the DUT is verified for each of the four lanes of Test Mode 5 signal. These pairs are identified as Pair A, Pair B, Pair C and Pair D.

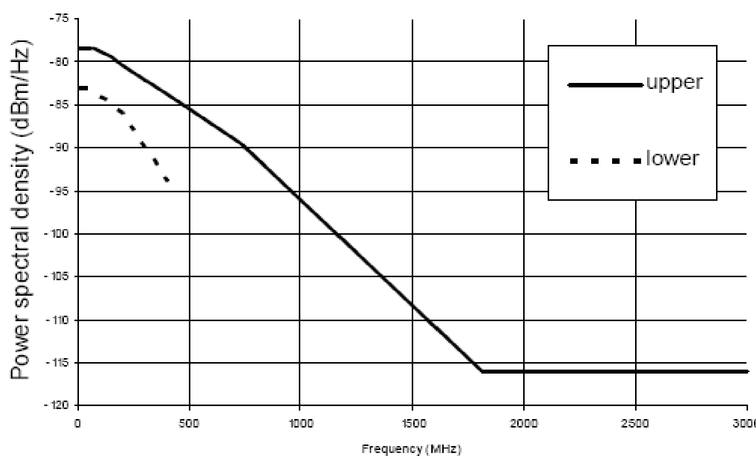


Figure 16 PSD vs. Frequency for a 10GBase-T DUT

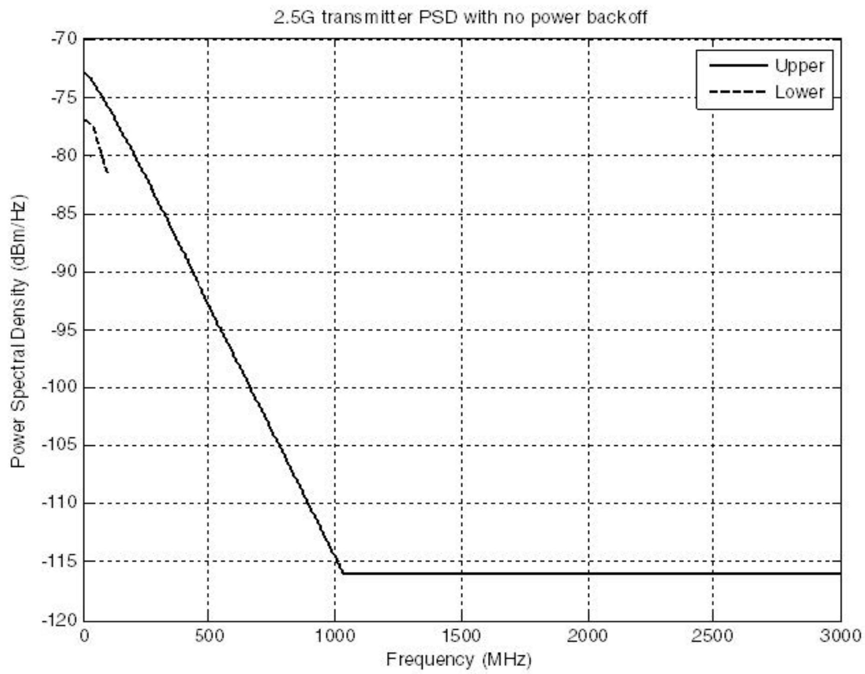


Figure 17 PSD vs. Frequency for 2.5G MGBase-T DUT

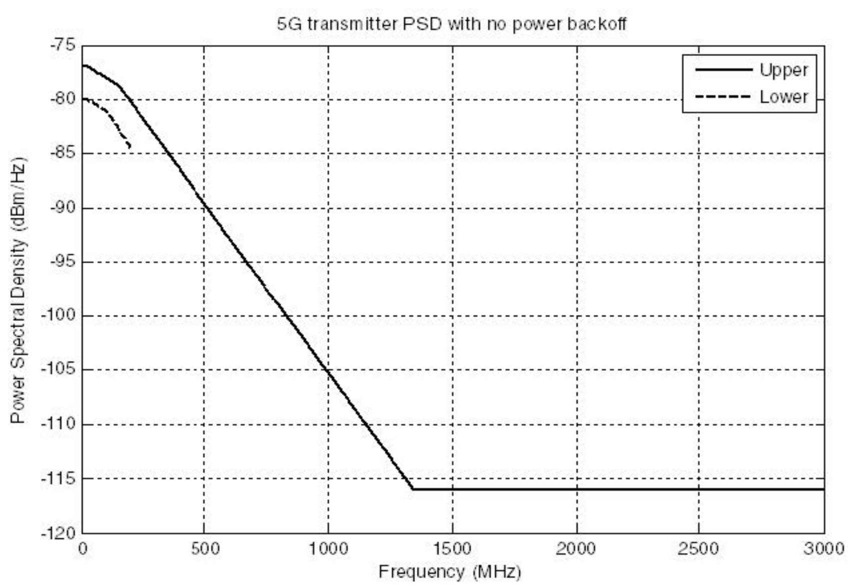


Figure 18 PSD vs. Frequency for 5G MGBase-T DUT

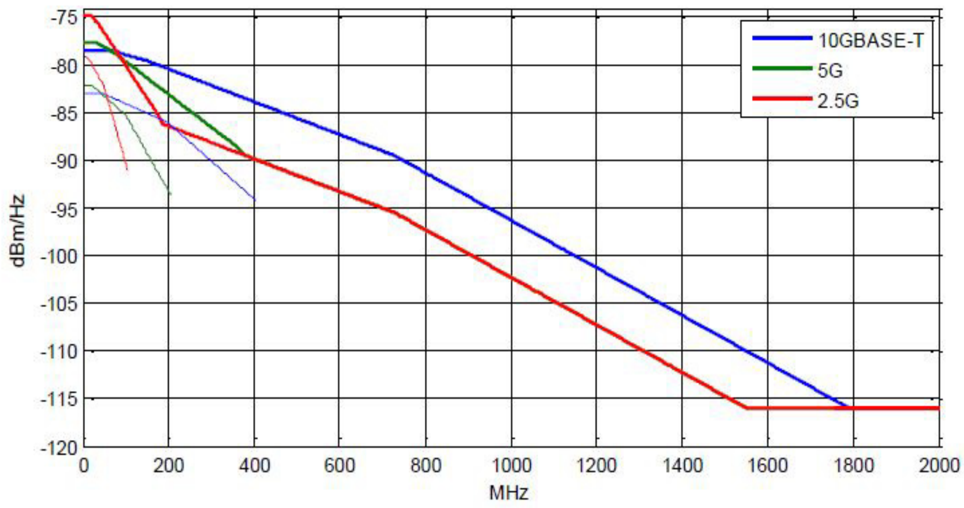


Figure 19 PSD vs. Frequency for 2.5G & 5G NBase-T DUT

## Test Definition Notes from the Specification

### IEEE 802.3—2018 Clause 55.5.3.4 Power Spectral Density

The power spectral density of the transmitter, measured into a 100 W load using the test fixture for a 10GBase-T DUT, shall be between the upper and lower masks specified in the equations shown in Figure 20. The masks are shown graphically in Figure 16.

$$\text{Upper PSD}(f) \le \begin{cases} -78.5 \text{ dBm/Hz} & 0 < f \le 70 \\ -78.5 - \left(\frac{f-70}{80}\right) \text{dBm/Hz} & 70 < f \le 150 \\ -79.5 - \left(\frac{f-150}{58}\right) \text{dBm/Hz} & 150 < f \le 730 \\ -79.5 - \left(\frac{f-330}{40}\right) \text{dBm/Hz} & 730 < f \le 1790 \\ -116 \text{ dBm/Hz} & 1790 < f \le 3000 \end{cases} \quad (55\text{–}9)$$

$$\text{Lower PSD}(f) \ge \begin{cases} -83 \text{ dBm/Hz} & 5 \le f \le 50 \\ -83 - \left(\frac{f-50}{50}\right) \text{dBm/Hz} & 50 < f \le 200 \\ -86 - \left(\frac{f-200}{25}\right) \text{dBm/Hz} & 200 < f \le 400 \end{cases} \quad (55\text{–}10)$$

Figure 20 Equations for PSD Masks applicable to 10GBase-T DUT

### MGBase-T Ethernet Specification, Transmitter Power Spectral Density section

The power spectral density of the transmitter measured into a 100 W load using the test fixture for the MGBase-T (2.5G) and MGBase-T (5.0G) DUT shall be between the upper and lower masks specified in the respective equations shown in Figure 21 and Figure 22. The masks are shown graphically in Figure 17 and Figure 18 respectively.

$$
Upper\ PSD\ (f) \le \begin{cases} -72.5\ \text{dBm/Hz} & 0 < f \le 17.5 \\ -72.5 - \left(\dfrac{f-17.5}{20}\right)\ \text{dBm/Hz} & 17.5 < f \le 37.5 \\ -73.5 - \left(\dfrac{f-37.5}{14.5}\right)\ \text{dBm/Hz} & 37.5 < f \le 182.5 \\ -73.5 - \left(\dfrac{f-82.5}{10}\right)\ \text{dBm/Hz} & 182.5 < f \le 507.5 \\ -116\ \text{dBm/Hz} & 507.5 < f \le 3000 \end{cases}
$$

$$
Lower\ PSD\ (f) \le \begin{cases} -77\ \text{dBm/Hz} & 1.25 < f \le 12.5 \\ -77 - \left(\dfrac{f-12.5}{12.5}\right)\ \text{dBm/Hz} & 12.5 < f \le 50 \\ -80 - \left(\dfrac{f-50}{6.25}\right)\ \text{dBm/Hz} & 50 < f \le 100 \end{cases}
$$

Figure 21 Equations for PSD Masks applicable to 2.5G MGBase-T DUT

$$
Upper\ PSD\ (f) \le \begin{cases} -75.5\ \text{dBm/Hz} & 0 < f \le 35 \\ -75.5 - \left(\dfrac{f-35}{40}\right)\ \text{dBm/Hz} & 35 < f \le 75 \\ -76.5 - \left(\dfrac{f-75}{29}\right)\ \text{dBm/Hz} & 75 < f \le 365 \\ -76.5 - \left(\dfrac{f-165}{20}\right)\ \text{dBm/Hz} & 365 < f \le 955 \\ -116\ \text{dBm/Hz} & 955 < f \le 3000 \end{cases}
$$

$$
Lower\ PSD\ (f) \le \begin{cases} -80\ \text{dBm/Hz} & 2.5 < f \le 25 \\ -80 - \left(\dfrac{f-25}{25}\right)\ \text{dBm/Hz} & 25 < f \le 100 \\ -83 - \left(\dfrac{f-100}{12.5}\right)\ \text{dBm/Hz} & 100 < f \le 200 \end{cases}
$$

Figure 22 Equations for PSD Masks applicable to 5G MGBase-T DUT

### NBase-T, Spec IEEE 802.3—2018, Clause 126.5.3.4 Transmit Power Spectral Density (PSD)

The power spectral density of the transmitter measured into a 100 W load using the test fixture for the NBase-T (2.5G) and NBase-T (5.0G) DUT shall be between the upper and lower masks specified in the respective equations shown in Figure 23. The masks are shown graphically in Figure 19.

$$\mathrm{PSD1}(f) \le \begin{cases} -77.7 - 10 \times \log_{10}(S) & \text{dBm/Hz} \quad 0 < 2\frac{f}{S} \le 70 \\ -77.7 - 10 \times \log_{10} S - \frac{\left(2\frac{f}{S} - 70\right)}{80} & \text{dBm/Hz} \quad 70 < 2\frac{f}{S} \le 150 \\ -78.7 - 10 \times \log_{10} S - \frac{\left(2\frac{f}{S} - 150\right)}{58} & \text{dBm/Hz} \quad 150 < 2\frac{f}{S} \le 730 \\ -78.7 - 10 \times \log_{10} S - \frac{\left(2\frac{f}{S} - 330\right)}{40} & \text{dBm/Hz} \quad 730 < 2\frac{f}{S} \le 1822 - 400 \times \log_{10}(S) \\ -116 & \text{dBm/Hz} \quad S \times (911 - 200 \times \log_{10}(S)) < f \le 3000 \end{cases}$$

$$\mathrm{UpperPSD}(f) \le \max(\mathrm{PSD1}(f), (\text{Equation 55-9}) - 6\ \mathrm{dB})$$

(126–9)

and

$$\text{Lower PSD } (f) \ge \begin{cases} -82.2 - 10 \times \log_{10}(S) & \text{dBm/Hz} \quad 5 < 2\frac{f}{S} \le 50 \\ -82.2 - 10 \times \log_{10} S - \frac{\left(2\frac{f}{S} - 50\right)}{50} & \text{dBm/Hz} \quad 50 < 2\frac{f}{S} \le 200 \\ -85.2 - 10 \times \log_{10} S - \frac{\left(2\frac{f}{S} - 200\right)}{25} & \text{dBm/Hz} \quad 200 < 2\frac{f}{S} \le 400 \end{cases} \qquad (126\text{–}10)$$

where

$f$ is in MHz

Figure 23 Equations for PSD Masks applicable to NBase-T (2.5G & 5.0G) DUT

## Pass Condition

The signal obtained from the Test Mode 5 must fit within the PSD mask shown in Figure 16, Figure 17, Figure 18 or Figure 19.

### Measurement Algorithm When Using an External Spectrum Analyzer

1. Configure the DUT to produce Test Mode 5 signal.
2. Configure the following parameters in the **Configure** tab of the 110GBASE-T Ethernet Test Application to set up the External Spectrum Analyzer:
   - *a* Start frequency = 3 MHz and Stop frequency = 3 GHz
   - *b* Resolution bandwidth = 3 MHz (for 90000-Series DSO, MXR Oscilloscopes, and UXR Oscilloscopes)
   - *c* Averaging (default value is 50)
3. Configure the following parameters on the Spectrum Analyzer:
   - *a* Noise marker function
   - *b* DC coupling (not applicable for the Economic Spectrum Analyzers)
4. Collect the data from the Spectrum Analyzer to the 10GBASE-T Ethernet Test Application and plot the graph.
5. Set the Spectrum Analyzer to AC coupling mode.
6. Compare each point of the graph with the upper and lower limits with respective to the frequency.

### Measurement Algorithm When Using the Oscilloscope

1. Configure the DUT to produce Test Mode 5 signal.
2. On the Infiniium Oscilloscope,
   - *a* Trigger and collect the waveform from the Oscilloscope.
   - *b* Apply the selected windowing function to the sampled waveform.
   - *c* Compute the power spectra as:

$$\text{power spectra} = \frac{1}{N}\sum_{i=0}^{N-1}\left|\text{FFT amplitude[i]}\right|^2$$

   Where N = number of segments or cycles to compute.

   - *d* Apply a correction factor to the signal to compensate windowing losses:

$$\text{Correction factor} = \frac{\text{nfft}}{\left\{\sum(\text{window function})^2\right\}}$$

   - *e* Normalize the power spectra to get the power spectral density:

$$\text{power spectral density }(V^2/\text{Hz}) = \text{Power spectra}/F_s$$

   - *f* Convert the amplitude of the power spectral density from Vp^2 to Vrms^2.
   - *g* Compare each point of the result to the upper and lower limits with respect to the frequency.

## Test References

See Clause 55.5.3.4 Transmitter Power Spectral Density in the *IEEE 802.3-2018 Standard* for the 10GBase-T DUT.

See Transmitter Power Spectral Density section in the *MGBase-T Ethernet Specification* for an MGBase-T DUT.

Also See Section 2.8.1, Transmit Power and PSD in the *NBASE-T PHY Specification, V1.1 Standard*. for a NBASE-T DUT.

# 9 Power Level Test



This section provides the Methods of Implementation (MOIs) for Power Level test using a Keysight Infiniium 90000-Series DSO Oscilloscope, a Keysight Infiniium MXR Oscilloscope, or a Keysight Infiniium UXR Oscilloscope; Spectrum Analyzer, 10GBase-T Transmitter Test Fixture and the 10GBASE-T Ethernet Test Application.

There are two methods of running the Power Level test:

- Using an External Spectrum Analyzer.
- Using the Oscilloscope.

## Procedure for Power Level Test Using an External Spectrum Analyzer

Running the Power Level Test using the 10GBASE-T Ethernet Test Application

1. Start the 10GBASE-T Ethernet Test Application as described in “Starting the 10GBASE-T Ethernet Test Application" on page 19.
2. To make connections for the Power Level test, refer to “Connections for Compliance Tests" on page 21.
3. Connect one end of the RJ45 cable to the DUT and another end to J1 connector on the Section 1 of the 10GBase-T Transmitter Test Fixture.
4. Connect the SMP connector pairs, for example A+ and A- SMP connectors to the Balun by using the SMP to SMA cables.
5. Connect the Balun to the Spectrum Analyzer by using the SMA cable.
6. Use a LAN or GPIB to USB cable to connect the Spectrum Analyzer to the Oscilloscope.
7. In the 10GBASE-T Ethernet Test Application, click the **Set Up** tab.
8. Select one of the following options under **Technology** to run tests on the DUT based on the respective technology standards. The **Select Tests** tab lists tests based on the technology you select.
   - **Specification: IEEE** and **Data Rate: 10G**,
   - **Specification: MGBASE-T** and **Data Rate: 5.0G** or **2.5G**,
   - **Specification: NBASE-T** and **Data Rate: 5.0G** or **2.5G**
9. In the **Spectral Analysis** area, select **Use Spectrum Analyzer**.
10. Ensure that the application detects the Spectrum Analyzer connection to the Oscilloscope. If the status indicates **Not Connected**, click the **Connect...** button in the **Spectrum Analyzer** area of the **External Instruments** section of the 10GBASE-T Ethernet Test Application.

11 A pop-up box appears where you can enter either the VISA/SICL address or the IP address. Enter the information and click the **Verify** button, followed by the **Done** button to close this box. The VISA/SICL address or the IP address can be obtained from the Keysight Connection Expert application, as shown in Figure 24.

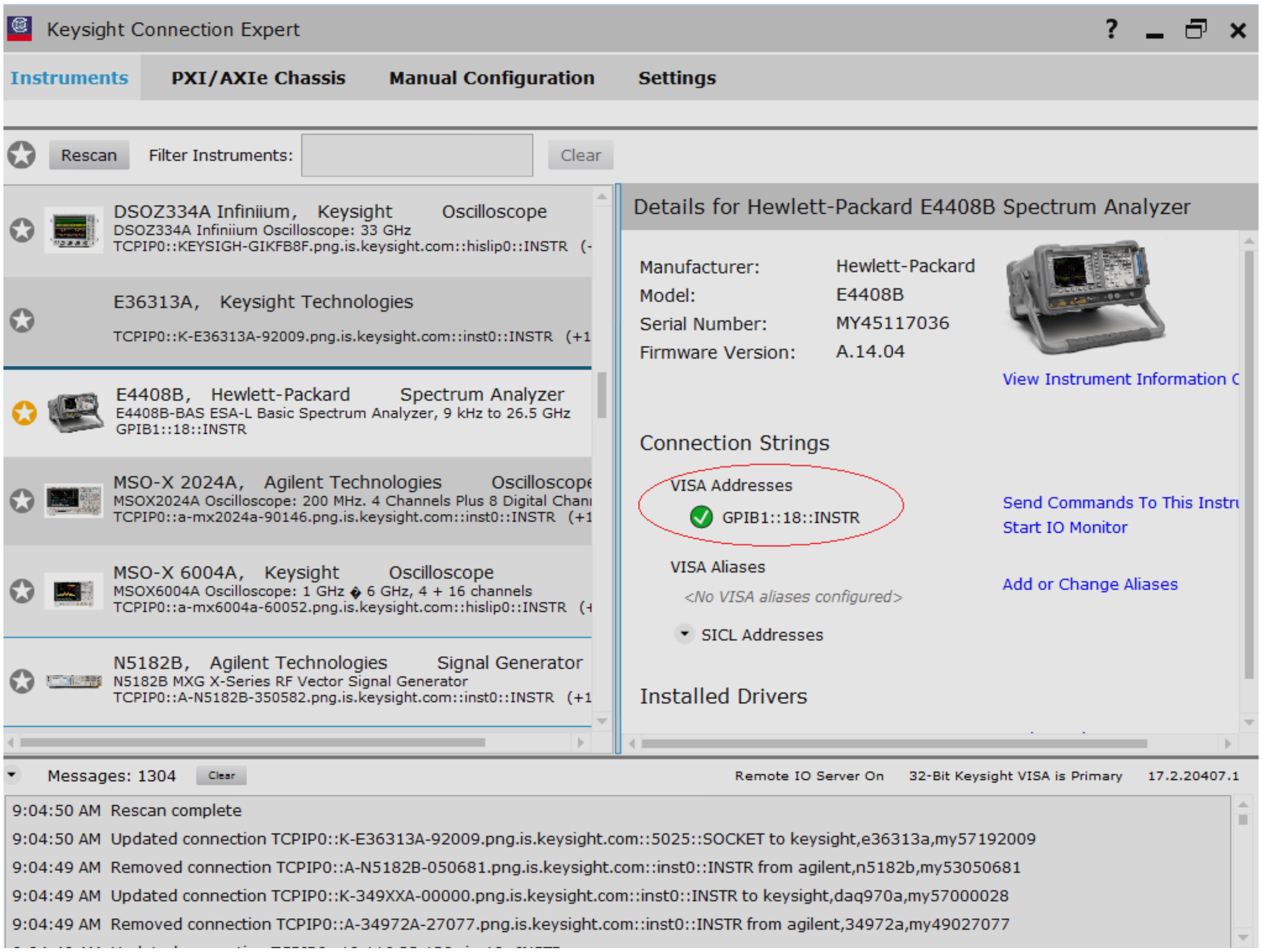


Figure 24 Checking VISA/SICL Address for Spectrum Analyzer in the Keysight Connection Expert

12 Once the 10GBASE-T Ethernet Test Application detects the Spectrum Analyzer, it is indicated on the **Set Up** tab as shown in Figure 25.

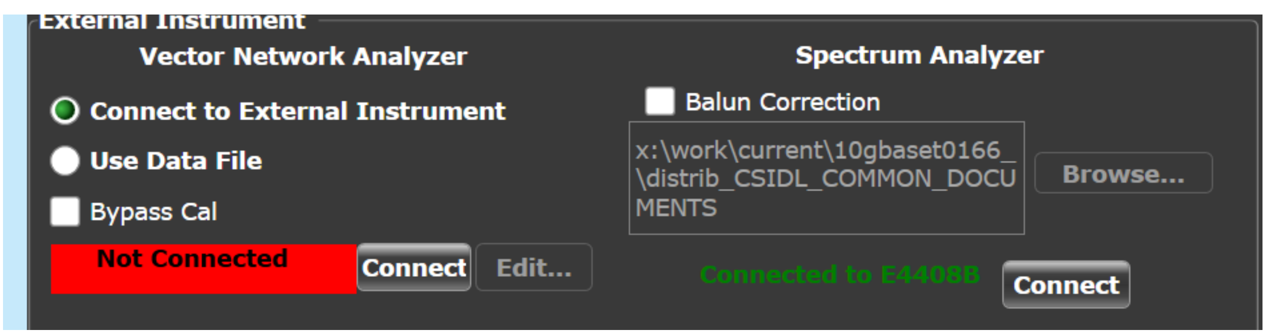


Figure 25 Connection status after the Test App detects the Spectrum Analyzer

13 Enter your comments in the **Comments** text box.
14 Click the **Select Tests** tab and check the tests you want to run. Check the parent node or group to check all the available tests within the group.
15 Follow the 10GBASE-T Ethernet Test Application's task flow to set up the configuration options (see Table 6), run the test, and view the test results.

**Table 6 Test Configuration Options Using Spectrum Analyzer**

| Configuration Option | Description |
|---|---|
| **Power Test** | |
| Start Frequency | The start frequency for the Spectrum Analyzer. |
| Stop Frequency | The stop frequency for the Spectrum Analyzer. |
| Resolution Bandwidth | The resolution bandwidth for the Spectrum Analyzer. |
| Test Type | The test type for the Power Level test. |
| Command File [Debug Mode] | The command file for the Spectrum Analyzer. |
| Reference Level | The reference level for the Spectrum Analyzer. |
| #Averages | The number of averages for Power Level test using the Spectrum Analyzer. |

Note: The **Configure** tab of the 10GBASE-T Ethernet Test Application displays the default values for the options listed in the table. Refer to the 10GBASE-T Ethernet Test Application's Online Help to see how to change the values, if required.

## Procedure for Power Level Test Using the Oscilloscope

### Running the Power Level Test using the 10GBASE-T Ethernet Test Application

1 Start the 10GBase-T Compliance Test Application as described in "Starting the 10GBASE-T Ethernet Test Application" on page 19.
2 To make connections for the Power Level test, refer to "Connections for Compliance Tests" on page 21.
3 Connect one end of the RJ45 cable to the DUT and another end to J1 connector on the Section 1 of the 10GBase-T Transmitter Test Fixture.
4 Connect the SMP connector pairs, for example A+ and A- SMP connectors to the Oscilloscope.
5 In the 10GBASE-T Ethernet Test Application, click the **Set Up** tab.
6 Select one of the following options under **Technology** to run tests on the DUT based on the respective technology standards. The **Select Tests** tab lists tests based on the technology you select.
   - **Specification: IEEE** and **Data Rate: 10G**,
   - **Specification: MGBASE-T** and **Data Rate: 5.0G** or **2.5G**,
   - **Specification: NBASE-T** and **Data Rate: 5.0G** or **2.5G**
7 In the **Spectral Analysis** area, select **Use Oscilloscope**.
8 Enter your comments in the **Comments** text box.
9 Click the **Select Tests** tab and check the tests you want to run. Check the parent node or group to check all the available tests within the group.
10 Follow the 10GBASE-T Ethernet Test Application's task flow to set up the configuration options (see Table 7), run the test, and view the results.

**Table 7 Test Configuration Options Using Oscilloscope**

| Configuration Option | Description |
|---|---|
| Connection Pair (Positive) | The channel number for connection pair positive. |
| Connection Pair (Negative) | The channel number for connection pair negative. |
| **Power Test** | |
| Start Frequency | The start frequency for the Spectrum Analyzer. |
| Stop Frequency | The stop frequency for the Spectrum Analyzer. |
| Resolution Bandwidth | The resolution bandwidth for the Spectrum Analyzer. |
| Input Impedance | The Input Impedance configured on the Oscilloscope. |
| Memory Depth | Memory Depth configured on the Oscilloscope. |
| Signal Type | Type of signal generated on the Oscilloscope. |
| Sampling Rate [Debug Mode] | Sampling Rate configured on the Oscilloscope. |
| Spectral Windowing | Windowing function applied to the input data segment before implement FFT using Oscilloscope. |

Note: The **Configure** tab of the 10GBASE-T Ethernet Test Application displays the default values for the options listed in the table. Refer to the 10GBASE-T Ethernet Test Application's Online Help to see how to change the values, if required.

### Selecting Transmitter Power Level Test

Figure 26 shows the tests available under the **Power Tests** group of the **Select Tests** tab.

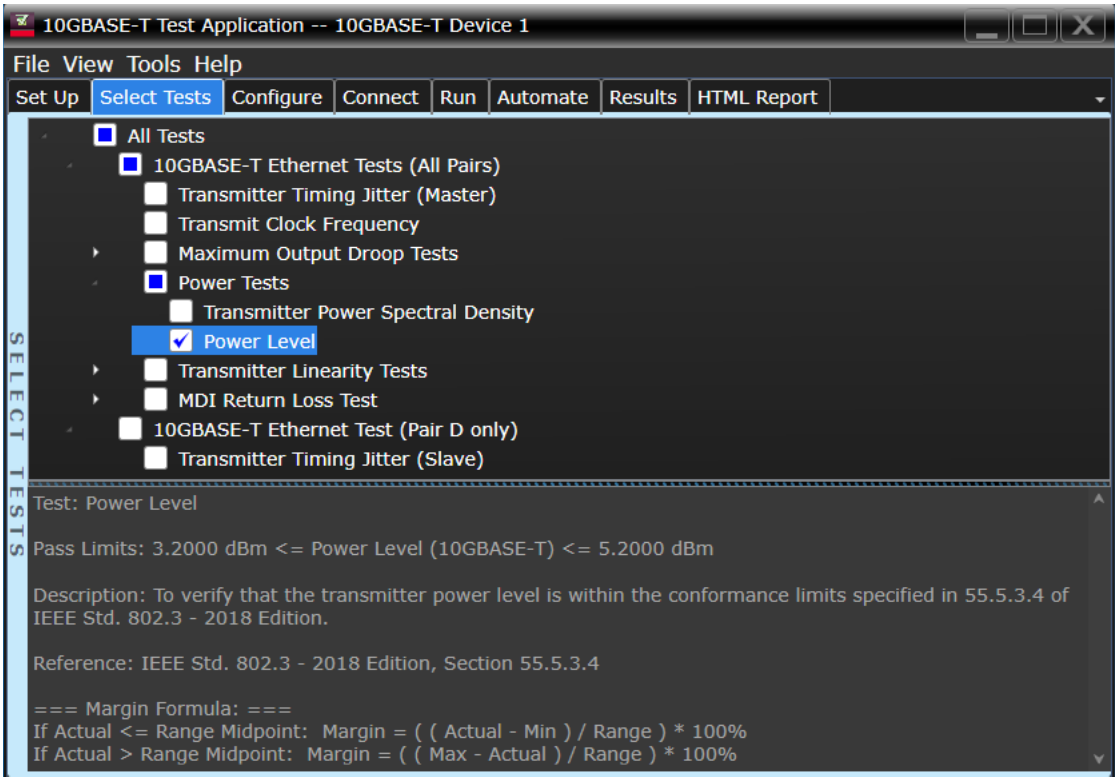


Figure 26 Selecting Power Level Test

# Power Level Test—Implementation Methodology

The purpose of the Power Level test is to verify that the power level of the device under test (DUT) meets the specification requirement as specified in clause 55.5.3.4 of *IEEE 802.3-2018*.

For this test, the obtained power level for a DUT in 10GBASE-T and MGBASE-T mode, must be between 3.2dBm and 5.2dBm. This value is verified for each of the four pairs of the Test Mode 5 signaling for a particular DUT. These pairs are identified as Pair A, Pair B, Pair C and Pair D.

For a NBASE-T DUT, the obtained power level must be between 1.0dBm and 3.0dBm. This is 2.2dBm below 10BASE-T bounds to limit emission on CAT5e, while still allows reasonable signal-to-noise ratio (SNR).

## Test Definition Notes from the Specification

### IEEE 802.3—2018 Clause 55.5.3.4 Power Spectral Density

In Test Mode 5 (normal operation with no power backoff), the transmit power shall be in the range 3.2dBm to 5.2dBm.

### NBASE-T PHY Spec V1.1, Section 2.8.1, Transmit Power and PSD

Total transmit power: 1.0 to 3.0 dBm. This is 2.2 dB below 10GBASE-T bounds to limit emission on CAT5e while still allows reasonable SNR.

## Pass Condition

The obtained Power Level must be between 3.2dBm and 5.2dBm from the frequency range of 3 MHz to 400 MHz for a 10GBASE-T and MGBASE-T DUT. For a NBASE-T DUT the obtained Power Level must be between 1.0dBm and 3.0dBm.

## Measurement Algorithm Using an External Spectrum Analyzer

1 Configure the DUT to produce Test Mode 5 signal.
2 Configure the following parameters in the **Configure** tab of the 10GBase-T Compliance Test Application:
   *a* Start frequency = 3 MHz, Stop frequency = 400 MHz
   *b* Resolution bandwidth = 3 MHz (for 90000-Series DSO, MXR, and UXR Oscilloscopes)
   *c* Averaging (default value is 50)
3 Configure the following parameters on the Spectrum Analyzer:
   *a* Band/Interval Power marker function
   *b* DC coupling (not applicable for the Economy Spectrum Analyzers)
   *c* Measure the Power Level within range of 3 MHz to 400 MHz
4 Collect the data from the Spectrum Analyzer to the 10GBASE-T Ethernet Test Application and plot the graph.
5 Set the Spectrum Analyzer to AC coupling mode.
6 Compare the test result with the compliance test limit.

## Measurement Algorithm Using the Oscilloscope

1 Configure the DUT to produce Test Mode 5 signal.

2 On the Infiniium Oscilloscope,

*a* Trigger and collect the waveform from the Oscilloscope.

*b* Apply the selected windowing function to the sampled waveform.

*c* Compute the amplitude spectra as:

$$\text{Amplitude spectra(f)} = \frac{1}{N}\sum_{i=0}^{N-1} \text{FFT amplitude[i]}$$

Where N = number of segments or cycles to compute.

*d* Apply a correction factor to the signal to compensate windowing losses:

$$\text{Correction factor} = \frac{\text{n}}{\left\{\sum(\text{window function})\right\}}$$

*e* Convert the amplitude to dBm.

*f* Calculate the band power:

$$\text{BP} = (\text{Bs}/\text{Bp}) \cdot \frac{1}{\text{n2} - \text{n1} + 1} \cdot \sum 10^{P[i]/10}$$

Where:

- Bs = specified bandwidth (400 MHz - 3 MHz)
- Bn = equivalent noise bandwidth of frequency resolution
- n1 = index of first point
- n2 = insex of last point
- P = power in Watts

*g* Compare the result to the compliance limit.

## Test References

See Clause 55.5.3.4 Power Level in the *IEEE 802.3-2018 Standard*.

Also See Section 2.8.1 Transmit Power and PSD in the *NBASE-T PHY Spec, V1.1 Standard*.

# 10 Transmitter Linearity Tests



This section provides the Methods of Implementation (MOIs) for Transmitter Linearity tests using a Keysight Infiniium 90000-Series DSO Oscilloscope, a Keysight Infiniium MXR Oscilloscope, or a Keysight Infiniium UXR Oscilloscope; Spectrum Analyzer, 10GBase-T Transmitter Test Fixture and the 10GBASE-T Ethernet Test Application.

There are two methods of running the Transmitter Linearity tests:

- Using an External Spectrum Analyzer.
- Using the Oscilloscope.

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## Procedure for Transmitter Linearity Tests Using an External Spectrum Analyzer

### Running the Transmitter Linearity Tests using the 10GBASE-T Ethernet Test Application

1 Start the 10GBASE-T Ethernet Test Application as described in "Starting the 10GBASE-T Ethernet Test Application" on page 19.
2 To make connections for the Transmitter Linearity tests, refer to "Connections for Compliance Tests" on page 21.
3 Connect one end of the RJ45 cable to the DUT and another end to J1 connector on the Section 1 of the 10GBase-T Transmitter Test Fixture.
4 Connect the SMP connector pairs, for example A+ and A- SMP connectors to the Balun by using the SMP to SMA cables.
5 Connect the Balun to the Spectrum Analyzer by using the SMA cable.
6 Use a LAN or GPIB to USB cable to connect the Spectrum Analyzer to the Oscilloscope.
7 In the 110GBASE-T Ethernet Test Application, click the **Set Up** tab.
8 Select one of the following options under **Technology** to run tests on the DUT based on the respective technology standards. The **Select Tests** tab lists tests based on the technology you select.
   - **Specification: IEEE** and **Data Rate: 10G**,
   - **Specification: MGBASE-T** and **Data Rate: 5.0G** or **2.5G**,
   - **Specification: NBASE-T** and **Data Rate: 5.0G** or **2.5G**
9 In the **Spectral Analysis** area, select **Use Spectrum Analyzer**.
10 Ensure that the application detects the Spectrum Analyzer connection to the Oscilloscope. If the status indicates **Not Connected**, click the **Connect...** button in the **Spectrum Analyzer** area of the **External Instruments** section of the 10GBASE-T Ethernet Test Application.

11 A pop-up box appears where you can enter either the VISA/SICL address or the IP address. Enter the information and click the **Verify** button, followed by the **Done** button to close this box. The VISA/SICL address or the IP address can be obtained from the Keysight Connection Expert application, as shown in Figure 27.

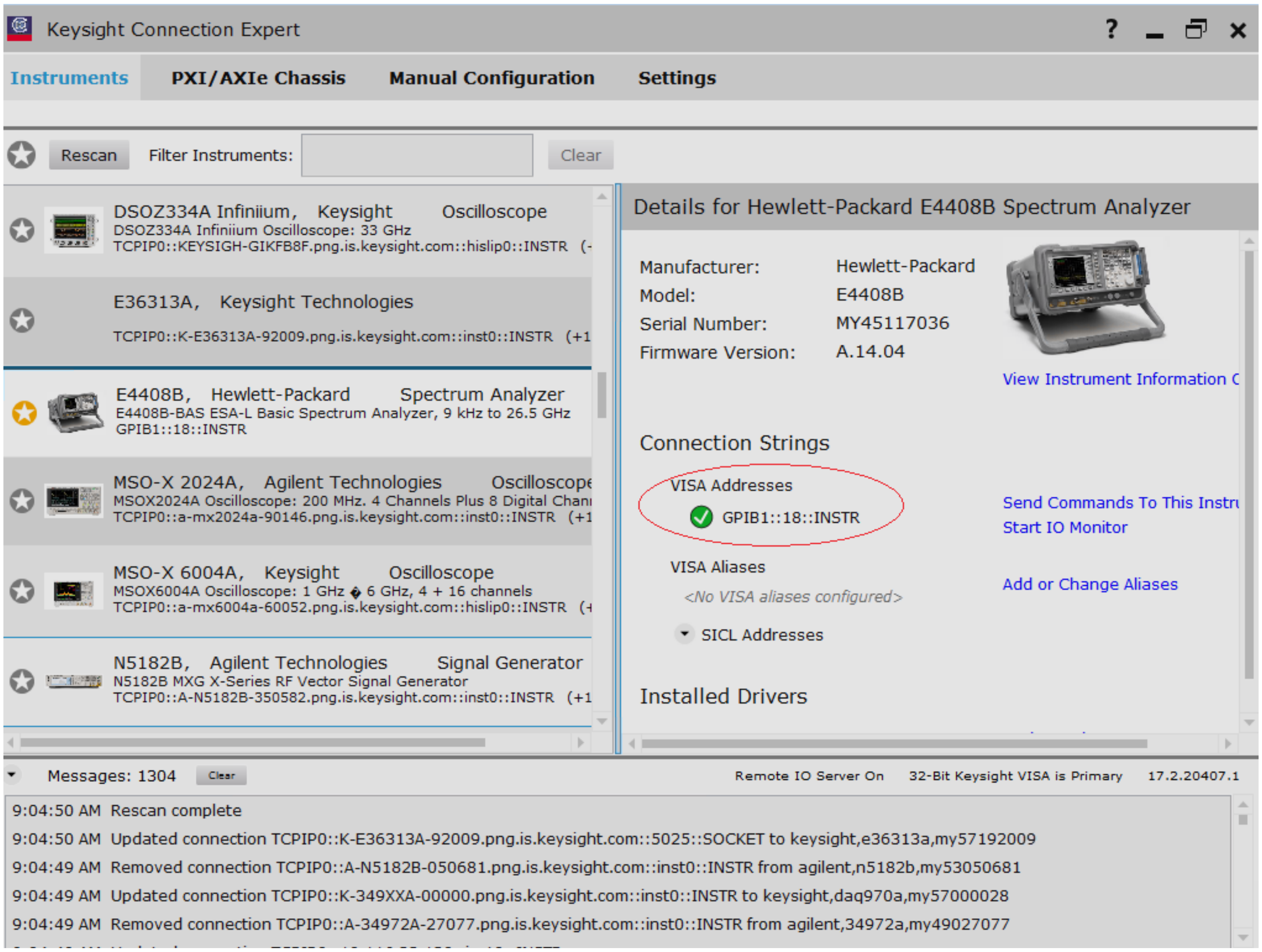

Figure 27 Checking VISA/SICL Address for Spectrum Analyzer in the Keysight Connection Expert

12 Once the 10GBASE-T Ethernet Test Application detects the Spectrum Analyzer, it is indicated on the **Set Up** tab as shown in Figure 28.

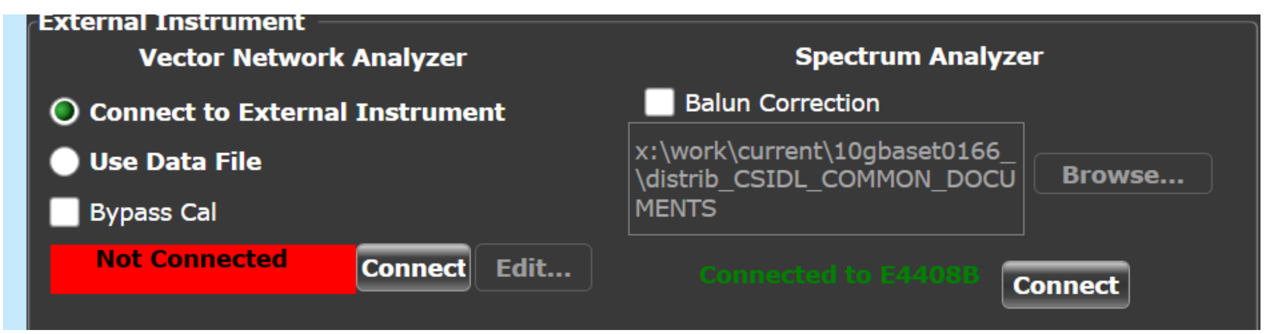


Figure 28 Connection status after the Test App detects the Spectrum Analyzer

13 Enter your comments in the **Comments** text box.
14 Click the **Select Tests** tab and check the tests you want to run. Check the parent node or group to check all the available tests within the group.
15 Follow the 10GBASE-T Ethernet Test Application's task flow to set up the configuration options (see Table 8), run the test, and view the test results.

**Table 8 Test Configuration Options Using Spectrum Analyzer**

| Configuration Option | Description |
|---|---|
| **Transmitter Linearity Tests** | |
| Start Frequency | The start frequency for the Spectrum Analyzer. |
| Stop Frequency | The stop frequency for the Spectrum Analyzer. |
| Resolution Bandwidth | The resolution bandwidth for the Spectrum Analyzer. |
| Reference Level | The reference level for the Spectrum Analyzer. |
| Intermodulation Tolerance | The tolerance for intermodulation. |
| Test Type | The test type for Transmitter Linearity tests. |
| Command File [Debug Mode] | The command file for the Spectrum Analyzer. |
| Timeout [Debug Mode] | The timeout configured for the Spectrum Analyzer. |
| #Averages | The number of averages for Power Level test using the Spectrum Analyzer. |

Note: The **Configure** tab of the 10GBASE-T Ethernet Test Application displays the default values for the options listed in the table. Refer to the 10GBASE-T Ethernet Test Application's Online Help to see how to change the values, if required.

## Procedure for Transmitter Linearity Tests Using the Oscilloscope

### Running the Transmitter Linearity Tests using the 10GBase-T Test Application

1. Start the 10GBase-T Compliance Test Application as described in "Starting the 10GBASE-T Ethernet Test Application" on page 19.
2. To make connections for the Power Level test, refer to "Connections for Compliance Tests" on page 21.
3. Connect one end of the RJ45 cable to the DUT and another end to J1 connector on the Section 1 of the 10GBase-T Transmitter Test Fixture.
4. Connect the SMP connector pairs, for example A+ and A- SMP connectors to the Oscilloscope.
5. In the 10GBASE-T Ethernet Test Application, click the **Set Up** tab.
6. Select one of the following options under **Technology** to run tests on the DUT based on the respective technology standards. The **Select Tests** tab lists tests based on the technology you select.
   - **Specification: IEEE** and **Data Rate: 10G**,
   - **Specification: MGBASE-T** and **Data Rate: 5.0G** or **2.5G**,
   - **Specification: NBASE-T** and **Data Rate: 5.0G** or **2.5G**
7. In the **Spectral Analysis** area, select **Use Oscilloscope**.
8. Enter your comments in the **Comments** text box.
9. Click the **Select Tests** tab and check the tests you want to run. Check the parent node or group to check all the available tests within the group.
10. Follow the 10GBASE-T Ethernet Test Application's task flow to set up the configuration options (see Table 9), run the test, and view the results.

**Table 9 Test Configuration Options Using Oscilloscope**

| Configuration Option | Description |
|---|---|
| Connection Pair (Positive) | The channel number for connection pair positive. |
| Connection Pair (Negative) | The channel number for connection pair negative. |
| **Transmitter Linearity Tests** | |
| Start Frequency | The start frequency for the Spectrum Analyzer. |
| Stop Frequency | The stop frequency for the Spectrum Analyzer. |
| Resolution Bandwidth | The resolution bandwidth for the Spectrum Analyzer. |
| Intermodulation Tolerance | The tolerance for intermodulation. |
| Memory Depth | Memory Depth configured on the Oscilloscope. |
| Spectral Windowing | Windowing function applied to the input data segment before implement FFT using Oscilloscope. |

Note: The **Configure** tab of the 10GBASE-T Ethernet Test Application displays the default values for the options listed in the table. Refer to the 10GBASE-T Ethernet Test Application's Online Help to see how to change the values, if required.

## List of Transmitter Linearity Tests

Figure 29 shows the tests available under the **Transmitter Linearity Tests** group of the **Select Tests** tab.

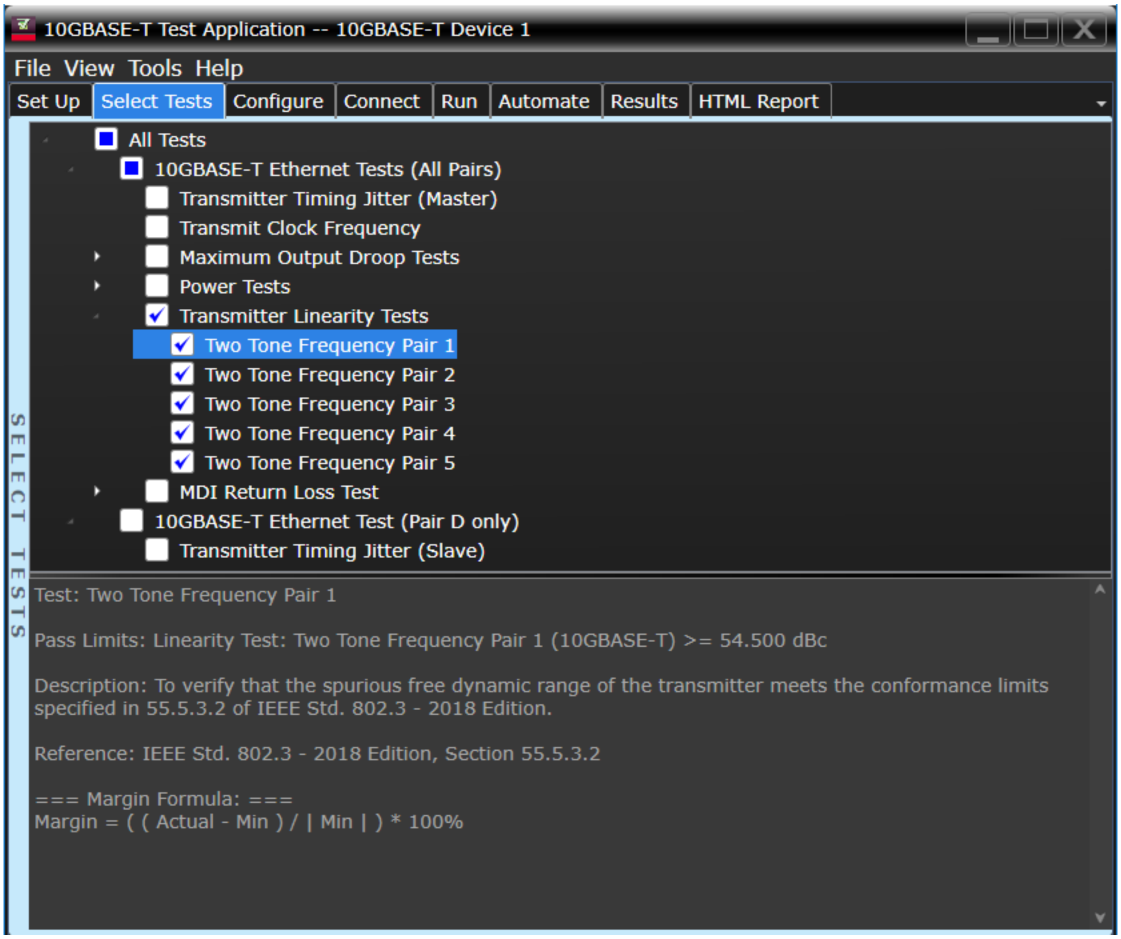


Figure 29 Selecting Transmitter Linearity Tests

## Transmitter Linearity Tests—Implementation Methodology

The purpose of the Transmitter Linearity tests is to verify that the device under test (DUT) conforms to the Spurious Free Dynamic Range (SFDR) requirements specified in clause 55.5.3.2 of IEEE 802.3-2018.

This SFDR will be verified for each of the four pairs of 10G Test Mode 4 with dual tone input signaling for a particular DUT. These pairs are identified as Pair A, Pair B, Pair C and Pair D.

### Test Definition Notes from the Specification

#### IEEE 802.3—2018 Clause 55.5.3.2 Transmitter Linearity

When in Test Mode 4 and observing the spectrum of the differential signal output at the MDI using transmitter test fixture 2, for each pair, with no intervening cable, the transmitter linearity mask is defined as follows:

The SFDR of the transmitter, with dual tone inputs as specified in Test Mode 4, shall meet the requirement that:

SFDR $\geq$ 2.5 + min{52,58 - 20 X $\log_{10}(f/25)$} (55-7)

where *f* is the maximum frequency of the two test tones in MHz and SFDR is the ratio in dB of the minimum RMS value of either input tone to the RMS value of the worst inter-modulation product in the frequency range of 1 MHz to 400 MHz.

This specification on transmit linearity is derived from the requirement for interoperability with the far-end device.

### Pass Condition

1 The SFDR of the transmitter for each Lane should meet the below requirement:
SFDR $\geq$ 2.5 + min {52, 58 - 20$\log_{10}(f/25)$}

Where, *f* = maximum frequency of the two test tones

SFDR = Ratio of the minimum RMS value between two input tone and worst intermodulation product of RMS.

2 The test limit of SFDR for each Lane should be different for different transmit frequency.

**Table 10 Test Limit of SFDR for 10GBase-T**

| Transmit Frequency | Frequency Pair (MHz) | Test Limit (dBc) |
|---|---|---|
| 1 | 36.718 & 41.406 | $\geq$ 54.5 |
| 2 | 78.906 & 80.469 | $\geq$ 50.346 |
| 3 | 139.844 & 141.406 | $\geq$ 45.449 |
| 4 | 216.406 & 219.531 | $\geq$ 41.629 |
| 5 | 310.156 & 313.281 | $\geq$ 38.540 |

**Table 11 Test Limit of SFDR for MGBase-T and NBase-T**

| Transmit Frequency | Frequency Pair for 2.5G (MHz) | Test Limit for 2.5G(dBc) | Frequency Pair for 5.0G (MHz) | Test Limit for 5.0G(dBc) |
|---|---|---|---|---|
| Dual Tone 1 | 9.1795 & 10.3515 | ≥ 54.5 | 18.359 & 20.703 | ≥ 54.5 |
| Dual Tone 2 | 19.7265 & 20.11725 | ≥ 54.5 | 39.453 & 40.2345 | ≥ 54.5 |
| Dual Tone 3 | 34.961 & 35.3515 | ≥ 54.5 | 69.922 & 70.703 | ≥ 51.47 |
| Dual Tone 4 | 54.1015 & 54.88275 | ≥ 53.67 | 108.203 & 109.7655 | ≥ 47.649 |
| Dual Tone 5 | 77.539 & 78.32025 | ≥ 50.581 | 155.078 & 156.6405 | ≥ 44.561 |

### Measurement Algorithm When Using the External Spectrum Analyzer

1 Configure the DUT to produce Test Mode 4 signal and set the test frequency.

2 Configure the following parameters in the **Configure** tab of the 10GBASE-T Ethernet Test Application:

   *a* Start frequency = 1 MHz

   *b* Stop frequency = 400 MHz

   *c* Resolution bandwidth:

   - 300 kHz (for 90000-Series DSO Oscilloscopes)
   - 200 kHz (for UXR and MXR Oscilloscopes)

**NOTE** **When using an external spectrum analyzer, the resolution bandwidth configuration shares the same variable as in oscilloscope usage.**

   *d* Averaging (default value is 50)

3 Configure the following parameter on the Spectrum Analyzer:

   *a* DC coupling (not applicable for the Economic Spectrum Analyzers)

4 Collect the data from the Spectrum Analyzer to the 10GBASE-T Ethernet Test Application and plot the graph.

5 Calculate the Intermodulation Product Frequency with the below equation:

   Even Order = n(A+B), n(A-B)

   where, n = 2,4,6,8,10......120

   Odd Order = N(A)+/- (N-1)(B), N(B)+/- (N-1)(A)

   where,

   N = n - ((n/2)-0.5) and n = 3,5,7,9....119

   A, B = Two frequency components

6 Keep the list of the calculated frequency, L1.

7 Get the peak product frequency from the Spectrum Analyzer and keep it in another list, L2.

8 Compare L1 with L2 and keep the list of the peak value (obtained from the Spectrum Analyzer), L3 with the condition:

   - Frequency values that are close to the frequency (with default tolerance of 500 kHz) in L1.

9 SFDR = Highest Peak (L3) - Third Highest Peak (L3)

10 Set the Spectrum Analyzer to AC coupling mode.

11 Compare the test result with the compliance test limit.

### Measurement Algorithm When Using the Oscilloscope

1 Configure the DUT to produce Test Mode 4 signal.
2 Configure the following parameters in the **Configure** tab of the 10GBASE-T Ethernet Test Application:
   *a* Start frequency = 1 MHz
   *b* Stop frequency = 400 MHz
   *c* Resolution bandwidth:
   - 300 kHz (for 90000-Series DSO Oscilloscopes)
   - 200 kHz (for MXR and UXR Oscilloscopes)

   *d* Averaging (default value is 50)
3 On the Infiniium Oscilloscope,
   *a* Trigger and collect the waveform from the Oscilloscope.
   *b* Apply the selected windowing function to the sampled waveform.
   *c* Compute the amplitude spectra as:

$$\text{amplitude spectra} = \frac{1}{N} \sum_{i=0}^{N-1} |\text{FFT amplitude[i]}|$$

   Where N = number of segments or cycles to compute.
   *d* Apply a correction factor to the signal to compensate windowing losses:

$$\text{Correction factor} = \frac{n}{\left\{\sum (\text{window function})\right\}}$$

   *e* Convert the amplitude to dBm.
   *f* Calculate the Intermodulation Product Frequency with the equation:
   Even Order = n(A+B), n(A-B)
   where, n = 2,4,6,8,10......120
   Odd Order = N(A)+/- (N-1)(B), N(B)+/- (N-1)(A)
   where,
   N = n - ((n/2)-0.5) and n = 3,5,7,9....119
   A, B = Two frequency components
4 Keep the list of the calculated frequency, L1.
5 Get the peak product frequency from the amplitude spectra (calculated in step 3c above) and keep it in another list, L2.
6 Compare L1 with L2 and keep the list of the peak value, L3, which is obtained from the amplitude spectra (calculated in step 3c above), with the condition:
   - Frequency values close to the frequency (with default tolerance of 500 kHz) in L1.
7 SFDR = Highest Peak (L3) - Third Highest Peak (L3)
8 Compare the test result with the compliance test limit.

### Test References

See Clause 55.5.3.2 Transmitter Linearity in the *IEEE 802.3-2018 Standard*.

# 11 Transmitter Nonlinear Distortion Tests



This section provides the Methods of Implementation (MOIs) for Transmitter Nonlinear Distortion tests using a Keysight Infiniium 90000-Series DSO Oscilloscope, a Keysight Infiniium MXR Oscilloscope, or a Keysight Infiniium UXR Oscilloscope; Spectrum Analyzer, 10GBase-T Transmitter Test Fixture and the 10GBASE-T Ethernet Test Application.

There are two methods of running the Transmitter Nonlinear Distortion tests:

- Using an External Spectrum Analyzer.
- Using the Oscilloscope.

## Procedure for Transmitter Nonlinear Distortion tests Using an External Spectrum Analyzer

Running the Transmitter Nonlinear Distortion tests using the 10GBASE-T Ethernet Test Application

1. Start the 10GBASE-T Ethernet Test Application as described in "Starting the 10GBASE-T Ethernet Test Application" on page 19.
2. To make connections for the Transmitter Nonlinear Distortion tests, refer to "Connection Diagram using Spectrum Analyzer" on page 90.
3. Connect one end of the RJ45 cable to the DUT and another end to J1 connector on the Section 1 of the 10GBase-T Transmitter Test Fixture.
4. Connect the SMP connector pairs, for example A+ and A- SMP connectors to the Balun by using the SMP to SMA cables.
5. Connect the Balun to the port S of the power splitter using an SMA cable.
6. Connect the output of the AWG to Port 1 of the power splitter using an SMA cable.
7. Connect Port 2 of the Power Splitter to the Spectrum Analyzer using an SMA cable.
8. Use a LAN or GPIB to USB cable to connect the Spectrum Analyzer to the Oscilloscope.
9. In the 10GBase-T Compliance Test Application, click the **Set Up** tab.
10. Select **NBASE-T** and **2.5G** under **Technology** to run tests on the DUT based on the respective technology standards.
11. In the **Spectral Analysis** area, select **Use Spectrum Analyzer**.

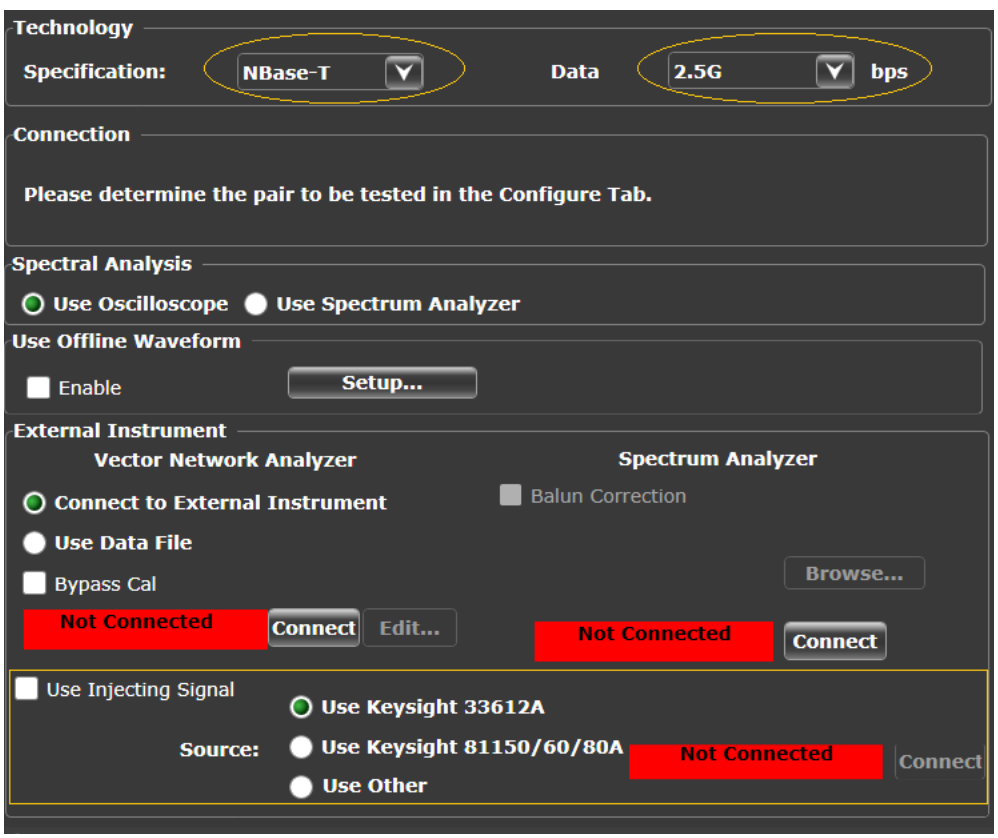


Figure 30 Set Up tab settings for Transmitter Nonlinear Distortion tests using Spectrum Analyzer

12 Ensure that the application detects the Spectrum Analyzer connection to the Oscilloscope. If the status indicates **Not Connected**, click the **Connect** button in the **Spectrum Analyzer** area of the **External Instruments** section of the 10GBASE-T Ethernet Test Application.

13 A pop-up box appears where you can enter either the VISA/SICL address or the IP address. Enter the information and click the **Verify** button, followed by the **Done** button to close this box. The VISA/SICL address or the IP address can be obtained from the Keysight Connection Expert application, as shown in Figure 32.

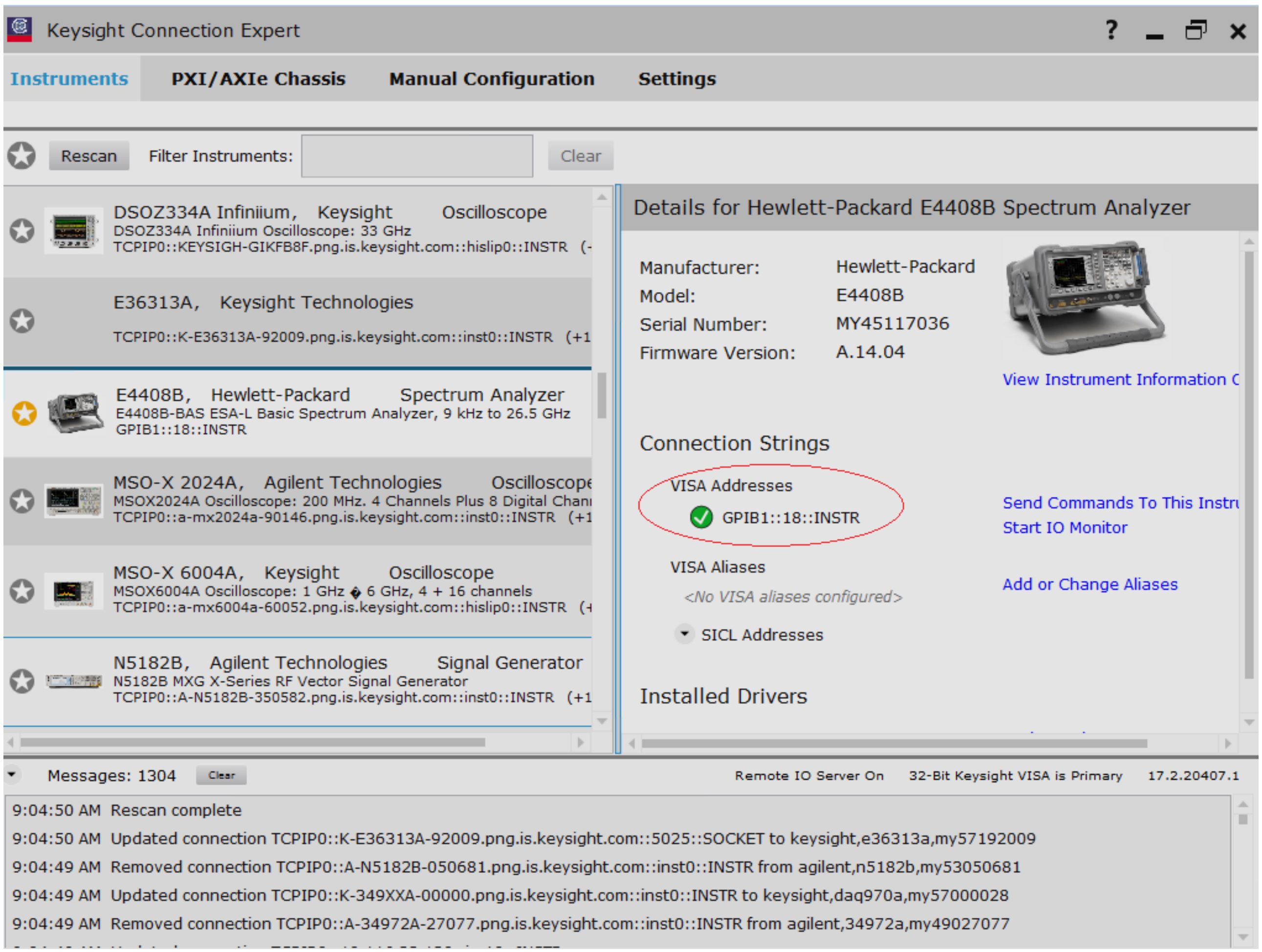


Figure 31 Checking VISA/SICL Address for Spectrum Analyzer in the Keysight Connection Expert

14 Select the **Use Injecting Signal** check box, as shown in Figure 30, so that the Test Application is able to connect to the waveform generator to run the Transmitter Nonlinear Distortion tests.

15 Select one of the Waveform Generator device names displayed in the **Source:** area.

16 Click the **Connect** button. A pop-up box appears where you can enter either the VISA/SICL address or the IP address. Enter the information and click the **Verify** button, followed by the **Done** button to close this box. The VISA/SICL address or the IP address can be obtained from the Keysight Connection Expert application, as shown in Figure 32.

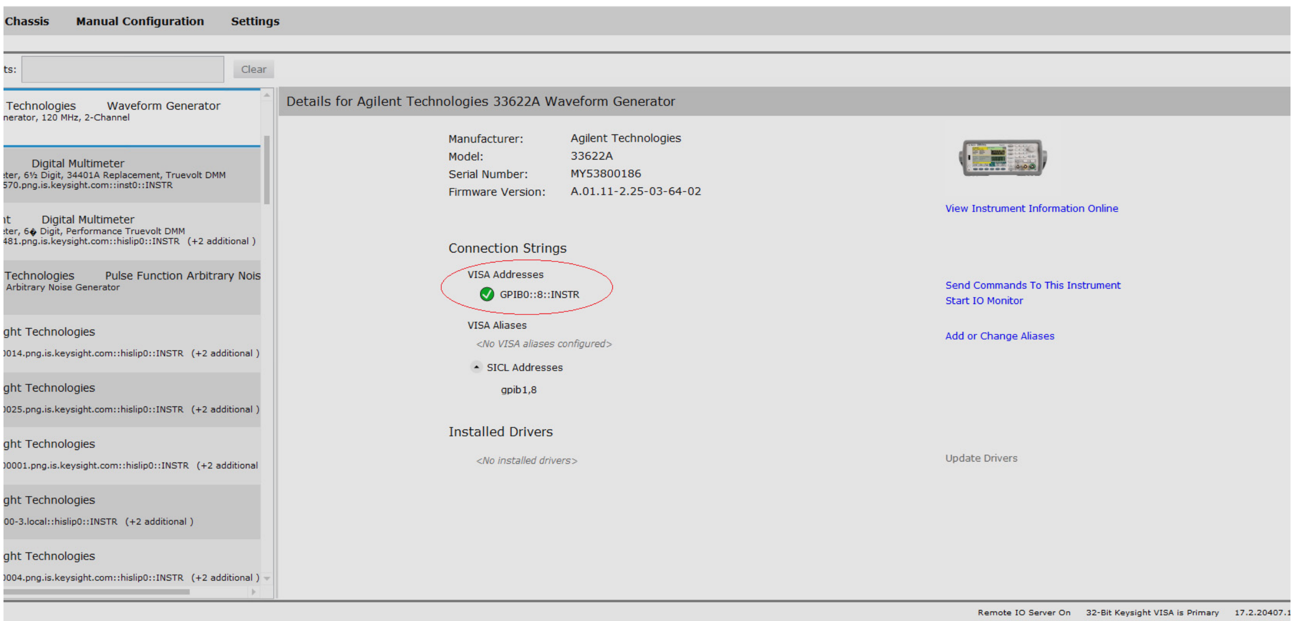


Figure 32 Checking VISA/SICL Address for Injecting Signal Source in the Keysight Connection Expert

17 Once the 10GBASE-T Ethernet Test Application detects the Spectrum Analyzer and Injecting Signal source, it is indicated on the **Set Up** tab as shown in Figure 33.

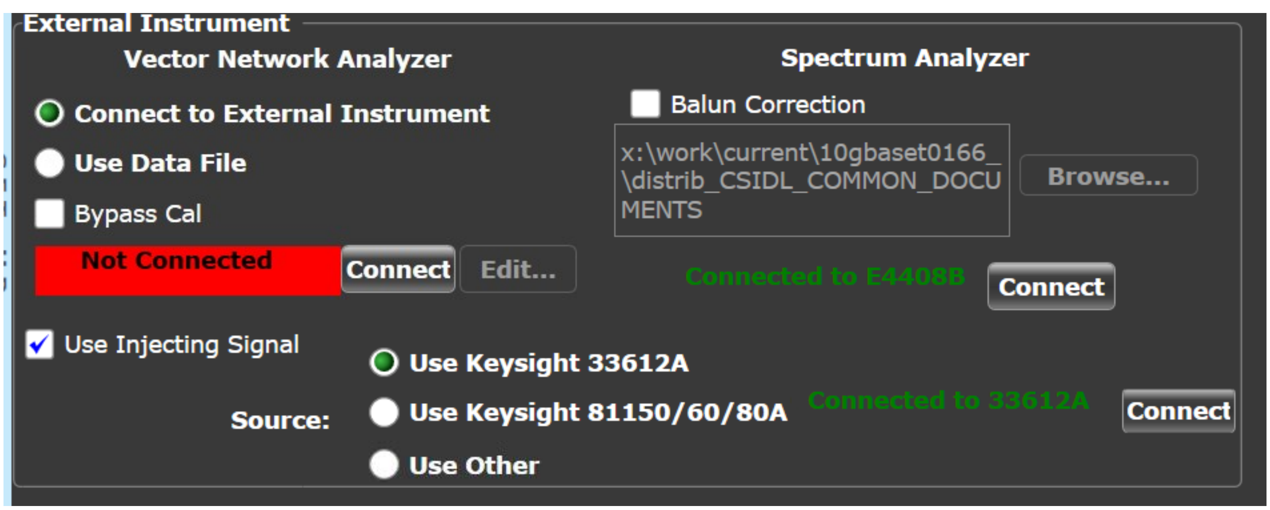


Figure 33 Connected status for Spectrum Analyzer & for Keysight 33612A as Injecting Signal Source


Figure 34 Connected status for Keysight 81160A as Injecting Signal Source

If you are using an external (non-Keysight) function generator, such as a 2-Channel signal generator that can output 45MHz Sine wave, select the **Use Other** option as the Injecting Signal Source. However, notice that the **Connect** button is grayed out because the 10GBASE-T Ethernet Test Application does not control the connectivity to the external device. You must manually set up the frequency and amplitude along with other settings on the external device.

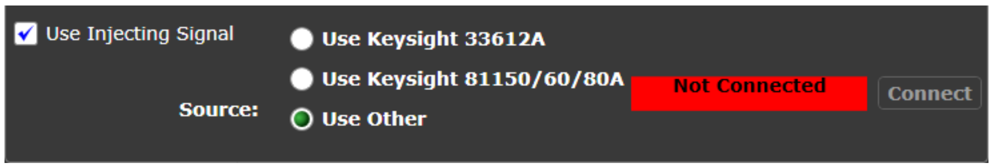


Figure 35 Connect button's unavailability for an external (non-Keysight) Injecting Signal Source

18 Enter your comments in the **Comments** text box.

19 Click the **Select Tests** tab and check the tests you want to run, as shown in Figure 38. Check the parent node or group to check all the available tests within the group.

20 Follow the 10GBASE-T Ethernet Test Application's task flow to set up the configuration options (see Table 12), run the test, and view the test results.

**Table 12 Test Configuration Options Using Spectrum Analyzer**

| Configuration Option | Description |
|---|---|
| **Transmitter Nonlinear Distortion tests** | |
| Start Frequency | The start frequency for the Spectrum Analyzer. |
| Stop Frequency | The stop frequency for the Spectrum Analyzer. |
| Resolution Bandwidth | The resolution bandwidth for the Spectrum Analyzer. |
| Reference Level | The reference level for the Spectrum Analyzer. |
| Intermodulation Tolerance | The tolerance for intermodulation. |
| Test Type | The test type for Transmitter Nonlinear Distortion tests. |
| Command File [Debug Mode] | The command file for the Spectrum Analyzer. |
| Timeout [Debug Mode] | The timeout configured for the Spectrum Analyzer. |
| #Averages | The number of averages for Power Level test using the Spectrum Analyzer. |

Note: The **Configure** tab of the 10GBASE-T Ethernet Test Application displays the default values for the options listed in the table. Refer to the 10GBASE-T Ethernet Test Application's Online Help to see how to change the values, if required.

## Procedure for Transmitter Nonlinear Distortion tests Using the Oscilloscope

Running the Transmitter Nonlinear Distortion tests using the 10GBASE-T Ethernet Test Application

1 Start the 10GBASE-T Ethernet Test Application as described in "Starting the 10GBASE-T Ethernet Test Application" on page 19.
2 To make connections for the Transmitter Nonlinear Distortion tests, refer to "Connection Diagram using Oscilloscope" on page 91.
3 Connect one end of the RJ45 cable to the DUT and another end to J1 connector on the Section 1 of the 10GBase-T Transmitter Test Fixture.
4 Connect Channel 1 of the AWG to Port 1 of the first Power Splitter.
5 Connect Channel 2 of the AWG to Port 1 of the second Power Splitter.
6 Connect the SMP connector pairs, for example A+, to Port S of the first Power Splitter and A- to Port S of the second Power Splitter.
7 Connect Port 2 of each Power Splitter to the Oscilloscope.
8 In the 10GBASE-T Ethernet Test Application, click the **Set Up** tab.
9 Select **NBASE-T** and **2.5G** under **Technology** to run tests on the DUT based on the respective technology standards.

10 In the **Spectral Analysis** area, select **Use Oscilloscope**.

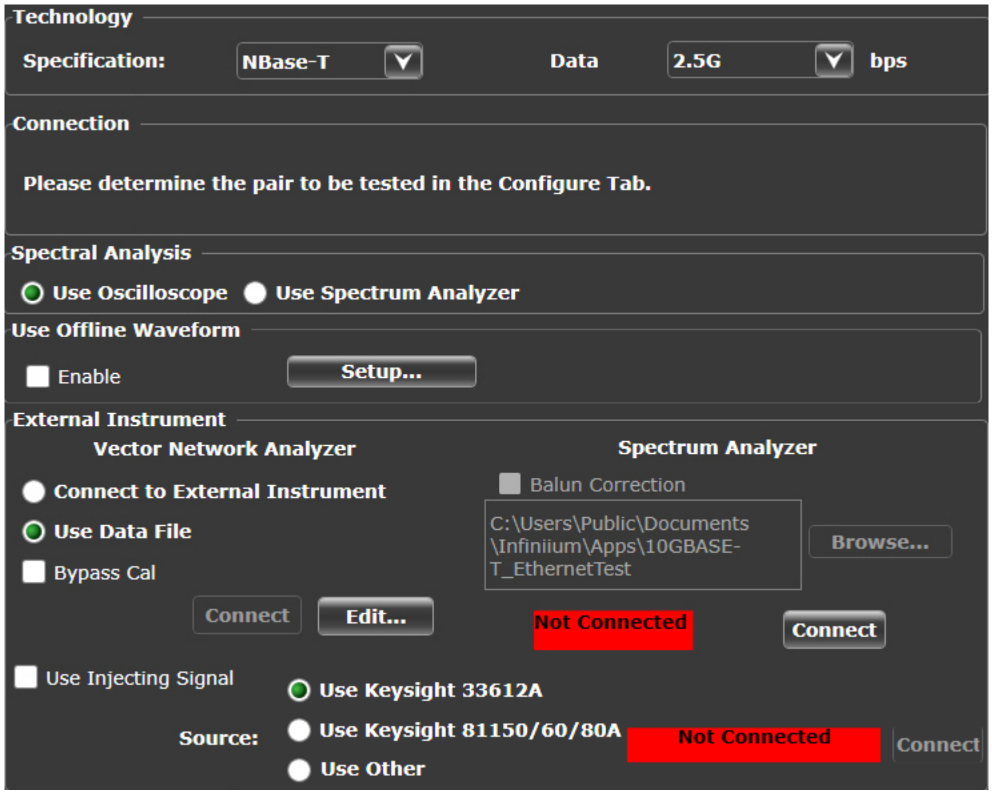


Figure 36 Set Up tab settings for Transmitter Nonlinear Distortion tests using Oscilloscope

11 Select the **Use Injecting Signal** check-box, as shown in Figure 36, so that the Test Application is able to connect to the waveform generator to run the Transmitter Nonlinear Distortion tests.

12 Select one of the Waveform Generator device names displayed in the **Source:** area.

13 Click the **Connect** button. A pop-up box appears where you can enter either the VISA/SICL address or the IP address. Enter the information and click the **Verify** button, followed by the **Done** button to close this box. The VISA/SICL address or the IP address can be obtained from the Keysight Connection Expert application, as shown in Figure 32.

**NOTE** As described earlier, the Connect button is unavailable when **Use Other** is selected as **Source** from the **Use Injecting Signal** options.

14 Once the 10GBASE-T Ethernet Test Application detects the Injecting Signal source, it is indicated on the **Set Up** tab as shown in Figure 37.

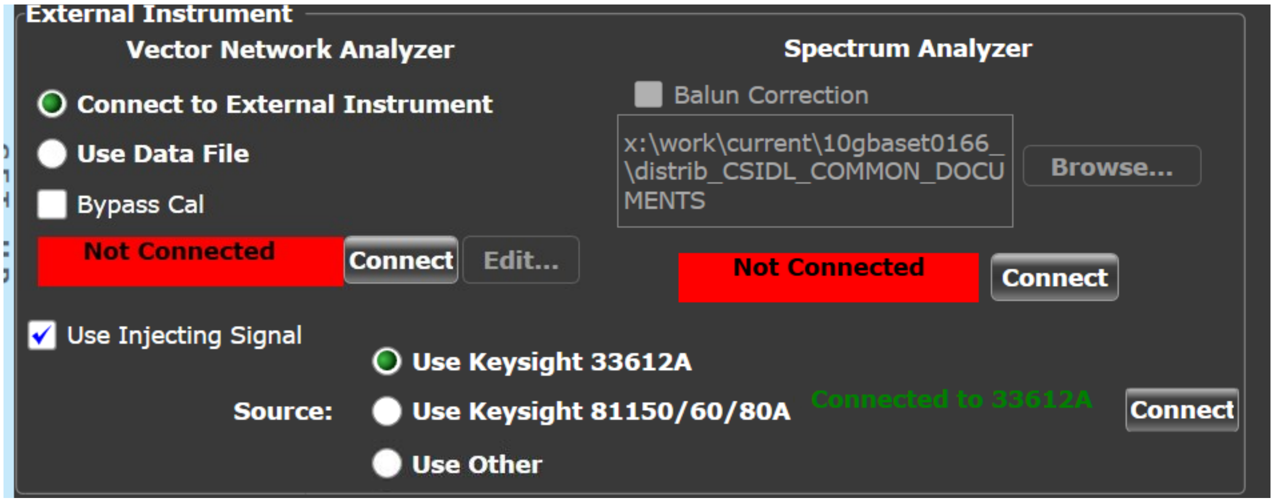


Figure 37 Connection status after the Application detects the Injecting Signal Source

15 Enter your comments in the **Comments** text box.

16 Click the **Select Tests** tab and check the tests you want to run. Check the parent node or group to check all the available tests within the group, as shown in Figure 38.

17 Follow the 10GBASE-T Ethernet Test Application's task flow to set up the configuration options (see Table 13), run the test, and view the results.

**Table 13 Test Configuration Options Using Oscilloscope**

| Configuration Option | Description |
|---|---|
| Connection Pair (Positive) | The channel number for connection pair positive. |
| Connection Pair (Negative) | The channel number for connection pair negative. |
| **Transmitter Nonlinear Distortion tests** | |
| Start Frequency | The start frequency for the Spectrum Analyzer. |
| Stop Frequency | The stop frequency for the Spectrum Analyzer. |
| Resolution Bandwidth | The resolution bandwidth for the Spectrum Analyzer. |
| Intermodulation Tolerance | The tolerance for intermodulation. |
| Memory Depth | Memory Depth configured on the Oscilloscope. |
| Spectral Windowing | Windowing function applied to the input data segment before implement FFT using Oscilloscope. |

Note: The **Configure** tab of the 10GBASE-T Ethernet Test Application displays the default values for the options listed in the table. Refer to the 10GBASE-T Ethernet Test Application's Online Help to see how to change the values, if required.

## List of Transmitter Nonlinear Distortion tests

Figure 38 shows the tests available under the **Transmitter Nonlinear Distortion tests** group of the **Select Tests** tab.

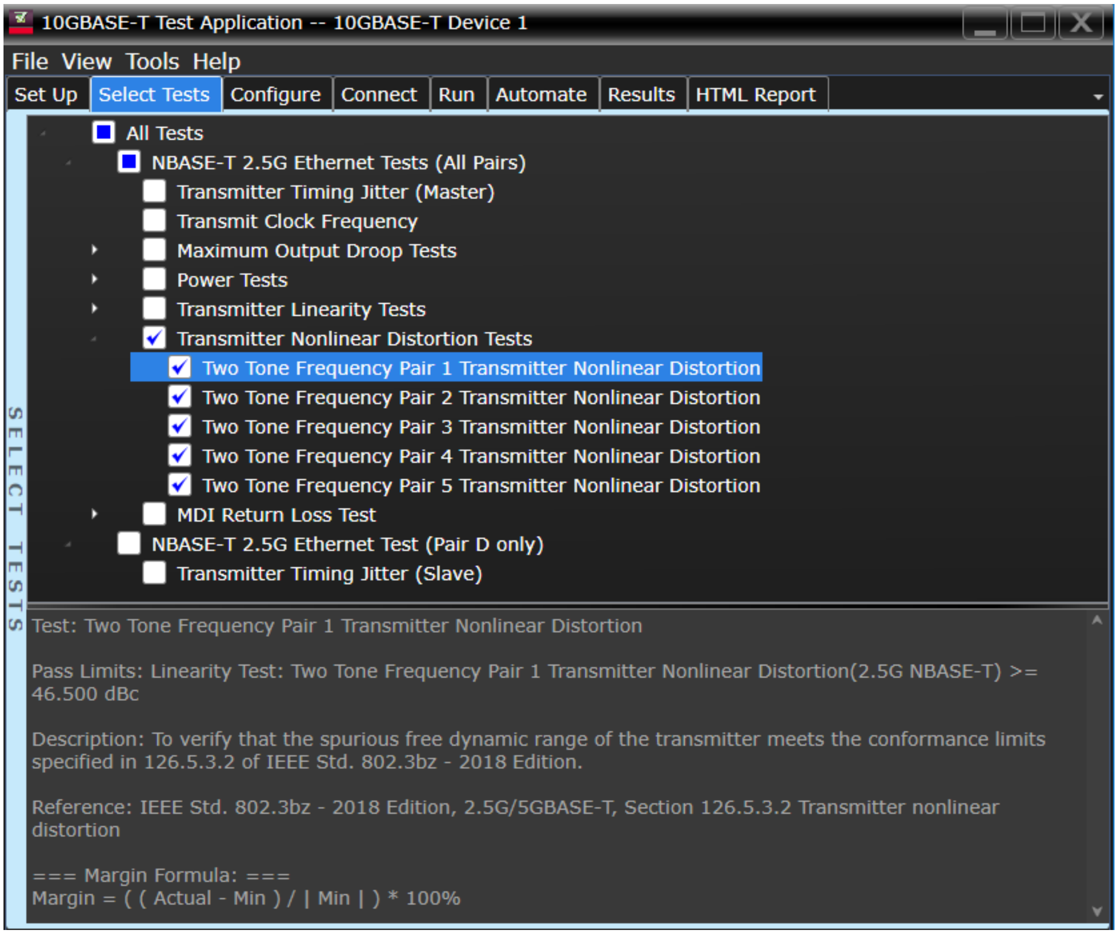


Figure 38 Selecting Transmitter Nonlinear Distortion tests

# Connection Diagrams for Transmitter Nonlinear Distortion tests

## Connection Diagram using Spectrum Analyzer

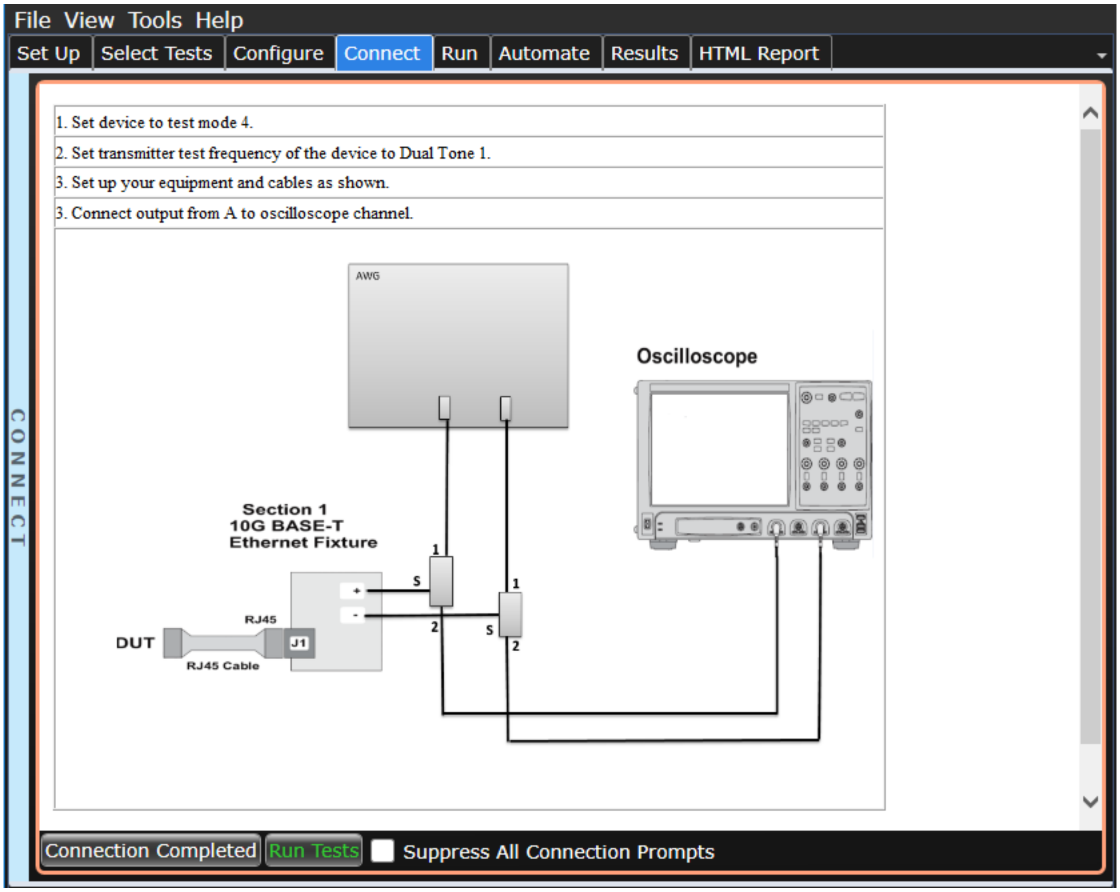


Figure 39 Connection Diagram for Transmitter Nonlinear Distortion tests with a Spectrum Analyzer

Connection Diagram using Oscilloscope

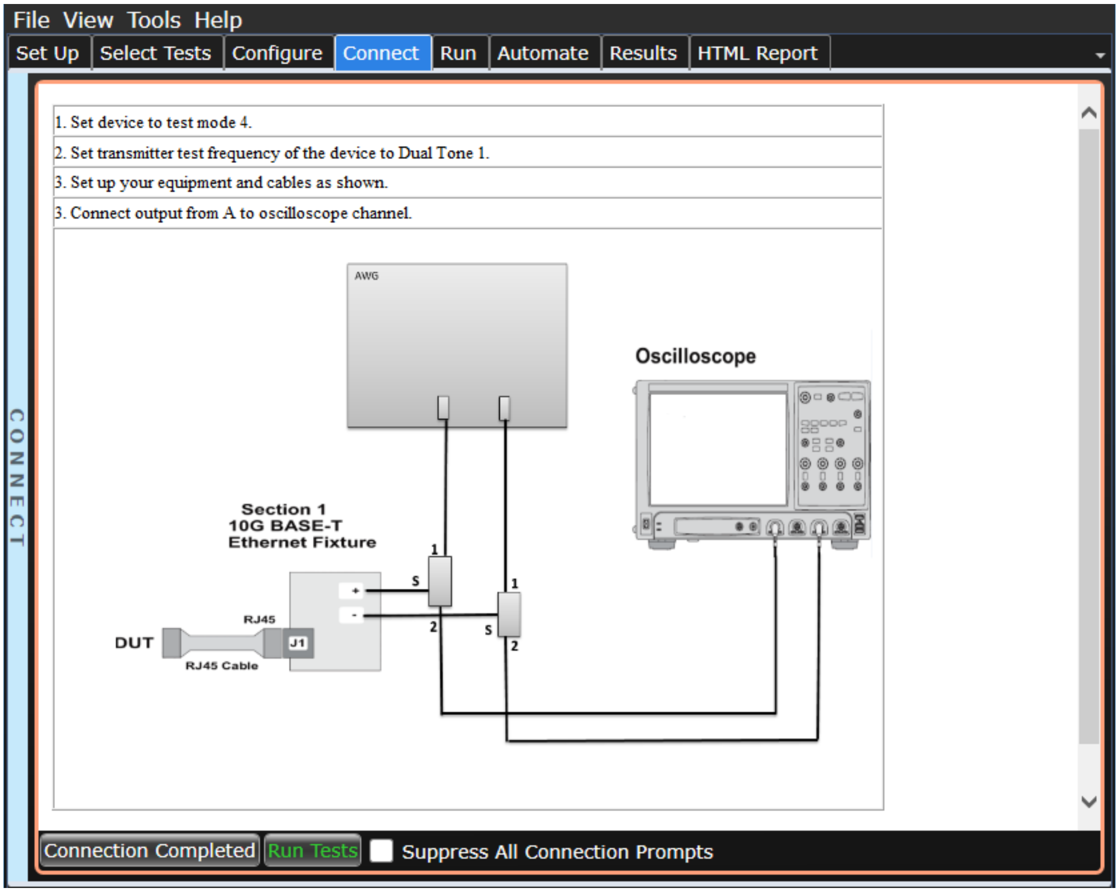


Figure 40 Connection Diagram for Transmitter Nonlinear Distortion tests with an Oscilloscope

# Transmitter Nonlinear Distortion tests—Implementation Methodology

The purpose of the Transmitter Nonlinear Distortion tests is to verify that the device under test (DUT) conforms to the Spurious Free Dynamic Range (SFDR) requirements specified in clause 126.5.3.2 of IEEE 802.3-2018.

This SFDR will be verified for each of the four pairs of 10G Test Mode 4 with dual tone input signaling for a particular DUT. These pairs are identified as Pair A, Pair B, Pair C and Pair D.

## Test Definition Notes from the Specification

### IEEE 802.3—2018 Clause 126.5.3.2 Transmitter Nonlinear Distortion

In Test Mode 4 at 0dB PBO along with observing the spectrum of the differential signal output at the MDI using transmitter test fixture 4, while injecting a 45 MHz sine wave from the signal generator so that it has an amplitude 7 dB below the peak of the transmitter at the MDI, with no intervening cable, the transmitter nonlinear distortion mask for each pair is defined as follows:

The SFDR of the transmitter, with dual tone inputs as specified in Test Mode 4, shall meet the requirement that:

$SFDR \geq -5.5 + \min\{52, 58 - 20\log_{10}(f/25)\}$

where, *f* is the maximum frequency of the two test tones in MHz and SFDR is the ratio in dB of the minimum RMS value of either input tones to the RMS value of the worst inter-modulation product in the frequency range of 1 MHz to 400 MHz.

This specification on transmitter nonlinear distortion is derived from the requirement for interoperability with the far-end device.

## Pass Condition

1 The SFDR of the transmitter for each Lane should meet the following requirement:
  $SFDR \geq -5.5 + \min\{52, 58 - 20\log_{10}(f/25)\}$

Where, *f* = maximum frequency of the two test tones

  SFDR = Ratio of the minimum RMS value between two input tone and worst intermodulation product of RMS.

2 The test limit of SFDR for each Lane should be different for different transmit frequency.

**Table 14 Test Limit of SFDR for NBase-T**

| Transmit Frequency | Frequency Pair for 2.5G (MHz) | Test Limit for 2.5G(dBc) |
|---|---|---|
| Dual Tone 1 | 9.1795 & 10.3515 | ≥ 54.5 |
| Dual Tone 2 | 19.7265 & 20.11725 | ≥ 54.5 |
| Dual Tone 3 | 34.961 & 35.3515 | ≥ 54.5 |
| Dual Tone 4 | 54.1015 & 54.88275 | ≥ 53.67 |
| Dual Tone 5 | 77.539 & 78.32025 | ≥ 50.581 |

### Measurement Algorithm When Using the External Spectrum Analyzer

1 Configure the DUT to produce Test Mode 4 signal and set the test frequency.
2 Configure the following parameters in the **Configure** tab of the 10GBase-T Compliance Test Application:
   *a* Start frequency = 1 MHz
   *b* Stop frequency = 400 MHz
   *c* Resolution bandwidth:
   - 300 kHz (for 90000-Series DSO Oscilloscopes)
   - 200 kHz (for UXR and MXR Oscilloscopes)

   *d* Averaging (default value is 50)
3 Configure the following parameter on the Spectrum Analyzer:
   *a* DC coupling (not applicable for the Economic Spectrum Analyzers)
4 Collect data from the Spectrum Analyzer to the 10GBASE-T Ethernet Test Application and plot the graph.
5 Calculate the Intermodulation Product Frequency with the following equation:
   Even Order = n(A+B), n(A-B)
   where, n = 2,4,6,8,10......120
   Odd Order = N(A)+/- (N-1)(B), N(B)+/- (N-1)(A)
   where,
   N = n - ((n/2)-0.5) and n = 3,5,7,9....119
   A, B = Two frequency components
6 Keep the list of the calculated frequency, L1.
7 Get the peak product frequency from the Spectrum Analyzer and keep it in another list, L2.
8 Compare L1 with L2 and keep the list of the peak values (obtained from the Spectrum Analyzer), L3 with the condition:
   - Frequency values that are close to the frequency (with default tolerance of 500 kHz) in L1.

9 SFDR = Highest Peak (L3) - Third Highest Peak (L3)
10 Set the Spectrum Analyzer to AC coupling mode.
11 Compare the test result with the compliance test limit.

### Measurement Algorithm When Using the Oscilloscope

1 Configure the DUT to produce Test Mode 5 signal.
2 On the Infiniium Oscilloscope,
   *a* Trigger and collect the waveform from the Oscilloscope.
   *b* Apply the selected windowing function to the sampled waveform.
   *c* Compute the amplitude spectra as:

$$\text{amplitude spectra} = \frac{1}{N}\sum_{i=0}^{N-1}|\text{FFT amplitude[i]}|$$

   Where N = number of segments or cycles to compute.
   *d* Apply a correction factor to the signal to compensate windowing losses:

$$\text{Correction factor} = \frac{n}{\left\{\sum (\text{window function})\right\}}$$

*e* Convert the amplitude to dBm.

*f* Calculate the Intermodulation Product Frequency with the equation:

Even Order = n(A+B), n(A-B)

where, n = 2,4,6,8,10......120

Odd Order = N(A)+/- (N-1)(B), N(B)+/- (N-1)(A)

where,

N = n - ((n/2)-0.5) and n = 3,5,7,9....119

A, B = Two frequency components

3 Keep the list of the calculated frequency, L1.

4 Get the peak product frequency from the amplitude spectra (calculated in step 2c above) and keep it in another list, L2.

5 Compare L1 with L2 and keep the list of the peak values, L3, which is obtained from the amplitude spectra (calculated in step 2c above), with the condition:

- Frequency values that are close to the frequency (with default tolerance of 500 kHz) in L1.

6 SFDR = Highest Peak (L3) - Third Highest Peak (L3)

7 Compare the test result with the compliance test limit.

## Test References

See Clause 126.5.3.2 Transmitter Nonlinear Distortion in the *IEEE 802.3-2018 Standard*.

# 12 MDI Return Loss Test



This section provides the Methods of Implementation (MOIs) for MDI Return Loss test using a Keysight Infiniium 90000-Series DSO Oscilloscope, a Keysight Infiniium MXR Oscilloscope, or a Keysight Infiniium UXR Oscilloscope; Vector Network Analyzer, 10GBase-T Transmitter Test Fixture and the 10GBASE-T Ethernet Test Application.

There are two methods of running the MDI Return Loss test:

- Using an External Vector Network Analyzer.
- Using the Oscilloscope.

## Procedure for MDI Return Loss Test

Running the MDI Return Loss Test using the 10GBASE-T Ethernet Test Application

1. Start the 10GBASE-T Ethernet Test Application as described in "Starting the 10GBASE-T Ethernet Test Application" on page 19.
2. To make connections for the MDI Return Loss test, refer to "Connections for Compliance Tests" on page 21.
3. Connect one end of the RJ45 cable to the DUT and another end to J1 connector on the Section 1 of the 10GBase-T Transmitter Test Fixture.
4. Connect the SMP connector pairs, for example A+ and A- SMP connectors to the Balun by using the SMP to SMA cables.
5. Connect the Balun to the Vector Network Analyzer by using the SMA cable.
6. Use a LAN or GPIB to USB cable to connect the Vector Network Analyzer to the Oscilloscope.
7. In the 10GBASE-T Ethernet Test Application, click the **Set Up** tab.
8. Select one of the following options under **Technology** to run tests on the DUT based on the respective technology standards. The **Select Tests** tab lists tests based on the technology you select.
   - **Specification: IEEE** and **Data Rate: 10G**,
   - **Specification: MGBASE-T** and **Data Rate: 5.0G** or **2.5G**,
   - **Specification: NBASE-T** and **Data Rate: 5.0G** or **2.5G**
9. Based on the test requirements, select the appropriate options and perform connections in the **Spectral Analysis** area.

10 Ensure that the application detects the Vector Network Analyzer connection to the Oscilloscope. If the status in the **Vector Network Analyzer** area of the **External Instruments** section of the 10GBASE-T Ethernet Test Application indicates **Not Connected**,

*a* With the default option **Connect to External Instrument** selected, click the **Connect...** button.

*b* A pop-up box appears where you can enter either the VISA/SICL address or the IP address. Enter the information and click the **Verify** button, followed by the **Done** button to close this box. The VISA/SICL address or the IP address can be obtained from the Keysight Connection Expert application, as shown in Figure 41.

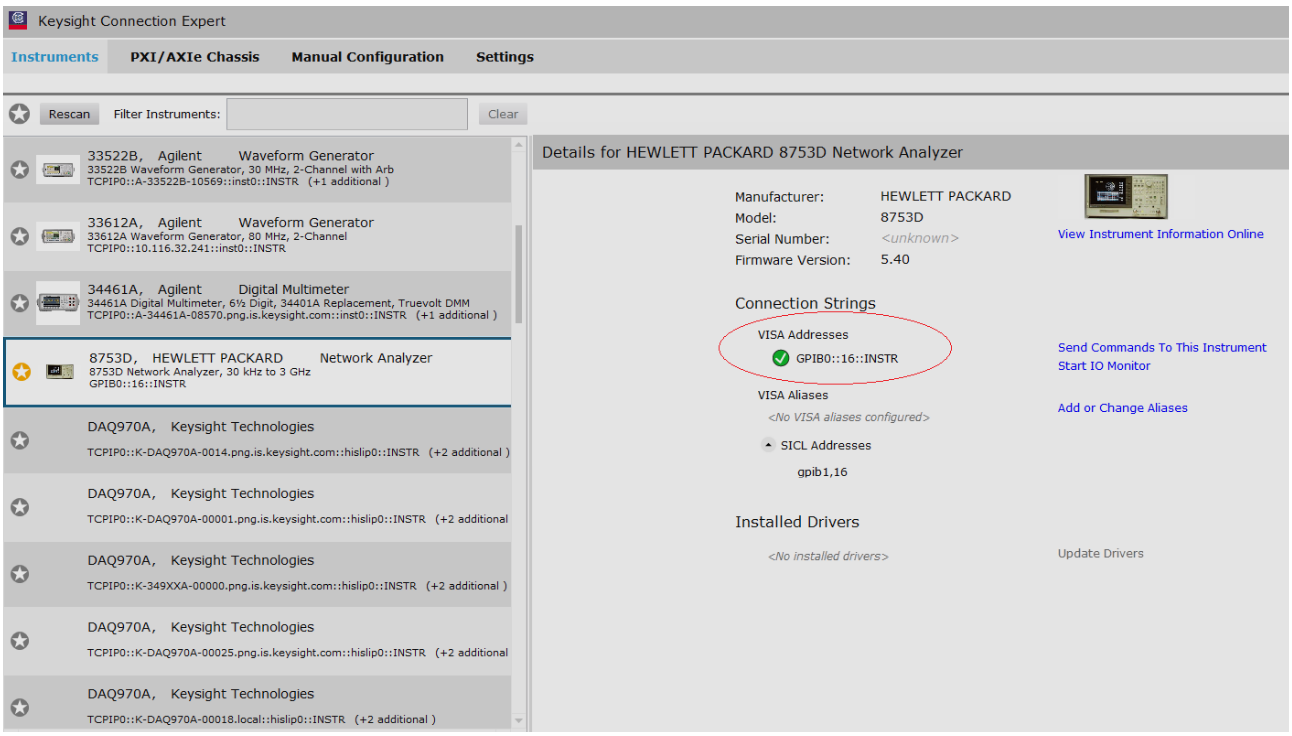


Figure 41 Checking VISA/SICL Address for Vector Network Analyzer in the Keysight Connection Expert

11 Once the 10GBASE-T Ethernet Test Application detects the Vector Network Analyzer, it is indicated on the **Set Up** tab as shown in Figure 42.

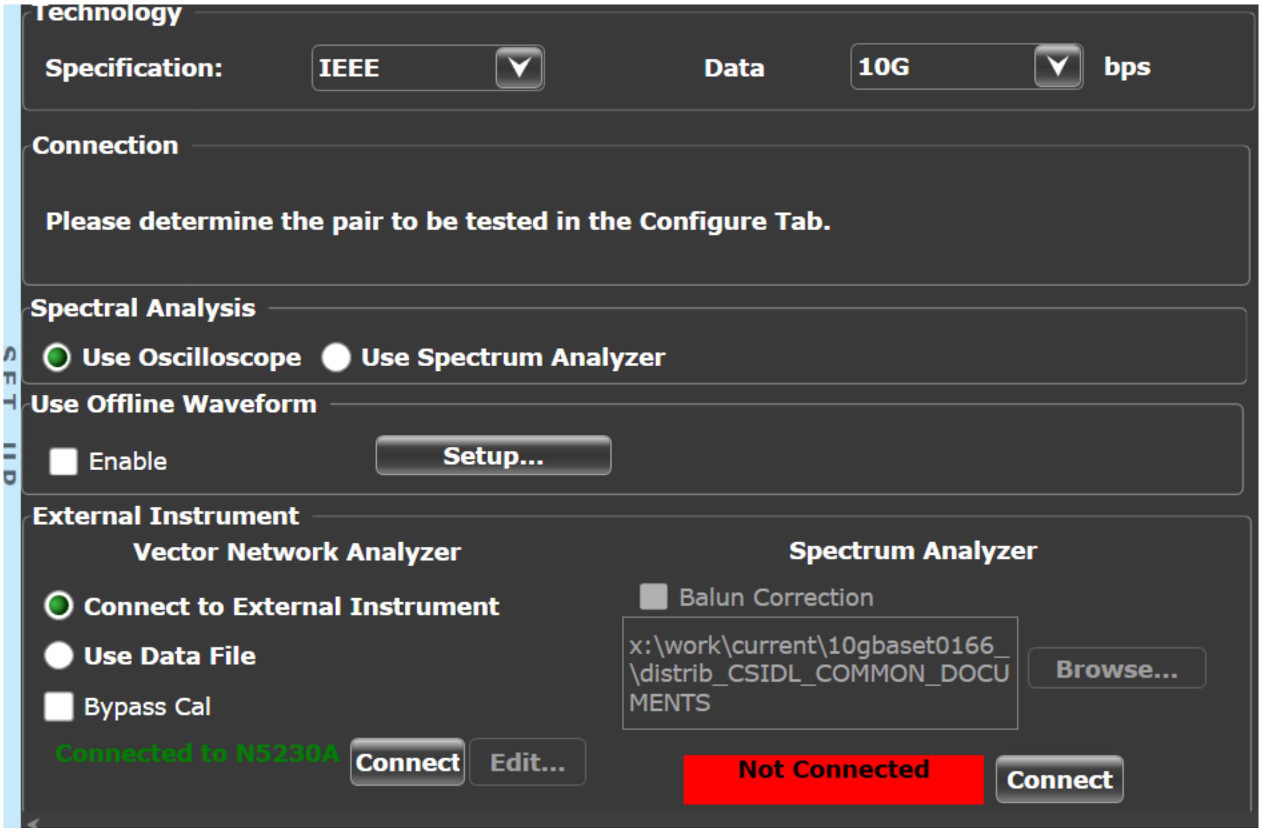


Figure 42 Connection status after the Test App detects the Vector Network Analyzer

12 Instead of connecting to the Vector Network Analyzer, you can also use the data file. Select the **Use Data File** check-box and the **Edit...** button appears, as shown in Figure 43.

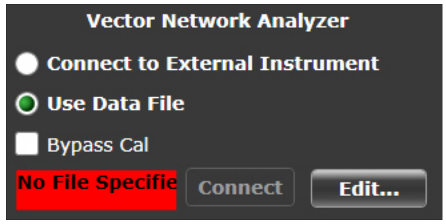


Figure 43 Use data file option for Vector Network Analyzer

13 Click the **Edit...** button to access the **Return Loss Data Files** dialog and select the data file for each pair, as shown in Figure 44.

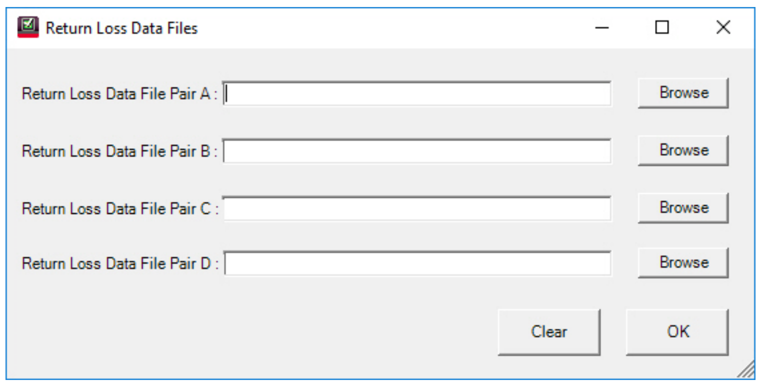


Figure 44 Data file selection pop-up box

14 Click **Browse** to access the data file on the local disk and assign it to each pair under test. Once you have selected the data files, click **OK**.

15 Once the 10GBASE-T Ethernet Test Application detects the user file, it is indicated on the **Set Up** tab as shown in Figure 45.

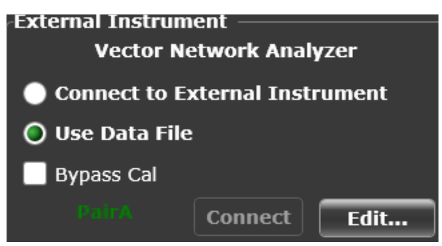


Figure 45 VNA Pair information after the Test App detects the data file

16 Enter your comments in the **Comments** text box.

17 Click the **Select Tests** tab and check the tests you want to run. Check the parent node or group to check all the available tests within the group.

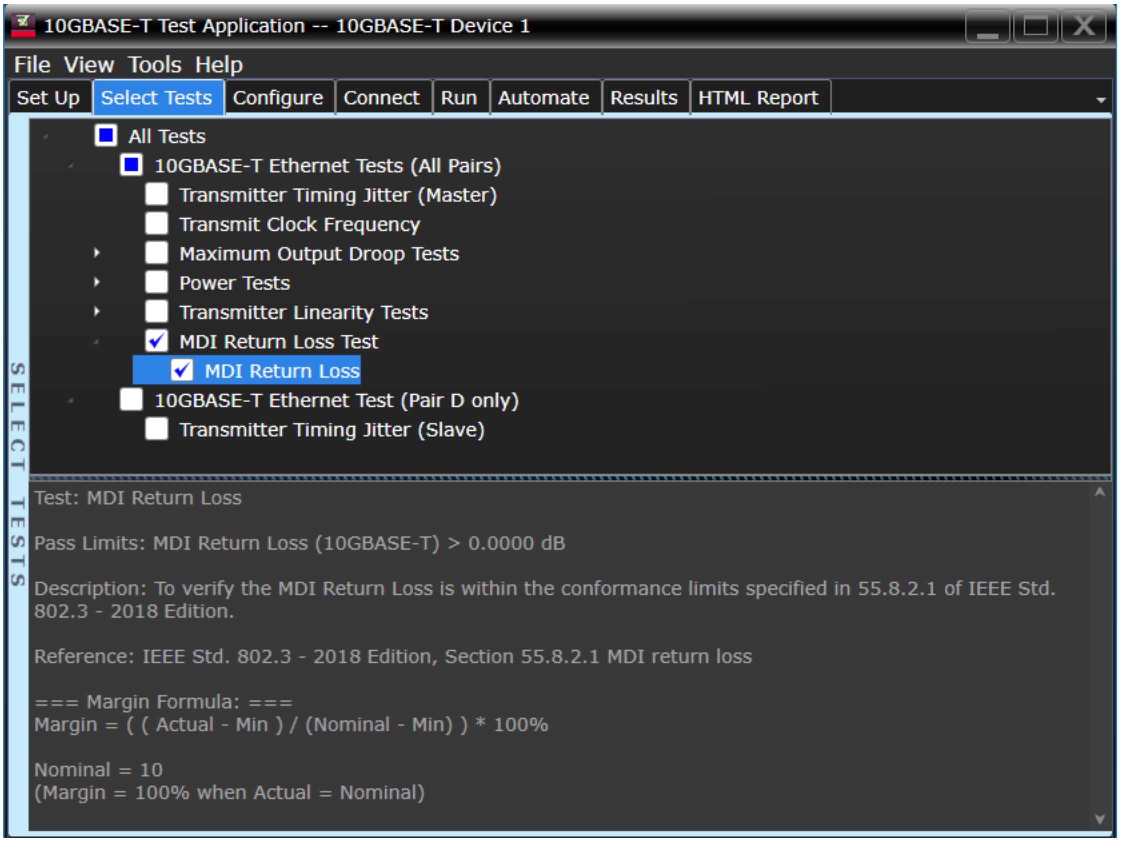


Figure 46 Selecting MDI Return Loss Test

18 Follow the 10GBASE-T Ethernet Test Application's task flow and run the test.

19 Before running the test, the application prompts you to calibrate the test setup. Connect the other end of RJ45 cable to Section 3 of the test fixture to calibrate the test setup. Test setup refers to the setup from the RJ45 cable connection point at Section 3 test fixture to the point where SMA cables are connected to the connector pairs.

20 A pop up message box will prompt you to connect the cal fixture to OPEN, SHORT, and LOAD port respectively. When this message is prompt, connect the mentioned port of Section 3 to another end of the RJ45 cable and click OK.

21 Once the calibration is done, the application continues to run the tests.

**NOTE** Test Configuration Options are not applicable for the Oscilloscope as the MDI Return Loss test uses the Vector Network Analyzer.

## MDI Return Loss Test—Implementation Methodology

The purpose of the MDI Return Loss test is to verify that the MDI return loss of the device under test (DUT) meets the specified eye template requirement as specified in clauses 55.8.2.1 & 126.8.2.2 of *IEEE 802.3-2018*.

MDI Return loss of the DUT is verified for each of the four lanes of the Test Mode 5 signaling for that particular DUT. These pairs are identified as Pair A, Pair B, Pair C and Pair D.

### Test Definition Notes from the Specification

#### IEEE 802.3—2018 Section 55.8.2.1 MDI Return Loss

The differential impedance at the MDI for each transmitter/receive channel shall be such that any reflection due to differential signals incident upon the MDI from a balanced cabling having a nominal differential characteristic impedance of 100 W is attenuated, relative to the incident signal as per the relationship shown below for 10GBase-T:

$$\text{Return loss} \geq \begin{cases} 16 & 1 \leq f \leq 40 \quad (\text{dB}) \\ 16 - 10\log_{10}(f/40) & 40 < f \leq 400 \quad (\text{dB}) \\ 6 - 30\log_{10}(f/400) & 400 < f \leq 500 \quad (\text{dB}) \end{cases} \qquad (55\text{–}54)$$

where $f$ is in MHz.

The following relationship shown below pertains to MGBase-T:

$$\textit{Return loss} \geq \begin{cases} 17 & 1 \leq f \leq 20 \\ 17 - 10\,log_{10}\left(\dfrac{f}{20}\right) & 20 < f \leq \text{Fc} \end{cases}$$

**where Fc is 100 MHz for 2.5G mode and 250 MHz for 5G mode.**

#### IEEE 802.3—2018 Section 126.8.2.2 MDI Return Loss

The following relationship shown below pertains to NBase-T:

$$\text{Return loss} \geq \begin{cases} 16 & 1 \leq f \leq 40 \quad (\text{dB}) \\ 16 - 10\log_{10}(f/40) & 40 < f \leq f_{\max} \quad (\text{dB}) \end{cases}$$

where

$f$ is in MHz

$f_{max}$ is 125 MHz for 2.5GBASE-T and 250 MHz for 5GBASE-T

### Pass Condition

- The return loss obtained for 10GBase-T must be at least 16dB from 1 MHz to 40 MHz, at least $16\text{-}10\log_{10}(f/40)$ from 40 MHz to 400 MHz and at least $6\text{-}30\log_{10}(f/400)$ from 400 MHz to 500 MHz.
- The return loss obtained for MGBase-T must be less than 19dB from 1 MHz to 40 MHz (for both 2.5G and 5.0G modes) and less than $19\text{-}10\log_{10}(\mathrm{f}/40)$ from 40 MHz to 125 MHz for 2.5G mode and less than $19\text{-}10\log_{10}(\mathrm{f}/40)$ from 40 MHz to 250 MHz for 5.0G mode.
- The return loss obtained for NBase-T must be at least 16dB from 1 MHz to 40 MHz and at least $16\text{-}10\log_{10}(f/40)$ from 40 MHz to either 125 MHz (for 2.5GBASE-T) or 250 MHz (for 5GBASE-T).

### Measurement Algorithm

1. Configure the DUT to produce Test Mode 5 signal.
2. Calibrate the Vector Network Analyzer with the calibration fixture (load, open and short).
3. Configure the following parameters in the **Configure** tab of the 10GBASE-T Ethernet Test Application:
   - Start frequency = 1 MHz and Stop frequency = 500 MHz
   - Averaging on.
4. Collect the data from the Vector Network Analyzer to the 10GBASE-T Ethernet Test Application and plot the graph.
5. Analyze the collected data by using a MATLAB script and compute the return loss for the Zs of 100W.
6. Compare the test result with the compliance test limit.

### Test References

See Sections 55.8.2.1 and 126.8.2.2 MDI Return Loss in the *IEEE 802.3-2018 Standard*.

# 13 Transmitter Timing Jitter (SLAVE) Test



This section provides the Methods of Implementation (MOIs) for Transmitter Timing Jitter (SLAVE) test using a Keysight 90000 Series Infiniium Oscilloscope, a Keysight Infiniium MXR Oscilloscope, or a Keysight Infiniium UXR Oscilloscope; 10GBase-T Transmitter Test Fixture and the 10GBase-T Compliance Test Application.

## Procedure for Transmitter Timing Jitter (SLAVE) Test

Running the Transmitter Timing Jitter (SLAVE) Test using the 10GBASE-T Ethernet Test Application

1 Start the 10GBASE-T Ethernet Test Application as described in "Starting the 10GBASE-T Ethernet Test Application" on page 19.
2 To make connections for the Transmitter Timing Jitter (SLAVE) test, refer to "Connections for Compliance Tests" on page 21.
3 Connect one end of the RJ45 cable to the SLAVE DUT and another end to the J2 connector on the Section 2 of the 10GBase-T Transmitter Test Fixture.
4 Similarly, connect one end of the RJ45 cable to the MASTER DUT and another end to the J3 connector on the Section 2 of the 10GBase-T Transmitter Test Fixture.
5 Connect the D+ and D- SMP connectors to the any two of the Oscilloscope Channels by using the SMP to SMA cables.
6 In the 10GBASE-T Ethernet Test Application, click the **Set Up** tab.
7 Select one of the following options under **Technology** to run tests on the DUT based on the respective technology standards. The **Select Tests** tab lists tests based on the technology you select.
   - **Specification: IEEE** and **Data Rate: 10G**,
   - **Specification: MGBASE-T** and **Data Rate: 5.0G** or **2.5G**,
   - **Specification: NBASE-T** and **Data Rate: 5.0G** or **2.5G**
8 Based on the test requirements, select the appropriate options and perform connections in the **Spectral Analysis** and **External Instruments** areas.
9 Enter your comments in the **Comments** text box.
10 Click the **Select Tests** tab and check the tests you want to run. Check the parent node or group to check all the available tests within the group.

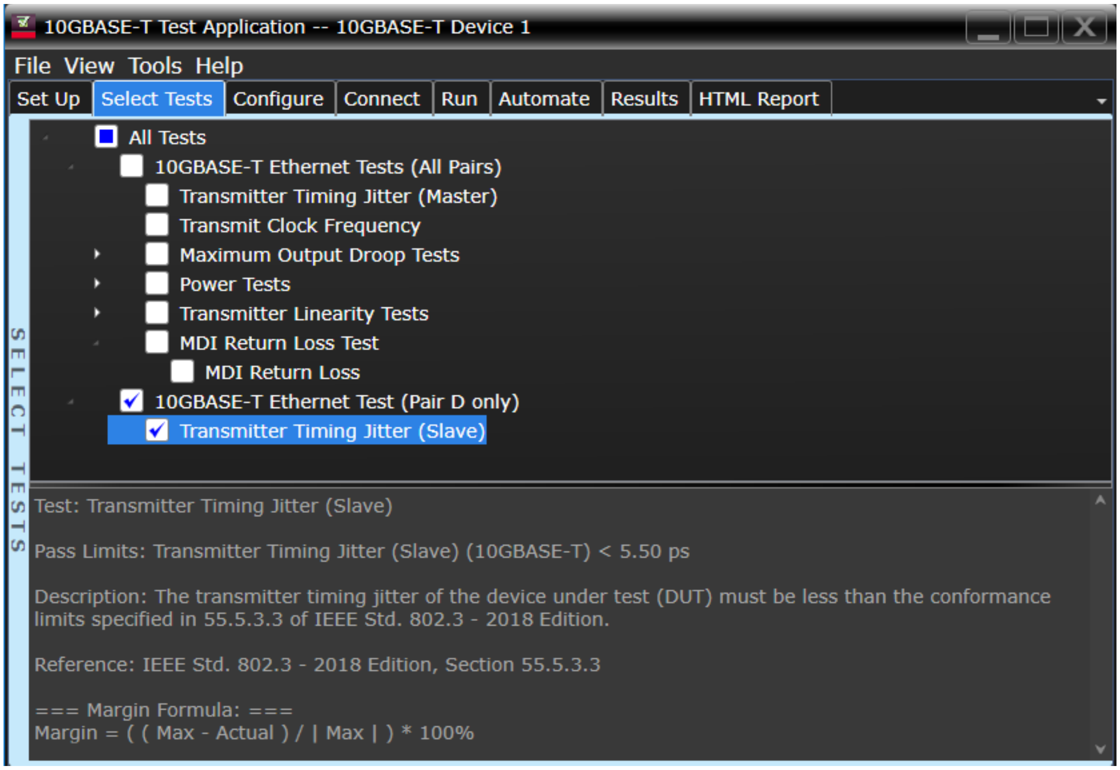


Figure 47 Selecting Transmitter Timing Jitter (SLAVE) Test

11 Follow the 10GBASE-T Ethernet Test Application's task flow to set up the configuration options (see Table 15), run the test, and view the test results.

**Table 15 Test Configuration Options**

| Configuration Option | Description |
|---|---|
| Connection Pair (Positive) | The channel number for connection pair positive. |
| Connection Pair (Negative) | The channel number for connection pair negative. |
| Signal Type | Type of signal generated on the Oscilloscope. |
| Sampling Rate [Debug mode] | Sampling Rate configured on the Oscilloscope. |
| Apply Band Pass Filter for Jitter Tests | Apply a a bandpass filter at the input for jitter tests. |
| Band Pass Filter Center Frequency [Debug Mode] | Center Frequency of the Band Pass Filter |
| Band Pass Filter Bandwidth [Debug Mode] | Bandwidth of the Band Pass Filter |

Note: The **Configure** tab of the 10GBASE-T Ethernet Test Application displays the default values for the options listed in the table. Refer to the 10GBASE-T Ethernet Test Application's Online Help to see how to change the values, if required.

# Transmitter Timing Jitter (SLAVE) Test—Implementation Methodology

The purpose of the Transmitter Timing Jitter (SLAVE) test is to verify that the SLAVE transmitter timing jitter of the device under test (DUT) is within the conformance limits specified in clause 55.5.3.3 of *IEEE 802.3-2018*.

For this test, the obtained timing jitter must be less than 5.5ps over a sample size of 200000 ± 20000. The jitter value is to be verified for Pair D only where the MASTER PHY is set to test mode 1 and SLAVE PHY is set in Test Mode 3.

## Test Definition Notes from the Specification

### IEEE 802.3—2018 Clause 55.5.3.3 Transmitter Timing Jitter

RMS period jitter over an integration time interval of 1ms ± 10% is defined as the root mean square period difference from the average period $(T - T_{avg})$ accumulated over a sample size of 200000 ± 20000.

$$RMS\ \ period\ \ jitter < \sqrt{\frac{(\sum [(T - Tavg)^2])}{Sample\ \ Size}}$$

## Pass Condition

The RMS period jitter measured at the MDI must be less than 5.5ps for all the pairs.

## Measurement Algorithm

1 Configure the SLAVE DUT to produce Test Mode 3 and the MASTER DUT to produce Test Mode 1 signal.

2 On the Infiniium Oscilloscope,

*a* Convert the single ended signal to differential signal:

FUNC2 = D+ (default Channel1) subtract D- (default Channel3) to get the differential signal.

*b* Trigger on the rising edge of D+. Set the trigger level to offset voltage of D+.

*c* In the **Configure** tab of the Compliance Test Application, set the sampling rate:

- On the 90000-series DSO Oscilloscopes, set the value either as 20 Gsa/s or as 40 Gsa/s.
- On the UXR Oscilloscopes, set the value either as 32 Gsa/s or as 64 Gsa/s.
- On the MXR Oscilloscopes, set the value either as 8 Gsa/s or as 16 Gsa/s.

*d* The number of acquisitions to be taken depends on the time range and the memory depth you select:

Number of Acq = Time Range / (Memory Depth * 1/Sampling Rate)

*e* Enable the histogram and measure the period to the acquired waveform.

*f* Take the standard deviation from the histogram statistics.

*g* Compare the test result with the compliance test limit.

## Test References

See Clause 55.5.3.3 Transmitter Timing Jitter in the *IEEE 802.3-2018 Standard*.

# Index

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