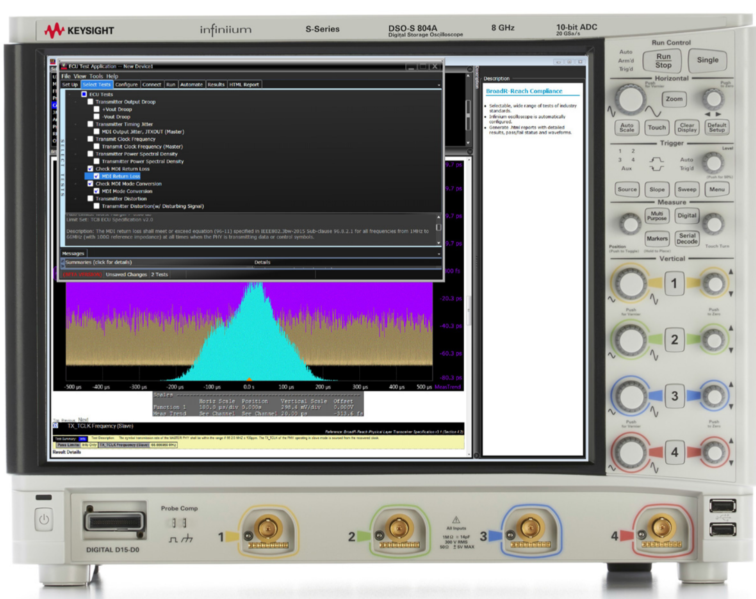
User Guide and
Methods of Implementation

Compliant to OPEN Alliance Specification

Keysight E6959A Automotive Ethernet TC8 ECU Compliance Solution



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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 Introduction

Overview of Keysight E6959A ECU Compliance Test Application 6

Installing the Compliance Test Application 7
Installing the License Key 7

Preparing to Take Measurements 8

Calibrate the Oscilloscope 8
General Test Setup 9

Starting the ECU Compliance Test Application 13

2 Tests and Test Report

Transmitter Droop Tests 18

Test Setup 18
Specification References 18
Transmitter Output Droop Positive Test Information 18
Transmitter Output Droop Negative Test Information 19

Transmitter Timing Jitter in MASTER Mode 20

Test Setup 20
Specification References 20
Transmitter Timing Jitter Test Information 20

Transmit Clock Frequency 21

Test Setup 21
Specification References 21
Transmit Clock Frequency Test Information 21

Transmitter Power Spectral Density (PSD) Test 22

Test Setup 22
Specification References 22
PSD Test Information 23

MDI Return Loss Test 24

Test Setup 24
Specification References 24
MDI Return Loss Test Information 25

MDI Mode Conversion Test 26

Test Setup 26
Specification References 26
MDI Mode Conversion Test Information 27

MDI Common Mode Emission Test 28

Test Setup 28
Specification References 28
MDI Common Mode Emission Test Information 28

Transmitter Distortion Test 30

Test Setup 30
Using the Optional E6961A Frequency Divider Board 32
Specification References 32
Transmitter Distortion Test Information 32

Viewing the Test Report 33

3 Appendix

Reference Documents 36

Other Keysight Automotive Ethernet Applications and Software 36

Setting Up the N5395C Ethernet Transmitter Test Fixture 37

Jumper Settings 38

Configuring External Instruments 40

Calibrating External Instruments 42

Calibrating the AWG 42
Calibrating the ENA 44

Using the E6960-66600 Frequency Divider Board 45

Static-safe Handling Procedures 45
Frequency Divider Board Test Setup 47
Connector Description 47
DIP Switch Description 48
LED Description 49

1 Introduction

Overview of Keysight E6959A ECU Compliance Test Application / 6
Preparing to Take Measurements / 8
Starting the ECU Compliance Test Application / 13

Overview of Keysight E6959A ECU Compliance Test Application

Testing an ECU PHY's transmitter characteristics is accomplished using various test modes defined in the 100BASE-T1 specification. See "Reference Documents" on page 36. The ECU PHY's transmitter would be referred to as the DUT or Device Under Test for the rest of the document.

Keysight's E6959A Automotive Ethernet TC8 ECU Compliance Test Application (provided as a software option to the E6961A Automotive Ethernet Solution) provides the means for testing and validating transmitted frequency, distortion, jitter and droop, as well as MDI Return Loss, Mode conversion and Common Mode Emission. 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.

Test	Test Mode/Configuration	Test Classification
Transmitter Output Droop	Test Mode 1	Optional[1]
Transmitter Timing Jitter	Test Mode 2/ Master	Mandatory[2]
Transmit Clock Frequency	Test Mode 2	Mandatory
Power Spectral Density	Test Mode 5	Optional
MDI Return Loss	Slave Mode. No test mode transmitted	Mandatory
MDI Mode Conversion	Slave Mode. No test mode transmitted	Mandatory
MDI Common Mode Emission	Test Mode 5	Optional
Transmitter Distortion	Test Mode 4	Optional

1 The test could be executed but not required for an official qualification pass/fail criterion.

2 The test is required and must be evaluated according to the specified pass/fail criterion.

Using the Keysight E6959A Automotive Ethernet TC8 ECU Compliance Test Application along with the N5395C Ethernet Test Fixture or equivalent fixture greatly simplifies compliance testing. The software automatically configures all the required test equipment as well as reducing the overall test time.

The E6959A 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 Application

1. Make sure you have the minimum version of Infiniium oscilloscope software (06.30.00701) by choosing **Help > About Infiniium...** from the main menu. (You can also refer to the software release notes for this information.)
2. To obtain the E6959A Compliance Test Application, go to Keysight website: http://www.keysight.com/find/E6959A.
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 certificate for more details.
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 E6959A 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 guide in the Keysight Probe Resource Center.

General Test Setup

Transmitter Output Droop, Transmitter Timing Jitter, Transmit Clock Frequency, Power Spectral Density and MDI Common Mode Emission require only the Infiniium oscilloscope and the device to be tested (Device Under Test or DUT). The test setup is described below. The signal supplied to the oscilloscope can either be a differential signal, or single ended signal.

Differential signaling type refers to connecting the differential automotive pair to the oscilloscope using only SMA cables. Refer to Figure 1 for more details.

Single ended signaling type here refers to connecting the differential automotive pair to the oscilloscope using a single differential probe. Refer to Figure 2 for more details. The only variation to the single ended signaling type would be the Common Mode Emission test that requires a specific fixture as well as the Power Spectral Density test that requires a balun.

Any variation from the above definition of signaling type is not recommended. The type of connection accepted can be selected in the **Set Up** tab of the test application.

Transmitter Distortion requires the N5395C Ethernet Test Fixture and an Arbitrary Waveform Generator (AWG). Refer to "Transmitter Distortion Test" on page 30 for specific setup details.

MDI Return Loss and MDI Mode Conversion requires a VNA to execute. Also the DUT has to be in Slave mode with no test mode being transmitted. Refer to "MDI Return Loss Test" on page 24 and "MDI Mode Conversion Test" on page 26.

Power Spectral Density can also use the N9010B Signal Analyzer. Refer to "Transmitter Power Spectral Density (PSD) Test" on page 22.

Similarly, MDI Common Mode Emission can also use the N9010B Signal Analyzer. Refer to "MDI Common Mode Emission Test" on page 28.

Differential Connection to Oscilloscope

Two SMA cables are needed to directly connect the output of the transmitter (ECU) 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.

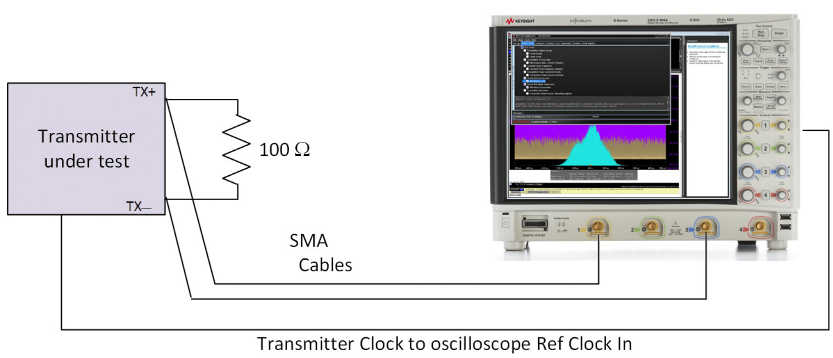


Figure 1 Connection to the Oscilloscope Using a Pair of SMA Cables

Single-ended Connection to Oscilloscope

A differential probe is used to connect the output of the transmitter (ECU) 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.

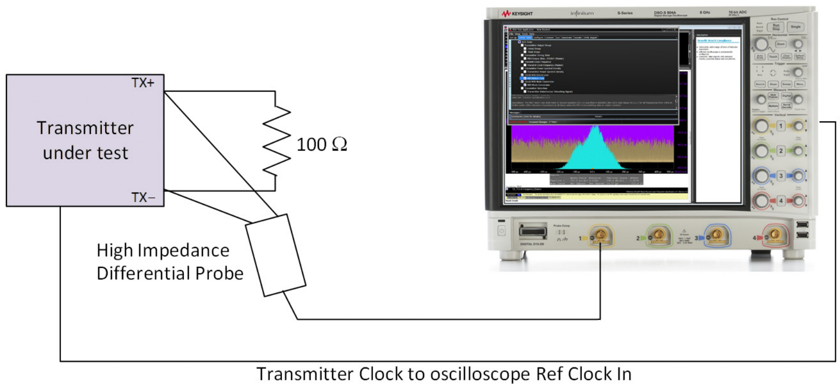


Figure 2 Connection to the Oscilloscope using a Differential Probe

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. This connection is only valid if the DUT has an RJ45 connector. The SMA connections shown in Figure 3 are for wire pair A (DA+ and DA–) in the RJ45 cable. To test to wire pair B, C, or D, connect the oscilloscope SMA cables to the appropriate Evaluation Board SMA connectors.

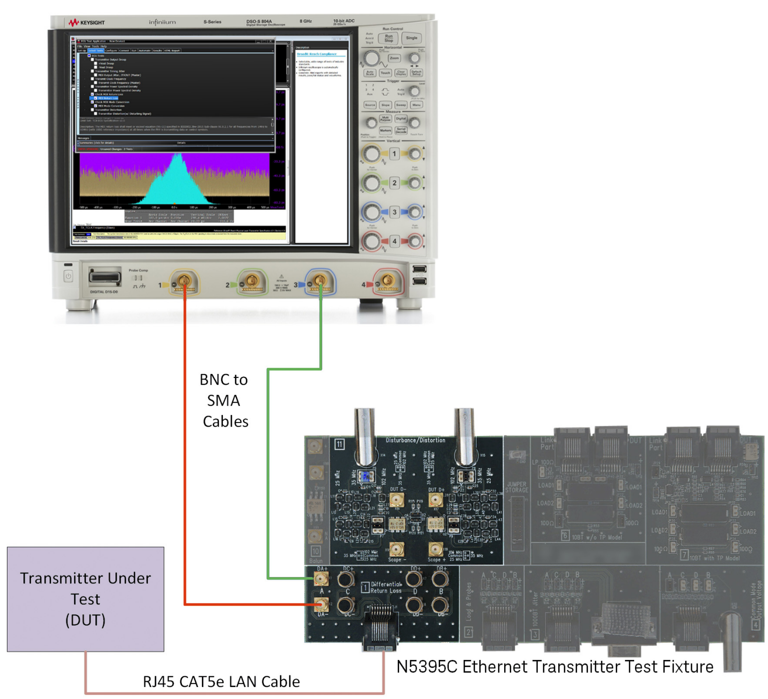


Figure 3 General Test Setup using the N5395C Evaluation Board

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

Connection Using the Automotive Ethernet SMA Adapter

Another option would be to use the Keysight Automotive Ethernet SMA Adapter to make connections to the DUT. This adapter is an alternative to using Section 1 of the N5395C Ethernet 10/100/1G Transmitter Electrical Test Fixture shown in Figure 3 above.

This adapter is designed as outlined in OPEN Alliance Automotive Ethernet ECU Test Specification, v2.0, Section 2.2.2, Test OABR_PMA_TX_05 and OABR_PMA_TX_06. It is designed in line with the definitions of IEEE 100BASE-T1 Definitions for Communication Channel, Version 1.0.

If you need a similar fixture, please contact your Keysight sales representative for more details.

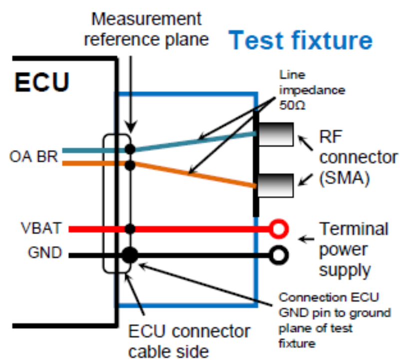


Figure 4 Design of Recommended Test Fixture from OABR

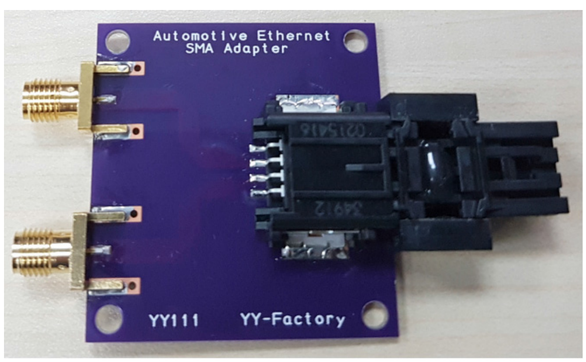


Figure 5 Example of Automotive Ethernet SMA Adapter (Molex to SMA)
Available as custom order through Keysight.

Connection Using the Common Mode Emission Test Adapter

The Common Mode Emission test adapter is designed as outlined in OPEN Alliance Automotive Ethernet ECU Test Specification, v2.0, Section 2.2.2, Test OABR_PMA_TX_07. This adapter was designed in line with the definitions of IEEE 100Base-T1 EMC Test Specifications for Transceivers, Appendix D, D.1 Test Conditions.

If you need a similar fixture, please contact your Keysight sales representative for more details.

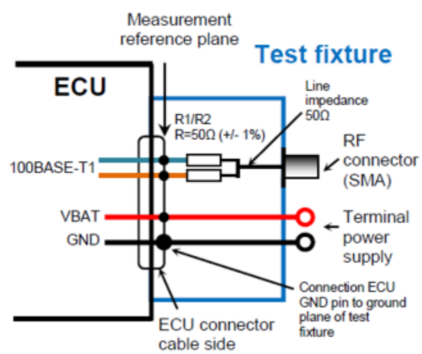


Figure 6 Design of Recommended Common Mode Emission Test Fixture from OABR

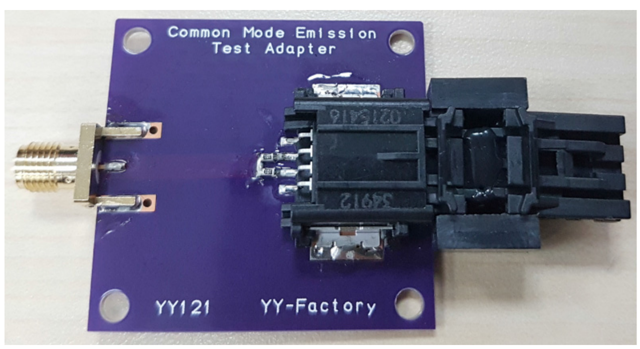


Figure 7 Example of Common Mode Emission Test Adapter (Molex to SMA)
Available as custom order through Keysight.

Starting the ECU Compliance Test Application

1 Ensure that the ECU's PHY transmitter (DUT) is operating and set to desired test modes.

2 To start the ECU Compliance Test Application from the Infiniium oscilloscope's main menu, select **Analyze > Automated Test Apps > E6959A ECU Test App**.

Figure 8 Launching the ECU Compliance Test Application

Requires Frequency Divider Board. See "Using the E6960-66600 Frequency Divider Board" on page 45.

Refer to "Calibrating External Instruments" on page 42.

Refer to "Configuring External Instruments" on page 40.

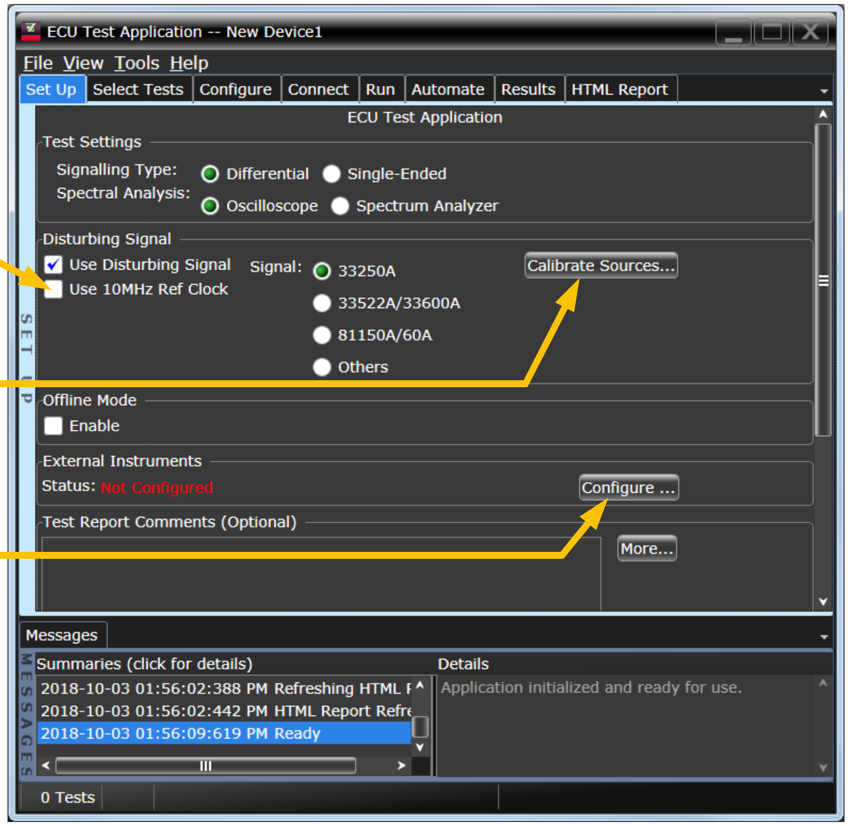


Figure 9 ECU Compliance Test Application Main Window

The Compliance Test Application automatically sets frequency, etc. of the external instruments (oscilloscope, ENA, generators, etc.) if they are properly configured. Refer to "Configuring External Instruments" on page 40.

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

Displays test limits, test description, and IEEE specification reference for the selected test.

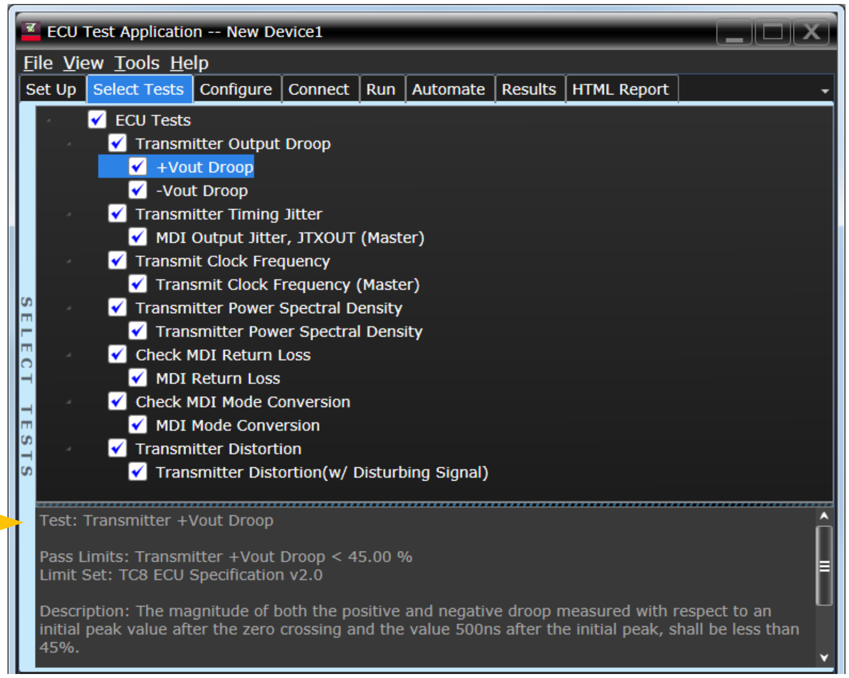


Figure 10 Select Tests Tab with All Tests Selected

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 33.

The Configure Tab allows you to select different oscilloscope channels and measurement attributes.

For example, the signal input can be changed from a differential probe to two SMA cables.

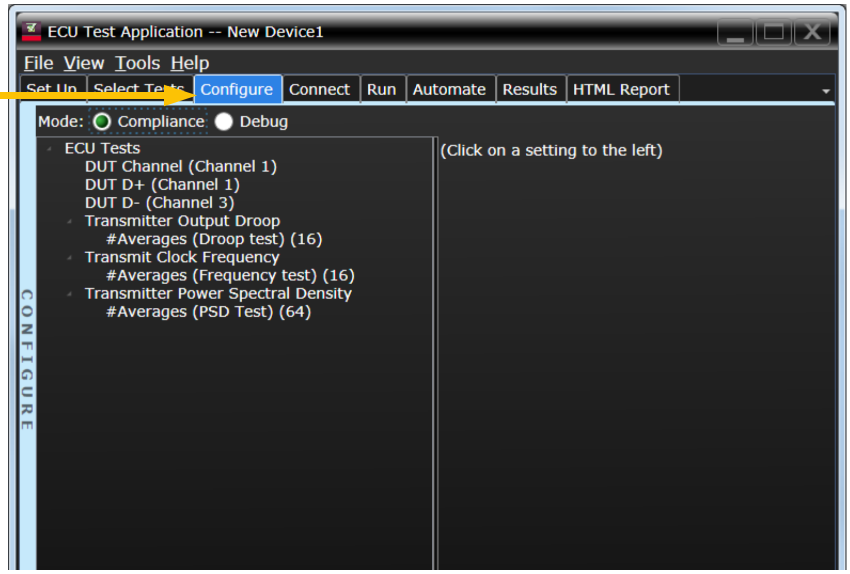


Figure 11 Configure Tab for Transmitter Droop Tests

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.

Click Connection Completed before clicking Run Tests.

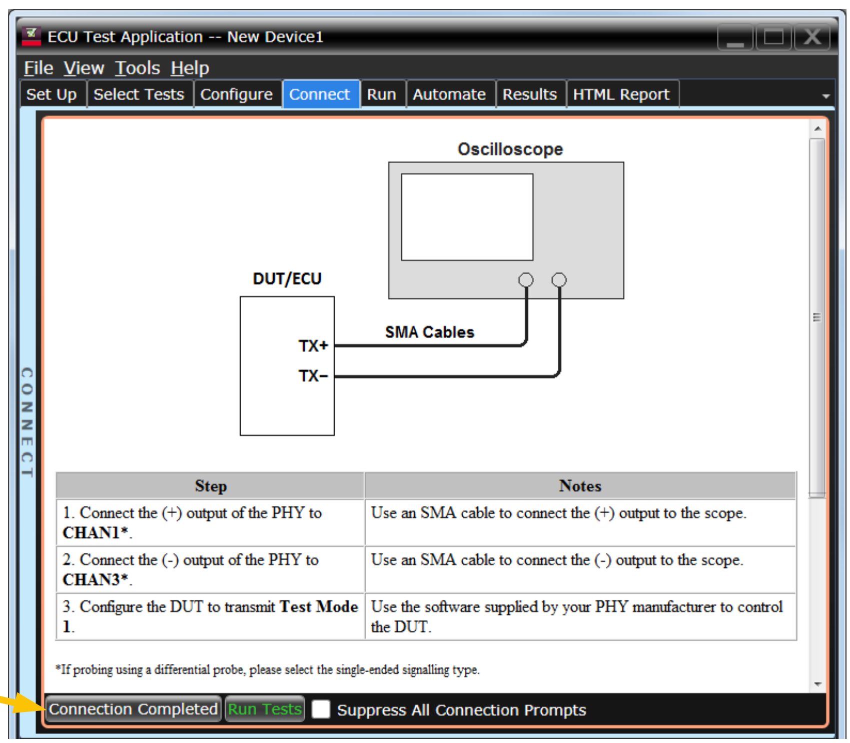


Figure 12 Connect Tab for Transmitter Droop Tests

2 Tests and Test Report

Transmitter Droop Tests / 18
Transmitter Timing Jitter in MASTER Mode / 20
Transmit Clock Frequency / 21
Transmitter Power Spectral Density (PSD) Test / 22
MDI Return Loss Test / 24
MDI Mode Conversion Test / 26
MDI Common Mode Emission Test / 28
Transmitter Distortion Test / 30
Viewing the Test Report / 33

Transmitter Droop Tests

Test Setup

This test may be run using either a differential output or single-ended output from the transmitter (MDI). Refer to "General Test Setup" on page 9 for connection details.

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

Specification References

[1] OPEN Alliance Automotive Ethernet ECU Test Specification, v2.0, Section 2.2.2, Test OABR_PMA_TX_01

[2] 100Base-T1, IEEE Std 802.3bwTM – 2015, Section 96.5.4.1

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 the initial peak value after the zero crossing and the value 500 ns after the initial peak, shall be less than 45%.

The application triggers the Test Mode 1 signal on the rising edge and determines the time the positive peak occurred and the voltage at that specific instance. The application then measures the voltage 500 ns after the peak. 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.

Typical Waveform

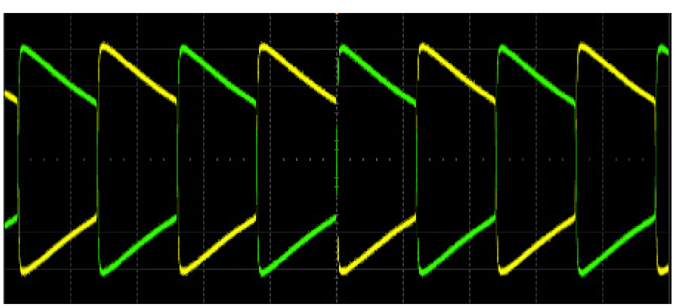


Figure 13 Typical Positive Droop Test Waveform (using a pair of SMA cables)

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 the initial peak value after the zero crossing and the value 500 ns after the initial peak, shall be less than 45%.

The application triggers the Test Mode 1 signal on the falling edge and determines the time the negative peak occurred and the voltage at that specific instance. The application then measures the voltage 500 ns after the peak. 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.

Typical Waveform

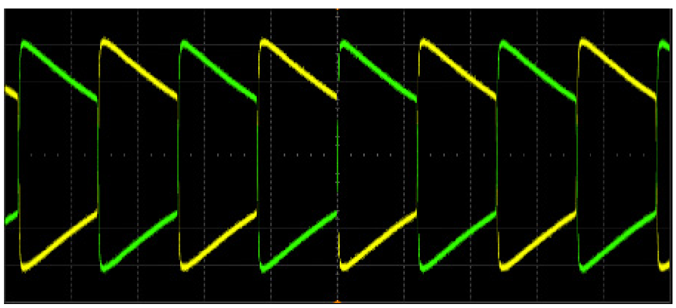


Figure 14 Typical Negative Droop Test Waveform (using a pair of SMA cables)

Transmitter Timing Jitter in MASTER Mode

Test Setup

This test may be run using either a differential output or single-ended output from the transmitter (MDI). Refer to "General Test Setup" on page 9 for connection details.

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

Specification References

[1] OPEN Alliance Automotive Ethernet ECU Test Specification, v2.0, Section 2.2.2, Test OABR_PMA_TX_02.

[2] 100Base-T1, IEEE Std 802.3bwTM – 2015, Section 96.5.4.3

Transmitter Timing Jitter Test Information

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.

Reference [1] and [2] specifies that when in test mode 2, the RMS (Root Mean Square) TIE value of the MDI output jitter, JTXOUT, relative to an unjittered reference shall be less than 50 ps.

Typical Waveform

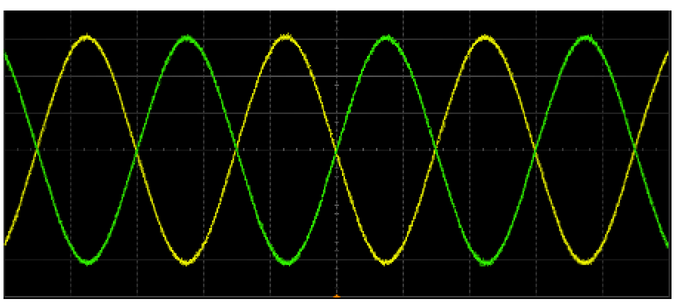


Figure 15 Typical MASTER TX Out Test Waveform (using a pair of SMA cables)

Transmit Clock Frequency

Test Setup

This test may be run using either a differential output or single-ended output from the transmitter (MDI). Alternatively, this test can also be run using the TX_TCLK. Refer to "General Test Setup" on page 9 for connection details.

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

Specification References

[1] OPEN Alliance Automotive Ethernet ECU Test Specification, v2.0, Section 2.2.2, Test OABR_PMA_TX_03

[2] 100Base-T1, IEEE Std 802.3bwTM – 2015, Section 96.5.4.5

Transmit Clock Frequency Test Information

This test measures the frequency of the transmitter clock when the PHY is operating in MASTER mode.

Reference [1] and [2] specifies the symbol transmission rate of a compliant PHY. The symbol transmission rate of the MASTER PHY shall be within the range of 66 2/3 MHz ±100 ppm.

The Reference [1] and [2] specifies that Test Mode 2 shall transmit the data symbol sequence {+1, -1} repeatedly on the channel. The transmitter shall time the transmitted symbols from a symbol rate clock in the MASTER timing mode. The measured data rate of the Test Mode 2 signal is thus equal to the MASTER Transmit Clock Frequency of the PHY.

Typical Waveform

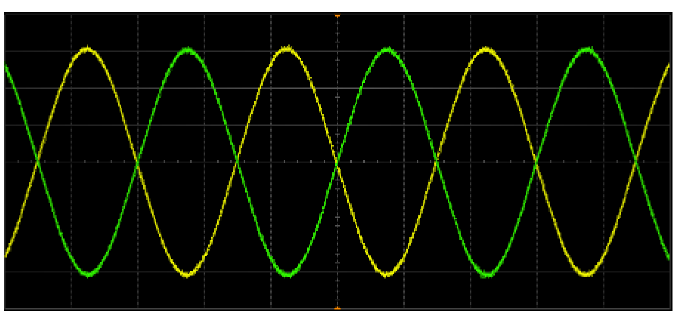


Figure 16 Typical MASTER Clock Test Waveform (using a pair of SMA cables)

Transmitter Power Spectral Density (PSD) Test

Test Setup

The Power Spectral Density (PSD) Test can be run using either a spectrum analyzer or an oscilloscope. When using the oscilloscope, "General Test Setup" on page 9 for testing using oscilloscope.

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 17. This is a similar setup used when selecting single ended signaling to run the Power Spectral Density test; the only difference being the Signal Analyzer is replaced with an oscilloscope instead.

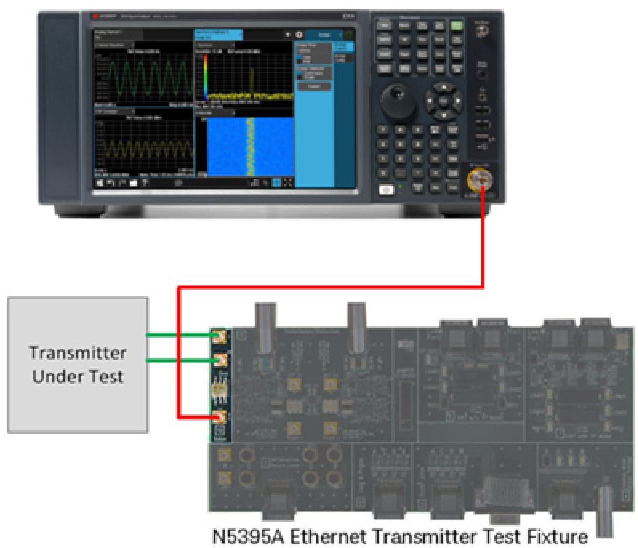


Figure 17 Power Spectral Density Test Using N9010B Signal Analyzer

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

Specification References

[1] OPEN Alliance Automotive Ethernet ECU Test Specification, v2.0, Section 2.2.2, Test OABR_PMA_TX04

[2] 100Base-T1, IEEE Std. 802.3bw-2015, Section 96.5.4.4

PSD Test Information

Reference [1] and [2] specifies that in Test Mode 5, the power spectral density (PSD) of the transmitter shall be between the upper and lower bounds specified in the table below.

Frequency	PSD Upper Bound (dBm/Hz)[1]	PSD Lower Bound (dBm/Hz)[1]
@1 MHz	-63.3	-70.9
@20 MHz	-64.8	-75.8
@40 MHz	-68.5	-89.2
57 MHz–200 MHz	-76.5	–

1 Settings: RBW=10 kHz, VBW=30 kHz, sweep time >1 min, RMS detector.

The upper and lower limits are piece-wise linear masks connecting points given in the table above. A lower PSD mask is provided to ensure the tolerances.

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

Typical Waveform

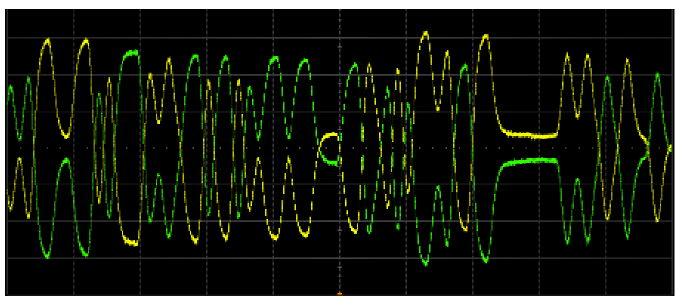


Figure 18 Typical Spectral Density Loss Test Waveform

MDI Return Loss Test

Run the Management Data Input (MDI) Return Loss test with a vector network analyzer connected externally to the oscilloscope.

Test Setup

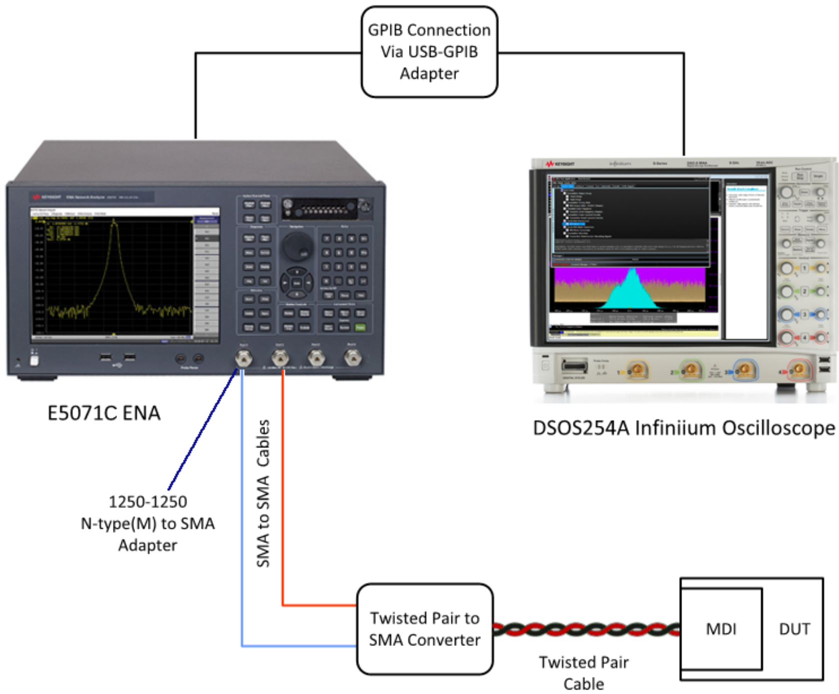


Figure 19 Connection Setup for MDI Return Loss test

Specification References

[1] OPEN Alliance Automotive Ethernet ECU Test Specification, v2.0, Section 2.2.2, Test OABR_PMA_TX05

[2] 100Base-T1, IEEE Std. 802.3bw-2015, Section 96.8.2.1

NOTE Where possible, it is recommended to use the Automotive Ethernet SMA Adapter described on page 11.

MDI Return Loss Test Information

This test can run with an external vector network analyzer. However, an ENA exported data file in the Touchstone or CITI format can also be used in place of the external vector network analyzer. The DUT must be set to SLAVE Mode of operation and not transmitting any test symbols.

NOTE

Calibrate the ENA prior to running the tests. Set the ENA as follows:

– Measurement: Return Loss S_{dd11}
– Start Frequency: 1 MHz
– Stop Frequency: 1 GHz
– Sweep Type: Logarithmic
– Sweep Points: 1600
– Output Power: minimum -10 dBm
– Measurement Bandwidth: 100Hz
– Logic Port Impedance Differential Mode: 100 Ω
– Logic Port Impedance Common Mode: 25 Ω
– Turn Averaging On (at least 16 times)
– Smoothing function is deactivated

Reference [1] and [2] specifies that the MDI return loss shall meet or exceed the following equation for all frequencies ranging from 1 MHz to 66 MHz (with 100 reference impedance) at all times.

Frequency	Return Loss (dB)
1 – 30 MHz	20
30 – 66 MHz	20 – 20*log(f/30)

MDI Mode Conversion Test

Run the Management Data Input (MDI) Mode Conversion test with a vector network analyzer connected externally to the oscilloscope.

Test Setup

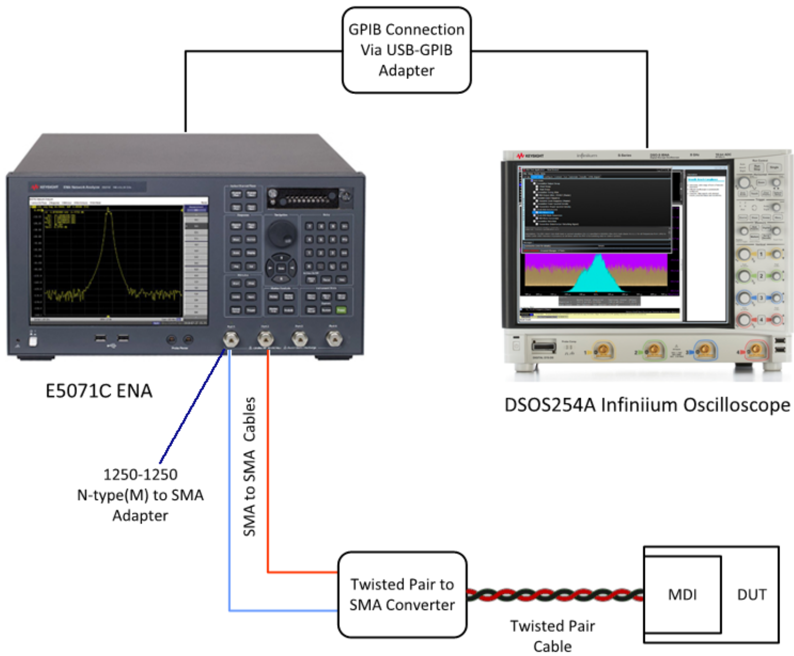


Figure 20 Connection Setup for MDI Mode Conversion test

Specification References

[1] OPEN Alliance Automotive Ethernet ECU Test Specification, v2.0, Section 2.2.2, Test OABR_PMA_TX06

[2] 100Base-T1, IEEE Std. 802.3bw-2015, Section 96.8.2.2

NOTE Where possible, it is recommended to use the Automotive Ethernet SMA Adapter described on page 11.

MDI Mode Conversion Test Information

This test can run with an external vector network analyzer. However, an ENA exported data file in the Touchstone or CITI format can also be used in place of the external vector network analyzer. The DUT must be set to SLAVE Mode of operation and not transmitting any test symbols.

NOTE

Calibrate the ENA prior to running the tests. Set the ENA as follows:

– Measurement: Mode Conversion S_{dc11}
– Start Frequency: 1 MHz
– Stop Frequency: 1 GHz
– Sweep Type: Logarithmic
– Sweep Points: 1600
– Output Power: minimum -10 dBm
– Measurement Bandwidth: 100Hz
– Logic Port Impedance Differential Mode: 100 Ω
– Logic Port Impedance Common Mode: 25 Ω
– Turn Averaging On (at least 16 times)
– Smoothing function is deactivated

Reference [1] and [2] specifies that the MDI Mode Conversion shall meet or exceed the following equation for all frequencies ranging from 1 MHz to 200 MHz at all times.

Frequency	Return Loss (dB)
@1 MHz	–60
@22 MHz	–60
@100 MHz	–47
@200 MHz	–37

MDI Common Mode Emission Test

Test Setup

The MDI Common Mode Emission Test can be run using either a spectrum analyzer or an oscilloscope.

When using the oscilloscope or N9010B Signal Analyzer, it is essential to use the Common Mode Emission Test adapter described on page 12 to condition and convert the signal to a single-ended output.

Any other test fixture/adapter can also be used but it must meet the conditions described in the IEEE 100Base-T1 EMC Test Specifications for Transceivers, Appendix D, D.1.

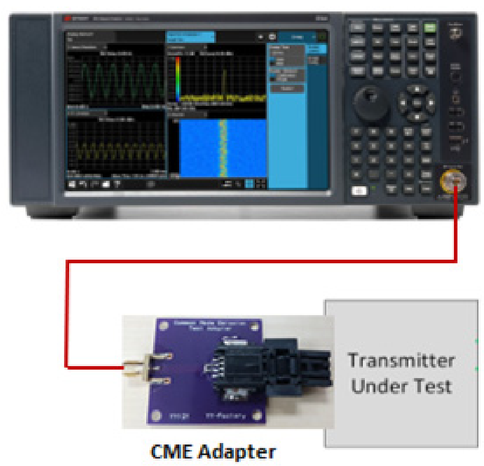


Figure 21 Common Mode Emission Test Using N9010B Signal Analyzer

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

Specification References

[1] OPEN Alliance Automotive Ethernet ECU Test Specification, v2.0, Section 2.2.2, Test OABR_PMA_TX07

[2] 100Base-T1, IEEE EMC Test Specification for Transceivers, Version 1, Appendix D

MDI Common Mode Emission Test Information

Reference [1] and [2] specifies that in Test Mode 5, the test shall be classified passed, if the value of the MDI common mode emission (CME) of the transmitter, fulfills the limit specified in the table below.

Frequency	CME Limit (dBµV)
@2 MHz	24
@70 MHz	24

This test could be run using an external spectrum analyzer or the oscilloscope. Recommended settings for CME measurement at MDI are shown below.

Table 1 Settings for Measurement Device for CME Test

Measuring Equipment	Spectrum Analyzer	EMI Measuring Receiver	Oscilloscope with Spectrum Analyzer Functionality
Measurement unit	dBμV		
Detector	Peak		–
Frequency range	1 MHz to 200 MHz		
Resolution bandwidth (RBW)	10 kHz	9 kHz	10 kHz
Video bandwidth (VBW)	> 3 x RBW	–	–
Number of passes	10 (max hold)	1	in minimum 10 (max hold)
Measurement time per step	–	≥ 1 ms	–
Frequency sweep time	≥ 20 s	–	–
Frequency step width	–	≤ 0.4 x RBW	–
Time Base	–	–	50 μs/div 500 kS in minimum 1 GSa/s
Amplitude	–	–	≤ 2 mV/div
Input			DC 50 Ω

Transmitter Distortion Test

Test Setup

Sections 1 and 11 of the N5395C Ethernet Test Fixture are used in this test. Automotive Ethernet SMA Adapter (page 11) or an equivalent adapter can be used to replace Section 1 of the N5395C Ethernet Test Fixture.

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.

Supported Function Generators	Number Required	Notes
Keysight 33250A	2	Keysight 82357B USB/GPIB interface and one additional GPIB cable required.
Keysight 33612A	1	LAN Cable required.
Keysight 81150A	1	LAN Cable required (2- channel, orderable through E6961A Compliance Test Solution).

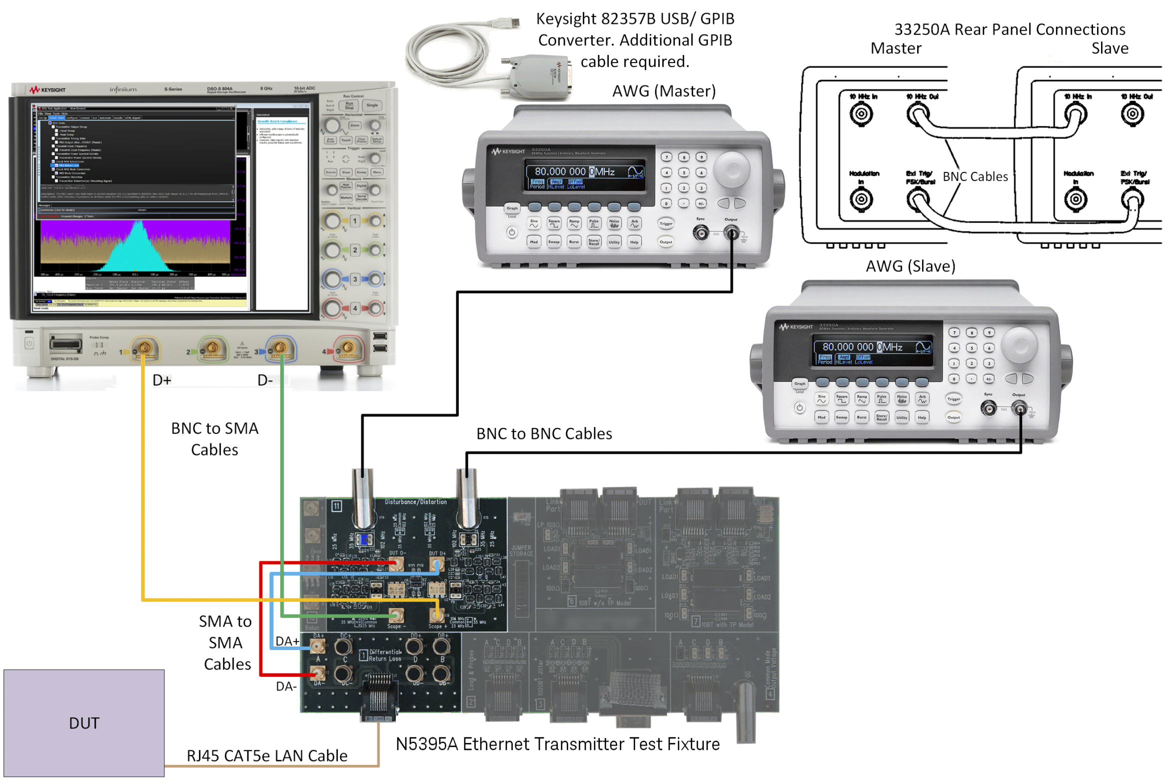


Figure 22 Transmitter Distortion Test Connection Using two Keysight 33250A Function Generators

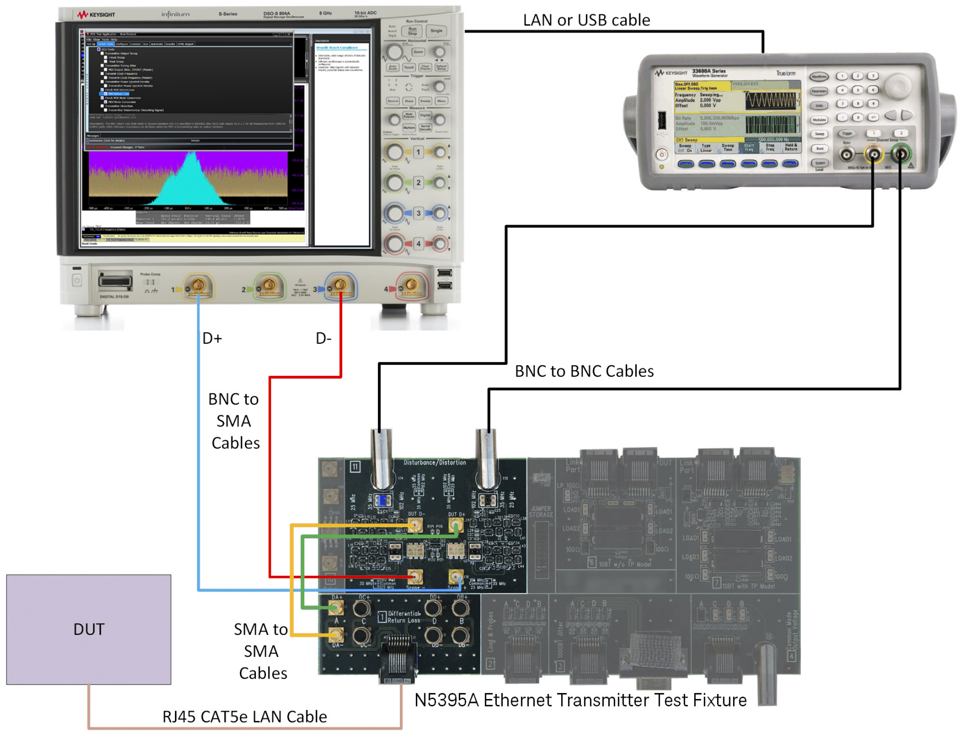


Figure 23 Connection for Transmitter Distortion Test Using Keysight 33612A Function Generator

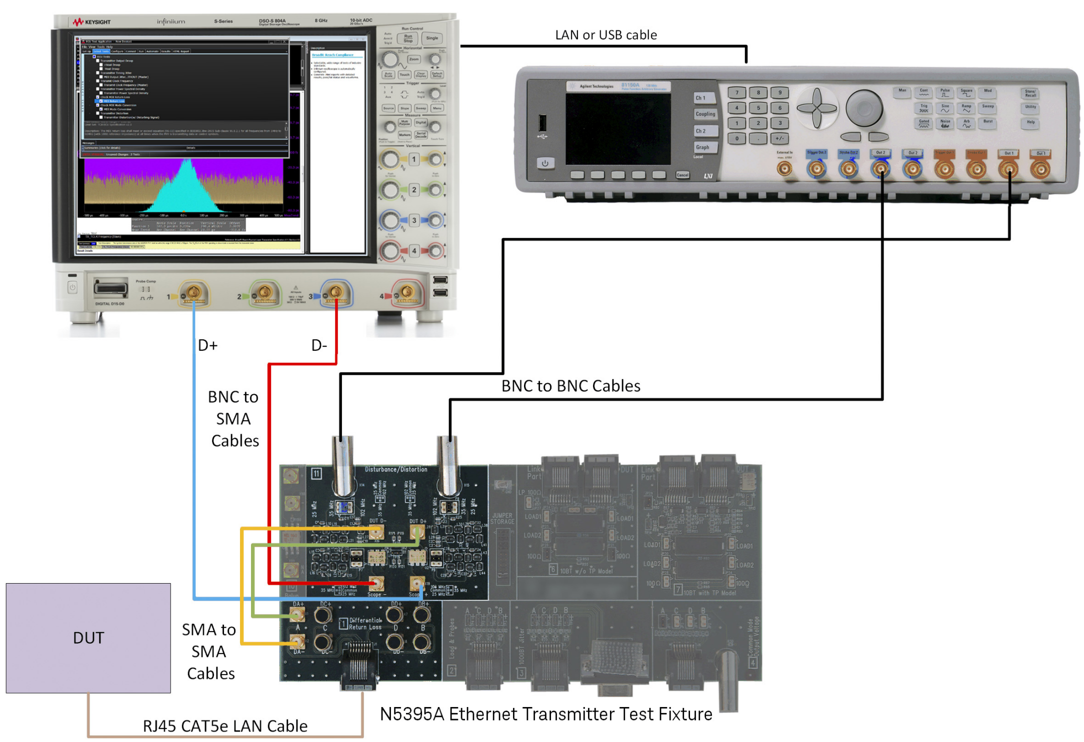


Figure 24 Connection for Transmitter Distortion Test Using Keysight 81150A Function Generator

Using the Optional E6961A Frequency Divider Board

If you want to use the optional Frequency Divider Board to provide a stable 10 MHz reference clock, refer to "Using the E6960-66600 Frequency Divider Board" on page 45 for detailed information.

Specification References

[1] OPEN Alliance Automotive Ethernet ECU Test Specification, v2.0, Section 2.2.2, Test OABR_PMA_TX08

[2] 100Base-T1, IEEE Std. 802.3bw-2015, Section 96.5.4.2

Transmitter Distortion Test Information

When operating in Test Mode 4 and capturing the waveform using Section 11 of the fixture, the peak distortion values, measured at a minimum of 10 equally-spaced phases of a single symbol period, 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] and [2] specify 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] and [2].

A software high pass filter is applied to the sampled signal before post-processing.

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

Typical Waveform

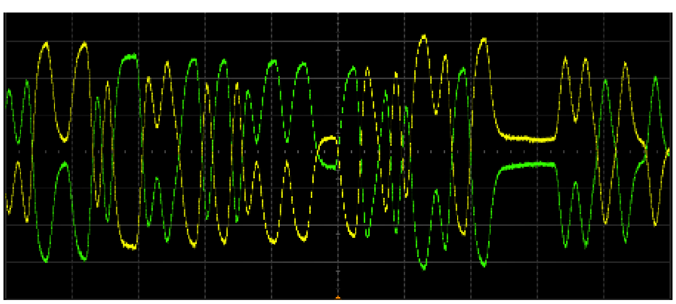


Figure 25 Typical Distortion Test Waveform (using a pair of SMA cables)

Viewing the Test Report

After running any or all of the 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 form the top pane; the test details are shown below. In Figure 26 below, the Transmitter Power Spectral Density test is selected and the test results, with waveform, is shown below.

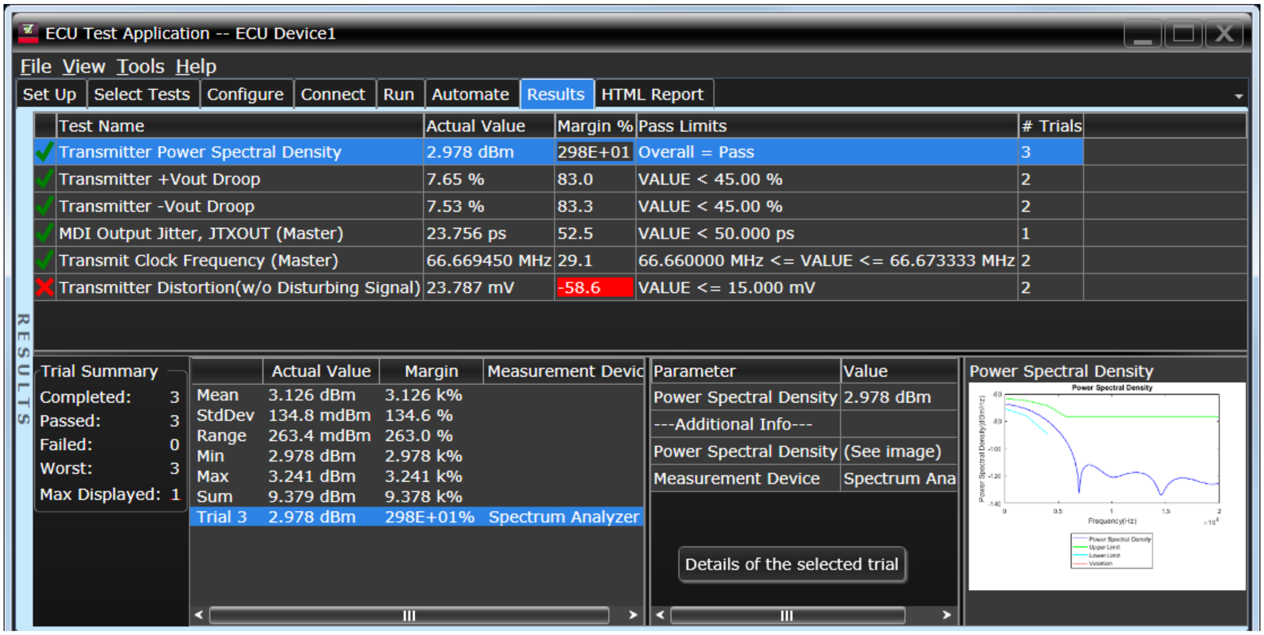
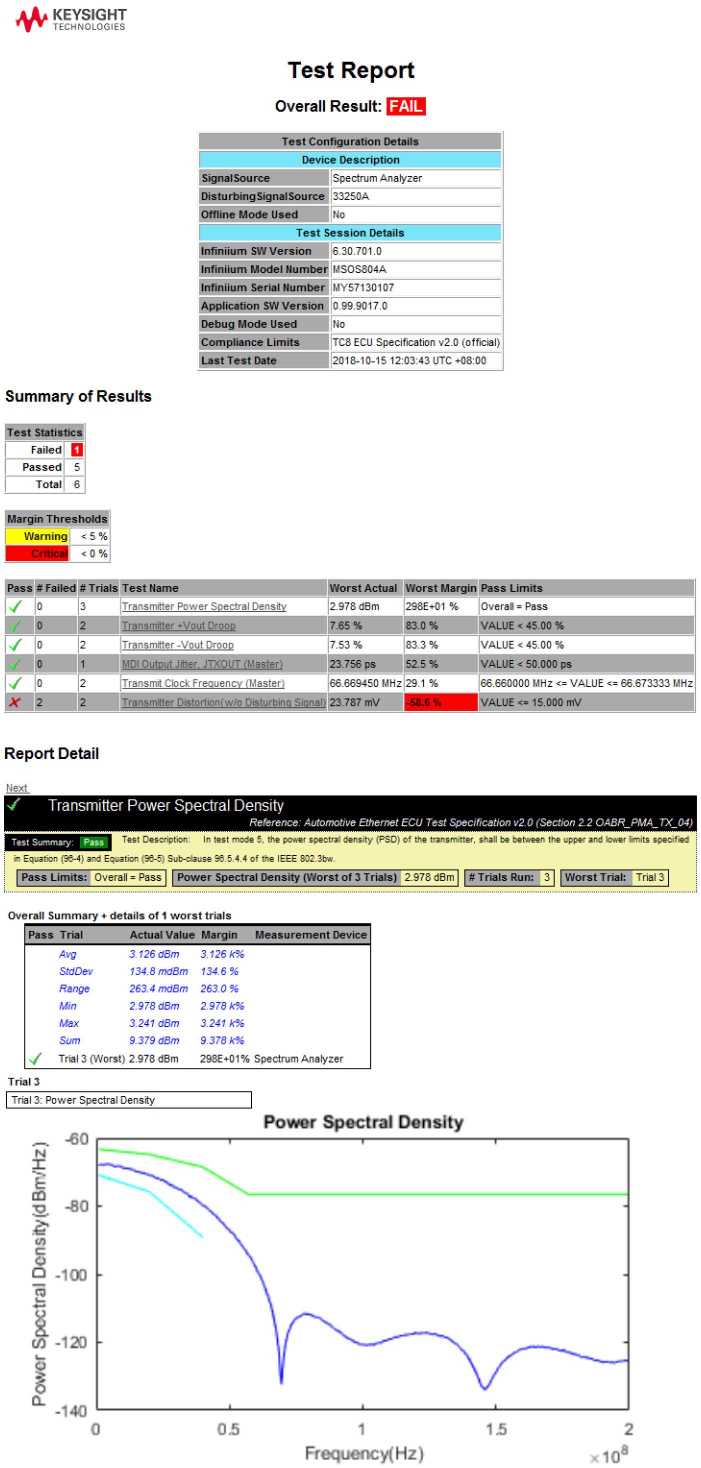


Figure 26 Typical Results Tab

Figure 27 on page 34 shows a portion of a typical **HTML Report**. Below this segment are waveforms and more test data.



KEYSIGHT TECHNOLOGIES

Test Report

Overall Result: FAIL

Test Configuration Details	
Device Description	
SignalSource	Spectrum Analyzer
DisturbingSignalSource	33250A
Offline Mode Used	No
Test Session Details	
Infiniium SW Version	6.30.701.0
Infiniium Model Number	MSOS804A
Infiniium Serial Number	MY57130107
Application SW Version	0.99.9017.0
Debug Mode Used	No
Compliance Limits	TC8 ECU Specification v2.0 (official)
Last Test Date	2018-10-15 12:03:43 UTC +08:00

Summary of Results

Test Statistics	
Failed	1
Passed	5
Total	6

Margin Thresholds	
Warning	< 5 %
Critical	< 0 %

Pass	# Failed	# Trials	Test Name	Worst Actual	Worst Margin	Pass Limits
✓	0	3	Transmitter Power Spectral Density	2.978 dBm	298E+01 %	Overall = Pass
✓	0	2	Transmitter +Vout Droop	7.65 %	83.0 %	VALUE < 45.00 %
✓	0	2	Transmitter -Vout Droop	7.53 %	83.3 %	VALUE < 45.00 %
✓	0	1	MDI Output Jitter, JTXOUT (Master)	23.756 ps	52.5 %	VALUE < 50.000 ps
✓	0	2	Transmit Clock Frequency (Master)	66.669450 MHz	29.1 %	66.660000 MHz <= VALUE <= 66.673333 MHz
✗	2	2	Transmitter Distortion(w/o Disturbing Signal)	23.787 mV	-58.6 %	VALUE <= 15.000 mV

Report Detail

Next

✓ Transmitter Power Spectral Density

Reference: Automotive Ethernet ECU Test Specification v2.0 (Section 2.2 OABR_PMA_TX_04)

Test Summary: Pass Test Description: In test mode 5, the power spectral density (PSD) of the transmitter, shall be between the upper and lower limits specified in Equation (96-4) and Equation (96-5) Sub-clause 96.5.4.4 of the IEEE 802.3bw.

Pass Limits: Overall = Pass | Power Spectral Density (Worst of 3 Trials) 2.978 dBm | # Trials Run: 3 | Worst Trial: Trial 3

Overall Summary + details of 1 worst trials

Pass	Trial	Actual Value	Margin	Measurement Device
	Avg	*3.126 dBm*	*3.126 k%*	
	StdDev	*134.8 mdBm*	*134.6 %*	
	Range	*263.4 mdBm*	*263.0 %*	
	Min	*2.978 dBm*	*2.978 k%*	
	Max	*3.241 dBm*	*3.241 k%*	
	Sum	*9.379 dBm*	*9.378 k%*	
✓	Trial 3 (Worst)	2.978 dBm	298E+01%	Spectrum Analyzer

Trial 3

Trial 3: Power Spectral Density

Figure 27 Top Portion of a Typical HTML Report

3 Appendix

Reference Documents / 36
Setting Up the N5395C Ethernet Transmitter Test Fixture / 37
Configuring External Instruments / 40
Calibrating External Instruments / 42
Using the E6960-66600 Frequency Divider Board / 45

Reference Documents

OPEN Alliance / ECU Specifications:
www.opensig.org or
www.ieee802.org

Keysight's Automotive Ethernet Test Solutions Web Page:
www.keysight.com/find/E6959A

E6961A Automotive Ethernet TX Compliance Solution Web Page:
www.keysight.com/find/E6961A

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 BroadR-Reach RX Compliance Application (100Base-T1 compliant) software:
  www.keysight.com/find/E6962A
- E6963A BroadR-Reach Automotive Ethernet Link Segment Compliance Solution – includes E6963A BroadR-Reach Link Segment Compliance Application (100Base-T1 compliant) software:
  www.keysight.com/find/E6963A
- N6467B BroadR-Reach 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

Setting Up the N5395C Ethernet Transmitter Test Fixture

Keysight's N5395C Ethernet 10/100/1G Transmitter Electrical Test Fixture includes a main test fixture board (N5392-66402), a short RJ45 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 of 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 28.

Compliance Test Board Section	Description	Compliance Test Mode
1	Differential Return Loss used for RJ45 devices	Conversion from RJ45 to SMA
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	Power Spectrum Density Test
11	Disturbance/Distortion	Transmitter Distortion Test

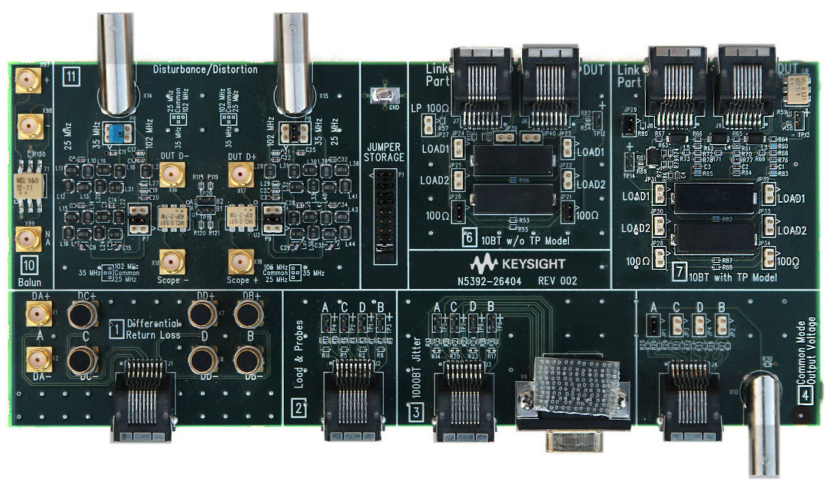


Figure 28 N5395C Ethernet Electrical Transmitter Test Fixture

Jumper Settings

Figure 29 and Table 2 on page 39 show the jumper positions for the Ethernet Test Fixture Section 11 applicable for various frequencies.

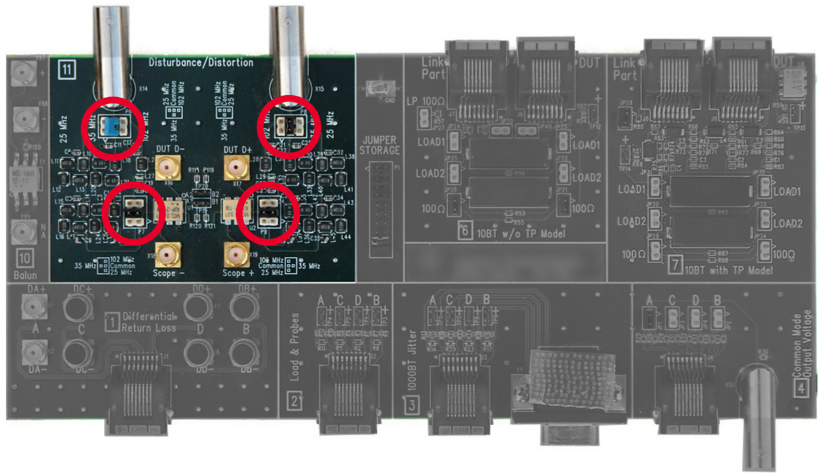
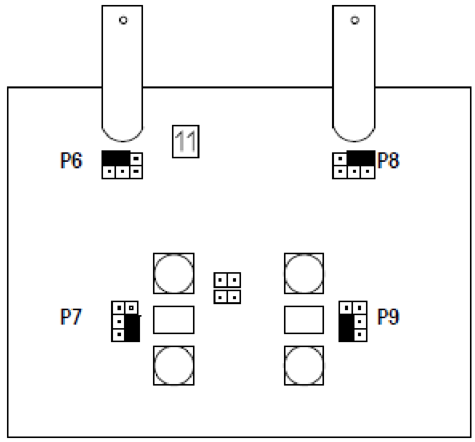
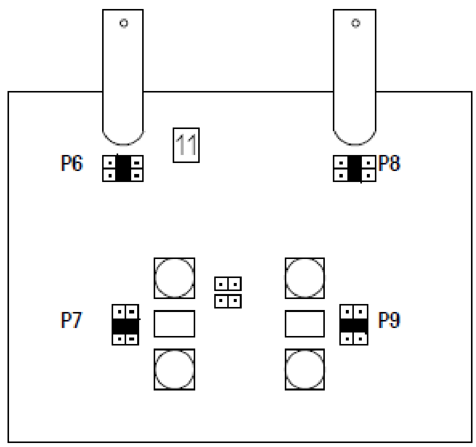
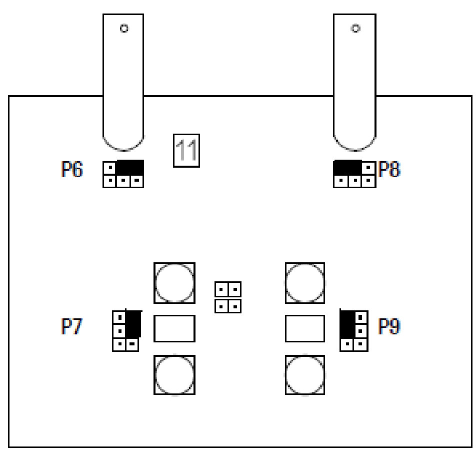


Figure 29 Section 11 on the Ethernet Test Fixture

Table 2 **Jumper Locations for Ethernet Test Fixture (Section 11 on Test Fixture)**

Filter Bandwidth	Jumper Location
25 MHz	
35 MHz	
102 MHz	

Configuring External Instruments

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 SCPI 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.

Note that the 33250A AWGs require an 82357B USB/GPIB interface. You must configure the Master and Slave 33250A AWGs separately.

1 On the ECU Compliance Test Application's **Set Up** tab, click the **Configure** button.

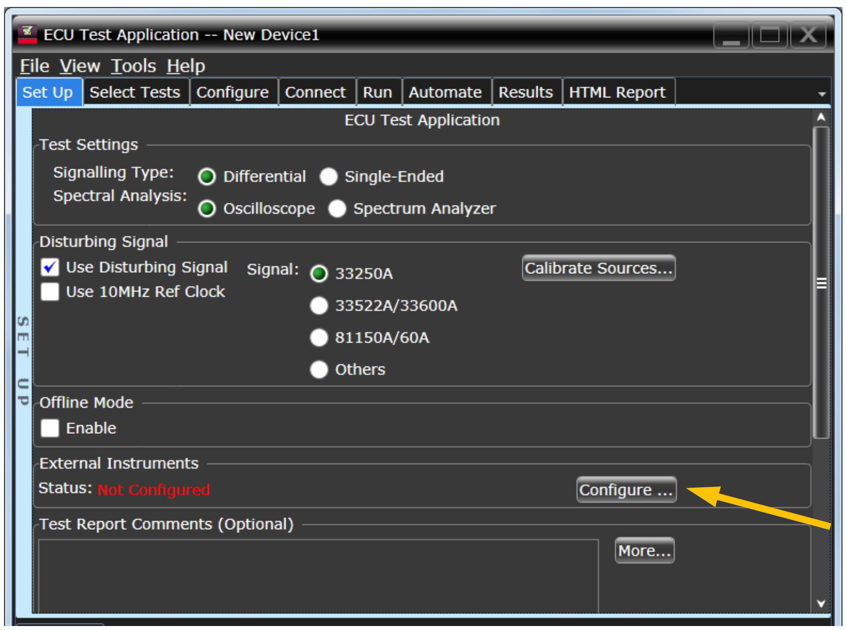


Figure 30 ECU Compliance Test Application Set Up Tab

This opens the **External Instruments List** dialog box.

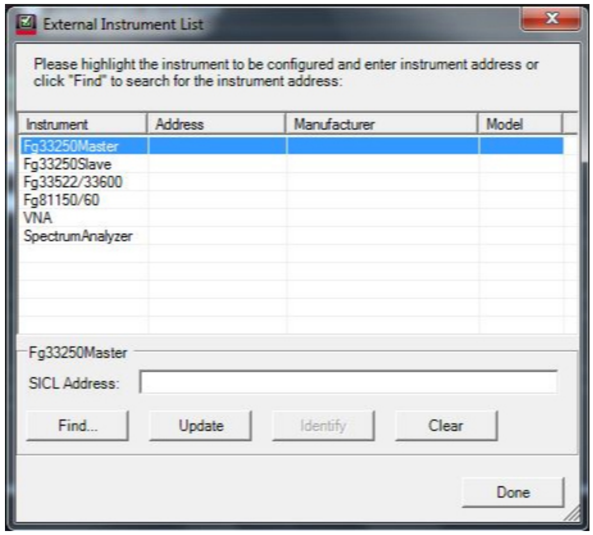


Figure 31 External Instruments List

2 Select the AWG used in your system. For the E6959A Solution, any of the AWG can be selected. For example, **Fg81150/60**.
3 Provide the SICL address:
   - If you know the SICL address (you can use K*eysight 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 Compliance Test Application will attempt to locate and identify the AWG.
4 Click the **Update** button.
5 Repeat steps 2 to 4 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 **Set Up** tab.
7 The External Instruments **Status** indicator turns green to indicate that all external instruments have been properly configured.

Calibrating External Instruments

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

Calibrating the AWG

Before running disturbing signal tests, the AWG(s) must be calibrated. Connect the equipment depending on the AWG used:

- When using two 33250A AWGs, see Figure 22 on page 30.
- When using a 33612A AWG, see Figure 23 on page 31.
- When using an 81150A AWG, see Figure 24 on page 31.

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 "Configuring External Instruments" on page 40.

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 32.

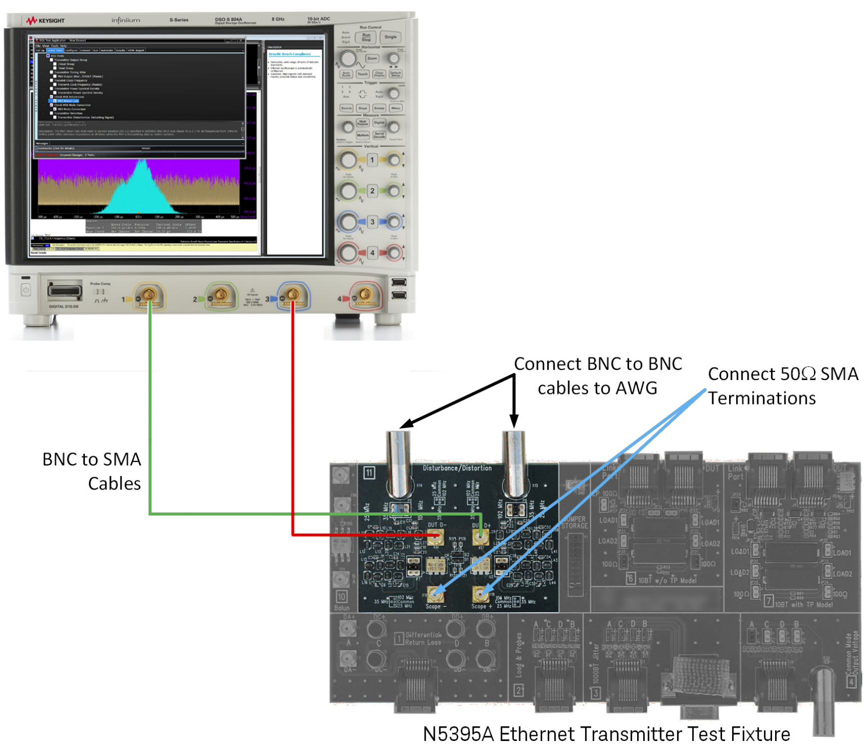


Figure 32 AWG Calibration Setup for the Disturbing Signal Source

Performing the AWG Calibration for the Disturbing Signal Source

1 On the ECU Compliance Test Application's **Set Up** tab, click the **Calibrate Sources** button.

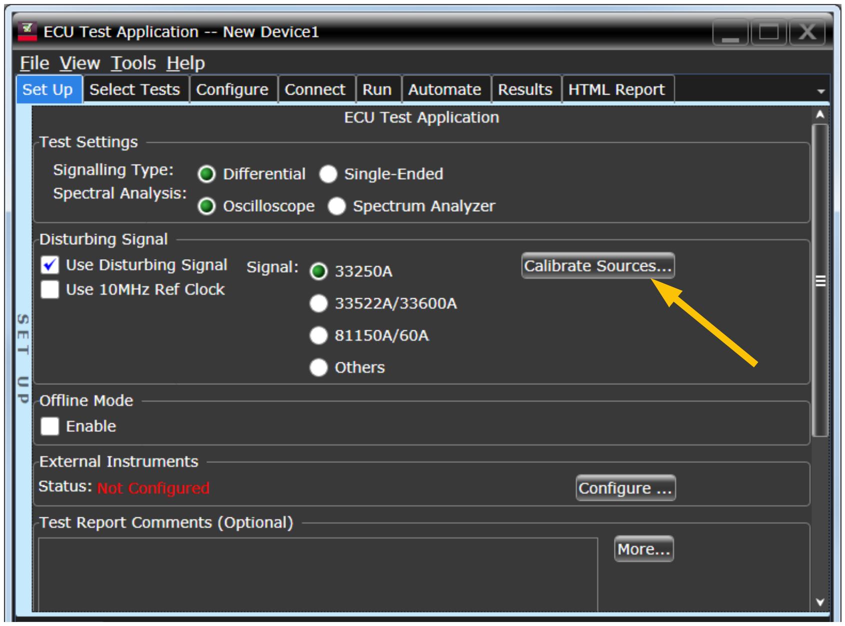


Figure 33 ECU Compliance Test Application Set Up Tab

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

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

3 When the software finishes the calibration, click the **Done** button to return to the Set Up tab.

Refer to the E6959A online help for a more detailed explanation.

Calibrating the ENA

Before using the ENA, it must be calibrated using the N4431B Ecal Kit. See Figure 34 below for the connection diagram. Calibrate the ENA using the instructions in the ENA's user guide.

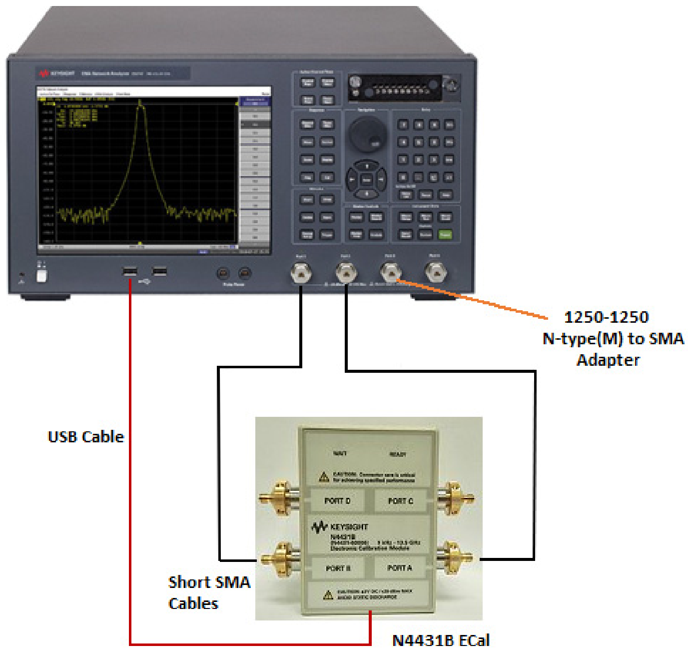


Figure 34 ENA Calibration Setup

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 either **Sdd11** or **Sdc11** depending on test.
   - Set **Start** to **1 MHz**.
   - Set **Stop** to 1 **GHz**.
   - Set **Format** to **Log Mag**.
   - Set **Sweep Type** to **Logarithmic**.
   - Set **Points** to **1600**.
   - Set **Output Power** to **0 dBm**.
   - Set **Measurement Bandwidth** to **100 Hz**.

Using the E6960-66600 Frequency Divider Board

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 Transmitter Distortion Test.

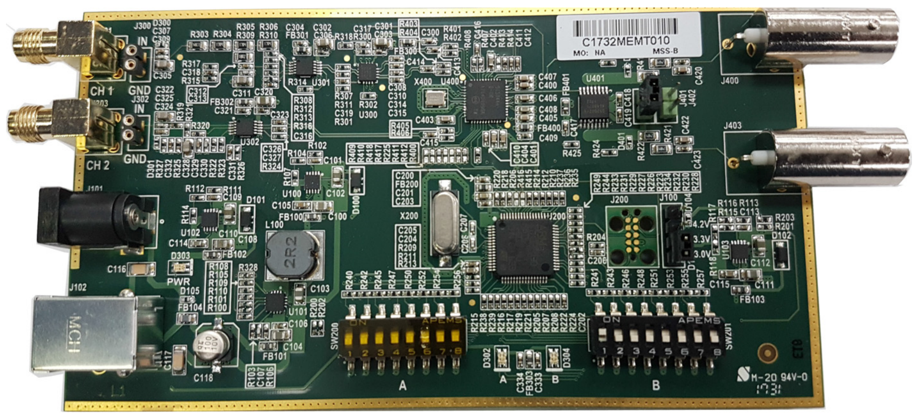
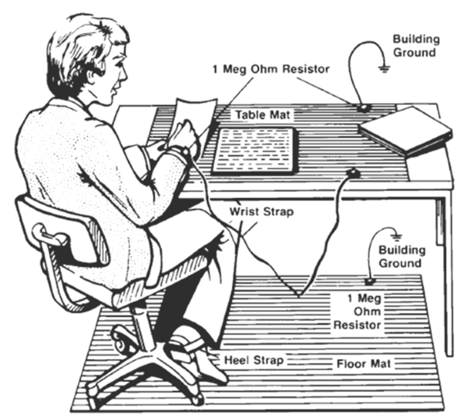


Figure 35 Keysight E6960-66600 Frequency Divider Board

Static-safe Handling Procedures



Electrostatic discharge (ESD) can damage or destroy electronic components. Use a static-safe work station to 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 and switches.

To use the divider board, check the **Use 10MHz Ref Clock** on the ECU Compliance Test Application Set Up tab.

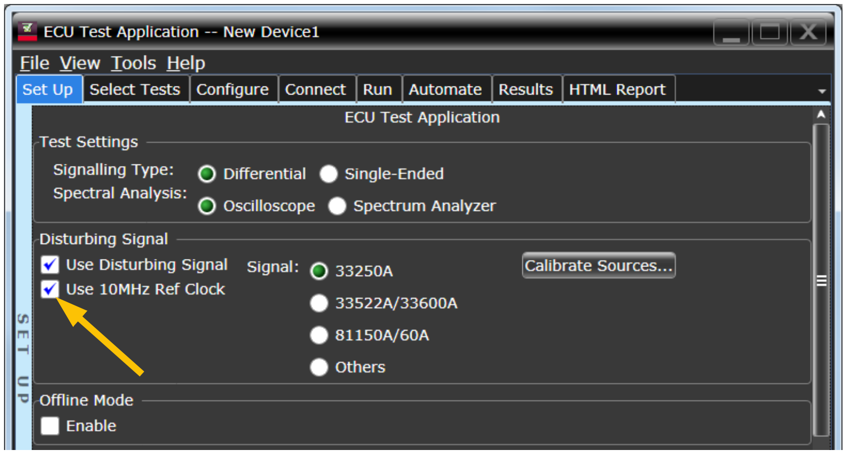


Figure 36 Select **Use 10MHz Ref Clock** on Set Up tab

Configure the test setup as shown below.

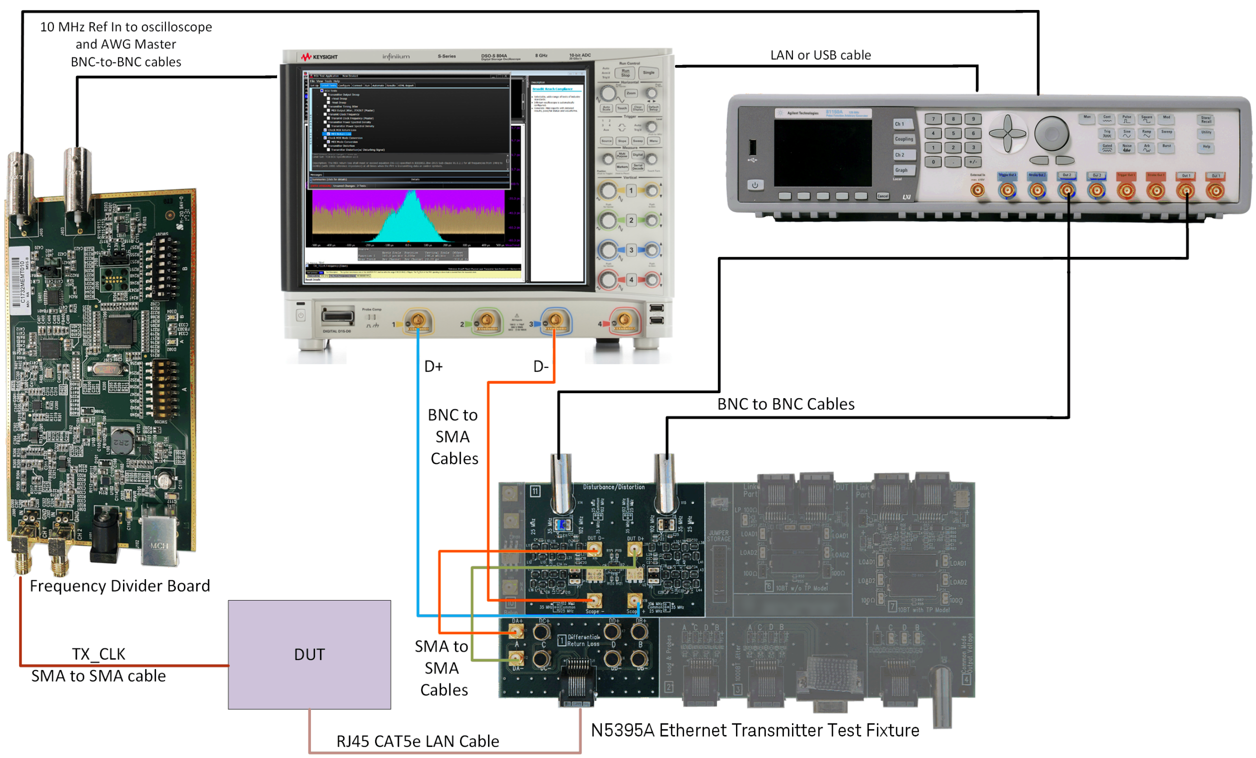


Figure 37 Test Setup for 10 MHz Frequency Reference

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.
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
– the LED A (D302) should light up as GREEN
– the LED B (D304) should light up as GREEN

Connector Description

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

Component	Description
USB type-B / DC Jack	Provides power to the fixture. Either the USB port or the 2.5 mm, center positive DC Power input jack may be used. The USB jack is not used for any other 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.

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.

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

NOTE Other combinations are not valid. if no valid switch setting is detected, the 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

Table 3 Power LED

	Green	Red
Input voltage below 4.5V	ON	Flash 1 Hz
Input voltage below 3.6V	ON	Flash 2 Hz
Input voltage above 5.5V	ON	ON

Table 4 LED A

	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 48 MHz reference	OFF	ON

Table 5 LED B

	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

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