Keysight E6960A 1000Base-T1 Transmitter Compliance Application

KEYSIGHT TECHNOLOGIES

User Guide and Method of Implementation

Notices

Copyright Notice

Trademarks

[Relevant acknowledgements should be included here. Reference “LA-403 When to Use the Trademark Symbol and Other Trademark Acknowledgements” for guidance. If no acknowledgements are required, remove the caption.]

Manual Part Number

E6960-90001

Edition

Edition 3.0, March 2019

Printed in:

Printed in Malaysia

Published by:

Keysight Technologies
Bayan Lepas Free Industrial Zone,
11900 Penang, Malaysia

Technology Licenses

The hardware and/or software described in this document are furnished under a license and may be used or copied only in accordance with the terms of such license.

Declaration of Conformity

Declarations of Conformity for this product and for other Keysight products may be downloaded from the Web. Go to http://www.keysight.com/go/conformity. You can then search by product number to find the latest Declaration of Conformity.

U.S. Government Rights

The Software is “commercial computer software,” as defined by Federal Acquisition Regulation (“FAR”) 2.101. Pursuant to FAR 12.212 and 27.405-3 and Department of Defense FAR Supplement (“DFARS”) 227.7202, the U.S. government acquires commercial computer software under the same terms by which the software is customarily provided to the public. Accordingly, Keysight provides the Software to U.S. government customers under its standard commercial license, which is embodied in its End User License Agreement (EULA), a copy of which can be found at http://www.keysight.com/find/sweula. The license set forth in the EULA represents the exclusive authority by which the U.S. government may use, modify, distribute, or disclose the Software. The EULA and the license set forth therein, does not require or permit, among other things, that Keysight: (1) Furnish technical information related to commercial computer software or commercial computer software documentation that is not customarily provided to the public; or (2) Relinquish to, or otherwise provide, the government rights in excess of these rights customarily provided to the public to use, modify, reproduce, release, perform, display, or disclose commercial computer software or commercial computer software documentation. No additional government requirements beyond those set forth in the EULA shall apply, except to the extent that those terms, rights, or licenses are explicitly required from all providers of commercial computer software pursuant to the FAR and the DFARS and are set forth specifically in writing elsewhere in the EULA. Keysight shall be under no obligation to update, revise or otherwise modify the Software. With respect to any technical data as defined by FAR 2.101, pursuant to FAR 12.211 and 27.404.2 and DFARS 227.7102, the U.S. government acquires no greater than Limited Rights as defined in FAR 27.401 or DFAR 227.7103-5 (c), as applicable in any technical data.

Warranty

THE MATERIAL CONTAINED IN THIS DOCUMENT IS PROVIDED “AS IS,” AND IS SUBJECT TO BEING CHANGED, WITHOUT NOTICE, IN FUTURE EDITIONS. FURTHER, TO THE MAXIMUM EXTENT PERMITTED BY APPLICABLE LAW, KEYSIGHT DISCLAIMS ALL WARRANTIES, EITHER EXPRESS OR IMPLIED, WITH REGARD TO THIS MANUAL AND ANY INFORMATION CONTAINED HEREIN, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. KEYSIGHT SHALL NOT BE LIABLE FOR ERRORS OR FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH THE FURNISHING, USE, OR PERFORMANCE OF THIS DOCUMENT OR OF ANY INFORMATION CONTAINED HEREIN. SHOULD KEYSIGHT AND THE USER HAVE A SEPARATE WRITTEN AGREEMENT WITH WARRANTY TERMS COVERING THE MATERIAL IN THIS DOCUMENT THAT CONFLICT WITH THESE TERMS, THE WARRANTY TERMS IN THE SEPARATE AGREEMENT SHALL CONTROL.

Safety Information

CAUTION

A CAUTION 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 damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.

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.

Table of Contents

List of Figures

List of Tables

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK.

1 Overview

Introduction

Testing a 1000Base-T1 PHY's transmitter is accomplished through the use of various test modes defined in the 1000Base-T1 specification. See "Reference Documents" on page 44.

Keysight's E6960A 1000Base-T1 TX Compliance Application Software (provided as a software option to the E6961A Automotive Ethernet Solution) provides five test modes for the testing and validating the transmitter waveform, transmitter distortion, transmitted jitter, and transmitter droop. The test modes change only the data symbols provided to the transmitter circuitry and do not alter the electrical and jitter characteristics of the transmitter and receiver from those of normal operation.

Table 1-1 Test Modes

Test Mode	Description
1	Setting Master and Slave PHYs for Transmit Clock Jitter in Linked Mode
2	Transmit MDI jitter test in MASTER mode
3	Not Used
4	Transmitter distortion test
5	Normal Operation in Idle Mode. Power Spectral Density (PSD) mask and power level test.
6	Transmitter Droop Test

NOTE **This E6960A User Guide is written as a guide to using the E6960A 1000Base-T1 TX Compliance Application software.**

Using the Keysight E6960A 1000Base-T1 Compliance application software along with an N5395C Ethernet Test Fixture greatly simplifies compliance testing. The software automatically configures all of the required test equipment reducing the overall test time.

The E6960A Software:

– Lets you select individual or multiple test to run.

- Lets you identify the device being tested and its configuration.
- Shows you how to make oscilloscope connections to the device under test.
- Automatically checks for proper oscilloscope configuration.
- Automatically sets up the oscilloscope for each test.
- Allows you to determine the number of trials for averaging in each test.
- Provides detailed information of each test that has been run. The result of maximum 64 worst trials can be displayed at any one time.
- Creates a printable HTML report of the tests that have been run. This report includes pass/fail limits, margin analysis, and screen captures.

Installing the Compliance Test Solution Software

1. Make sure you have the minimum version of Infiniium oscilloscope software (see the software release notes) by choosing **Help > About Infiniium...** from the main menu.
2. To obtain the E6960A Compliance Application software, go to Keysight website: http://www.keysight.com/find/E6960A.
3. Click the **Trials & Licenses** tab.
4. Click the **Details & Download** button.
5. Read and verify the Prerequisites and installation information. Follow the instructions to download and install the application software. Click the red **Download** button.

Installing the License Key

1. Request a license code from Keysight by following the instructions on the Entitlement Certificate. You will need the oscilloscope's "Option ID Number", which you can find in the **Help > About Infiniium...** dialog box.
2. After you receive your license code from Keysight, choose **Utilities > License Manager > Legacy Licenses....** Depending on the license acquired, select either Local License or Server License.
3. In the Install Option License dialog box, enter your license code and click **Install License.** Additional information is required for server based licensing. Please refer to your entitlement.
4. Click **OK** in the dialog box that tells you to restart the Infiniium oscilloscope application software to complete the license installation.
5. Click **Close** to close the Install Option License dialog box.
6. Choose **File > Exit**.
7. Restart the Infiniium oscilloscope application software to complete the license installation.

You can also install the license using Keysight License Manager. For detailed instructions, refer to the online help for the Keysight License Manager.

Preparing to Take Measurements

Before running the E6960A automated compliance tests, you should calibrate the oscilloscope and probe. After calibrating the oscilloscope and probe, you are ready to start the Compliance Test Application and perform the measurements.

Calibrate the Oscilloscope

For information on performing the internal diagnostic and calibration cycle for your Keysight Infiniium oscilloscope, refer to the "User Calibration" topic in your oscilloscope's online help.

NOTE If the ambient temperature changes more than 5 °C 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.

Probe Calibration

Before performing the automated tests, you should calibrate the probes. Calibration of the solder-in probe heads consists of a vertical calibration and a skew calibration. The vertical calibration should be performed before the skew calibration. Both calibrations should be performed for best probe measurement performance.

For information on performing probe vertical and skew calibration in your Keysight Infiniium oscilloscope, refer to the "*DC Attenuation/Offset Calibration*" and "*Skew Calibration*" topics in your oscilloscope's online help.

For more information on calibration/deskew procedures for your particular probe, refer to the probe's user's guide in the Keysight Probe Resource Center.

General Test Setup

Test Modes 1, 2, 5, and 6 require only the Infiniium oscilloscope and the device to be tested (Device Under Test or DUT). The test setup is described below. Differential Signal supplied to the Oscilloscope can be achieved either by using **Two Oscilloscope Channels** or a **Single Differential Probe**. The type of connection accepted can be selected in the **Setup** tab of the test application.

Two Oscilloscope Channels refers to connecting the differential automotive pair to the oscilloscope using only SMA cables. Refer to Figure 1-1 for more details.

Single Differential Probe refers to connecting the differential automotive pair to the Oscilloscope using a single differential probe. Refer to Figure 1-2 for more details. The only variation would be the Power Level Test that requires a balun.

Any variation from the above definition of differential signaling type is not recommended.

Test Mode 4 requires the N5395C Ethernet Test Fixture and an Arbitrary Waveform Generator (AWG). Refer to "Test Mode 4. Transmitter Distortion and MDI Return Loss" on page 29 for specific setup details.

Test Mode 4 also includes an MDI S-Parameter Test.

Test Mode 5 can also use the N9010B Signal Analyzer. Refer to "Test Mode 5. Transmitter Power Spectral Density, Transmitter Power Level and Transmitter Peak Differential Output Tests" on page 36 for specific setup details.

NOTE **For all tests, use the software supplied with your transmitter PHY to control the Device Under Test.**

Two Oscilloscope Channels Connection to Oscilloscope

Two SMA cables are needed to directly connect the output of the transmitter to the oscilloscope. The specific oscilloscope channel used can be selected in the **Configure** tab of the application.

An optional TX_TCLK may be supplied to the oscilloscope to run the tests.

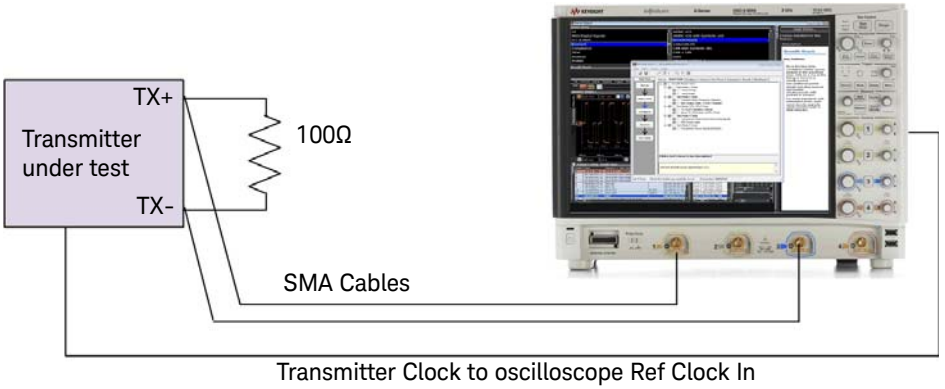


Figure 1-1 Connection to the Oscilloscope Using a Pair of SMA Cables

Single Differential Probe Connection to Oscilloscope

A differential probe is used to connect the output of the transmitter to the oscilloscope. The specific oscilloscope channel used can be selected in the **Configure** tab of the application.

An optional TX_TCLK may be supplied to the oscilloscope to run the tests.

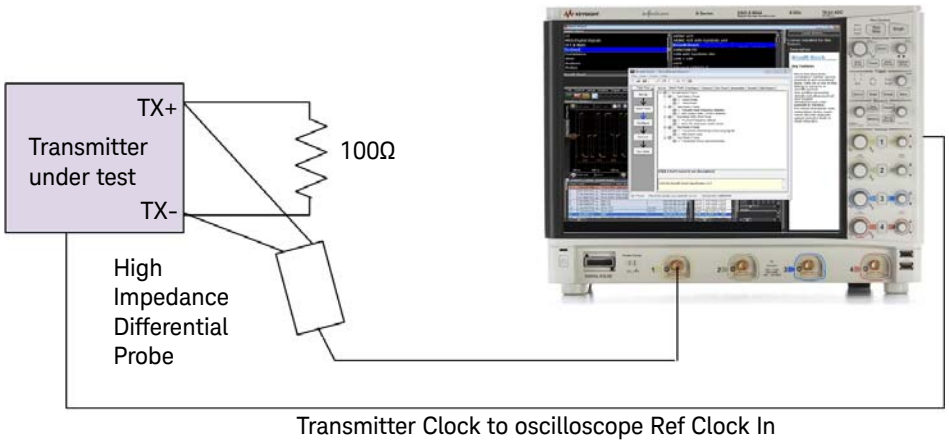


Figure 1-2 Connection to the Oscilloscope using a Differential Probe

Connection Using the N5395C Ethernet Transmitter Test Fixture

Alternately, you can use Section 1 of the N5395C Ethernet 10/100/1G Transmitter Electrical Test Fixture to make connections to the Transmitter under test. The SMA connections shown are for wire pair A (DA+ and DA–). This connection is only valid if the DUT has an RJ45 connector. To test to wire pair B, C, or D, connect the oscilloscope SMA cables to the appropriate Evaluation Board SMA connectors. See Figure 1-3 below. In the event the DUT does not have an RJ45 connector, user will need to replace Section 1 with any adapter that converts the differential automotive pair to SMA.

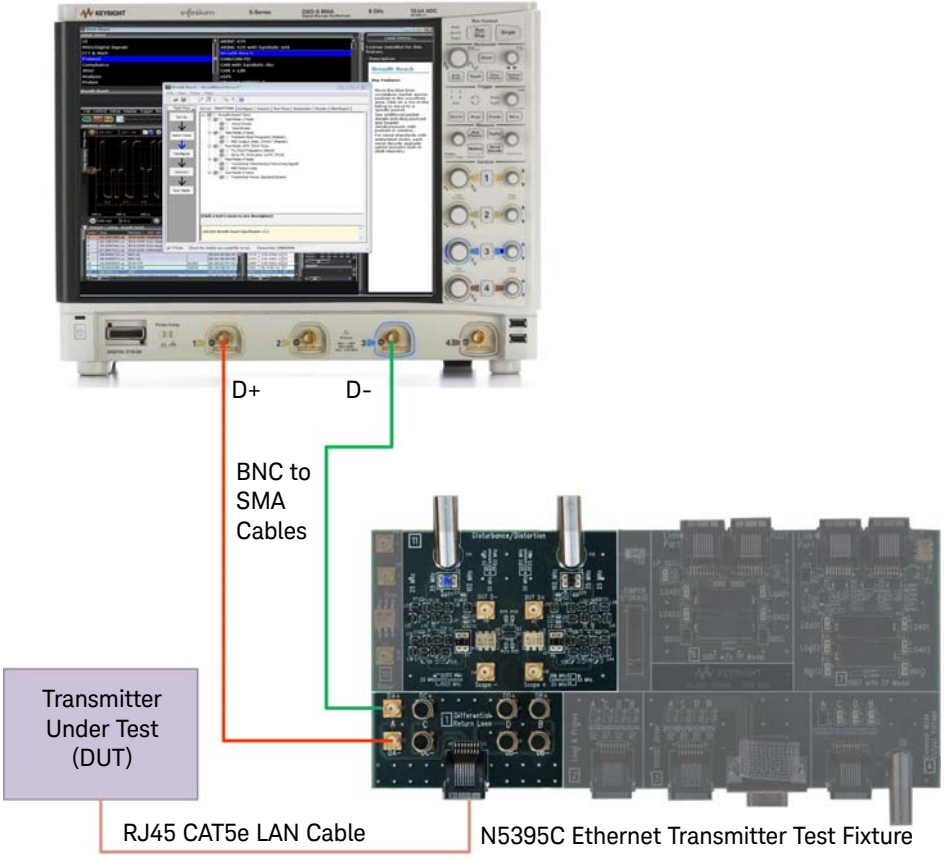


Figure 1-3 General Test Setup using the N5395C Evaluation Board

Starting the Automotive Ethernet Compliance Test Solution Software

1. Ensure that the 1000Base-T1 Device Under Test (DUT) transmitter is operating and set to desired test modes.
2. To start the Compliance Test Application from the Infiniium oscilloscope's main menu, select **Analyze > Automated Test Apps > E6960A 1000Base-T1 Test App.**

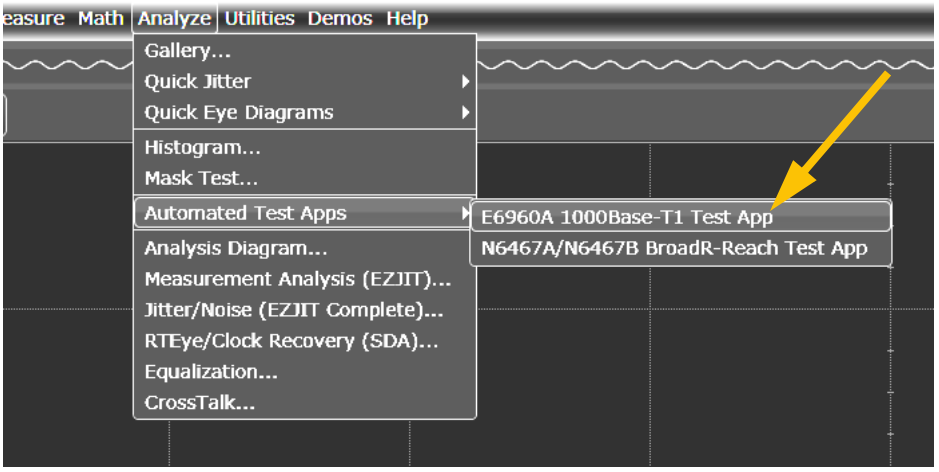


Figure 1-4 Launching the E6960A Compliance Test Application

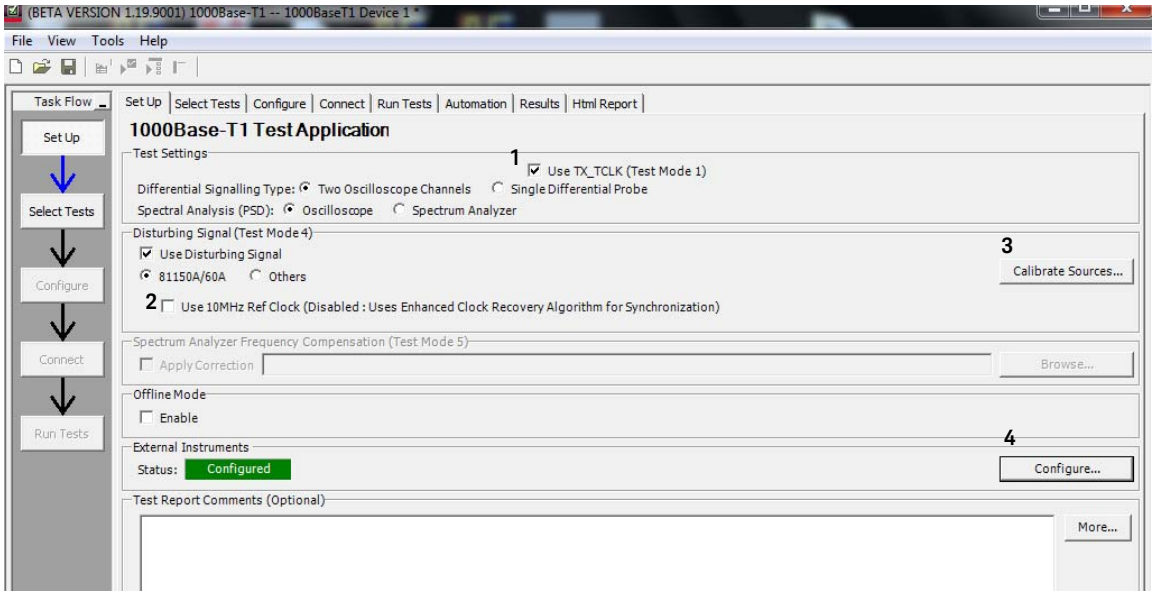


Figure 1-5 E6960A 1000Base-T1 Compliance Test Application Main Window

Item	Description
1	Use TX_CLK. Check this if your DUT has its own Transmit Clock. Otherwise, the default clock signal is used.
2	Requires Frequency Divider Board. Refer Appendix D "Using the E6960-66600 Frequency Divider Board" on page 63
3	Refer to Appendix C "External Instrument Calibration" on page 55
4	Refer to Appendix B "Configure External Instruments" on page 51

3 Figure 1-5 above shows the E6960A 1000Base-T1 Compliance Test Application main window.

4 The Compliance Application software automatically sets frequency, etc. of the external instruments (oscilloscope, ENA, generators, etc.) if they are properly configured. Refer to Appendix B, "Configure External Instruments" on page 51.

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

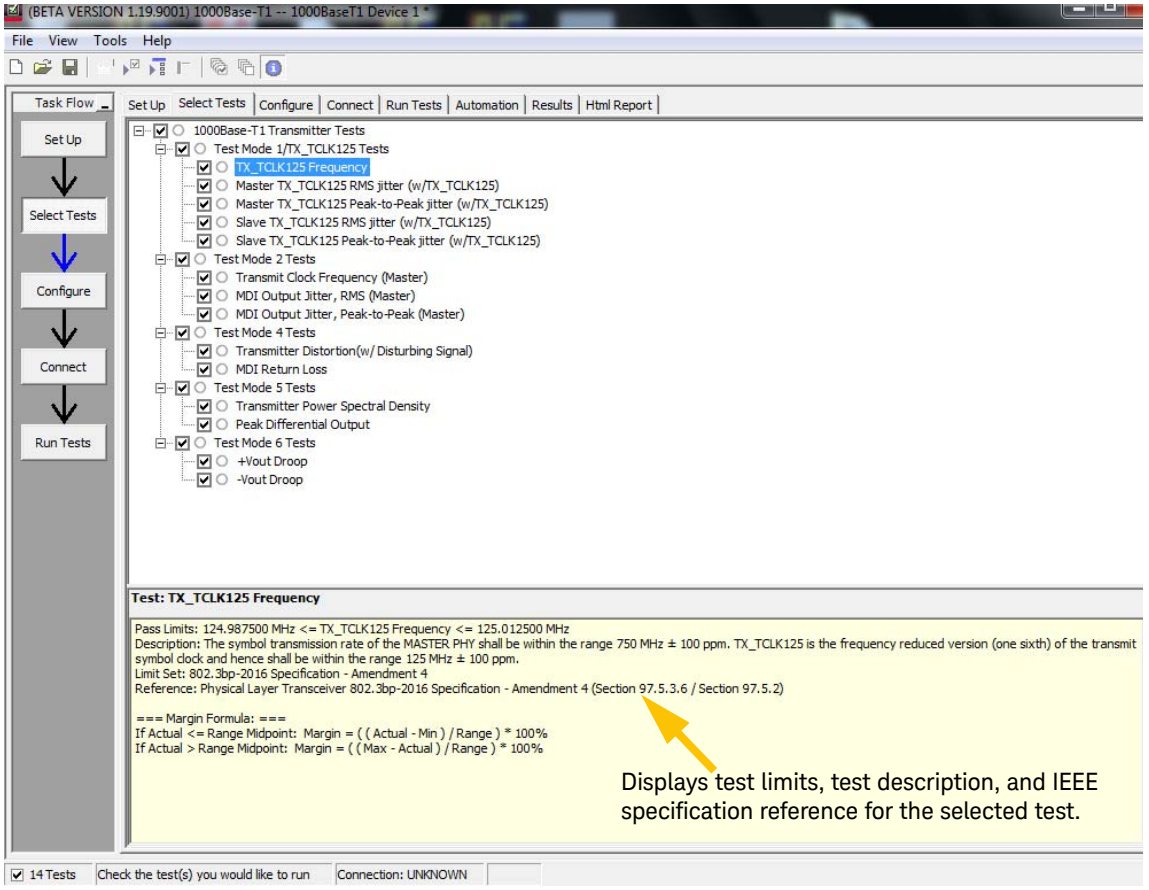


Figure 1-6 Select Tests Menu with all tests selected

6 Figure 1-6 above shows all the tests that are available in E6960A 1000Base-T1 Compliance Test Application.

Table 1-2 Tabs Menu functions

Tab	Description
Set Up	Lets you identify and set up the test environment.
Select Tests	Lets you select the tests you want to run. After tests are run, status indicators show which tests have passed, failed, or have not run.
Configure	Lets you configure test parameters (for example, oscilloscope channels used in test, number of averages, etc.).
Connect	Shows you how to connect the oscilloscope to the device under test.
Run Tests	Starts the automated tests. If the connections to the device under test need to be changed, the test pauses, shows how change the connection, and waits for you to confirm that the changes were made before continuing.
Automation	Lets you construct scripts of commands to 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	Report Shows a compliance test report that can be printed. See "Viewing the Test Report" on page 42

7 Table 1-2 above shows the function description of each tab in the Tabs Menu.

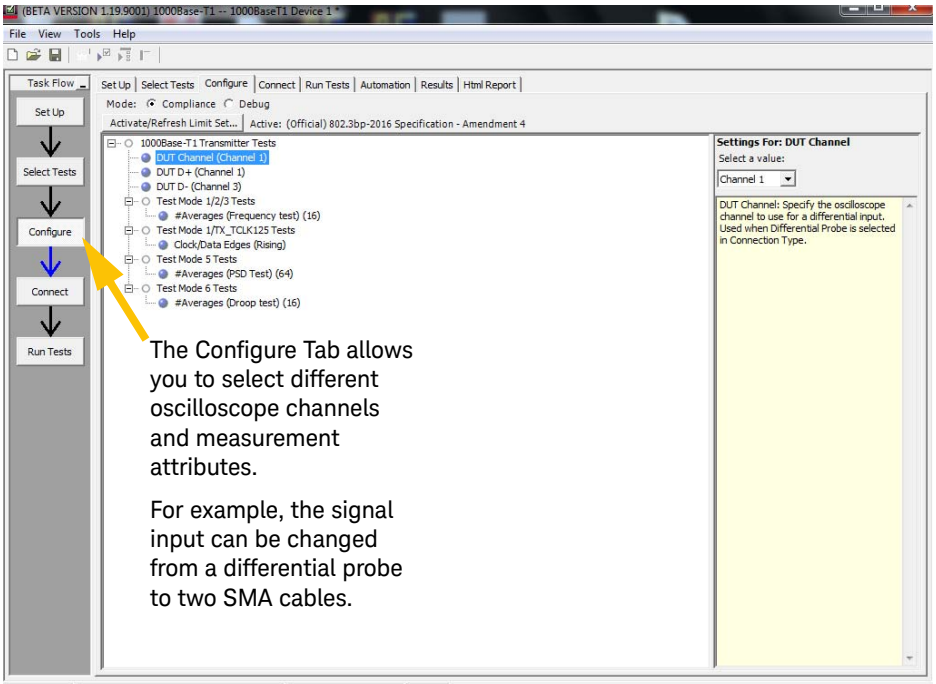
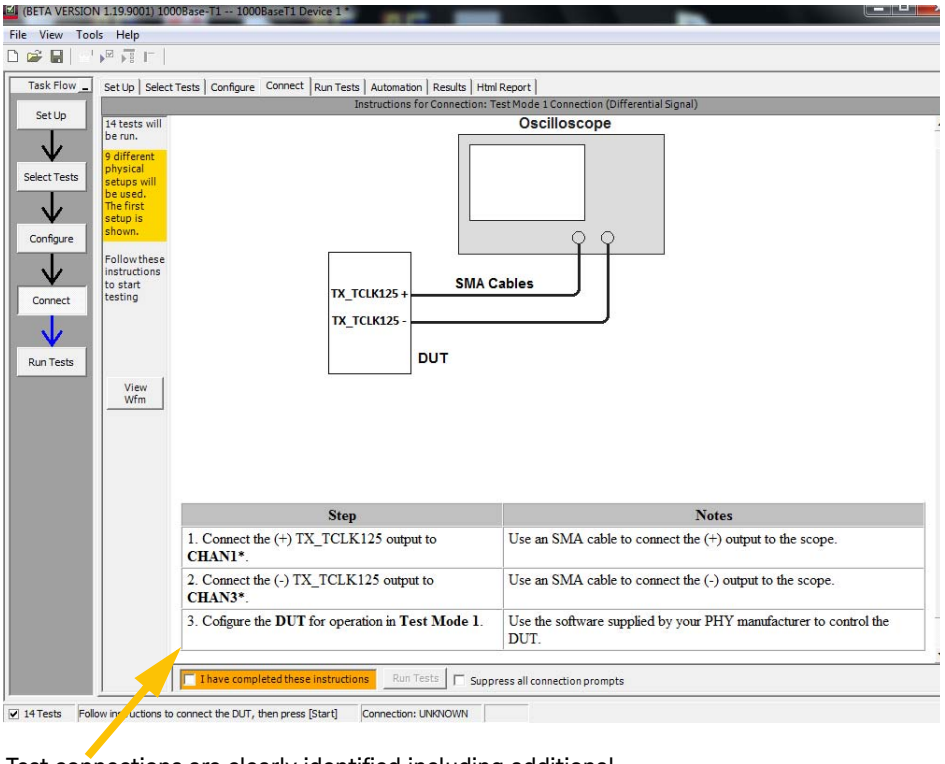


Figure 1-7 Configure Tab for Test Mode 1

8 Figure 1-7 above shows the figure tab that allows you to select different oscilloscope channels and measurement attributes.



Test connections are clearly identified including additional hardware and cables. When you make multiple tests where the connections must be changed, the software prompts you with appropriate connection diagrams.

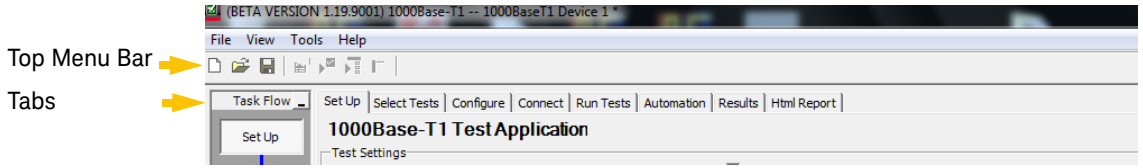
Check the, **"I have completed these instructions"** box before clicking the **Run Tests** button.

Figure 1-8 Connect Tab for Test Mode 1

9 Figure 1-8 above shows the connect tab of the E6960A 1000Base-T1 Compliance Test Application.

Top Menu Bar

The top menu bar of the compliance application offers several features:



Top Menu Bar icons from left to right:

Start a new project: Closes existing project and opens a new project.

Open an existing project: If you saved a previous project, this icon allows you to open it. You can load a sample project from: **C:\Users\Public\Documents\Infiniium\Apps\1000BT1\ProjectSamples\1000BaseT1 Device1.proj.**

Save the current project: Saves the current project in the following folder: **C:\Users\Public\Documents\Infiniium\Apps\1000BT1\1000BaseT1 Device 1.proj.**

Configure checked tests: Same as the **Configure** tab.

Run all checked tests: Runs all of the selected tests. Same as the **Run Tests** tab.

Run selected branch only: Runs only the selected test.

View results: Opens the HTML Report window. Same as the **Html Report** tab.

Tabs

The tabs across the top correspond to the Task Flow icons on the left side of the main display.

Test Mode 1. TX_TCLK125 Frequency and Transmit Jitter Tests

Test Setup

This test may be run using either two oscilloscope channels or a single differential probe from the transmitter (MDI). Refer to "General Test Setup" on page 14 for connection details.

NOTE **Use the software supplied with your transmitter PHY to control the Device Under Test.**

Specification References

[1] 1000Base-T1 IEEE Std 802.3bp-2016, Section 97.5.3.6.

[2] 1000Base-T1 IEEE Std 802.3bp-2016, Section 97.5.2.

[3] 1000Base-T1 IEEE Std 802.3bp-2016, Section 97.5.3.3

TX_TCLK125 Frequency Test

This test measures the frequency of the TX_TCLK125 clock.

Reference [1] specifies the symbol transmission rate of a compliant PHY. The symbol transmission rate of the MASTER PHY shall be within the range of 750 MHz ±100 ppm.

Reference [2] specifies that Test Mode 1 shall provide access to a frequency reduced version of the transmit symbol clock or TX_TCLK125. This 125 MHz test clock is one sixth frequency divided version of the TX_TCLK that times the transmitted symbols.

The measured frequency of TX_TCLK125 should fall within 125 MHz ±100 ppm.

Transmit Clock Jitter (MASTER/SLAVE)

Test Mode 1 enables testing of timing jitter on MASTER and SLAVE transmitters. MASTER and SLAVE transmitters are connected over a link segment. The transmitter timing jitter is measured by capturing the TX_TCLK125 waveforms in both MASTER and SLAVE configurations.

Reference [3] specifies that when in test mode 1, and the link is up and the two PHYs have established link, the RMS (Root Mean Square) value of the MASTER TX_TCLK125 jitter relative to an unjittered reference shall be less than 5 ps. The peak-to-peak value of the MASTER TX_TCLK125 jitter relative to an unjittered reference shall be less than 50 ps.

Reference [3] specifies that when in test mode 1, and the link is up and the two PHYs have established link, the RMS (Root Mean Square) value of the SLAVE TX_TCLK125 jitter relative to an unjittered reference shall be less than 10 ps. The peak-to-peak value of the SLAVE TX_TCLK125 jitter relative to an unjittered reference shall be less than 100 ps.

This test measures the clock time interval error of the TX_TCLK125 signal at the MDI. The ideal reference clock is selected automatically by the oscilloscope and compared to the original signal to determine the clock time interval error.

Test Mode 2. Transmit Clock Frequency (MASTER) and MDI Output Jitter (MASTER) Tests

Test Setup

This test may be run using either two oscilloscope channels or a single differential probe from the transmitter (MDI). Refer to "General Test Setup" on page 14 for connection details.

NOTE **Use the software supplied with your transmitter PHY to control the Device Under Test.**

Specification References

[1] 1000Base-T1 IEEE Std 802.3bp-2016, Section 97.5.3.6.

[2] 1000Base-T1 IEEE Std 802.3bp-2016, Section 97.5.2.

[3] 1000Base-T1 IEEE Std 802.3bp-2016, Section 97.5.3.3.

Transmit Clock Frequency

Reference [1] specifies the symbol transmission rate of a compliant PHY. The symbol transmission rate of the MASTER PHY shall be within the range of 750 MHz ±100 ppm.

Reference [2] specifies that in Test Mode 2 the PHY shall transmit a continuous pattern of three {+1} symbols followed by three {-1} symbols, with the transmitted symbols timed from its local clock source of 750 MHz. The transmitter output is a 125 MHz signal. Hence the accuracy of the transmit clock frequency is also 125 MHz ±100 ppm.

MDI Output Jitter (MASTER)

Reference [3] specifies that when in test mode 2, the RMS (Root Mean Square) value of the MDI output jitter, relative to an unjittered reference shall be less than 5 ps.

Reference [3] specifies that when in test mode 2, the peak-to-peak value of the MDI output jitter, relative to an unjittered reference shall be less than 50 ps.

This test measures the data time interval error of the test mode 2 signal at the MDI. The ideal reference data rate is selected automatically by the oscilloscope and compared to the original signal to determine the data time interval error.

Test Mode 4. Transmitter Distortion and MDI Return Loss

Test Setup

Sections 1 and 11 of the N5395C Ethernet Test Fixture are used in this test.

A disturbing signal source is required to test for compliance. There is an option to test without a disturbing signal source, but the test result is not applicable for compliance. The test accepts only a differential signal.

When using a supported function generator, there is an automatic calibration process to calibrate the function generators. If an unsupported model is used, the user will have to manually calibrate the function generators.

Only the Keysight 81150A Function Generator is supported in this test.

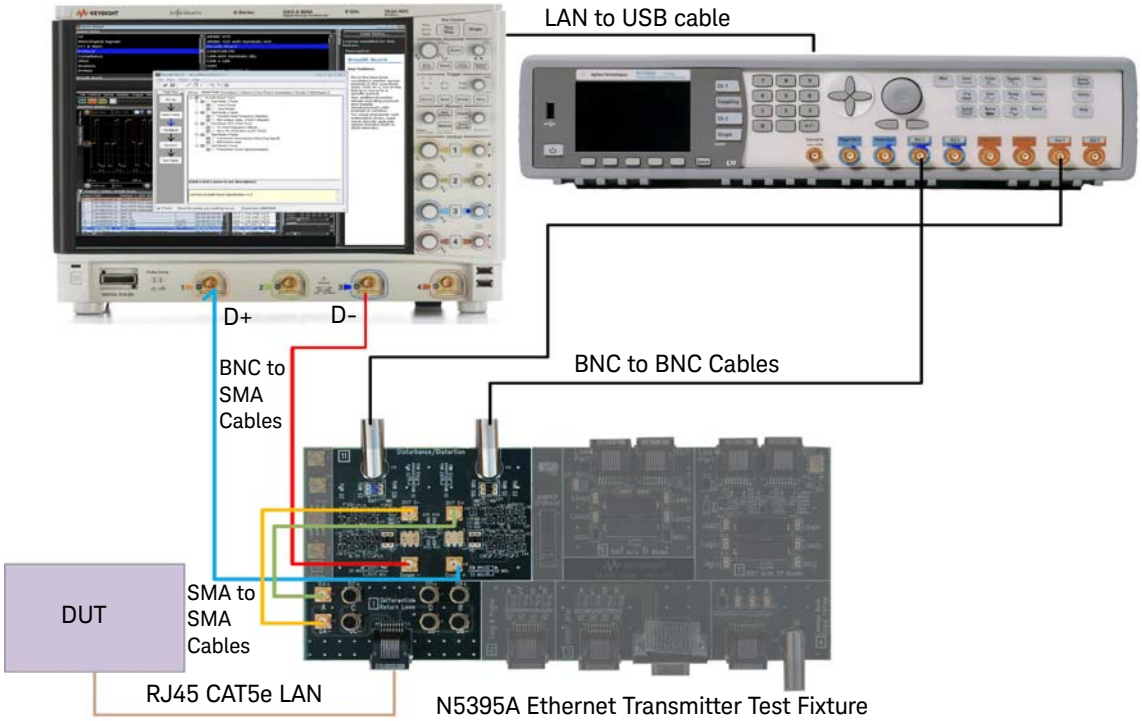


Figure 1-9 Connection for Transmitter Distortion Test Using Keysight 81150A Function Generator

Using the Optional E6960A Frequency Divider Board

If you want to use the optional E6960-66600 Frequency Divider Board to provide a stable 10 MHz reference clock, refer to Appendix D "Using the E6960-66600 Frequency Divider Board" on page 63 for detailed information.

Specification References

[1] 1000Base-T1 IEEE Std 802.3bp-2016, Section 97.5.3.2.

[2] 1000Base-T1 IEEE Std 802.3bp-2016, Section 97.7.2.1.

Transmitter Distortion Tests Information

When operating in Test Mode 4 and capturing the waveform using the Section 11 of the fixture, the peak distortion shall be less than 15 mV.

NOTE **If using the Frequency Divider, connect the 10 MHz output(s) of the divider to the 10 MHz Ref In Input of the oscilloscope and function generator for clock synchronization.**

Reference [1] specifies that the peak distortion is determined by sampling the differential signal output with the symbol rate clock at an arbitrary phase and processing a block of any 2047 consecutive samples with MATLAB code in Reference [1].

Alternatively, this test can also be run without the disturbing signal, but the result cannot be used to determine compliance.

Transmitter Distortion Enhance Clock Recovery Algorithm

Keysight employs an enhanced clock recovery algorithm when the TX_TCLK is not available. The algorithm conditions the signal to the nominal bitrate. This is enabled by default when the **Use 10MHz Ref Clock** checkbox is disabled.

When the **Use 10MHz Ref Clock** checkbox is enabled, the E6960-66600 Frequency Divider board as well as access to TX_TCLK to is required for synchronization.

NOTE This test can only be run using a differential output from the transmitter (MDI). Refer to "General Test Setup" on page 14 for connection details. A differential probe cannot be used for this test.

MDI Return Loss Test

This test is run with an external vector network analyzer. However, a VNA exported data file in the Touchstone or CITI format can also be used in place of the external vector network analyzer. The external vector network analyzer will need to be manually calibrated prior to use.

User has the option to either run a differential measurement, by selecting **Two Oscilloscope Channels** on the Setup tab or a single ended measurement(using BALUN) by selecting the **Single Differential Probe** signaling type. Please refer to "Calibrating the ENA" on page 59.

Test Setup

Single Ended Connection Setup

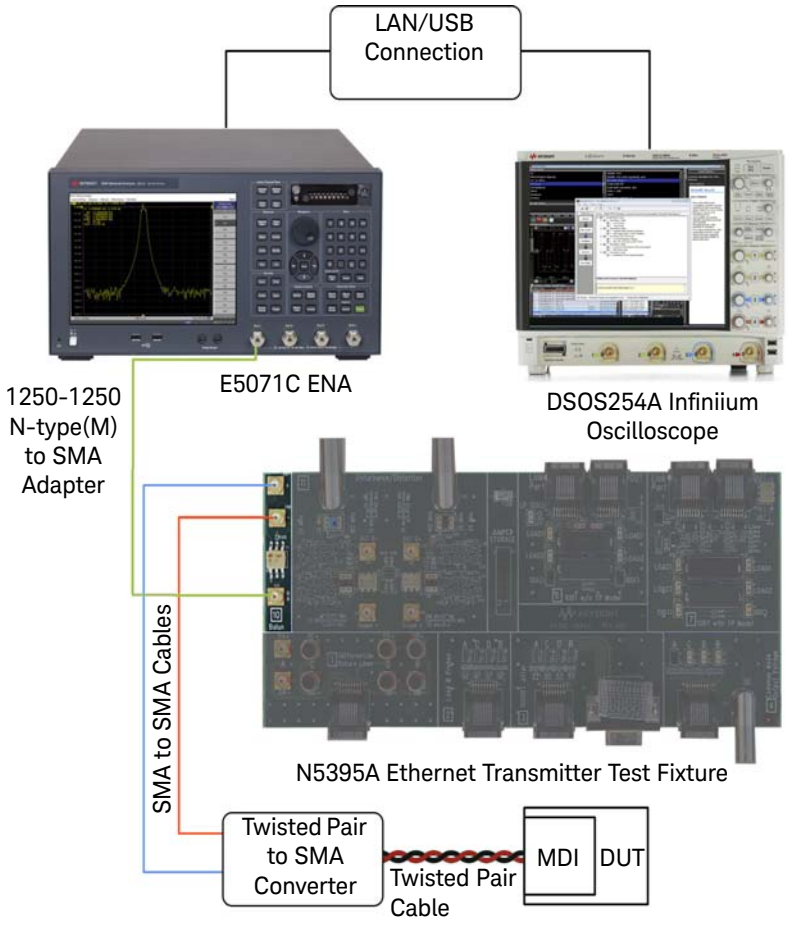


Figure 1-10 Single Ended Connection Setup for MDI Return Loss Test

Differential Connection Setup

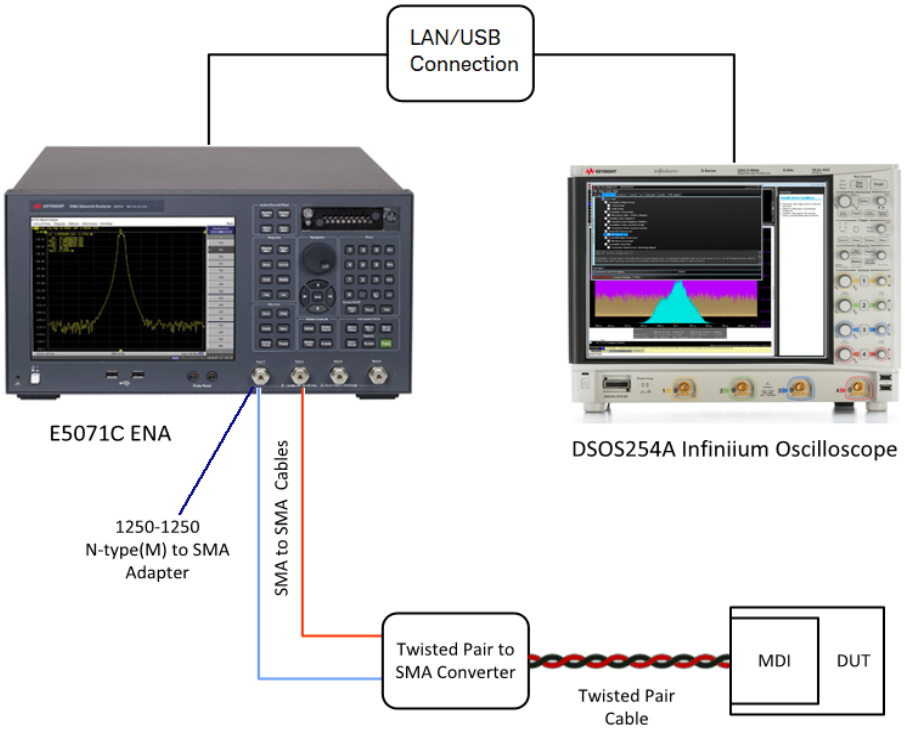


Figure 1-11 Differential Connection Setup for MDI Return Loss Test

MDI Return Loss Test Information

Reference [2] specifies that the differential impedance at the MDI for each transmit/receive channel shall be such that any reflection (due to differential signals incident upon the MDI with a test port having a differential impedance of 100 Ω) is attenuated relative to the incident signal as per the equation below.

$$\mathrm{ReturnLoss}(f) \geq \begin{bmatrix} 18 - 18(\log_{10})\frac{20}{f} & 2 \leq f < 20 \\ 18 & 20 \leq f < 100 \\ 18 - 16.7(\log_{10})\frac{f}{100} & 100 \leq f \leq 600 \end{bmatrix}$$

where f is the frequency in MHz.

In other words, the return loss shall meet or exceed the equation above for all frequencies ranging from 2 MHz to 600 MHz (with 100 Ω differential impedance) at all times when the PHY is transmitting data or control symbols.

Test Mode 5. Transmitter Power Spectral Density, Transmitter Power Level and Transmitter Peak Differential Output Tests

Test Setup

The Power Spectral Density (PSD) Test can be run using either a spectrum analyzer or an oscilloscope. When using the oscilloscope, refer to "General Test Setup" on page 14.

If you use the N9010B Signal Analyzer, convert the differential output to a single-ended output using a balun. Use the balun on the N5395C Ethernet Test Fixture as shown in Figure 1-12 below.

The Power Level Test can be run using either the spectrum analyzer or and oscilloscope. For this particular test, irrespective of equipment used, convert the differential output to a single-ended output using a balun. Use the balun on the N5395C Ethernet Test Fixture as shown in Figure 1-12 below.

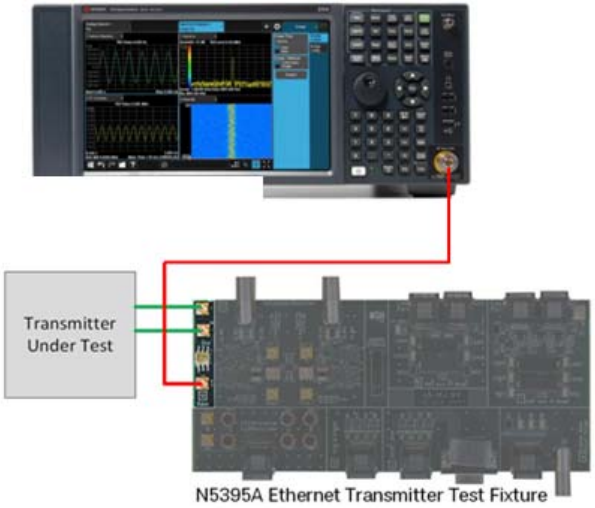


Figure 1-12 Power Spectral Density Test Using N9010B Signal Analyzer

NOTE Use the software supplied with your transmitter PHY to control the Device Under Test.

Specification References

[1] 1000Base-T1 IEEE Std 802.3bp-2016, Section 97.5.3.4.

[2] 1000Base-T1 IEEE Std 802.3bp-2016, Section 97.5.3.5.

Transmitter Power Spectral Density (PSD)

Reference [1] specifies that in Test Mode 5, the power spectral density (PSD) of the transmitter, shall be between the upper and lower masks specified by the equations below.

$$\mathrm{UpperPSD(f)} = \begin{bmatrix} -80 & \frac{\mathrm{dBm}}{\mathrm{Hz}} & 0 < \mathrm{f} \le 100 \\ -76 - \frac{\mathrm{f}}{25} & \frac{\mathrm{dBm}}{\mathrm{Hz}} & 100 < \mathrm{f} \le 400 \\ -85.6 - \frac{\mathrm{f}}{62.5} & \frac{\mathrm{dBm}}{\mathrm{Hz}} & 400 < \mathrm{f} \le 600 \end{bmatrix}$$

$$\mathrm{LowerPSD(f)} = \begin{bmatrix} -86 & \frac{\mathrm{dBm}}{\mathrm{Hz}} & 40 < \mathrm{f} \le 100 \\ -82 - \frac{\mathrm{f}}{25} & \frac{\mathrm{dBm}}{\mathrm{Hz}} & 100 < \mathrm{f} \le 400 \end{bmatrix}$$

where f is the frequency in MHz.

The resolution bandwidth of 100 kHz and sweep time of larger than 1 second are considered in PSD measurements.

This test could be run using an external spectrum analyzer or the oscilloscope.

Transmitter Power Level

Reference [1] specifies that in Test Mode 5, the transmit power shall be less than 5 dBm.

Transmitter Peak Differential Output

Reference [2] specifies that in Test Mode 5, when measured with 100 Ω termination, the transmit differential signal at MDI shall be less than 1.30 Volt peak-to-peak.

Test Mode 6. Output Droop Tests

Test Setup

This test may be run using either two oscilloscope channels or a single differential probe from the transmitter (MDI). Refer to “General Test Setup” on page 14 for connection details.

NOTE **Use the software supplied with your transmitter PHY to control the Device Under Test.**

Specification References

[1] 1000Base-T1 IEEE Std 802.3bp-2016, Section 97.5.3.1.

Transmitter Output Droop Positive Test Information

This test measures the positive output droop of the transmitter.

Reference [1] specifies the positive output droop of a compliant PHY. The positive droop measured with respect to an initial value at 4 ns after the zero crossing and a final value of 16 ns after the zero crossing, shall be less than 10%.

The application triggers the Test Mode 6 signal on the rising edge and determines the time the positive peak occurred at 4 ns after the zero crossing. The application then measures the voltage 12 ns after the initial peak crossing. The Droop is calculated as:

Droop = 100 X (Vd/Vpk)%

Where:

- Vd is the magnitude of the droop.
- Vpk is the initial peak after the zero crossing.

Transmitter Output Droop Negative Test Information

This test measures the negative output droop of the transmitter.

Reference [1] specifies the negative output droop of a compliant PHY. The negative droop measured with respect to an initial value at 4 ns after the zero crossing and a final value of 16 ns after the zero crossing, shall be less than 10%.

The application triggers the Test Mode 6 signal on the falling edge and determines the time the negative peak occurred at 4 ns after the zero crossing. The application then measures the voltage 12 ns after the initial peak crossing. The Droop is calculated as:

Droop = 100 X (Vd/Vpk)%

Where:

- Vd is the magnitude of the droop.
- Vpk is the initial peak after the zero crossing.

Viewing the Test Report

After running any or all of the five Compliance tests, the **Results** tab shows which tests passed and details about the individual tests. For test result details, select any one of the tests from the top pane; the test details are shown below. In Figure 1-13 below, the jitter test is selected and the test results, with waveform, is shown below.

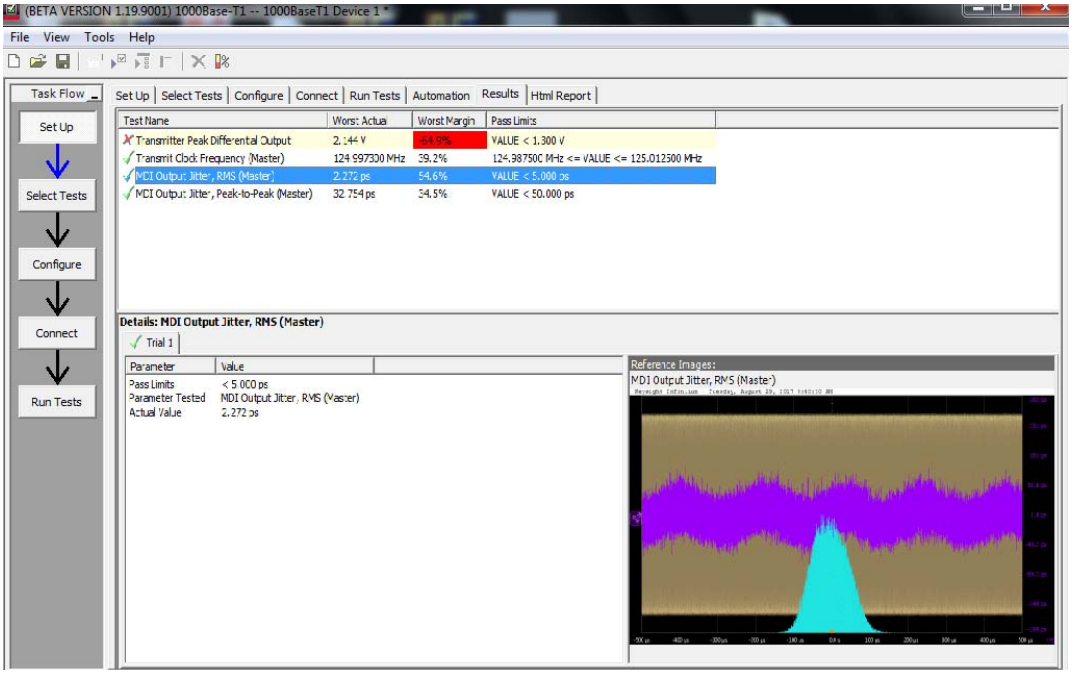


Figure 1-13 Typical Results Tab

Figure 1-14 below shows a portion of a typical **HTML Report**. Below this segment are waveforms and more test data.

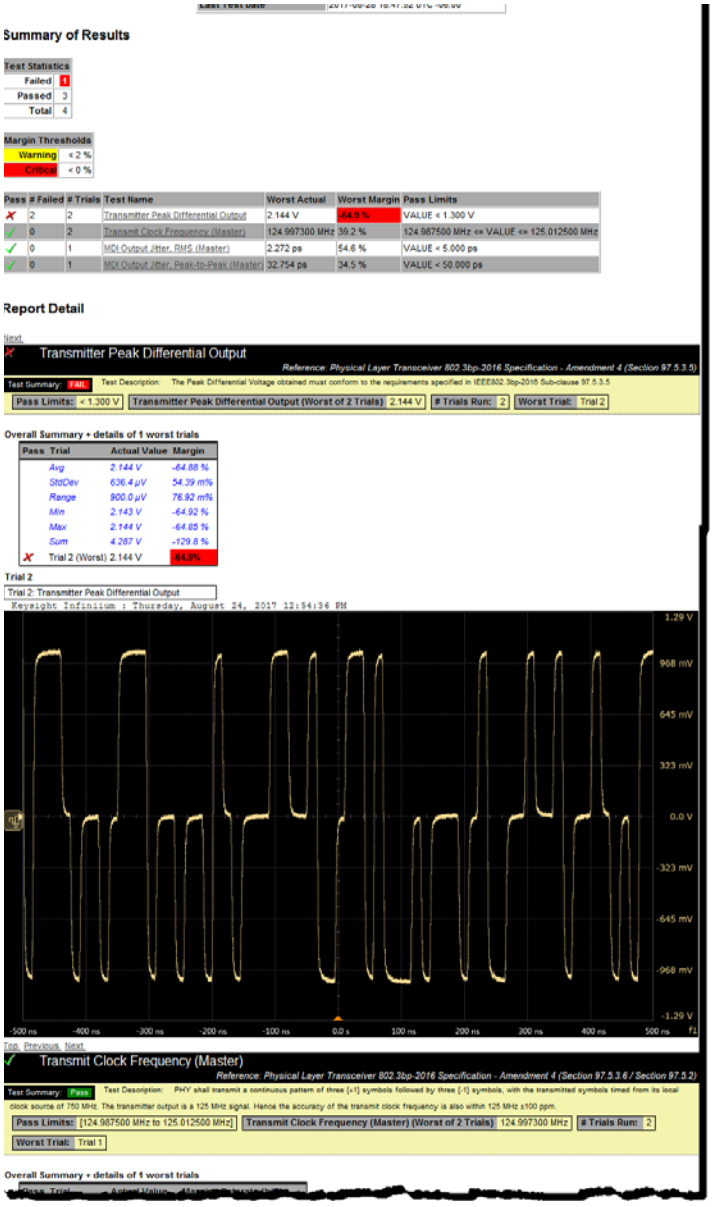


Figure 1-14 Top Portion of a Typical HTML Report

Reference Documents

IEEE 802.3 Ethernet Working Group:

www.ieee802.org/3/index.html

Keysight's Automotive Ethernet Test Solutions Web Page:

www.keysight.com/find/broadr-reach

E6960A Automotive Ethernet TX Compliance Solution Web Page:

www.keysight.com/find/E6960A

Other Keysight Automotive Ethernet Applications and Software

- E6960A 1000Base-T1 TX Compliance Application:
  www.keysight.com/find/E6960A
- E6961A Automotive Ethernet TX Compliance Solution:
  www.keysight.com/find/E6961A
- E6962A Automotive Ethernet RX Compliance Solution – includes E6962A RX Compliance Application (100Base-T1 compliant) software:
  www.keysight.com/find/E6962A
- E6963A Automotive Ethernet Link Segment Compliance Solution – includes E6963A Link Segment Compliance Application (100Base-T1 compliant) software:
  www.keysight.com/find/E6963A
- N6467B Transmit Compliance Application Software (100Base-T1 compliant):
  www.keysight.com/find/N6467B
- N8847A Protocol Triggering and Decoder Software (100Base-T1 compliant)
  www.keysight.com/find/N8847A

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK.

A Setting Up the N5395C Ethernet Transmitter Test Fixture

Introduction

Keysight's N5395C Ethernet 10/100/1G Transmitter Electrical Test Fixture includes a main test fixture board (N5392-66402), a short RJ-45 interconnect cable (N5392-61601), and a small Return Loss impedance calibration board (N5392-66401).

Keysight's N5395C Ethernet Test Fixture is recommended for the Compliance Test Mode 4. A different, comparable fixture may be used, but is not guaranteed to produce the same result.

Notice that the main Test Fixture board is divided into eight sections plus an area to store jumpers. Not all sections are used in this demo/evaluation. Refer to Figure A-1 on page 47.

Table A-1 List of Compliance Test Board Sections

Compliance Test Board Section	Description	Compliance Test Mode Number
1	Differential Return Loss used for RJ45 devices	Test Mode 4, Transmitter Distortion Test
2	Load & Probes	Not Used
3	100BT Jitter	Not Used
4	Common Mode Output Voltage	Not Used
6	10BT w/o TP Model	Not Used
7	10BT with TP Model	Not Used
10	Balun used for Power Spectrum Density Test	Test Mode 5, PSD and Power Level Test
11	Disturbance/Distortion	Test Mode 4, Transmitter Distortion Test

The Return Loss impedance calibration board is Board Section 8. See Figure A-2 below. This board is used for calibrating the ENA. Refer to "Calibrating the ENA" on page 59. This board is only applicable if your DUT has an RJ45 connector. For other DUT's that do not have a RJ45 connector, user will need to fabricate a custom calibration kit.

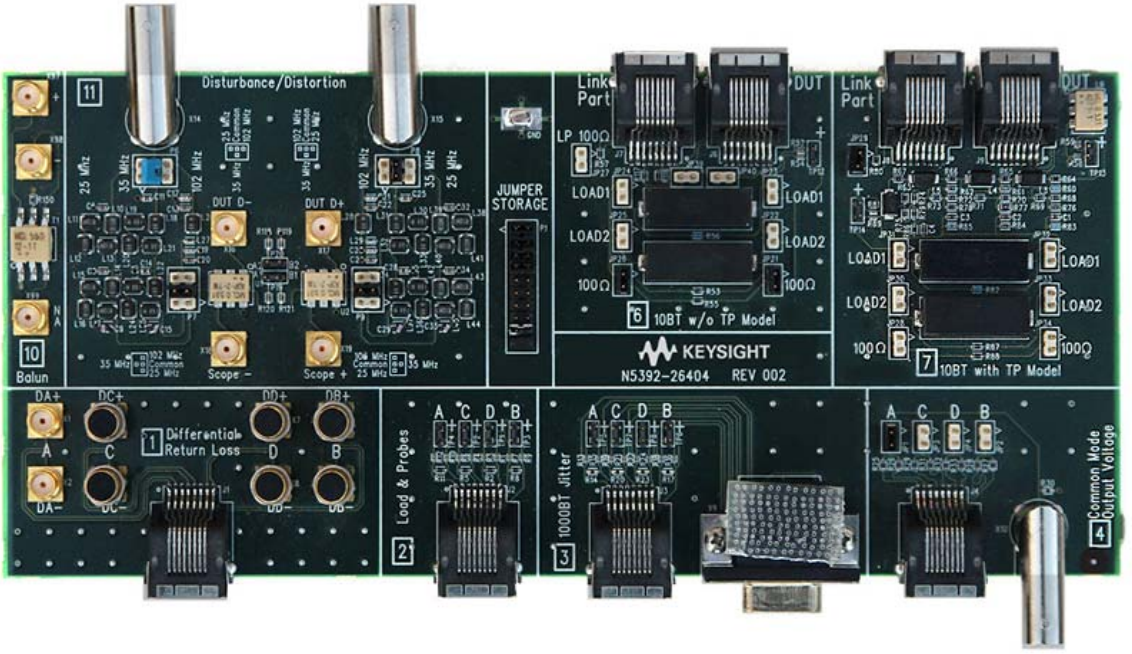


Figure A-1 N5395C Ethernet Electrical Transmitter Test Fixture

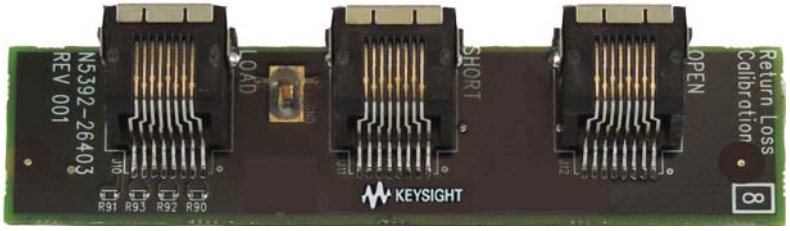


Figure A-2 Return Loss Impedance Calibration Board

Jumper Settings

Figure A-4 shows the jumper position for the Ethernet Test Fixture Section 11 applicable for E6960A Compliance Test.

Section 11 Jumpers. See Figure A-4 for settings.

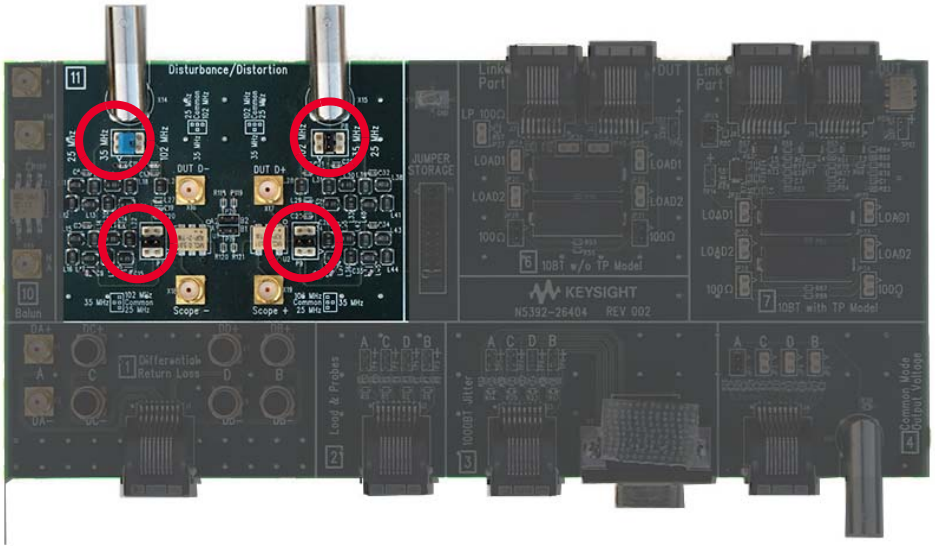


Figure A-3 Section 11 on the Ethernet Test Fixture.

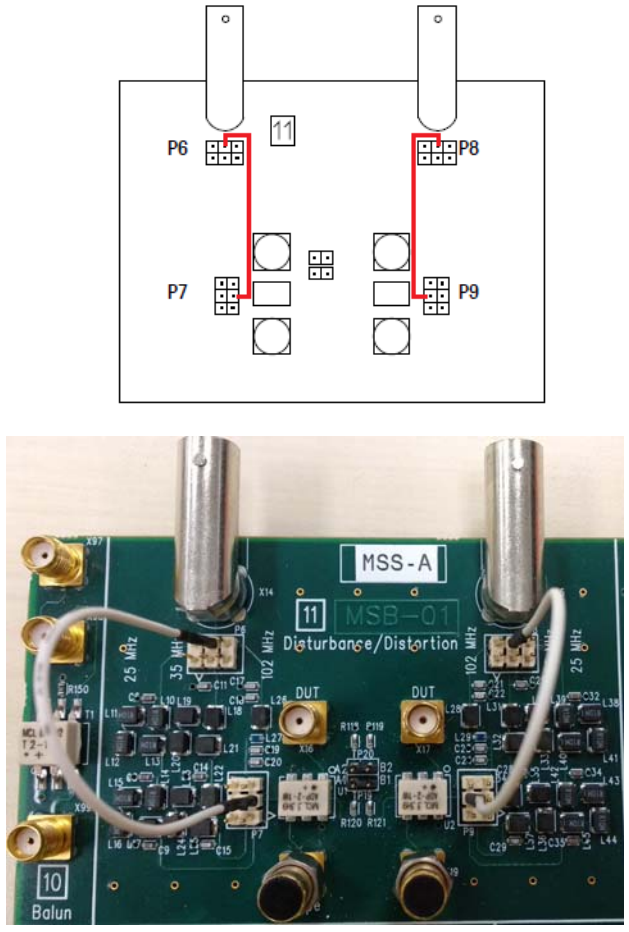


Figure A-4 Jumper Location for Ethernet Test Fixture

NOTE If you need similar jumper cables, please contact your Keysight sales representative for more details.

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK.

B Configure External Instruments

Introduction

For each test, the DSOS254A Infiniium Oscilloscope automatically configures any external instruments (AWG, E5071C ENA, and N9010B EXA Signal Analyzer) as required for the test. In order to do this, however, the oscilloscope must know the SICL address of each instrument. The External Instruments **Status** indicator is red if the instruments are not properly configured.

NOTE **The instruments must be connected to the oscilloscope prior to configuring them. This is generally through a USB connection.**

1 From the Compliance Test Application Set Up tab, click the **Configure** button. This opens the **External Instruments List** dialog box.

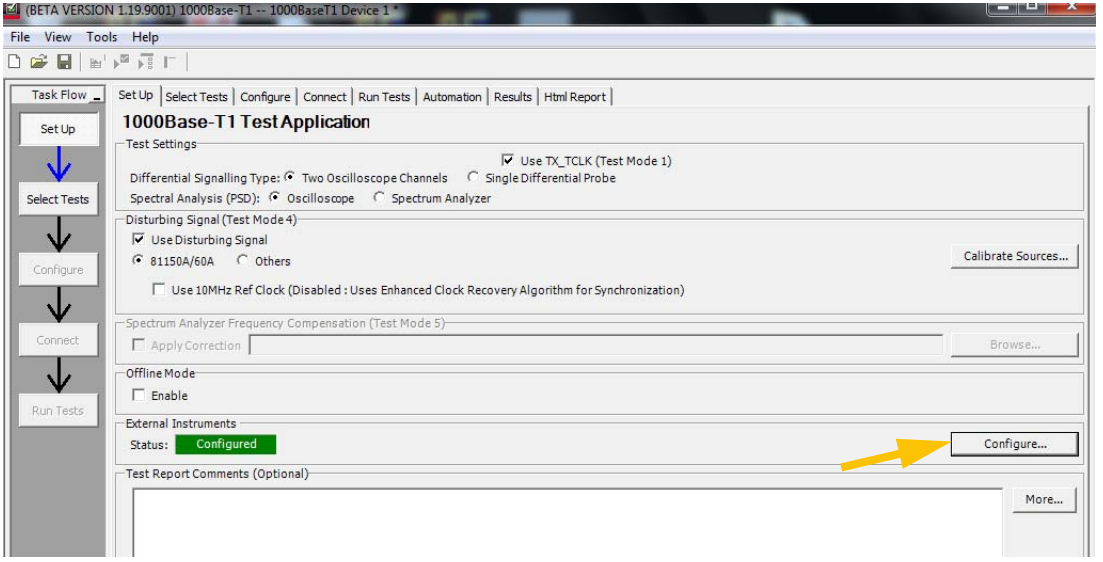


Figure B-1 E6960A Compliance Test Application Main Menu

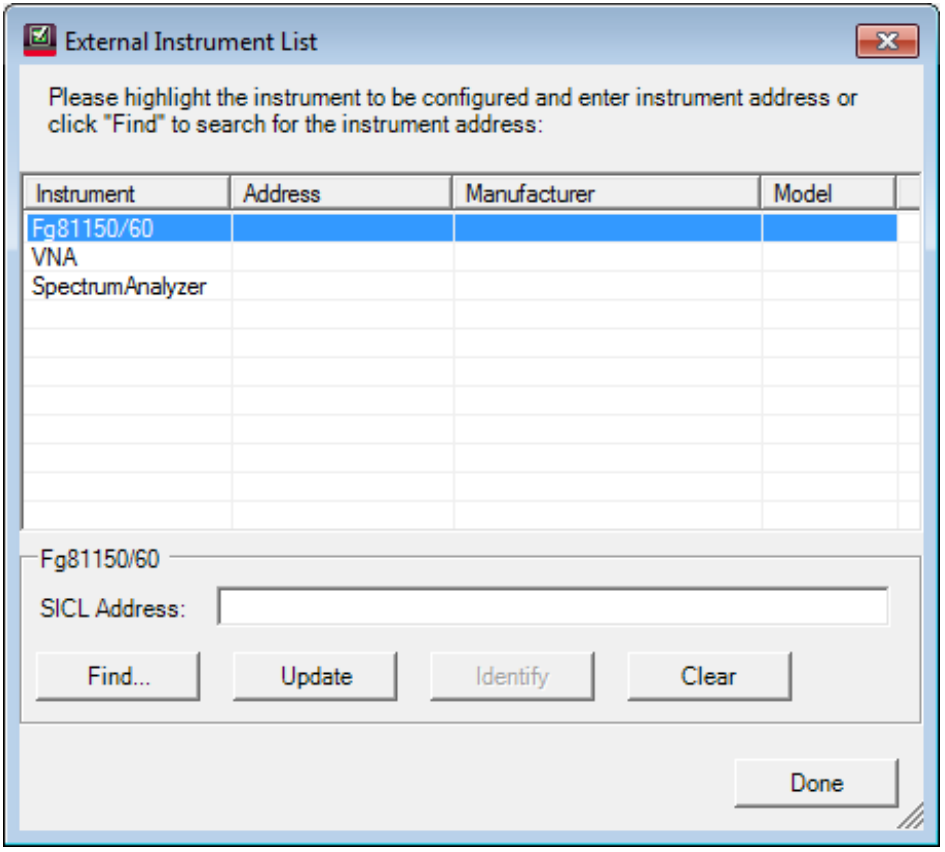


Figure B-2 BroadR-Reach Compliance Test Application External Instruments List

2 Select the AWG used in your system. For the E6961A Solution, this would be the **Fg81150/60.**

3 If you know the SICL address (you can use *Keysight IO Libraries Suite Connection Expert* utility to obtain the SICL address) enter it in the SICL Address field. If you do not know the SICL address, click the **Find** button and the Test Compliance Software will attempt to locate and identify the AWG.

4 Click the **Update** button.

5 Repeat steps 3, 4, and 5 for the E5071C ENA and the N9010B EXA Spectrum (or Signal) Analyzer.

6 When you are finished, click the **Done** button to return to the Main Menu.

7 The External Instruments **Status** indicator turns green to indicate that all external instruments have been properly configured.

C External Instrument Calibration

Introduction

All instruments must be calibrated prior to running the Compliance tests. The compliance application software guides you in calibrating the AWG and the ENA.

Calibrating the AWG

Before running disturbing signal tests, the AWG must be calibrated. Connect the equipment as shown in Figure 1-9 on page 29.

NOTE The AWG Disturbing Signal Source must be Configured before attempting to Calibrate it. If the system is not physically configured to perform the calibration, the application prompts you to change the physical configuration. Refer to “Appendix B. “Configure External Instruments” on page 51

NOTE Instead of connecting SMA to SMA cables on the N5393C Evaluation Board, connect 50 Ω Terminators to the two DUT SMA Connectors on the Evaluation Board. This is shown in Figure C-1 below

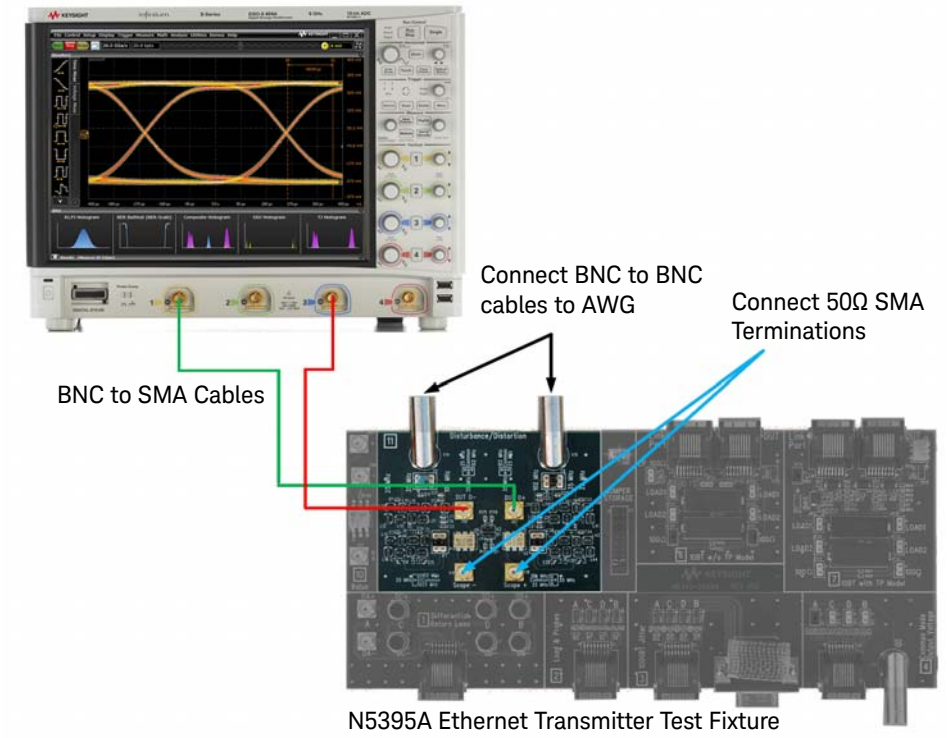


Figure C-1 AWG Calibration Setup for the Disturbing Signal Source

Performing the AWG Calibration for the Disturbing Signal Source

1 From the E6960A Compliance Test Application software main menu, click the **Calibrate Sources** button.

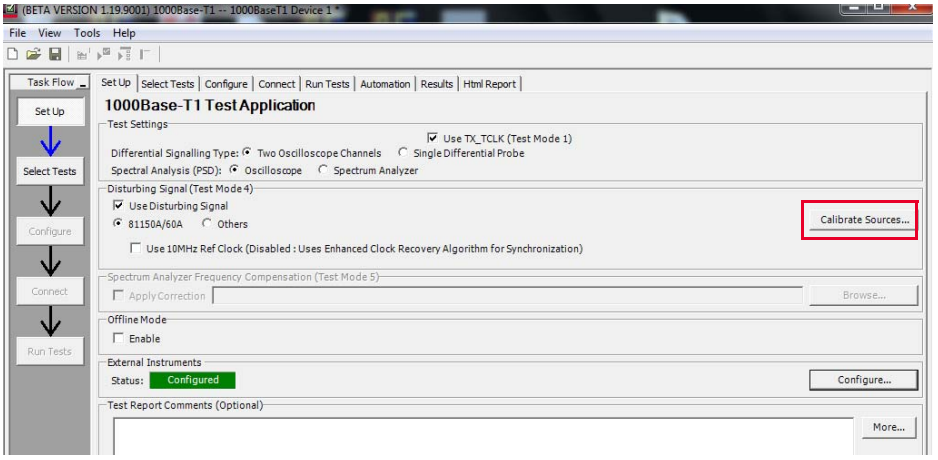


Figure C-2 E6960A Compliance Test Application Main Menu

2 This opens the **Calibrate Disturbing Signal** dialog box for the selected AWG.

3 With the appropriate AWG Address set and the correct oscilloscope channels selected, click the **Calibrate** button to start the calibration process.

4 When the software finishes the calibration, click the **Done** button to return to the Main Menu. Refer to the E6960A online help for a more detailed explanation.

Calibrating the ENA

Using the Return Loss Calibration board

Before using the ENA, it must be calibrated using the Return Loss Calibration board. See Figure C-3 below for the connection diagram. Calibrate the ENA using the instructions in the ENA's User's Guide.

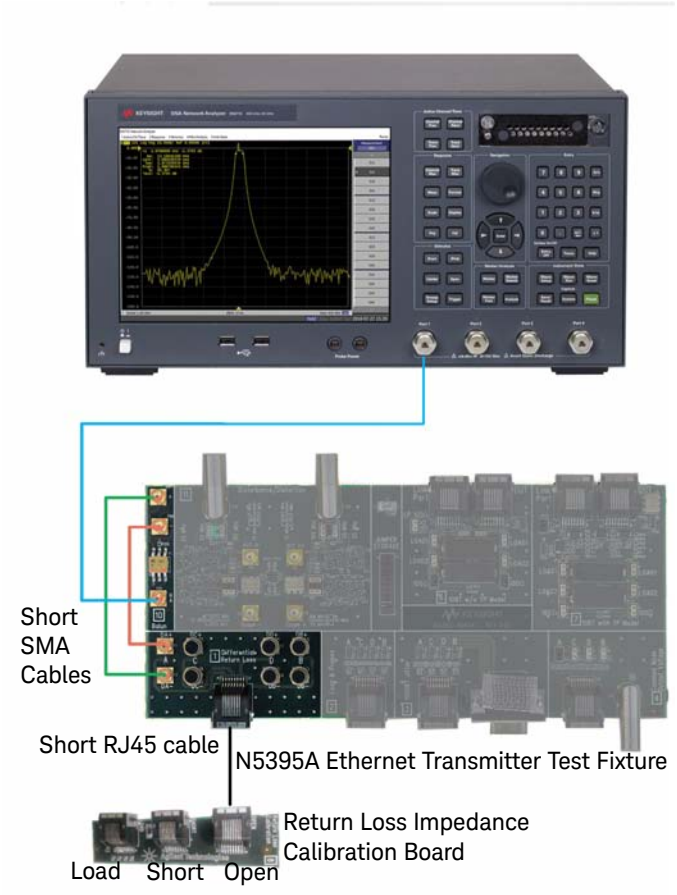


Figure C-3 ENA Calibration Setup (Return Loss)

1. Connect the Return Loss Calibration board RJ45 connector labeled OPEN to the RJ45 connector on the main test fixture board using a short straight-through UTP cable.
2. Connect one end of two short SMA-to-SMA cables to the SMA test points for the pair you are testing (A, B, C, or D) on Section 1 of the test fixture. Connect the other end to the two SMA test points on Section 10 on the test fixture.
3. Connect a ENA input to the SMA test point on Section 10 on the test fixture.
4. Calibrate the ENA using the instructions in the ENA's User's Guide. The following is a list of setup requirements.
   - Set **Measurement** to Ref1 Fwd S_{11}.
   - Set **Start** to 2 MHz.
   - Set **Stop** to 600 MHz.
   - Set **Format** to **Log Mag**.
   - Set **Scale** Div to 5.
   - Set **Scale Ref** to reference line position 9.
5. Run the calibration for the OPEN, SHORT, and LOAD connections.

NOTE For connectors other than RJ45, a custom calibration kit will need to be developed.

Using ECal Module

Before using the ENA, it must be calibrated using the N4431B ECal Kit. See Figure C-4 below for the connection diagram. Calibrate the ENA using the instructions in the ENA's user guide.

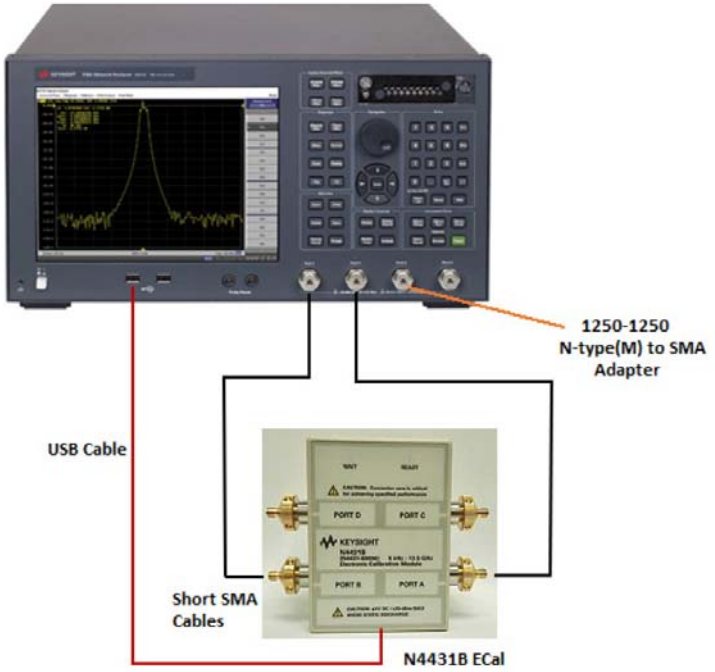


Figure C-4 ENA Calibration Setup (ECal Module)

1. Connect the USB port on the ECal module with the USB port on the E5071C via a USB cable. This connection may be done while the E5071C's power is on.
2. Allow the Ecal module to warm up for 15 minutes until the module indicator changes from **WAIT** to **READY**.
3. Connect port A and port B on the Ecal module to the ENA's test ports (using SMA cables) to be calibrated. Use the N-type (M) to SMA Adapter for easy connection of SMA cables.
4. Press **Channel Next/Channel Prev** keys to select the channel for which you want to perform the calibration.

5 Click **ECal.**

6 Click **2 Port ECal**.

- When using a 2-port E5071C, pressing this key performs a 2-port ECal.
- When using a 3-port or 4-port E5071C, click one of the softkeys to start a full 2-port calibration.

7 The following is a list of setup requirements prior to running the calibration routine.

- Set **Measurement** to S_{dd11}.
- Set **Start** to 2 MHz.
- Set **Stop** to 600 MHz.
- Set **Format** to **Log Mag**.

D Using the E6960-66600 Frequency Divider Board

Introduction

Keysight's E6960-66600 Frequency Divider Board produces two identical clock signal outputs (10 MHz) that are phase locked to the input clock. This Frequency Divider Board is recommended for Compliance Test Mode 4, Transmitter Distortion Test.

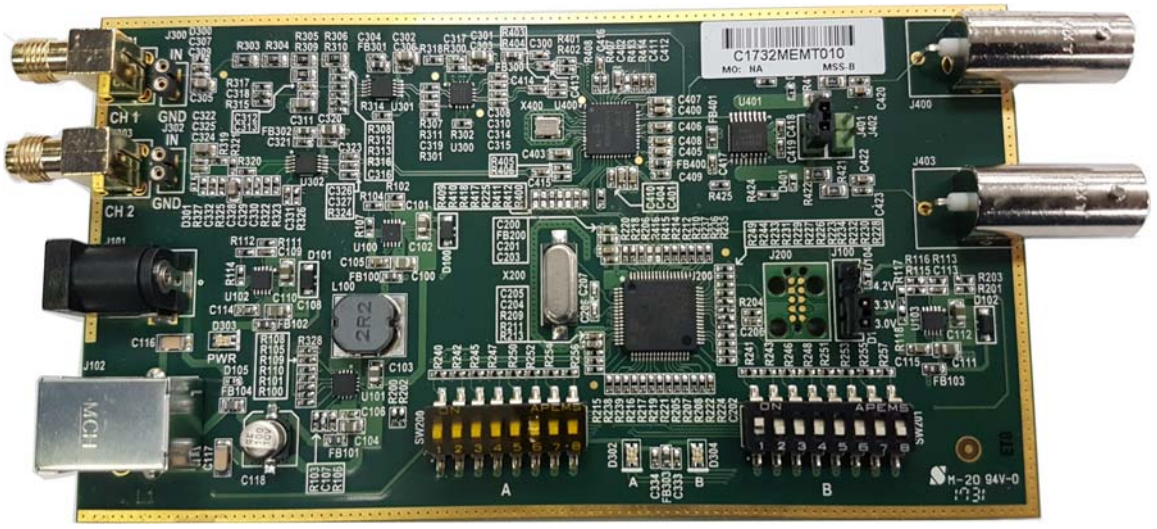
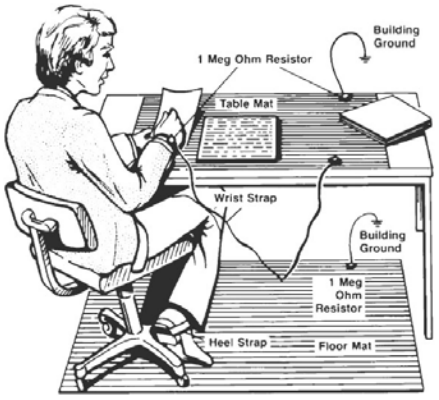


Figure D-1 Keysight's E6960-66600 Frequency Divider Board

Static-safe Handling Procedures



Electrostatic discharge (ESD) can damage or destroy electronic components. Use a static-safe work station to perform at work on electronic assemblies. This figure shows a static-safe work station using two types of ESD protection:

- Conductive table-mat and wrist-strap combination
- Conductive floor-mat and heel-strap combination

Both types, when used together, provide a significant level of ESD protection. Of the two, only the table-mat and wrist-strap combination provides adequate ESD protection when used alone. To ensure user safety, the static-safe accessories must provide at least 1 MΩ of isolation from ground.

Observe appropriate ESD precautions before connecting and disconnecting cables and changing the positions of jumpers ans switches.

To use the divider board, check the Use 10MHz Ref Clock on the E6960A Main Application Window

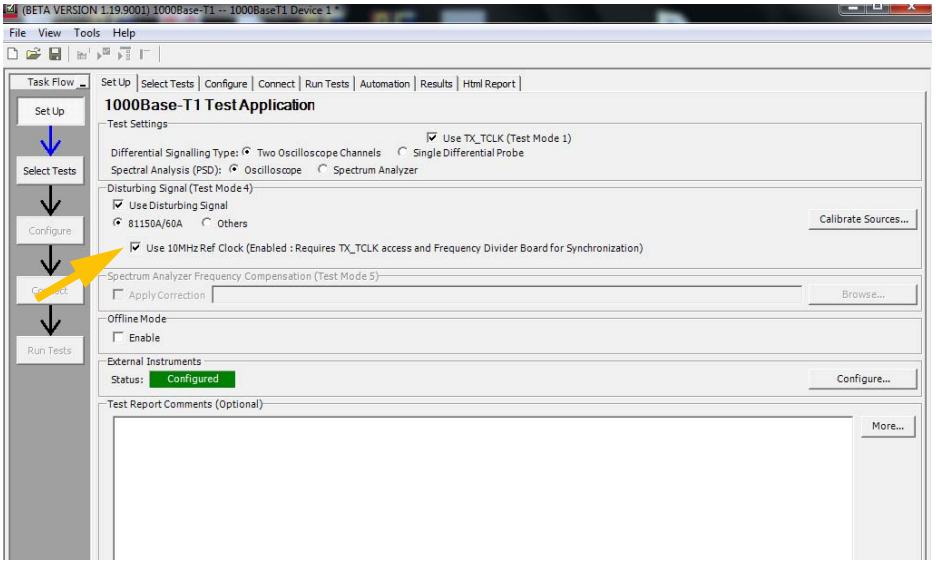


Figure D-2 Check the Use 10MHz Ref Clock on Main Application Window

Configure the test setup as shown below.

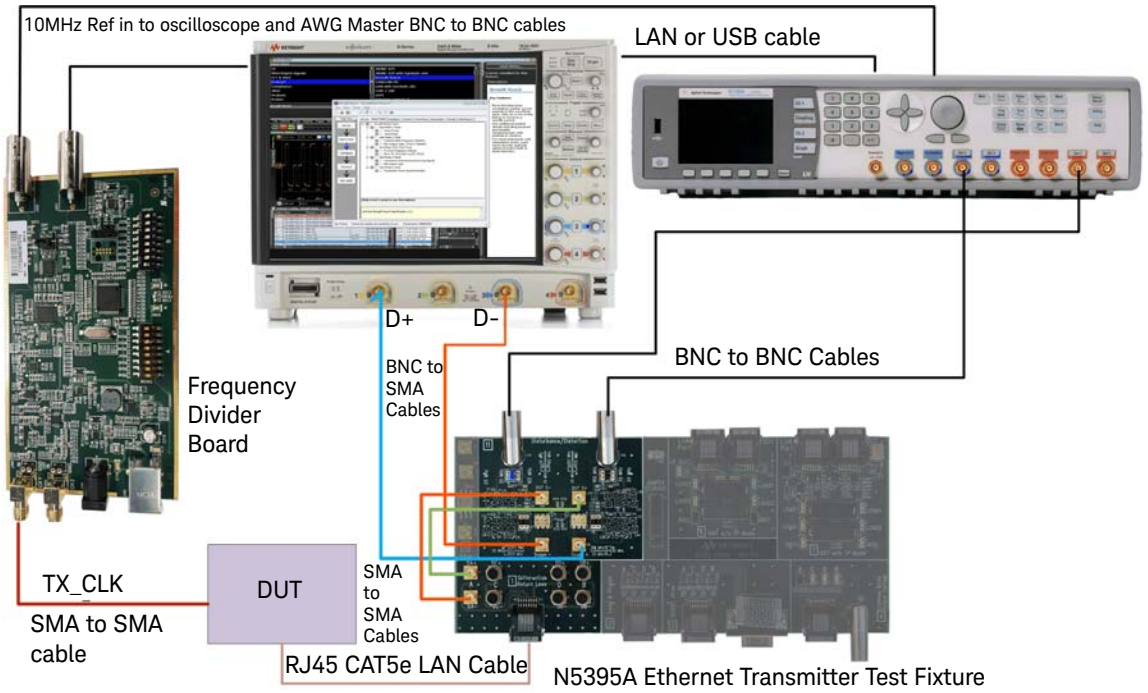


Figure D-3 Test Setup for 10 MHz Frequency Reference

Frequency Divider Board Test Setup

1. Connect CH1 SMA connector to the Device Under Test (DUT).
2. Use BNC to BNC cables to connect both J400 and J403 BNC connectors to the oscilloscope and the AWG 10 MHz In.
3. Select 4.2 Vpp output voltage by shorting Pin1 and Pin2 of J100 with jumper. Remark: 10MHz ref input amplitude and frequency specification for every oscilloscope might be different. Please ensure the oscilloscope that you use meets the specifications. In the event it doesn't, an attenuator might be required.
4. Select Normal Running mode by switching switch A1 to OFF.
5. Select Frequency Tracking mode by switching switch A2 to OFF.

6 Select CH1 as input by switching switch A6 to OFF.

7 Select Targeted 25 MHz input by switching switch B2 to ON.

8 Power on the board by connecting a power source to the USB connector or to the DC power jack. (4.5V to 5.5V @450mA).

At power on, the:

- Power LED PWR (D303) should light up as GREEN
- LED A (D302) should light up as GREEN
- LED B (D304) should light up as GREEN

Connector Description

This section describes the various user components on the E6960-66600.

USB type-B / DC Jack

Provides power to the fixture. Either the USB port or the 2.5 mm, center positive purpose. Input voltage is required to be within +4.5V to +5.5V @500mA. Any voltage that is out of specification will trigger a warning on the Power LED.

SMA

Provides an interface to feed the input signal into the test fixture. CH1 connector is 50 Ω terminated and CH2 connector is 10k Ω terminated.

BNC

Both J400 and J403 produce a separate output clock signal. The signals are back-terminated by 50 Ω.

Jumpers

Provides user the option to modify the test fixture circuitry.

J100 This jumper controls the output signal amplitude:

4.2Vpp: Connect pin 1 and pin 2

3.3Vpp: Connect pin 2 and pin 3

3.0Vpp: Connect pin 3 and pin 4

J300 & J302 This jumper allows user to probe the channel 1 and channel 2 inputs respectively

J401 This jumper shorts both outputs together.

J402 Parking location for unused jumpers.

DIP Switch Description

Switch A

Switch A sets the Fixture operating mode.

Table D-1 Switch A function states

Switches	Position	Operating mode	Comment
A1	off	Normal running mode	Normal operating mode
	on	Sleep mode	Change made to any of the switches are ignored
A2	off	Frequency Tracking Mode	Output frequency track to input frequency
	on	Lock Frequency Mode	Output clock is phase lock to input clock
A3	off	NA	NA
	on	NA	NA
A4	off	NA	NA
	on	NA	NA
A5	off	NA	NA
	on	NA	NA
A6	off	Select CH1 as input	NA
	on	Select CH2 as input	NA
A7	off	NA	NA
	on	NA	NA
A8	off	NA	NA
	on	NA	NA

Switch B

Switch B sets the frequency divider to the relevant setting.

Table D-2 Switch B function states

								Divider	Comment
B1	B2	B3	B4	B5	B6	B7	B8		To obtain 10 MHz output:
off	off	off	off	off	off	off	off	Not valid (def)	Free Run Mode
on	off	off	off	off	off	off	off	Div 1	Targeted 10MHz input clock
off	on	off	off	off	off	off	off	Div 5/2	Targeted 25MHz input clock
off	off	on	off	off	off	off	off	Div 20/3	Targeted 66.67MHz input clock
off	off	off	on	off	off	off	off	Div 25/2	Targeted 125MHz input clock
off	off	off	off	on	off	off	off	Div 75	Targeted 750MHz input clock

Note: Other combinations are not valid. if no valid switch setting is detected, LED will flash indicating invalid switch B configuration. After reset, if no valid position is detected, the board uses the “Free Run Mode” which generates an accurate 10 MHz signal.

LED Description

Power LED

Table D-3 LED indicators

	Green	Red
Input voltage below 4.5V	ON	Flash 1 Hz
Input voltage below3.6V	ON	Flash 2 Hz
Input voltage above 5.5V	ON	ON

LED A

Table D-4 LED A indicators

	Green	Red
Input signal locked (Normal condition)	ON	OFF
Lost of Lock	Flash 1 Hz	OFF
Lost of Signal	OFF	Flash 1 Hz
Lost of 48MHz reference	OFF	ON

LED B

Table D-5 LED B indicators

	Green	Red
Valid switch B configuration (Normal condition)	ON	OFF
Invalid switch B configuration	Flash 1 Hz	OFF
Missing input signal/ input signal out of range/ Warning. See LED A for list of warning	N/A	ON

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK.

Edition 3.0, March 2019

Printed in Malaysia

E6960A-90001

www.keysight.com