D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application

KEYSIGHT

METHODS OF IMPLEMENTATION

Notices

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Version

Version 2.11.35.0

Edition

March 2024

Available in electronic format only

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WARNING

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Contents

1 Overview

OIF-CEI 56G VSR/MR/LR Automated Testing—At a Glance

The Keysight D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application is an Ethernet test solution that covers the electrical timing parameters for PAM4 and NRZ specification (Optical Internetworking Forum - Clause 15, 16: CEI-56G-VSR-PAM4 Very Short Reach Interface, Clause 17: CEI-56G-MR-PAM4 Medium Reach Interface, Clause 21: CEI-56G-LR-PAM4 Long Reach Interface).

The main features of the OIF-CEI 56G VSR/MR/LR Test Application are:

- Data Analytics
- Complete coverage of OIF CEI 56G specification-based tests
- Test coverage for PAM4 and NRZ signals
- Coverage of Signal-to-Noise Distortion Ratio (SNDR)
- Support for User Interactive Pulse Response

The Keysight D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application:

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

NOTE

The tests performed by the Keysight D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application are intended to provide a quick check of the electrical health of the DUT. This testing is not a replacement for an exhaustive test validation plan.

Required Equipment and Software

To run automated tests on PAM4 and NRZ signals, you need the following equipment and software:

Hardware

- Use one of the following Oscilloscope models. Refer to www.keysight.com for the respective bandwidth ranges.
  - Keysight DSO-Z series Real-Time Infiniium Oscilloscopes:
    - Channels: Either 2 or 4
    - Bandwidth of up to 63GHz
    - Sample Rate of up to 160 GSa/s
  - Keysight UXR series Real-Time Infiniium Oscilloscopes:
    - Channels: 2
    - Minimum Bandwidth of 50GHz
    - Sample Rate of up to 160 GSa/s
- 2.92-inch cables
- Keyboard, qty = 1, (provided with the Keysight Infiniium oscilloscope)
- Mouse, qty = 1, (provided with the Keysight Infiniium oscilloscope)
- Keysight also recommends using a second monitor to view the test application.

Software

- The minimum version of Infiniium Oscilloscope Software (see the Keysight D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application Release Notes)
- Keysight D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application software

Licensing information

Refer to the *Data Sheet* pertaining to OIF-CEI 56G VSR/MR/LR Test Application to know about the licenses you must install along with other optional licenses. Visit "http://www.keysight.com/find/D9010CEIC" and in the web page's **Document Library** tab, you may view the associated Data Sheet.

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

The licensing format for Keysight License Manager 6 differs from its predecessors. See "Installing the License Key" on page 15 to see the difference in installing a license key using either of the applications on your machine.

2 Installing the Test Application and Licenses

If you purchased the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application separate from your Infiniium oscilloscope, you must install the software and license key.

Installing the Test Application

1. Make sure you have the minimum version of Infiniium Oscilloscope software (see the D9010CEIC release notes). To ensure that you have the minimum version, select **Help > About Infiniium...** from the main menu.
2. To obtain the OIF-CEI 56G VSR/MR/LR Test Application, go to Keysight website: "http://www.keysight.com/find/D9010CEIC".
3. In the web page's **Trials & Licenses** tab, click the **Details and Download** button to view instructions for downloading and installing the application software.

Installing the License Key

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

Using Keysight License Manager 5

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

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

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

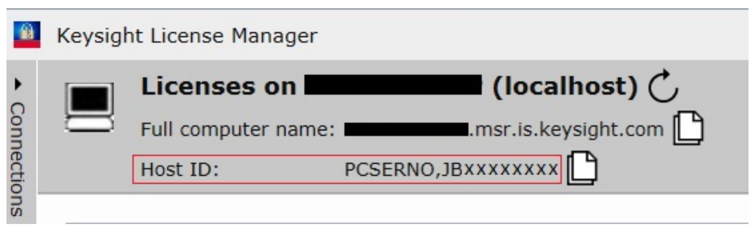


Figure 1 Viewing the Host ID information in Keysight License Manager 5

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

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

2 Launch Keysight License Manager.

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

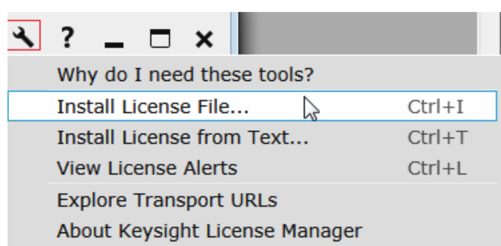


Figure 2 Configuration menu options to install licenses on Keysight License Manager 5

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

Using Keysight License Manager 6

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

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

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

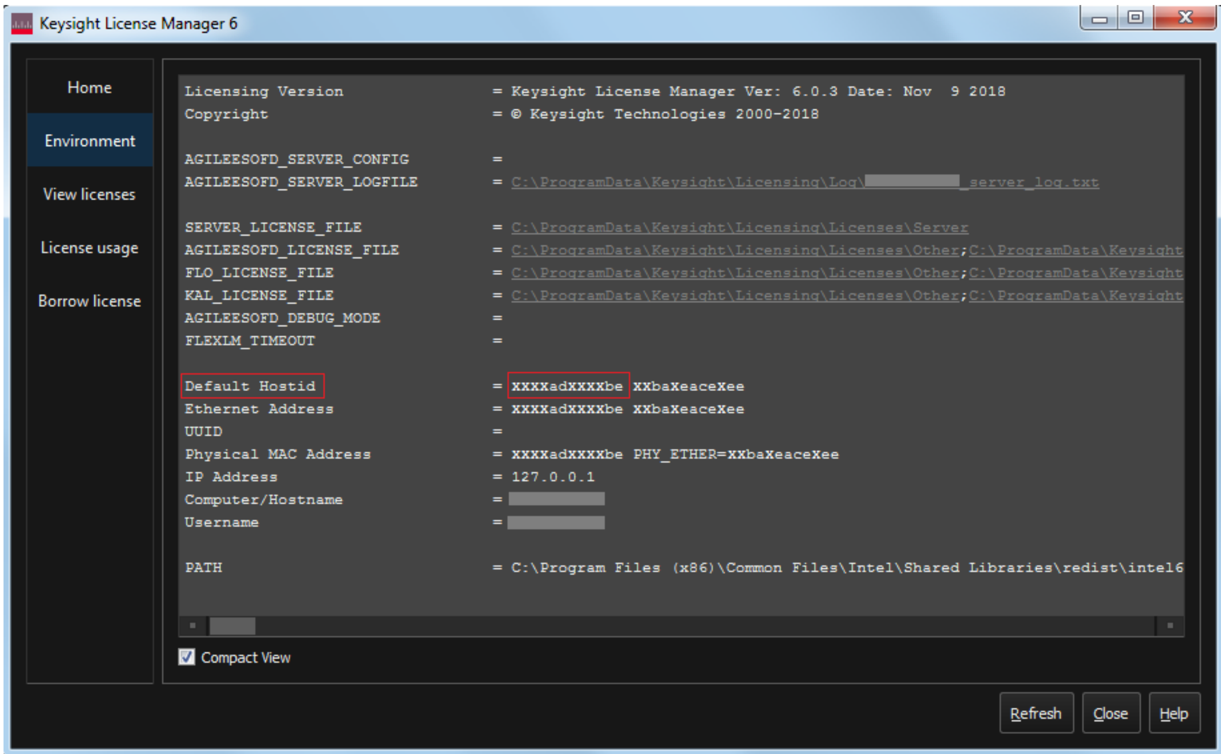


Figure 3 Viewing the Host ID information in Keysight License Manager 6

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

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

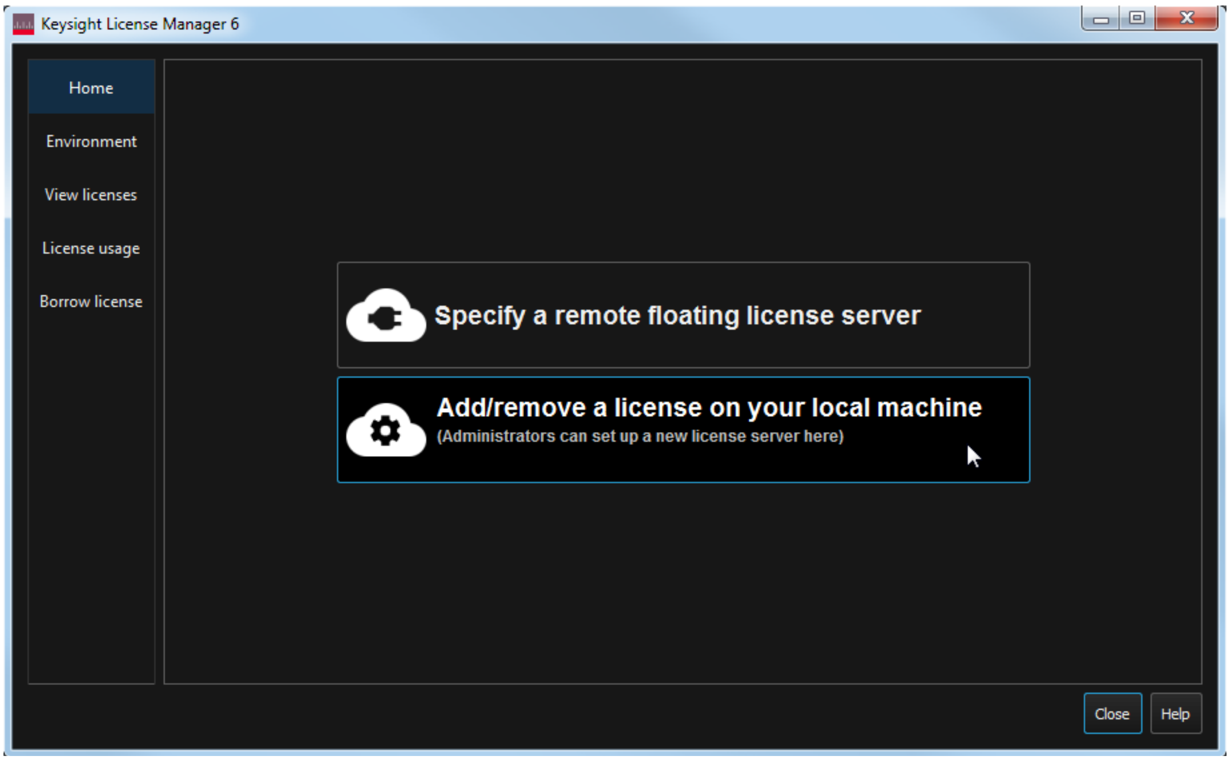


Figure 4 Home menu options to install licenses on Keysight License Manager 6

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

3 Preparing to Take Measurements

Before running the automated tests, you should calibrate the oscilloscope and probe. No test fixture is required for this application. After the oscilloscope and probe have been calibrated, you are ready to start the OIF-CEI 56G VSR/MR/LR Test Application and perform the measurements.

Calibrating the Oscilloscope

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

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

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

Starting the OIF-CEI 56G VSR/MR/LR Test Application

1. Ensure that the OIF-CEI 56G VSR/MR/LR Device Under Test (DUT) is operating and set to desired test modes.
2. To start the OIF-CEI 56G VSR/MR/LR Test Application: From the Infiniium Oscilloscope's main menu, select **Analyze > Automated Test Apps > D9010CEIC OIF-CEI 56G VSR/MR/LR Test App**.

- Figure 5 shows the Keysight D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application window as it appears when launched within the Infiniium application of the DSO Z-Series Oscilloscope. The Instrument Setup area in the Set Up tab displays Real Edge, which indicates Channels 1R and 3R on the oscilloscope.

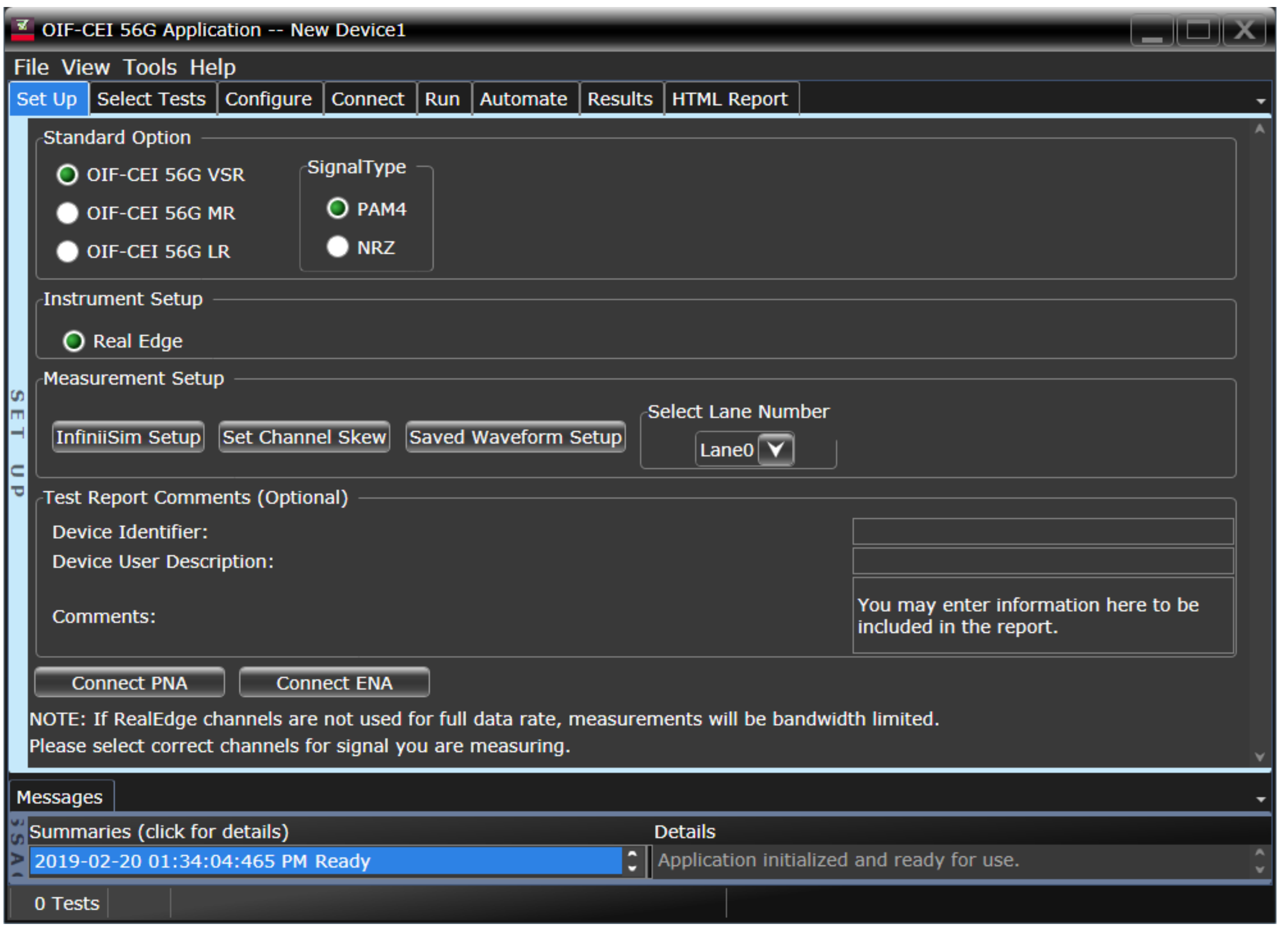


Figure 5 OIF-CEI 56G VSR/MR/LR Test Application main window on a Z-Series DSO

- Figure 6 shows the Keysight D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application window as it appears when launched within the Infiniium application of the UXR Oscilloscope. The Instrument Setup area in the Set Up tab displays the corresponding Channel assignments.

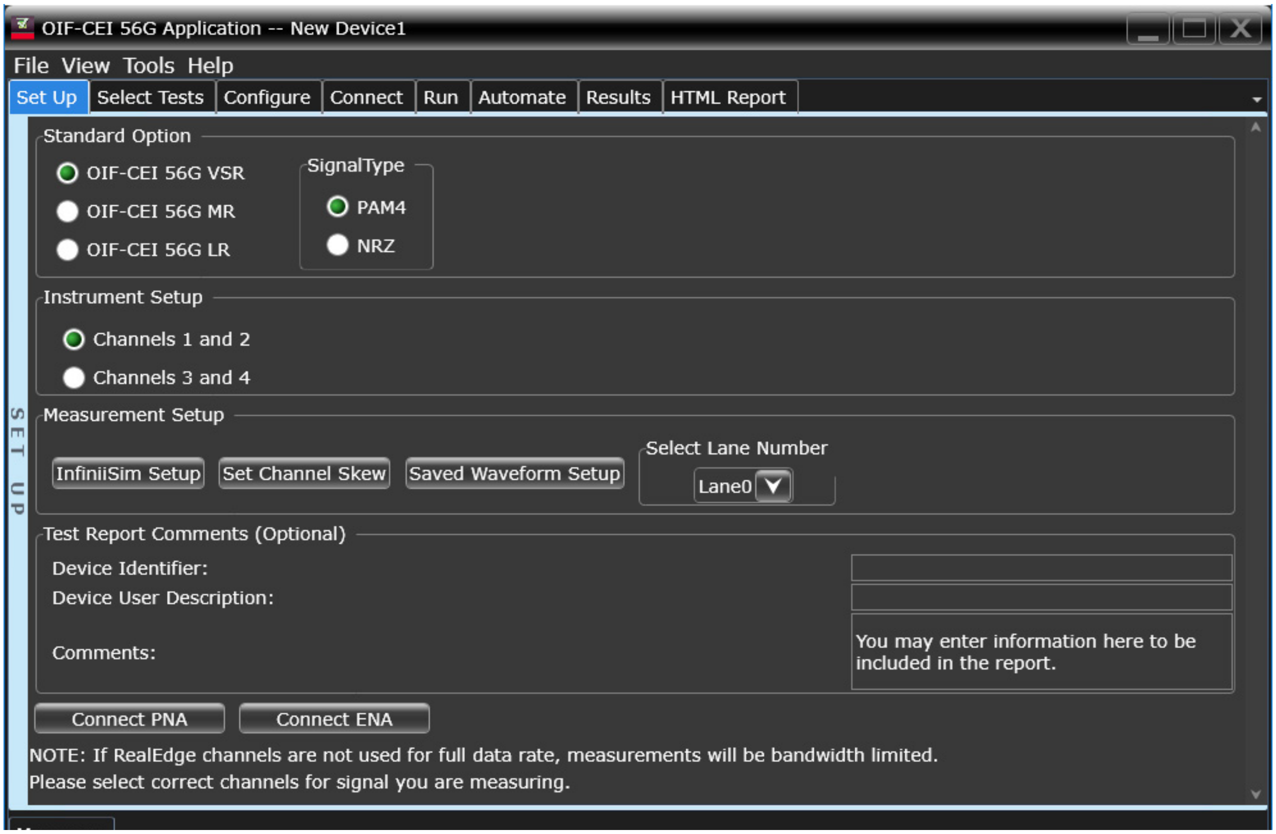


Figure 6 OIF-CEI 56G VSR/MR/LR Test Application main window on a UXR Oscilloscope

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

Set Up	Lets you identify and set up the test environment, including information about the device under test. The **Device Identifier**, **User Description**, and **Comments** are all printed in the final HTML report. Select the **Standard Option** and **SignalType** to be tested. For UXR scopes, select the appropriate Channel option in **Instrument Setup**. Set up InfiniiSim with the **InfiniiSim Setup** button. With the **Set Channel Skew** button, the channels can be visually adjusted and skewed. The **Saved Waveform Setup** button enables easy setup of saved waveforms. When waveforms are set up, the application makes all measurements on the saved waveforms. The **Select Lane Number** enables you to choose to test a single lane or with the switch matrix.
Select Tests	Lets you select the tests you want to run. The tests are organized hierarchically so you can select all tests in a group. After tests are run, status indicators show which tests have passed, failed, or not been run, and there are indicators for the test groups.
Configure	Lets you configure test parameters (for example, channels used in test, voltage levels, etc.).
Connect	Shows you how to connect the oscilloscope to the device under test for the tests that are to be run.
Run	Starts the automated tests. If the connections to the device under test need to be changed while multiple tests are running, the tests pause, show you how to change the connection, and wait for you to confirm that the connections have been changed before continuing.
Automate	Lets you construct scripts of commands that drive execution of the application.
Results	Contains more detailed information about the tests that have been run. You can change the thresholds at which marginal or critical warnings appear.
HTML Report	Shows a compliance test report that can be printed.

NOTE

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

Configuring OIF-CEI 56G VSR/MR/LR Test Application for test runs

To run one or more compliance tests on the DUT, which is connected to Oscilloscope, proceed to configure the OIF-CEI 56G VSR/MR/LR Test Application:

1 In the **Set Up** tab (shown in Figure 5 and Figure 6), select the **Standard Option** and **SignalType** to filter the test groups in accordance with the connected DUT.

  Optionally, you may configure the rest of the settings as described in the task flow table in the previous section.

2 In the **Select Tests** tab, select one or more tests, which appear according to the configuration done under the **Set Up** tab. Each section of this manual displays the appearance of the **Select Tests** tab for each test type.

3 In the **Configure** tab, you may change the values assigned to one or more options to cater to the compliance requirements for the selected tests. By default, the OIF-CEI 56G VSR/MR/LR Test Application sets optimum values for each configuration parameter. The values for some parameters, such as sampling rate, memory depth and so on, vary based on the Oscilloscope model (DSO or UXR).

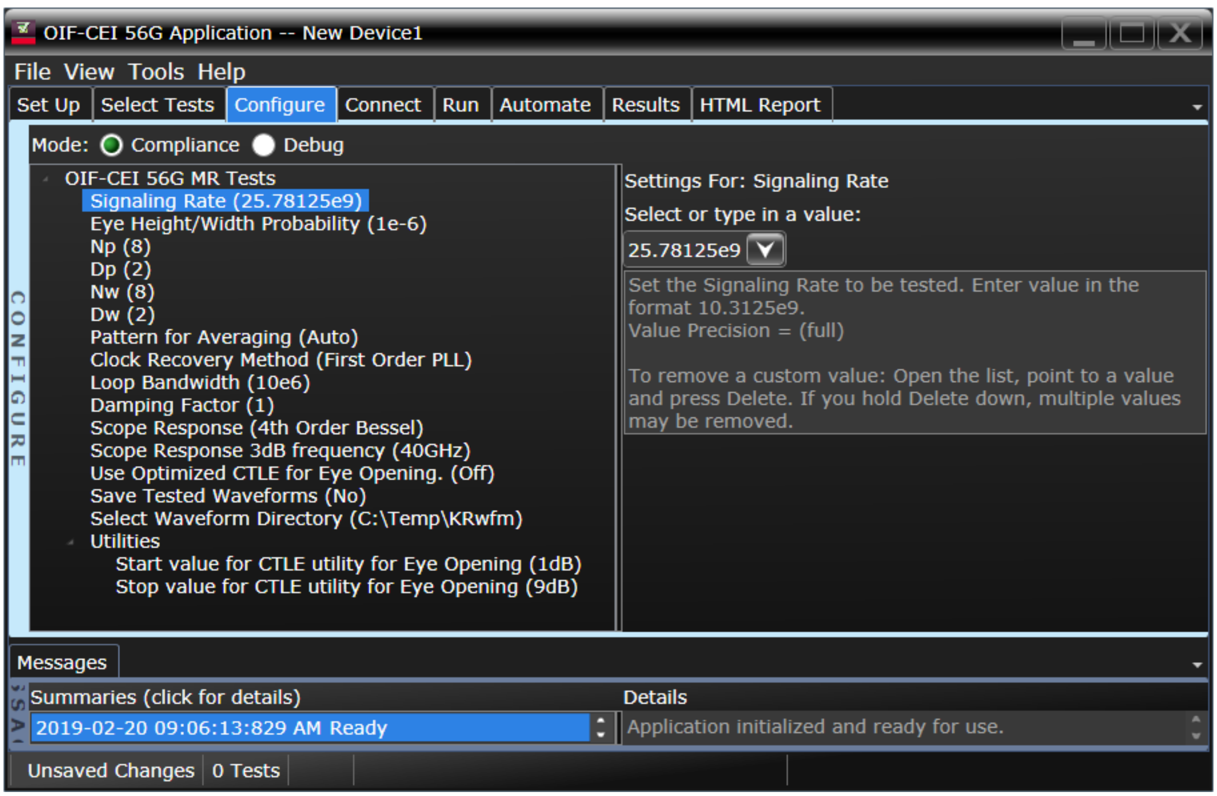


Figure 7 Configure tab in the OIF-CEI 56G VSR/MR/LR Test Application on a Z-Series DSO

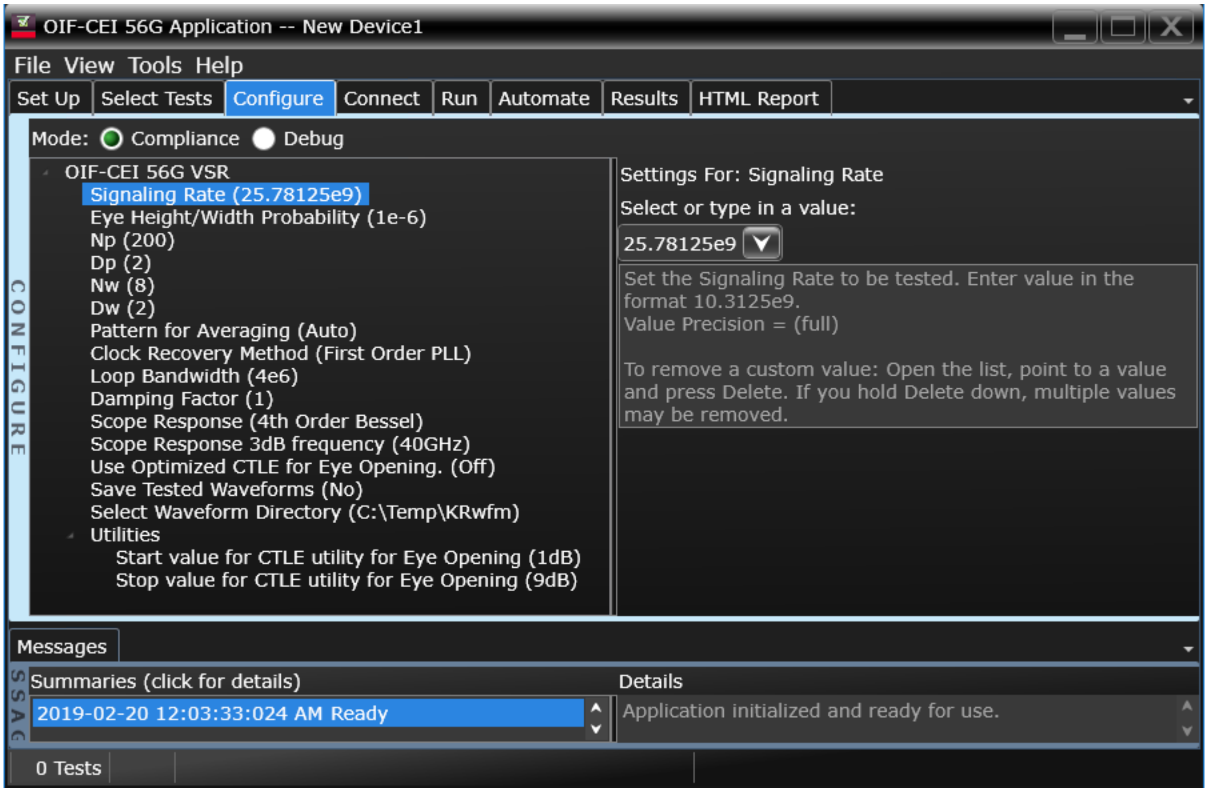


Figure 8 Configure tab in the OIF-CEI 56G VSR/MR/LR Test Application on a UXR Oscilloscope

4 In the **Connect** tab, view the instructions along with the connection digram to ensure that all requirements for the physical setup of the testing instruments and the DUT are met. Click **Connection Completed** to indicate to the Test Application that the required hardware setup is complete. The connection diagram for most of the tests matches the one shown in Figure 5 for DSO-Z Series Oscilloscopes and Figure 6 for UXR Series Oscilloscopes. However, it is a good practice to verify the connection diagram and instructions displayed under this tab. The Test Application automatically indicates any changes in connections, if needed, during test runs.

5 Click **Run Tests** under this tab if you wish to start running tests. However, if you wish to modify the run settings before performing test runs, switch to the **Run** tab.

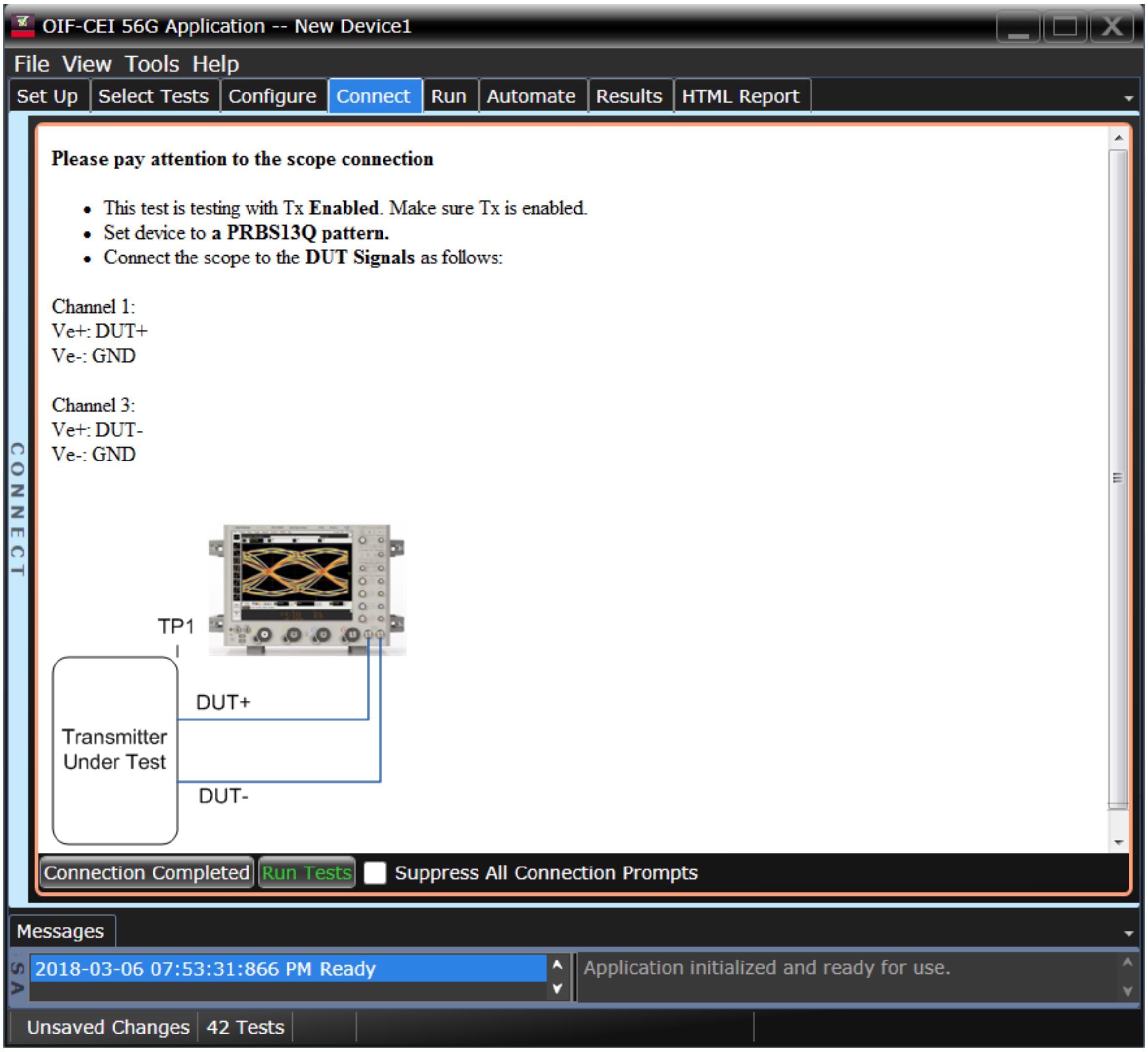


Figure 9 Connect tab in OIF-CEI 56G VSR/MR/LR Test Application on a Z-series DSO

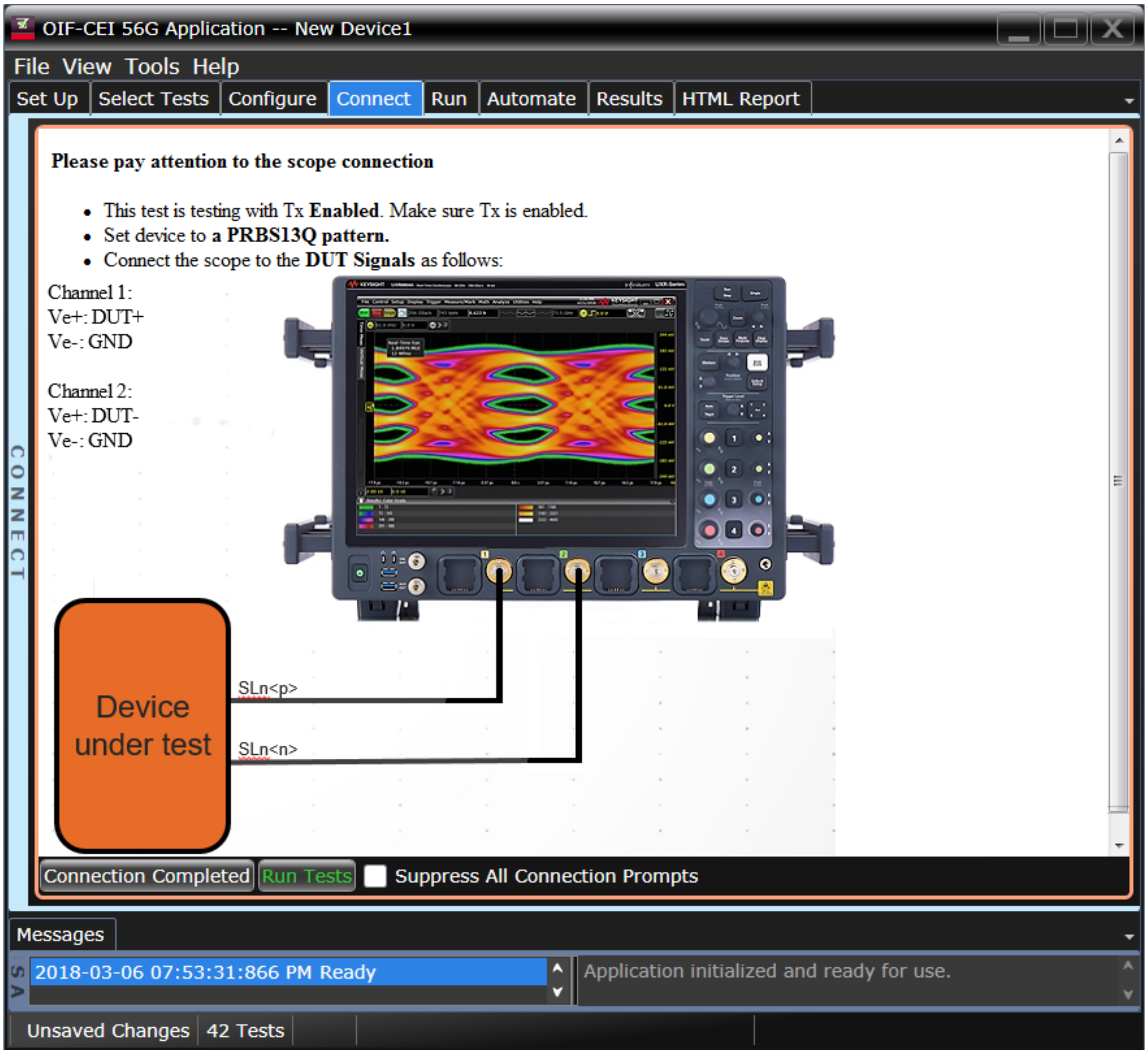


Figure 10 Connect tab in OIF-CEI 56G VSR/MR/LR Test Application on a UXR scope

6 In the **Run** tab, you may optionally modify one or more settings as described below, else click **Run** to start the test runs:
- determine the number of times each test must be run,
- automate specific actions in case of events,
- store results for certain type of test trials only,
- send email notifications if the test runs pause or stop during runs.

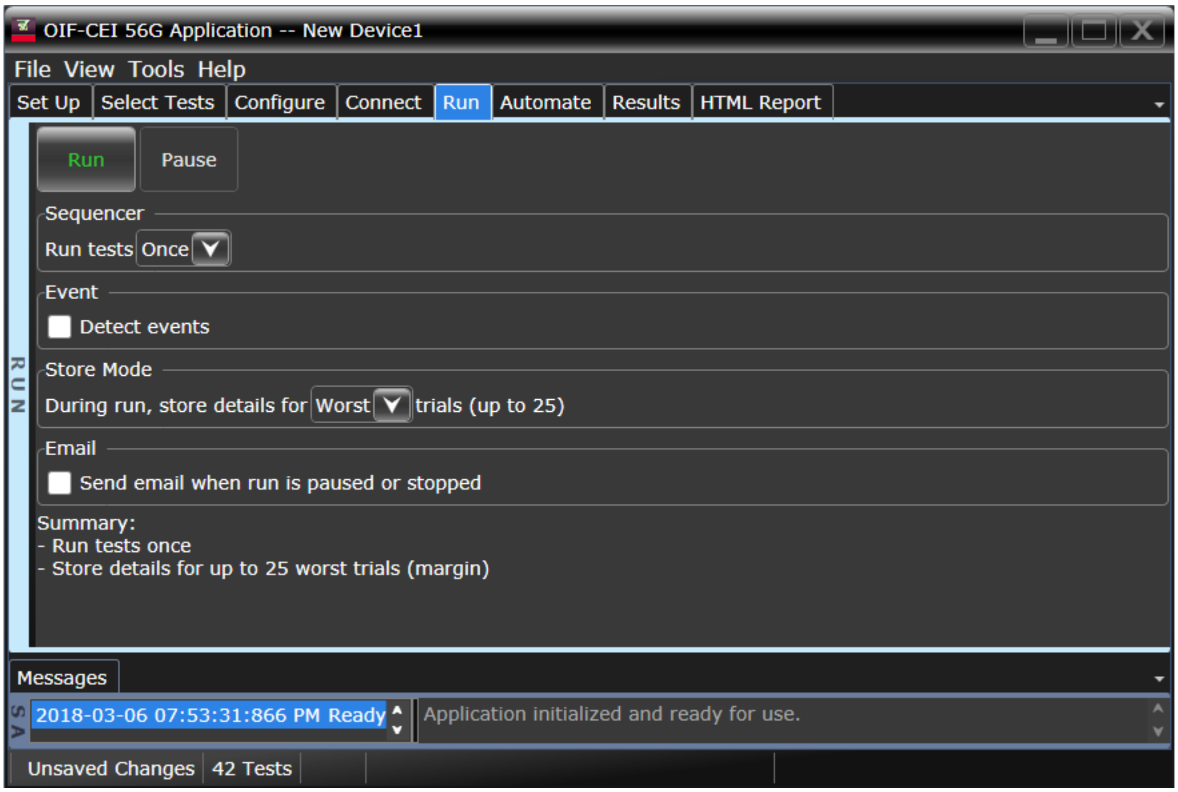


Figure 11 Run tab in OIF-CEI 56G VSR/MR/LR Test Application

7 In the **Automate** tab, you may optionally configure automation scripts to perform specific actions/sequences within the Test Application.

8 In the **Results** tab, which appears automatically after test runs are complete, view the test results displayed for each selected test.

9 In the **HTML Report** tab, view a comprehensive report for each test within the Application. The Test Application enables exporting these results in CSV or HTML format for the purpose of analysis.

10 To perform a high-level analysis on each measurement data, you may upload the results to the KS6800A Series Analytics Services Software. Refer to "Exporting Measurement Results to Repository" on page 29 to understand an overview on the functionality of this feature.

Exporting Measurement Results to Repository

The Upload Results To Repository feature is an add-on to the Keysight Test Application, where it expands the boundaries of storing and analyzing the measurement results to a wider audience, who may be based in multiple sites across various geographical locations. Along with the feature of exporting test results from the Test Application into your local disk in a CSV or HTML file format, you have the option to upload the test results to a Dataset on a Web Repository. Based on your requirements, you may either upload only a single measurement trial or upload huge volumes of measurement results to any Dataset.

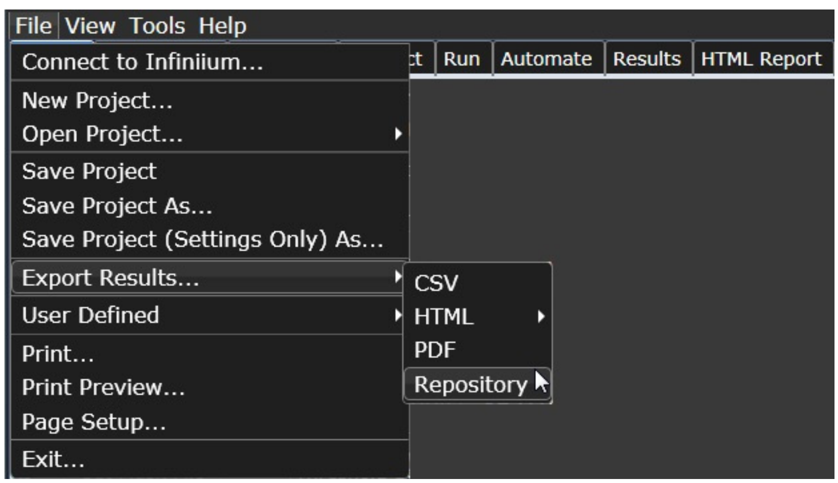
Not only can remote users with an active Internet connection access these Datasets and the corresponding test results on the Web Repository, but they have the option to add and delete Datasets on the Web Server. In the Upload Results To Repository feature, you can even modify the Dataset properties, which are helpful especially when performing a graphical analysis of the uploaded data.

In combination with the *Keysight KS6800A Series Analytics Software*, the Upload Results To Repository feature provides a comprehensive solution to export, view and perform analysis of the measurement results, thereby resulting in qualitative data to ensure that the Device Under Test (DUT) is compliant to the industry standards.

Refer to the *Keysight KS6800A Series Analytics Software Online Help* for more information about the functionality of various features in this software.

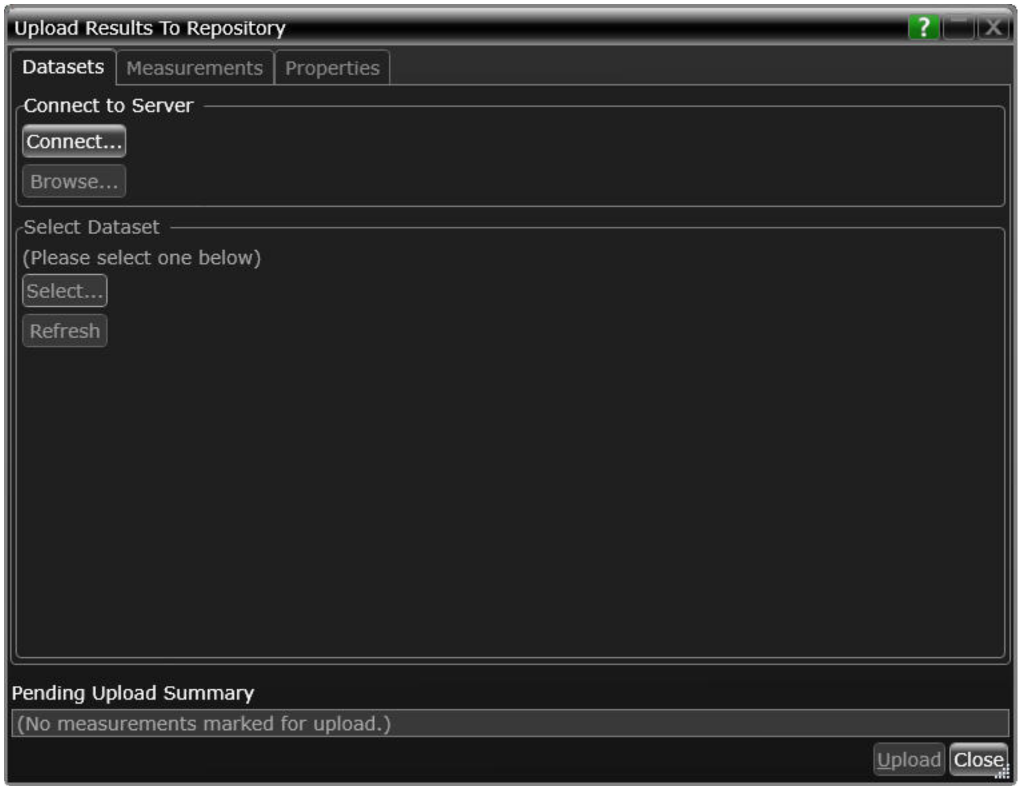
To export measurement results to the Repository after the completion of test runs,

1 From the Test Application's main menu, click **File > Export Results... > Repository**.



The **Upload Results to Repository** window appears.

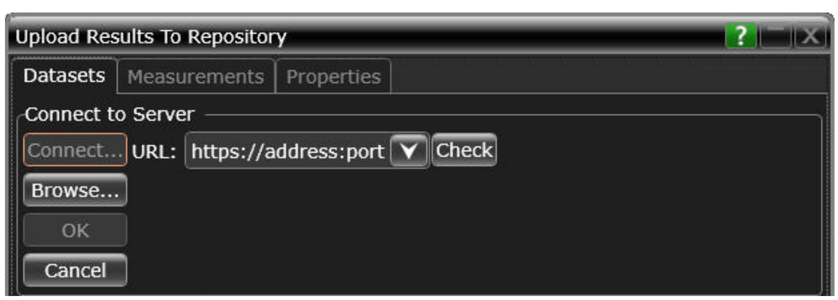
2 In the **Connect to Server** pane of the **Datasets** tab, click **Connect...** to login to the Dataset Repository server.



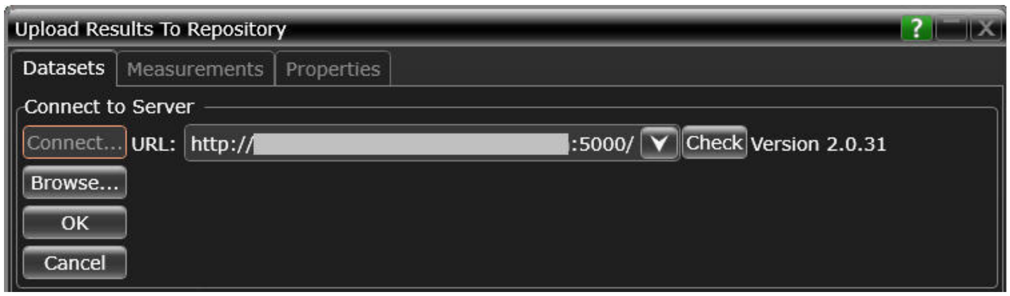
3 In the URL: drop-down text field that appears, replace the default text with the actual IP address or the URL along with the port number, if applicable.

You may enter the URL of the Web Repository server, which may be a self-hosted server on your machine (http://localhost:5000/), a remote server or an authentication server. Note that all such URLs accessed via this window appear as a drop-down list in the URL: field.

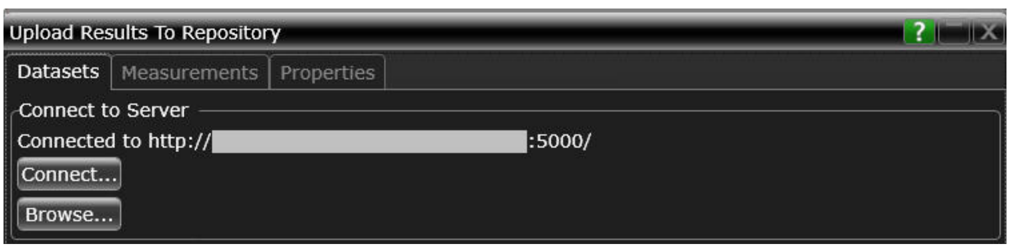
4 Click the Check button to verify that the KS6800A Series Analytics service is available on the specified web address. Repeat this step each time you edit the web address.



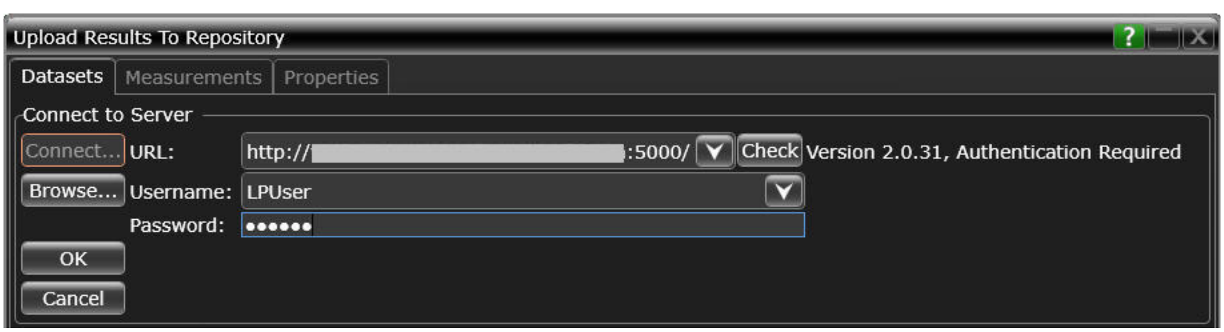
- For unrestricted access to the Repository
  a If the server does not require authentication and the KS6800A Series Analytics service is found on the specified web address, the version information is displayed adjacent to the Check button.



  b If you click OK, the Upload Results to Repository window displays the connectivity status to the Dataset Repository.
  c Click Browse... to navigate directly to the URL.



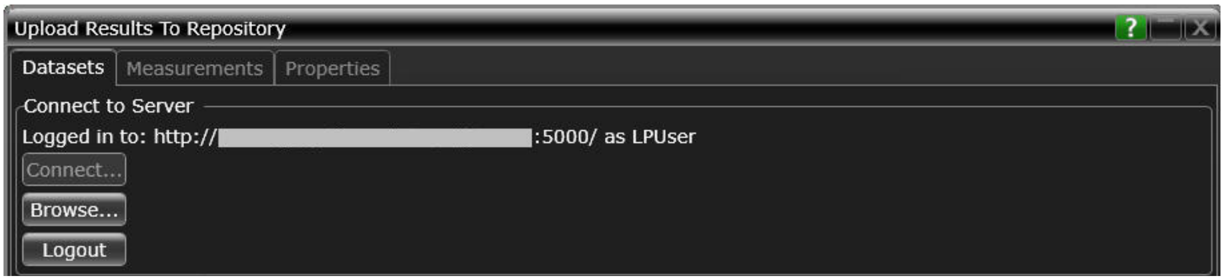
- For restricted access to the Repository
  a If service is found on the specified URL but access to the web server is restricted based on authentication, the version information is displayed along with the text Authentication Required adjacent to the Check button. Also, the Username: and Password: fields appear. The OK button remains disabled until the authentication credentials are entered.
  b Enter the user credentials in the respective fields, which are required for authentication to access those Datasets that have been created on the web server you are connecting to. For each URL that you access, the Username: drop-down box keeps a record and displays all user names used to access the respective URL.



c Click OK to connect to the entered URL/IP address.

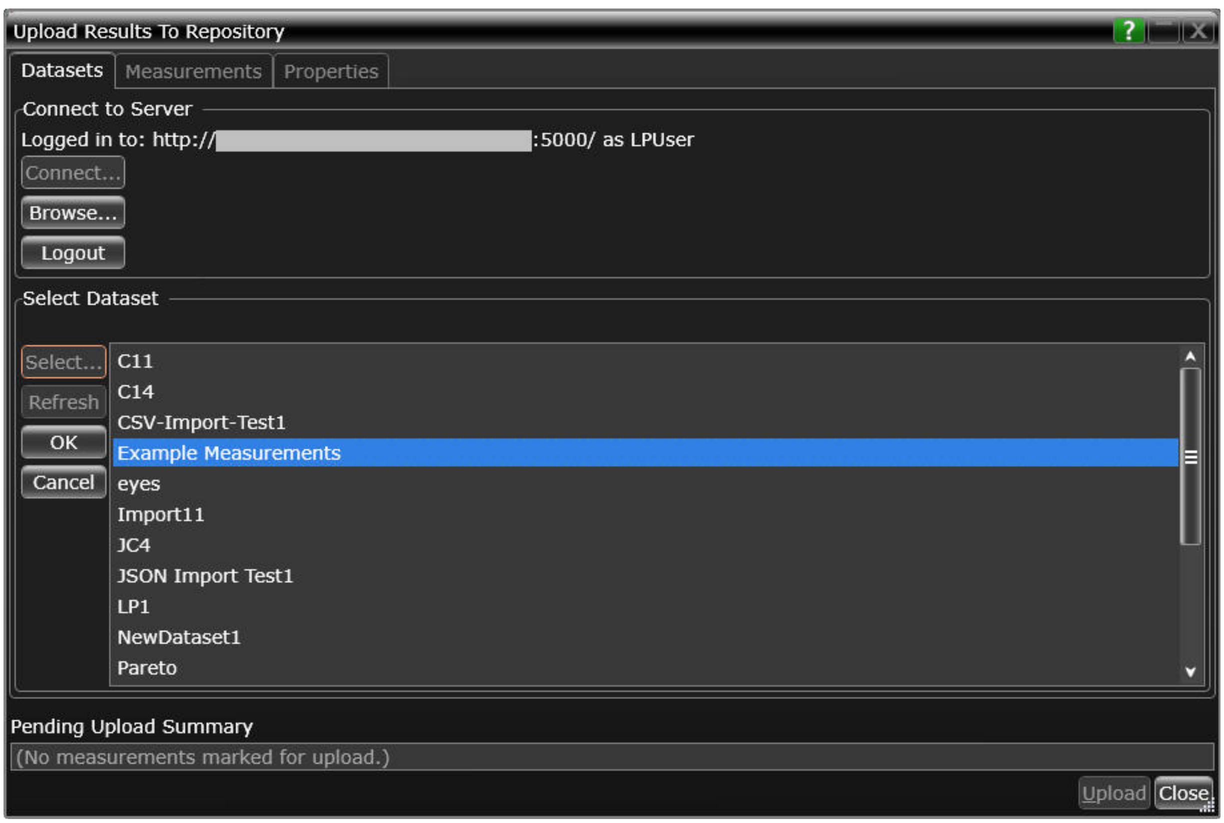
The Connect to Server area displays the connection status along with the username.

d Click Browse... to navigate directly to the URL.

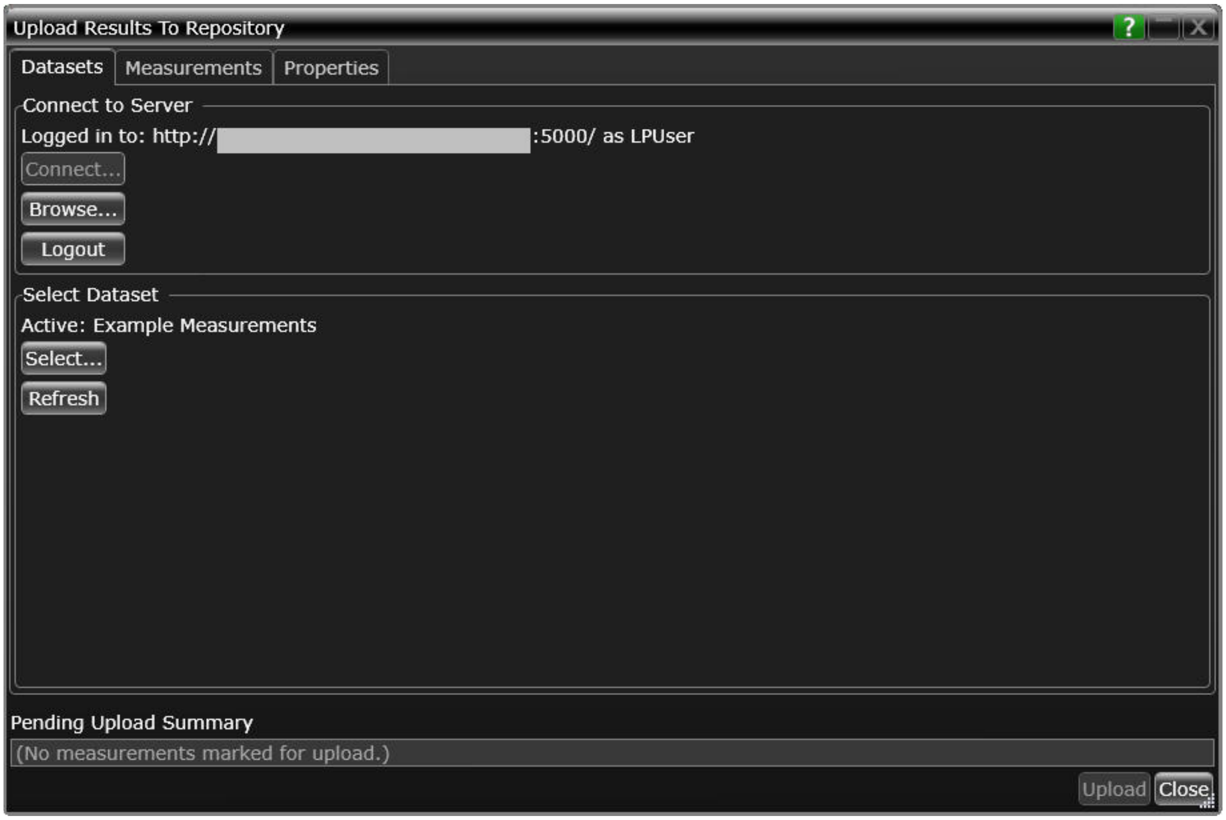


5 In the Select Dataset area, click Select... to view the list of Datasets created on the connected repository. Click Refresh to update the list of Datasets that appear in the Test Application's user interface.

6 Select the Dataset name where you wish to upload measurement results to. Click OK.

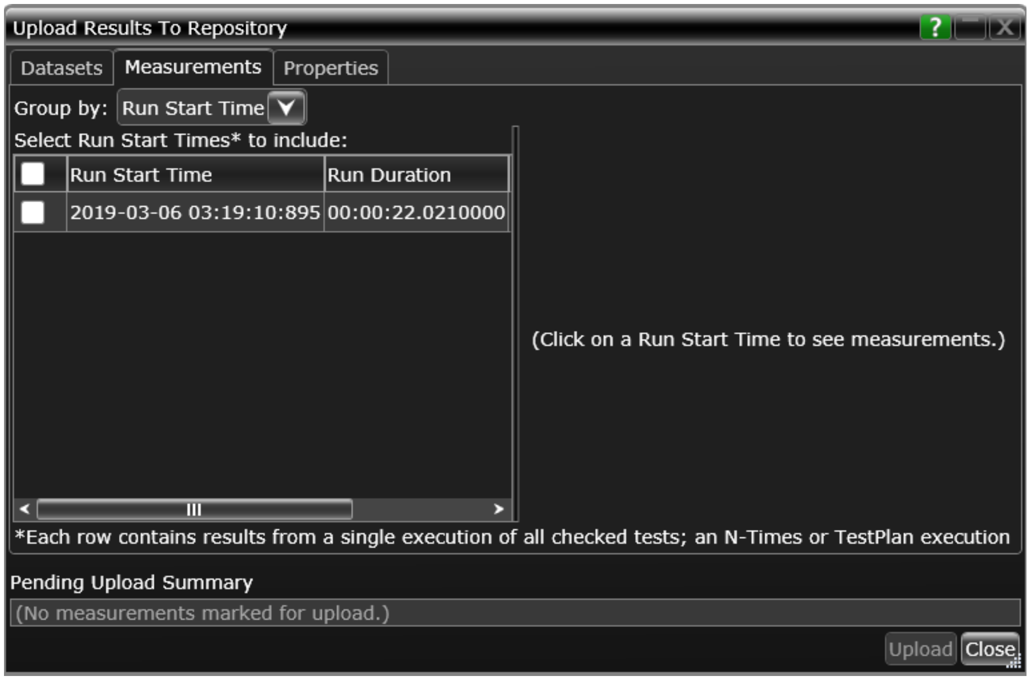


The Select Dataset area displays the selected Dataset as Active. The Measurements and Properties tabs are enabled after a Dataset is selected.



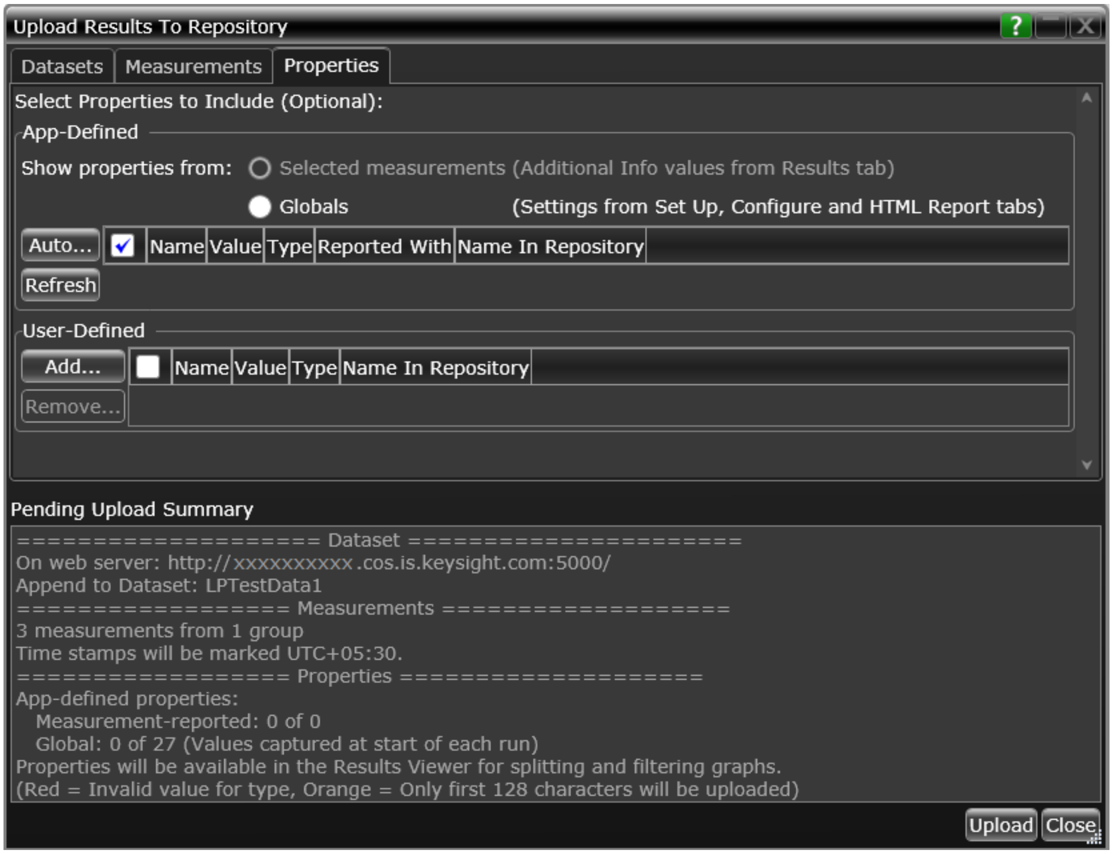
7 Click the **Measurements** tab where the test results from the last test run are displayed.

8 You may select and export multiple test results to the repository. You may change the format for the display of measurement data using the drop-down options in the **Group by:** field.

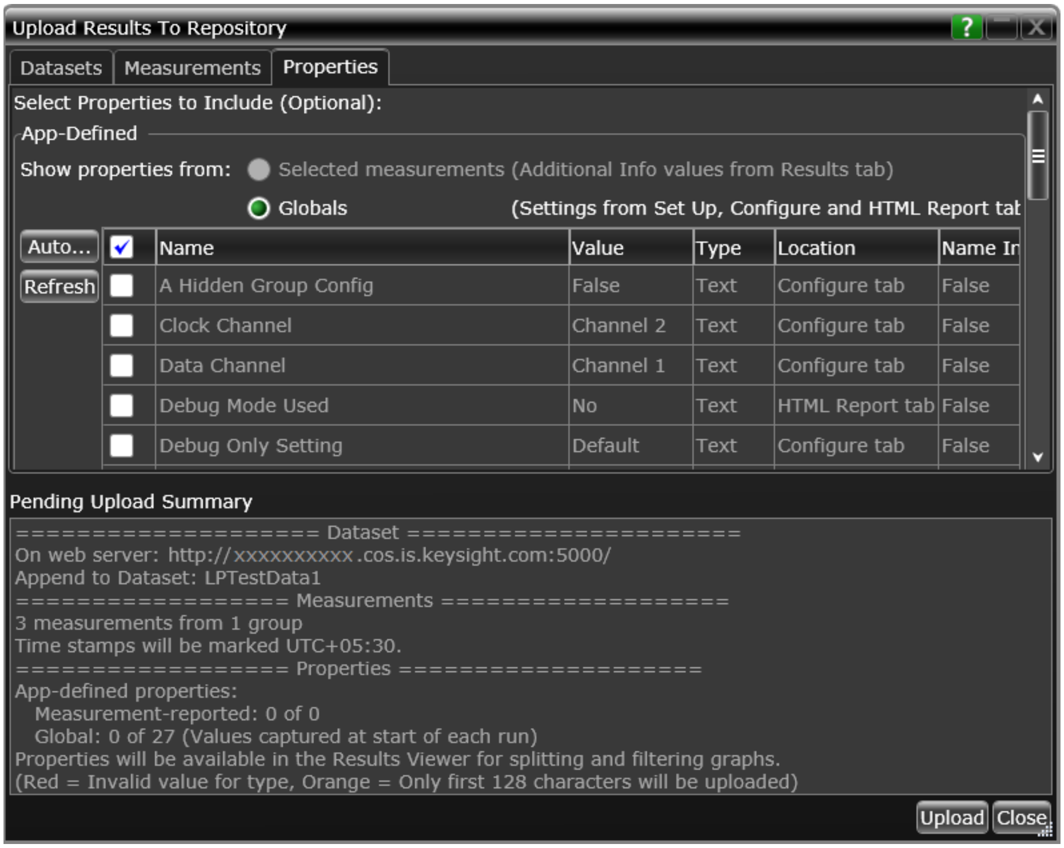


9 After selecting one or more measurements, either click **Upload** or switch to the **Properties** tab to associate one or more properties to the measurements that are being uploaded to the Web Server.

To perform an enhanced analysis on the measurement data using the *KS6800A Series Analytics Service Software*, Keysight recommends assigning properties to the measurements.



10 Click the **Properties** tab to assign properties for your measurement results that you select to upload. By default, the **App-Defined** properties are selected to be uploaded in association with the measurement data, wherein only certain aspects of the selected measurements are uploaded. However, you may switch to **Globals** to include as properties one or more options configured under the rest of the tabs of the Compliance Test Application or define one or more custom property values to be associated with the selected measurement data.



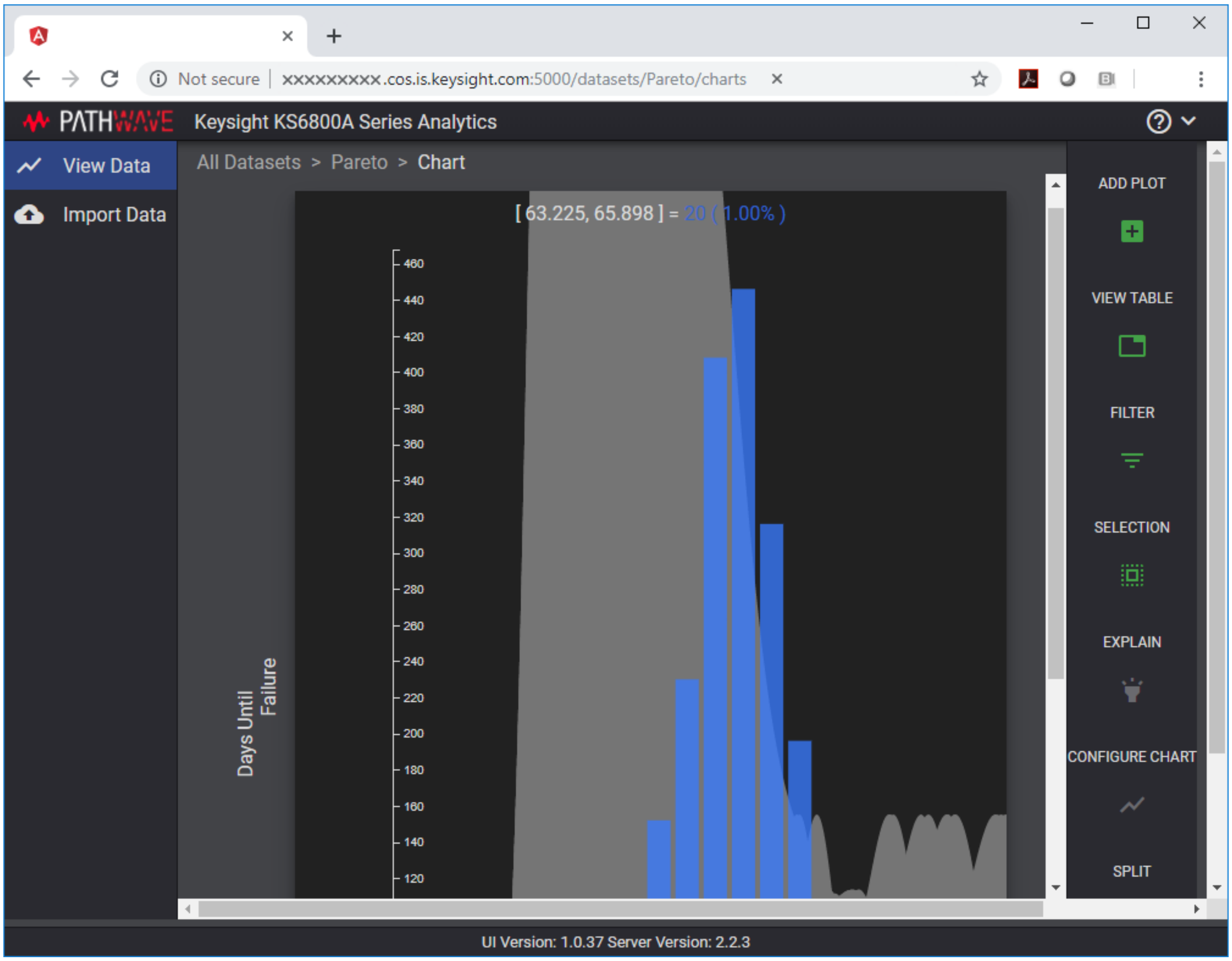
11 Click **Upload** to begin uploading measurement results.

12 Click **Close** to exit the **Upload Results to Repository** window and to return to the Compliance Test Application.

You may access the Dataset Repository using the Internet browser on your machine to view the measurement results graphically on the *KS6800A Series Analytics Service Software*.

KS6800A Series Analytics Service Software

The KS6800A Series Analytics Service software supports multiple data sources and also a wide range of data import clients. This web-based software provides various types of charts, such as Histogram, Box-and-Whisker, Line, Scatter, Eye Diagram and Constellation, each with split capability to enable data analysis. Once you upload the measurement results to a Dataset on the *KS6800A Series Analytics Service Software* via the **Upload Results to Repository** window of the Test Application, the measurement results can be viewed graphically as shown below:



For more information on the Data Analytics Web Service Software, visit KS6800A Series Analytics Service Software page on the Keysight website. You may refer to the Help manual provided within the software to understand the functionality of its features.

4 PAM4 Host-to-Module Electrical Recommendations at TP0a for OIF-CEI 56G VSR

This section provides the Methods of Implementation (MOIs) for the PAM4 OIF-CEI VSR 56G Transmitter Characteristics at TP0a as specified in CEI-56G-VSR-PAM4 Implementation Agreement (Clause 16, Document: OIF2014.230.13) Appendix 16.B.1.1, Table 16-10. Measurements are made at TP0a.

NOTE Ensure that the **Signaling Rate** setting in the **Configure** tab of the Compliance Test Application must match the frequency of the acquired input signal.

Host-to-Module transmitter output Electrical Recommendations

Table 1 Host-to-Module Electrical Recommendations at TP0a

Parameter	Symbol	Min. Value	Max. Value	Units	Conditions
Baud Rate		18.0	29.0	GBd	
Differential Voltage, pk-pk	T_Vdiff	750	-	mV	See Note 1
DC Common Mode Voltage	T_Vcm	-0.3	2.8	V	See Note 2
Differential Return Loss	T_SDD22	-	See Equation 17-4 in the specification	dB	at TP0
Transition Time: 20% to 80%	T_tr, T_tf	7.5	-	ps	With emphasis off
Common-mode return loss	T_SCC22	$-6 + 3*f/f_b$	-	dB	
Common Mode Noise, RMS	T_Ncm	-	12	mV	
Uncorrelated Unbounded Gaussian jitter (UUGJ)		-	0.01	UI_{RMS}	
Uncorrelated Bounded high probability jitter (UBHPJ)		-	0.05	UI	
Even-odd Jitter (EOJ)		-	0.019	UI	
Signal-to-noise-and-distortion ratio		31	-	dB	See section 17.3.1.6.4 in the specification

Note 1: Maximum voltage is limited by specifications at TP1a. Minimum voltage can be lower for low loss channels.

Note 2: Load type 0 with minimum T_Vdiff, AC-Coupling or floating load.

Jitter and Signaling Rate Measurements TP0a

The Jitter and Signaling Rate Measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

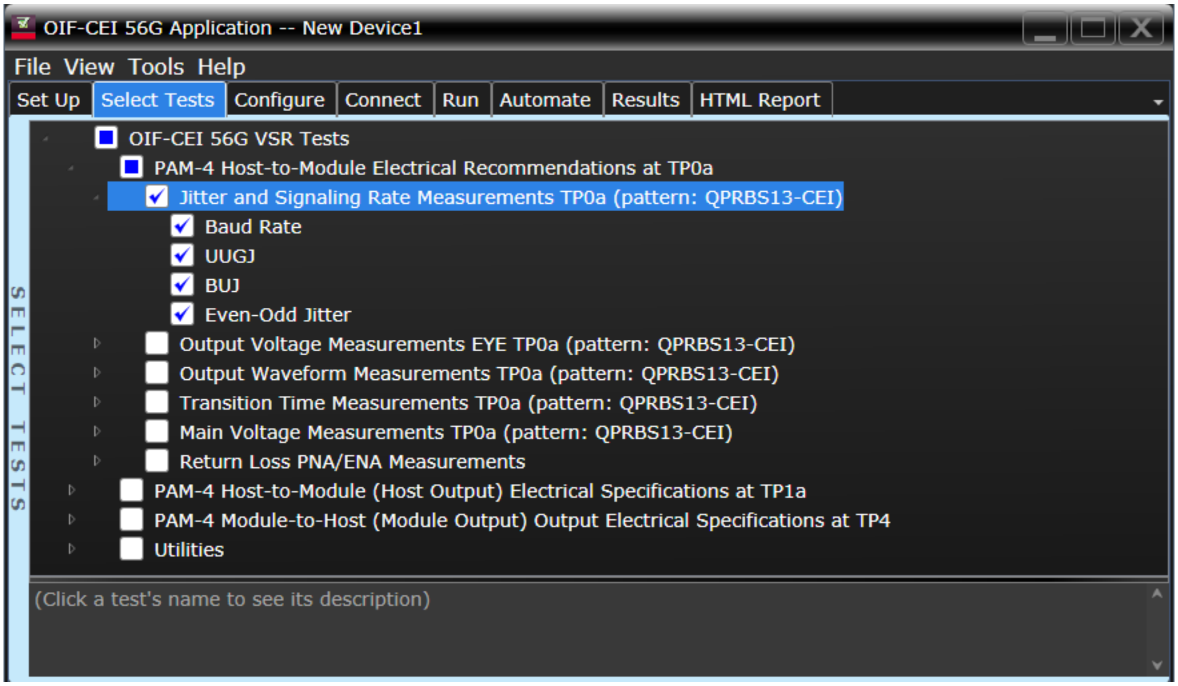


Figure 12 Selecting Jitter and Signaling Rate Measurement Tests

Refer to Table 1 for the pass limits for each test.

For information on the measurement algorithm for each Jitter and Signaling Rate Measurements TP0a (pattern: QPRBS13-CEI) tests, see:

- “Baud Rate” on page 42
- “UUGJ” on page 43
- “BUJ” on page 44
- “Even-Odd Jitter” on page 45

Baud Rate

Test Overview The purpose of this test is to verify that the baud rate is between 18 and 29 GBd.

Pass Condition Refer to Table 1.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Check that the signal is connected, has a bit-rate of 25.78125 Gbps and that data pattern exists (QPRBS13-CEI must be used for this test).
3 In the **Configure** tab, set **Signaling Rate** to 25.78125 Gb/s.
4 Measure minimum, maximum and mean baud rate.
5 Report minimum and maximum values.
6 Compare the baud rate value with the range between 18 and 29 GBd. Report the resulting value.

UUGJ

Test Overview The purpose of this test is to verify that differential signal's UUGJ is less than 0.01 UI_{RMS}. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Condition Refer to Table 1.

Measurement Algorithm

1 Obtain sample or acquire signal data. Set acquisition depth to five times the length of the QPRBS13-CEI pattern.

NOTE

For DSO-Z Series Oscilloscopes, connections must be established between Data+ to Channel 1R and Data- to Channel 3R to measure the defined 12 edges.

For UXR Series Oscilloscopes, connections must be established between Data+ to Channel 1 and Data- to Channel 2 to measure the defined 12 edges.

Irrespective of the Oscilloscope used, the signal must be of QPRBS13-CEI pattern.

2 In the **Configure** tab, set the value for the Signaling Rate as that of the Symbol Rate of the acquired signal.

3 On the Oscilloscope,

a Set Clock Recovery to OJTF First Order PLL with Nominal Data Rate (25.78125 Gbps) and Loop Bandwidth to 4 MHz.

b Using PAM4 jitter measurements, at least 10,000 QPRBS13-CEI patterns are captured to collect the measurement data of 12 edges.

c Set 4^{th} Order Bessel Thompson filter to 40 GHz.

NOTE

This measurement can run for a duration of 8-10 minutes.

4 Compare and report the UUGJ value to the respective maximum specification.

BUJ

Test Overview The purpose of this test is to verify that differential signal's BUJ is less than 0.05 UI. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Condition Refer to Table 1.

Measurement Algorithm

1 Obtain sample or acquire signal data. Set acquisition depth to five times the length of the QPRBS13-CEI pattern.

NOTE

For DSO-Z Series Oscilloscopes, connections must be established between Data+ to Channel 1R and Data- to Channel 3R to measure the defined 12 edges.

For UXR Series Oscilloscopes, connections must be established between Data+ to Channel 1 and Data- to Channel 2 to measure the defined 12 edges.

Irrespective of the Oscilloscope used, the signal must be of QPRBS13-CEI pattern.

2 In the **Configure** tab, set the value for the Signaling Rate as that of the Symbol Rate of the acquired signal.

3 On the Oscilloscope,

a Set Clock Recovery to OJTF First Order PLL with Nominal Data Rate (25.78125 Gbps) and Loop Bandwidth to 4 MHz.

b Using PAM4 jitter measurements, at least 10,000 QPRBS13-CEI patterns are captured to collect the measurement data of 12 edges.

c Set 4^{th} Order Bessel Thompson filter to 40 GHz.

NOTE

This measurement can run for a duration of 8-10 minutes.

4 Compare and report the BUJ value to the respective maximum specification.

Even-Odd Jitter

Test Overview The purpose of this test is to verify that differential signal's Even-Odd Jitter is less than 0.019 UI. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Condition Refer to Table 1.

Measurement Algorithm

1 Obtain sample or acquire signal data. Set acquisition depth to five times the length of the QPRBS13-CEI pattern.

NOTE

For DSO-Z Series Oscilloscopes, connections must be established between Data+ to Channel 1R and Data- to Channel 3R to measure the defined 12 edges.

For UXR Series Oscilloscopes, connections must be established between Data+ to Channel 1 and Data- to Channel 2 to measure the defined 12 edges.

Irrespective of the Oscilloscope used, the signal must be of QPRBS13-CEI pattern.

2 In the **Configure** tab, set the value for the Signaling Rate as that of the Symbol Rate of the acquired signal.

3 On the Oscilloscope,

a Set Clock Recovery to OJTF First Order PLL with Nominal Data Rate (25.78125 Gbps) and Loop Bandwidth to 4 MHz.

b Using PAM4 jitter measurements, at least 10,000 QPRBS13-CEI patterns are captured to collect the measurement data of 12 edges.

c Set 4^{th} Order Bessel Thompson filter to 40 GHz.

NOTE

This measurement can run for a duration of 8-10 minutes.

4 Compare and report the Even-Odd Jitter value to the respective maximum specification.

Output Voltage Measurements EYE TP0a

The Output Voltage Measurement EYE procedures for a signal with QPRBS13-CEI pattern that are described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

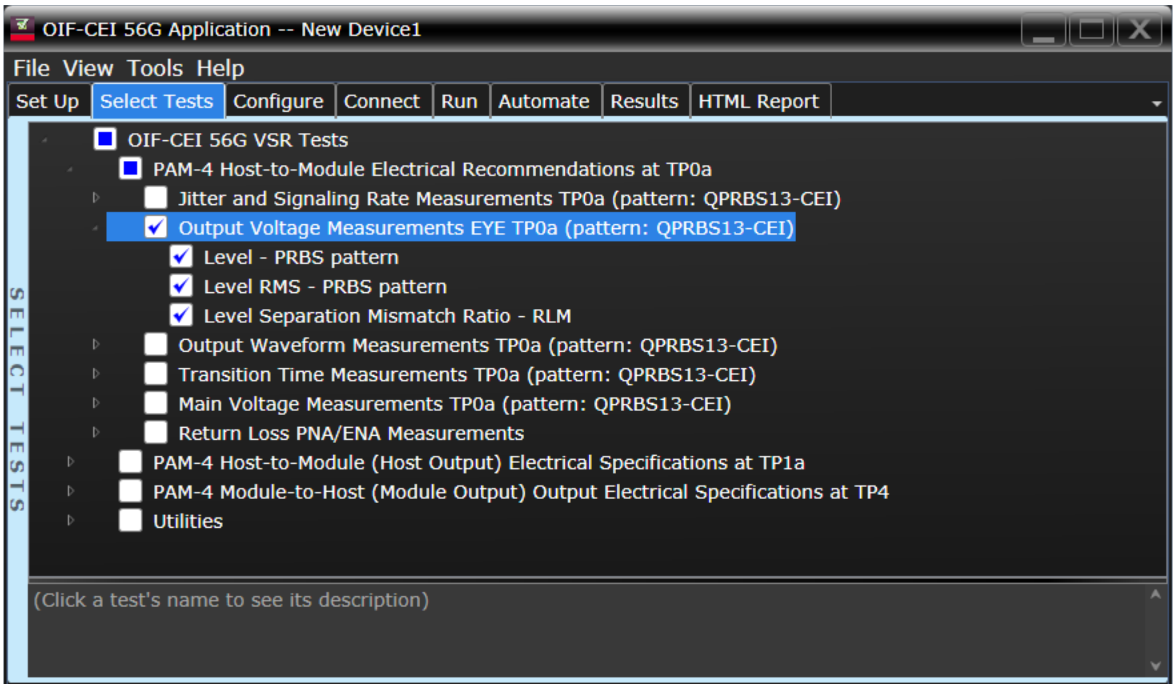


Figure 13 Selecting Output Voltage Measurements EYE Tests

Refer to Table 1 for the pass limits for each test.

For information on the measurement algorithm for each Output Voltage Measurements EYE TP0a (pattern: QPRBS13-CEI) tests, see:

- “Level - PRBS Pattern” on page 47
- “Level RMS - PRBS Pattern” on page 48
- “Level Separation Mismatch Ratio - RLM” on page 49

NOTE All the tests under the group Output Voltage Measurements EYE TP0a are considered as “Information-Only” tests and cannot be used for compliance validation.

Level - PRBS Pattern

Test Overview The purpose of this test is to obtain the mean voltage of each level of the signal with QPRBS13-CEI pattern.

Pass Condition Not applicable as the test result is considered as "Information Only".

Measurement Algorithm

1. Check that signal is connected and proper data pattern exists (QPRBS13-CEI pattern must be used for this test).
2. V_{-1}, $V_{-1/3}$, $V_{+1/3}$ and V_{+1} are the mean signal levels of the symbols corresponding to the PAM4 symbol levels -1, -1/3, +1/3 and +1 respectively, as defined in CEI-56G-VSR-PAM4 Implementation Agreement (Clause 16, Document: OIF2014.230.13) Section 16C.4.3. The calculation of mean signal levels is also defined in the same section.
3. The mean voltage level V_{mid} is defined by equation (16-15), which is,

$$V_{mid} = (V_{-1} + V_{+1}) / 2$$

4. Report this value for information-only purpose.

Level RMS - PRBS Pattern

Test Overview The purpose of this test is to obtain the of the RMS level of the signal with QPRBS13-CEI pattern.

Pass Condition Not applicable as the test result is considered as “Information Only”.

Measurement Algorithm

1. Run the Level - PRBS Pattern test as a prerequisite to this test.
2. The minimum signal level RMS is calculated, as defined in CEI-56G-VSR-PAM4 Implementation Agreement (Clause 16, Document: OIF2014.230.13) Section 16C.4.3.
3. Report this value for information-only purpose.

Level Separation Mismatch Ratio - RLM

Test Overview The purpose of this test is to obtain the of the Separation Mismatch Ratio level (RLM) of the signal with QPRBS13-CEI pattern.

Pass Condition Not applicable as the test result is considered as “Information Only”.

Measurement Algorithm

1 Run the Level - PRBS Pattern as a prerequisite to this test to calculate the mid-range level.

2 The mean signal levels are normalized so that V_{-1} corresponds to -1, $V_{-1/3}$ to -ES1, $V_{+1/3}$ to ES2 and V_{+1} to 1.

3 ES1 and ES2 are calculated using equations (16-16) and (16-17) of the CEI-56G-VSR-PAM4 Implementation Agreement (Clause 16, Document: OIF2014.230.13), respectively.

$$ES1 = (V_{-1/3} - V_{mid}) / (V_{-1} - V_{mid})$$

$$ES2 = (V_{+1/3} - V_{mid}) / (V_{+1} - V_{mid})$$

4 The level separation mismatch ratio R_{LM} is defined by equation (16-18) of the same specification.

$$R_{LM} = \min [(3 \times ES1), (3 \times ES2), (2 - 3 \times ES1), (2 - 3 \times ES2)]$$

5 Report this value for information-only purpose.

Output Waveform Measurements TP0a

The Transmitter Output Waveform Measurement procedures that are described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

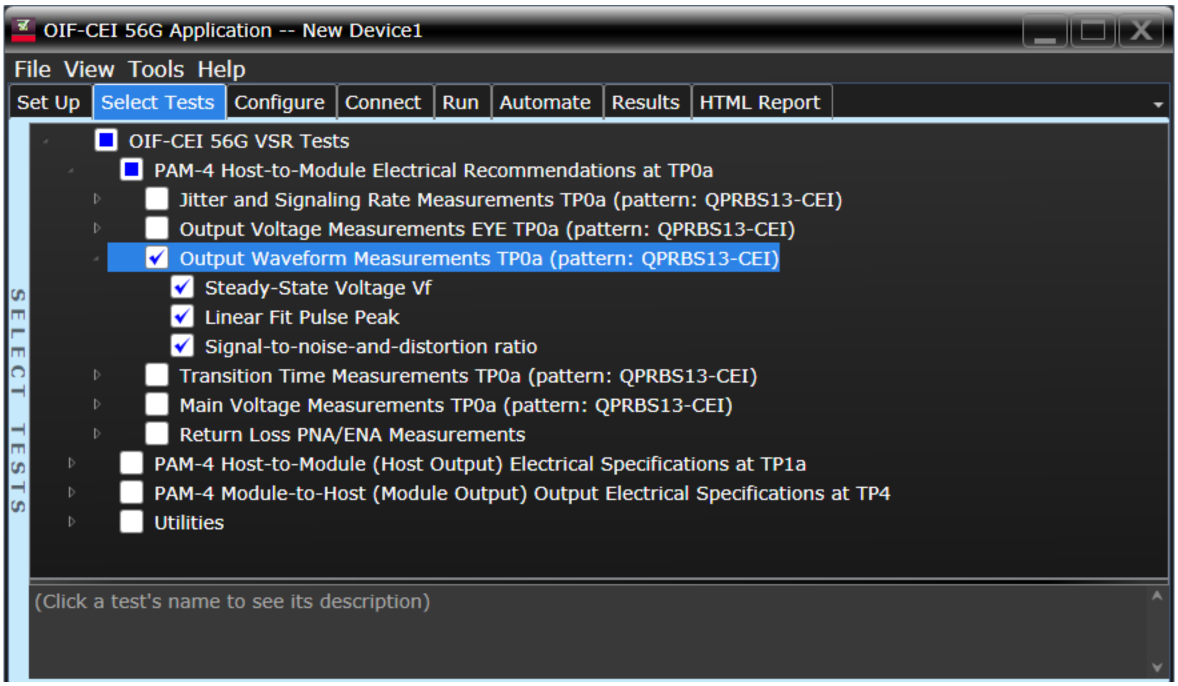


Figure 14 Selecting Output Waveform Measurements

Refer to Table 1 for the pass limits for each test.

For information on the measurement algorithm for each Output Waveform Measurements TP0a (pattern: QPRBS13-CEI) tests, see:

- "Steady State Voltage Vf" on page 51
- "Linear Fit Pulse Peak" on page 52
- "Signal-to-noise-and-distortion ratio" on page 53

NOTE **The tests Steady State Voltage Vf and Linear Fit Pulse Peak are considered as "Information-Only" tests and cannot be used for compliance validation.**

Steady State Voltage V_f

Test Overview The purpose of this test is to verify the Steady State Voltage.

Pass Condition Not applicable as the test result is considered as “Information Only”.

Measurement Algorithm

1 Check that signal is connected and proper data pattern exists (QPRBS13-CEI must be used for this test).

2 Enable (set to ON) pattern averaging to capture QPRBS13-CEI pattern at 32 points per UI for 16 averages.

3 Steady State Voltage V_f is calculated using the equations in section 85.8.3.3.5. The resulting value is the sum of columns of p(k)/M. N_p = 200, D_p = 2.

4 Report the result.

Linear Fit Pulse Peak

Test Overview The purpose of this test is to verify the Linear Fit Pulse Peak.

Pass Condition Not applicable as the test result is considered as "Information Only".

Measurement Algorithm

1. Check that signal is connected and proper data pattern exists (QPRBS13-CEI must be used for this test).
2. Enable (set to ON) pattern averaging to capture QPRBS13-CEI pattern at 32 points per UI for 16 averages.
3. Linear Fit Pulse Peak is calculated using the equations in section 85.8.3.3.5. The resulting value is the peak value of p(k). N_p = 200, D_p = 2.
4. Report the result.

Signal-to-noise-and-distortion ratio

Test Overview The purpose of this test is to verify that the Signal-to-noise-and-distortion ratio (SNDR) is greater than 31dB.

Pass Condition Refer to Table 1.

Measurement Algorithm

1 Calculate SNDR using measurements from Level RMS - PRBS pattern test and the error calculated from Linear Fit Pulse Peak test.

2 Compare and report the value of SNDR with 31dB.

Transition Time Measurements TP0a

The PAM4 Transition Time Measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

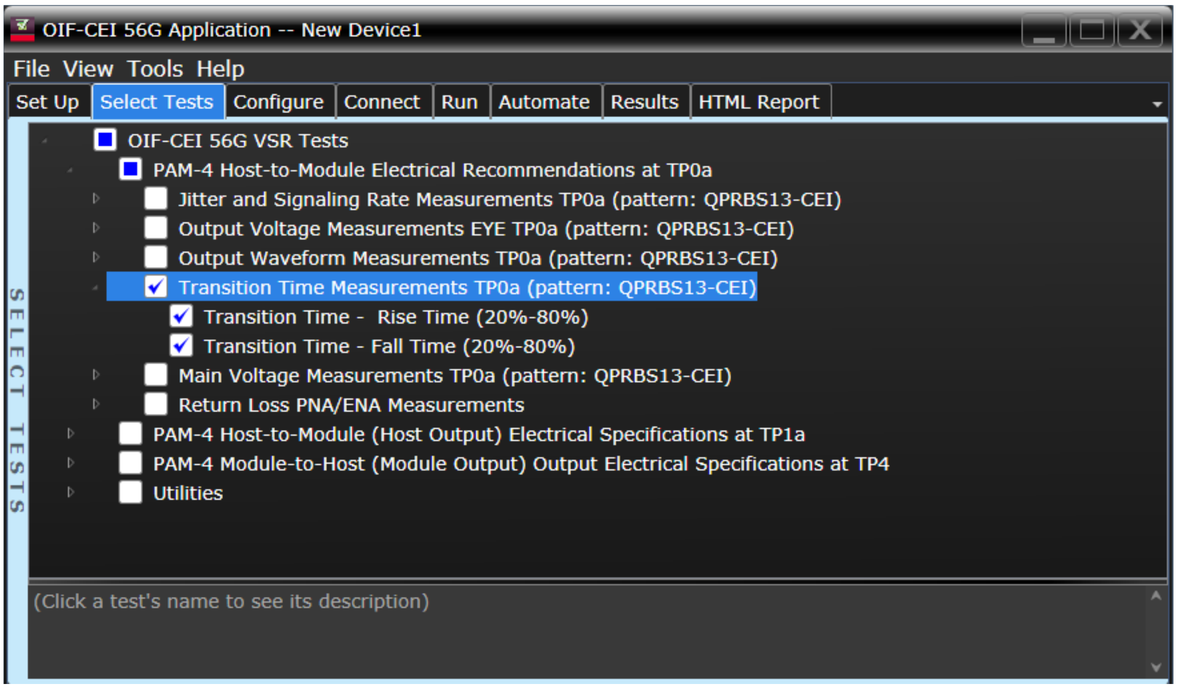


Figure 15 Selecting Transition Time Measurement Tests

Refer to Table 1 for the pass limits for each test.

For information on the measurement algorithm for each Transition Time Measurements TP0a (pattern: QPRBS13-CEI) tests, see:

- "Transition Time - Rise Time (20%-80%)" on page 55
- "Transition Time - Fall Time (20%-80%)" on page 56

Transition Time - Rise Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum rise time is 7.5ps.

Pass Condition Refer to Table 1.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is QPRBS13-CEI.
3 Find pattern 000333 for rise time.
4 Measure rise time from 20% to 80% of the signal amplitude.
5 Compare the minimum rise time with 7.5ps.

Transition Time - Fall Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum fall time is 7.5ps.

Pass Condition Refer to Table 1.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is QPRBS13-CEI.
3 Find pattern 333000 for fall time.
4 Measure fall time from 20% to 80% of the signal amplitude.
5 Compare the minimum fall time with 7.5ps.

Main Voltage Measurements TP0a

The PAM4 Main Voltage measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

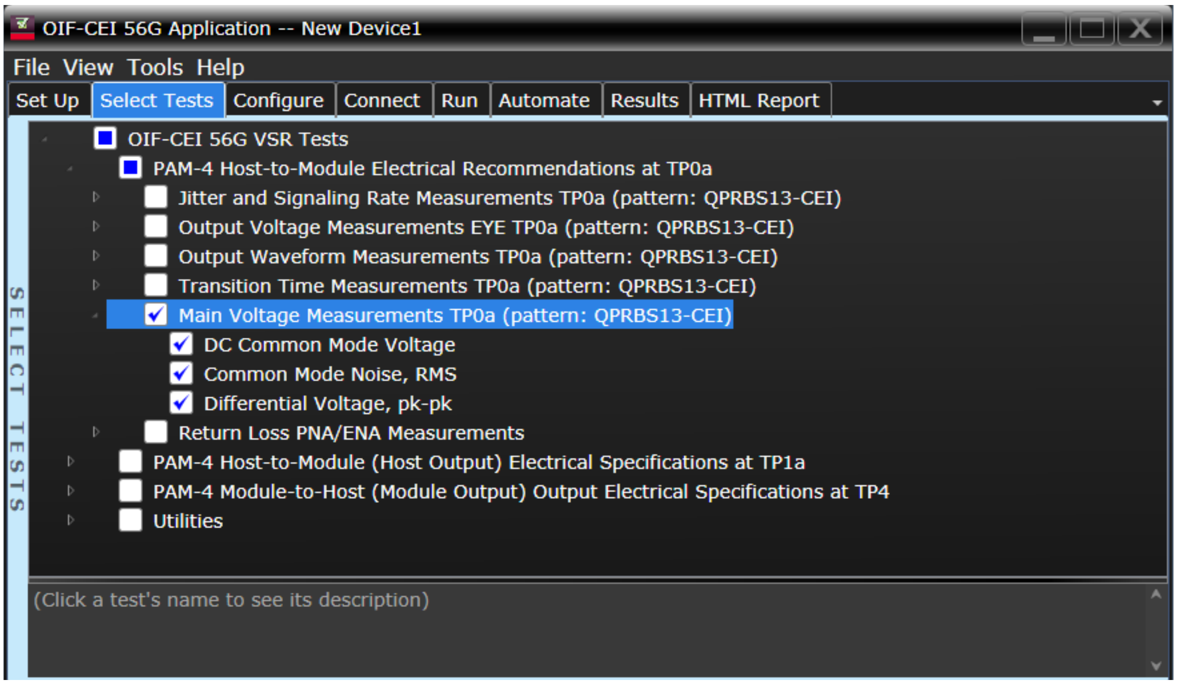


Figure 16 Selecting Main Voltage Measurement Tests

Refer to Table 1 for the pass limits for each test.

For information on the measurement algorithm for each Main Voltage Measurements TP0a (pattern: QPRBS13-CEI) tests, see:

- “DC Common Mode Output Voltage” on page 58
- “Common Mode Noise, RMS” on page 59
- “Differential Voltage, pk-pk” on page 60

DC Common Mode Output Voltage

Test Overview The purpose of this test is to verify that the common mode signal of the differential pair is between -0.3V to 2.8V.

> **NOTE** This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition Refer to Table 1.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that there is a signal and that the connection is dual single-ended.
3 Measure the DC Common Mode Output voltage.
- If the Test Application is running on the DSA/DSO Z-Series Oscilloscope, the **Instrument Setup** is preset to **Real Edge**.
- If the Test Application is running on the UXR Series Oscilloscope, perform the measurement with the **Instrument Setup** set to **Channels 1 and 2**. Repeat the measurement with the Instrument Setup set to **Channels 3 and 4**.

4 Compare the voltage measurement to the range from -0.3V to 2.8V.

Common Mode Noise, RMS

Test Overview The purpose of this test is to verify that the common mode signal of the differential pair rms voltage does not exceed 12mV.

NOTE This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition Refer to Table 1.

Measurement Algorithm

1. Obtain sample or acquire signal data.
2. Verify that there is a signal and that the connection is dual single-ended.
3. Measure the Common Mode Noise, RMS.

- If the Test Application is running on the DSA/DSO Z-Series Oscilloscope, the **Instrument Setup** is preset to **Real Edge**.
- If the Test Application is running on the UXR Series Oscilloscope, perform the measurement with the **Instrument Setup** set to **Channels 1 and 2**. Repeat the measurement with the Instrument Setup set to **Channels 3 and 4**.

4. Compare the voltage measurement to 12mV.

Differential Voltage, pk-pk

Test Overview The purpose of this test is to verify that the peak-to-peak voltage of the differential signal on a QPRBS13-CEI pattern is greater than 750mV.

Pass Condition Refer to Table 1.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is connected, has TX enabled and has a QPRBS13-CEI pattern.
3 Measure the peak-to-peak voltage of the differential signal of DUT+ and DUT-.
4 Compare the maximum peak-to-peak voltage to 750mV.

Return Loss ENA/PNA Measurements

The Return Loss ENA/PNA Measurement procedures that are described in this section are performed using a Keysight Infiniium oscilloscope, PNA or ENA and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application. The Compliance Test Application controls the PNA/ENA to set the test limits and run the tests. You must ensure that the connected PNA/ENA is calibrated.

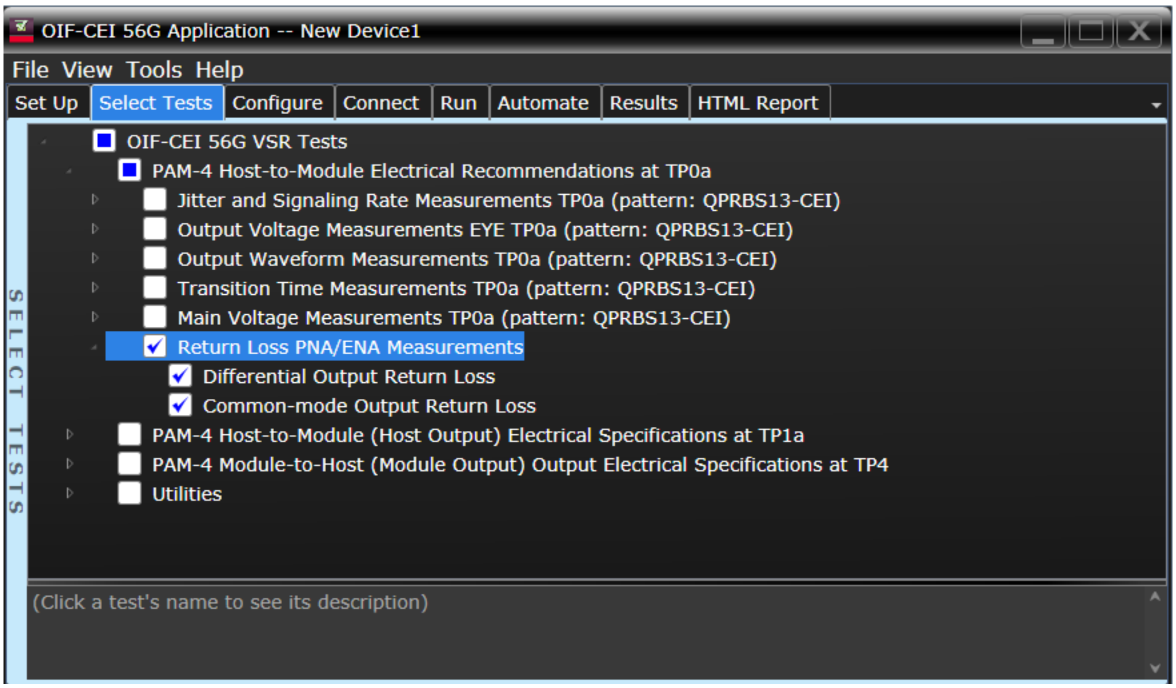


Figure 17 Selecting Return Loss Measurement Tests

Refer to Table 1 for the pass limits for each test.

For information on the measurement algorithm for each Return Loss ENA/PNA Measurements, see:

- "Differential Output Return Loss" on page 62
- "Common-mode Output Return Loss" on page 63

Differential Output Return Loss

Measurement Algorithm

1. Ensure that the PNA/ENA is physically connected and calibrated.
2. In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3. Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4. Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5. Compare the reported values with the specification to check for compliance.

Common-mode Output Return Loss

Measurement Algorithm

1 Ensure that the PNA/ENA is physically connected and calibrated.
2 In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3 Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4 Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5 Compare the reported values with the specification to check for compliance.

5 PAM4 Host-to-Module (Host Output) Electrical Specifications at TP1a for OIF-CEI 56G VSR

This section provides the Methods of Implementation (MOIs) for the PAM4 OIF-CEI VSR 56G Host Output Characteristics at TP1a as specified in CEI-56G-VSR-PAM4 Implementation Agreement (Clause 16, Document: OIF2014.230.13) Section 16.3.2, Table 16-1. Measurements are made at TP1a.

NOTE Ensure that the **Signaling Rate** setting in the **Configure** tab of the Compliance Test Application must match the frequency of the acquired input signal.

KEYSIGHT TECHNOLOGIES

Host-to-Module Electrical Specifications

Table 2 Host-to-Module Electrical Specifications at TP1a (host output), (See Note 5)

Parameter	Min. Value	Max. Value	Units	Conditions
Differential Voltage pk-pk	-	880	mV	See Note 1
Common Mode Noise RMS	-	17.5	mV	See section 16.3.5 in the specification
Common Mode Voltage (Vcm)	-0.3	2.8	V	Referred to host ground, See Note 2
Differential Return Loss (SDD22)	-	See Equation 16-1 in the specification	dB	See Note 3
Common Mode to Differential Mode Conversion (SDC22)	-	See Equation 16-3 in the specification	dB	See Note 3
Common Mode Return Loss (SCC22)	-	-2	dB	From 250 MHz to f_b GHz, See Note 3 in the specification
Transition Time	12	-	ps	See section 16.C.4.1 in the specification
Eye Width at 10^{-6} probability (EW6)	0.20	-	UI	See section 16.3.10 in the specification and Note 4
Eye Height at 10^{-6} probability (EH6)	32	-	mV	See section 16.3.10 in the specification and Note 4
Eye Linearity	0.85	-	-	See Equation 16-14 in the specification and Note 4

Note 1: The differential voltage measured using a QPRBS13-CEI pattern will be less than the in-service differential voltage due to host loss and length of the QPRB13-CEI pattern.

Note 2: Vcm is defined in Table 1-2 General Definitions of Section 1.6 in the specification.

Note 3: S-parameter specifications based on a differential reference impedance of 100Ω and a common mode reference impedance of 25Ω.

Note 4: Open eye is generated through the use of a reference Continuous Time Linear Equalizer (CTLE) applicable to all three PAM4 eyes (See 16.3.10.4 in the specification).

Note 5: The addition of a maximum VEC parameter is being considered as a maintenance action.

Main Voltage Measurements TP1a

The PAM4 Main Voltage Measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

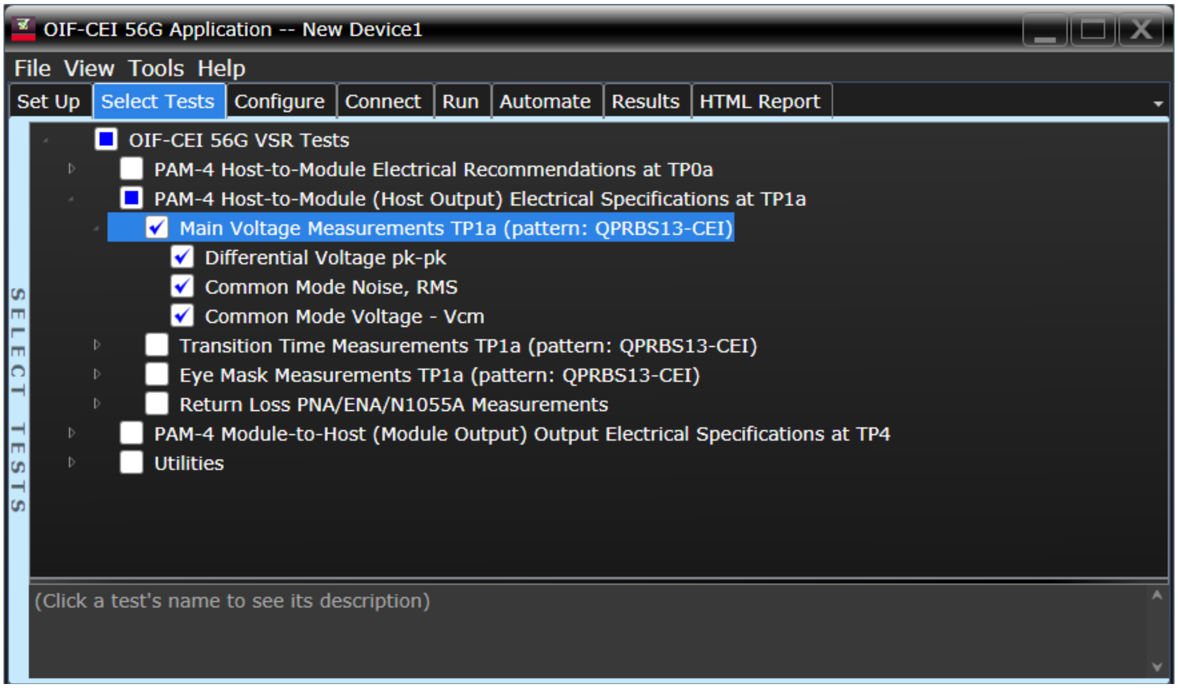


Figure 18 Selecting Main Voltage Measurement Tests

Refer to Table 2 for the pass limits for each test.

For information on the measurement algorithm for each Main Voltage Measurements TP1a (pattern: QPRBS13-CEI) tests, see:

- "Differential Voltage pk-pk" on page 68
- "Common Mode Noise, RMS" on page 69
- "Common Mode Voltage - Vcm" on page 70

Differential Voltage pk-pk

Test Overview The purpose of this test is to verify that the peak-to-peak voltage of the differential signal on a QPRBS13-CEI pattern is less than 880mV.

Pass Condition Refer to Table 2.

Measurement Algorithm

1. Obtain sample or acquire signal data.
2. Verify that the signal is connected, has TX enabled and has a QPRBS13-CEI pattern.
3. Measure the peak-to-peak voltage of the differential signal of DUT+ and DUT-.
4. Compare the maximum peak-to-peak voltage to 880mV.

Common Mode Noise, RMS

Test Overview The purpose of this test is to verify that the common mode signal of the differential pair rms voltage does not exceed 17.5mV.

NOTE This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition Refer to Table 2.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that there is a signal and that the connection is dual single-ended.
3 Measure the Common Mode Noise, RMS.

- If the Test Application is running on the DSA/DSO Z-Series Oscilloscope, the **Instrument Setup** is preset to **Real Edge**.
- If the Test Application is running on the UXR Series Oscilloscope, perform the measurement with the **Instrument Setup** set to **Channels 1 and 2**. Repeat the measurement with the Instrument Setup set to **Channels 3 and 4**.

4 Compare the voltage measurement to 17.5mV.

Common Mode Voltage - Vcm

Test Overview The purpose of this test is to verify that the common mode signal of the differential pair is between -0.3V to 2.8V.

NOTE This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition Refer to Table 2.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that there is a signal and that the connection is dual single-ended.
3 Measure the Common Mode Voltage.

- If the Test Application is running on the DSA/DSO Z-Series Oscilloscope, the **Instrument Setup** is preset to **Real Edge**.
- If the Test Application is running on the UXR Series Oscilloscope, perform the measurement with the **Instrument Setup** set to **Channels 1 and 2**. Repeat the measurement with the Instrument Setup set to **Channels 3 and 4**.

4 Compare the voltage measurement to the range from -0.3V to 2.8V.

Transition Time Measurements TP1a

The PAM4 Transition Time Measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

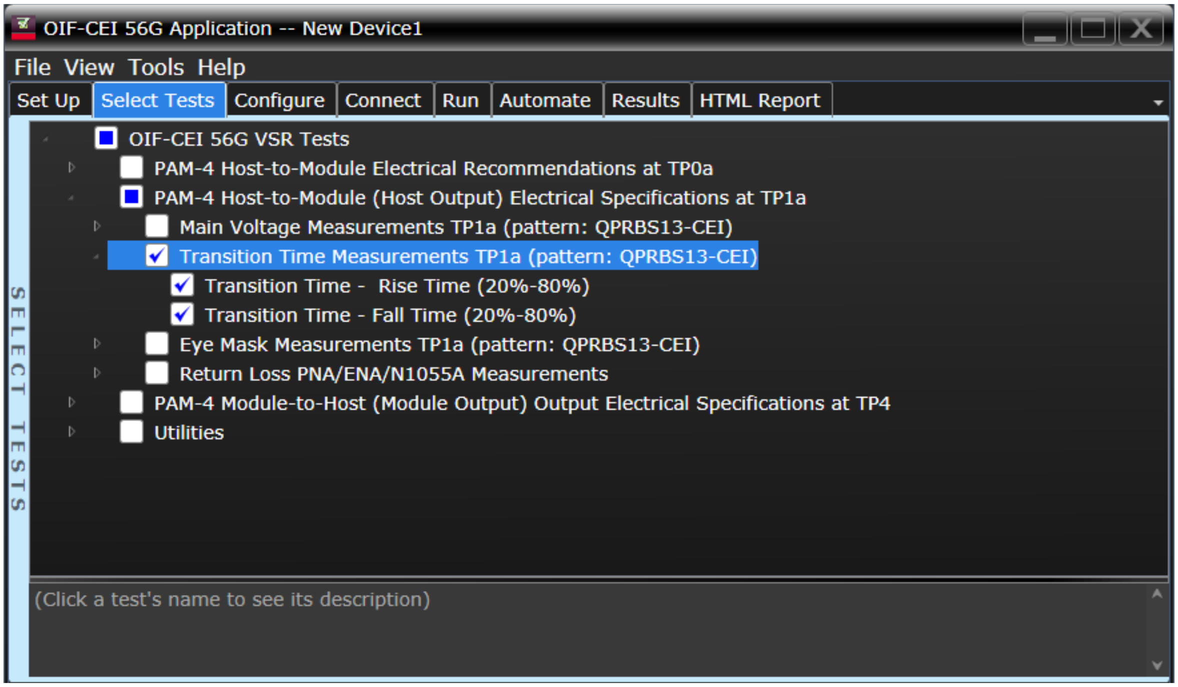


Figure 19 Selecting Transition Time Measurement Tests

Refer to Table 2 for the pass limits for each test.

For information on the measurement algorithm for each Transition Time Measurements TP1a (pattern: QPRBS13-CEI) tests, see:

- "Transition Time - Rise Time (20%-80%)" on page 72
- "Transition Time - Fall Time (20%-80%)" on page 73

Transition Time - Rise Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum rise time is 12ps.

Pass Condition Refer to Table 2.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is QPRBS13-CEI.
3 Find pattern 000333 for rise time.
4 Measure rise time from 20% to 80% of the signal amplitude.
5 Compare the minimum rise time with 12ps.

Transition Time - Fall Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum fall time is 12ps.

Pass Condition Refer to Table 2.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is QPRBS13-CEI.
3 Find pattern 333000 for fall time.
4 Measure fall time from 20% to 80% of the signal amplitude.
5 Compare the minimum fall time with 12ps.

Eye Mask Measurements TP1a

The Eye Mask Measurement procedures that are described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

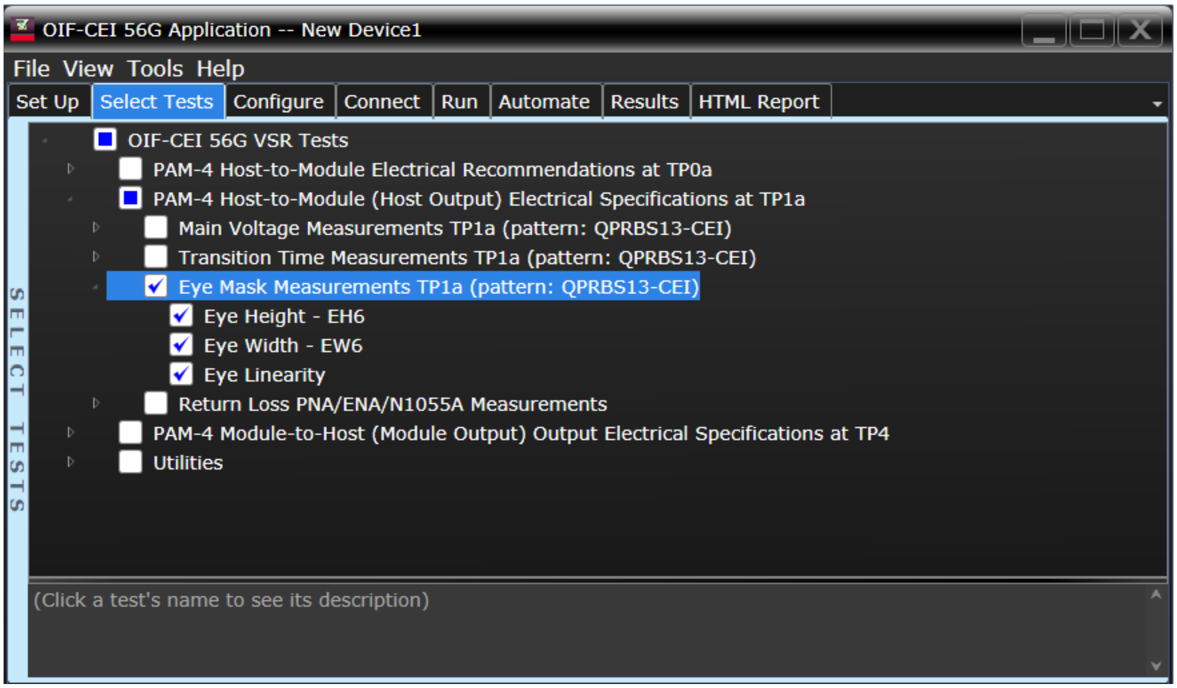


Figure 20 Selecting Eye Mask Measurement Tests

Refer to Table 2 for the pass limits for each test.

For information on the measurement algorithm for each Eye Mask Measurements TP1a (pattern: QPRBS13-CEI) tests, see:

- "Eye Height - EH6" on page 75
- "Eye Width - EW6" on page 76
- "Eye Linearity" on page 77

Eye Height - EH6

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Eye Height is greater than 32mV. The CTLE values range from 1dB lower than the user-defined optimal CTLE to 1dB higher than the user-defined optimal CTLE.

Pass Conditions Refer to Table 2.

Measurement Algorithm

1 Manually select the optimal CTLE setting in the **Use Optimized CTLE for Eye Opening** option in the **Configure** tab. The selected CTLE setting is called as 'User-defined optimal CTLE'.

2 Obtain sample or acquire signal data.

3 Set memory depth to capture the unit interval setting in the **Configure** tab. The Eye Height and Eye Width is measured at a memory depth of 1E-6.

4 On the Oscilloscope

   a Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate 25.78125Gb/s and Loop Bandwidth to 40 MHz.

   b Set 4^{th} Order Bessel Thompson filter to 40 GHz.

5 Compare the Eye Height with 32mV. Report the resulting value.

Eye Width - EW6

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Eye Width is greater than 0.20UI. The CTLE values range from 1dB lower than the user-defined optimal CTLE to 1dB higher than the user-defined optimal CTLE.

Pass Conditions Refer to Table 2.

Measurement Algorithm

1. Manually select the optimal CTLE setting in the **Use Optimized CTLE for Eye Opening** option in the **Configure** tab. The selected CTLE setting is called as ‘User-defined optimal CTLE’.
2. Obtain sample or acquire signal data.
3. Set memory depth to capture the unit interval setting in the **Configure** tab. The Eye Height and Eye Width is measured at a memory depth of 1E-6.
4. On the Oscilloscope
   - *a* Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate 25.78125Gb/s and Loop Bandwidth to 40 MHz.
   - *b* Set 4^{th} Order Bessel Thompson filter to 40 GHz.
5. Compare the Eye Width with 0.20UI. Report the resulting value.

Eye Linearity

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, Eye Linearity is greater than 0.85. The CTLE values range from 1dB lower than the user-defined optimal CTLE to 1dB higher than the user-defined optimal CTLE.

Pass Condition Refer to Table 2.

Measurement Algorithm

1 Manually select the optimal CTLE setting in the **Use Optimized CTLE for Eye Opening** option in the **Configure** tab. The selected CTLE setting is called as ‘User-defined optimal CTLE’.

2 Obtain sample or acquire signal data.

3 Set memory depth to capture the unit interval setting in the **Configure** tab. The Eye Linearity is measured at a memory depth of 1E-6.

4 On the Oscilloscope,

   a Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate 25.78125Gb/s and Loop Bandwidth to 40 MHz.

   b Set 4^{th} Order Bessel Thompson filter to 40 GHz.

5 Calculate Eye Linearity using the equation:

Eye Linearity = [min(AVupp,AVmid,AVlow) / max(AVupp,AVmid,AVlow)]

6 Compare the Eye Linearity with 0.85. Report the resulting value.

Return Loss ENA/PNA/N1055A Measurements

The Return Loss ENA/PNA/N1055A Measurement procedures that are described in this section are performed using a Keysight Infiniium oscilloscope, PNA, ENA or N1055A and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application. The Compliance Test Application controls the PNA/ENA/N1055A to set the test limits and run the tests. You must ensure that the connected PNA/ENA/N1055A is calibrated.

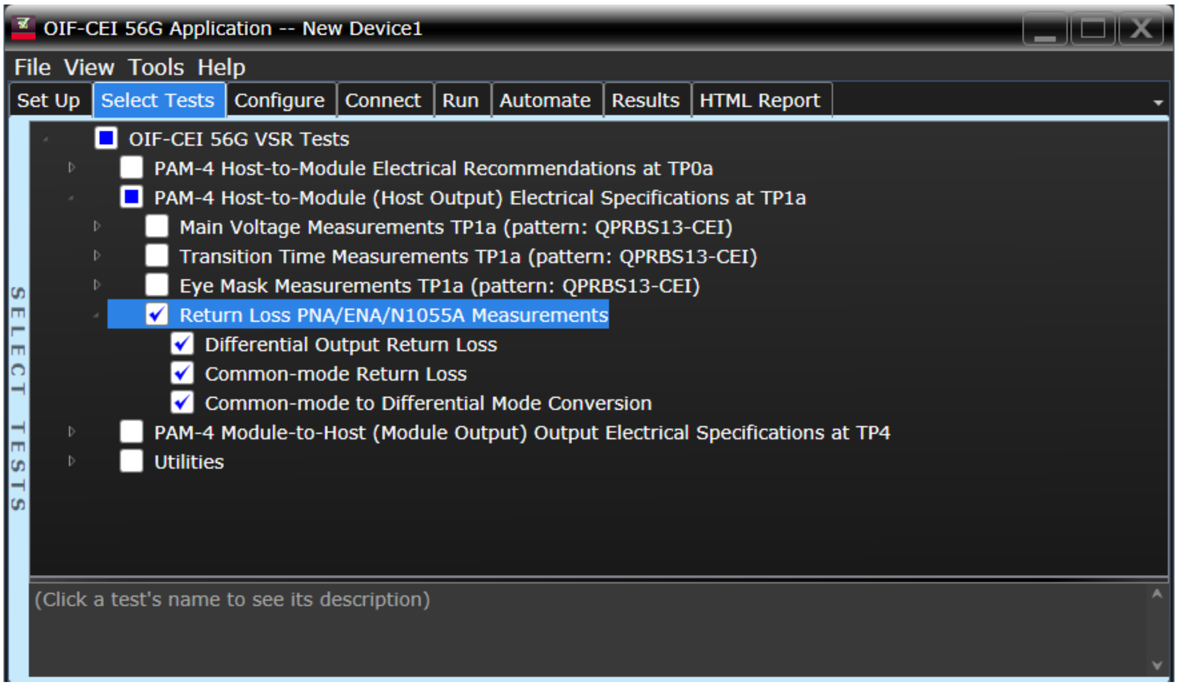


Figure 21 Selecting Return Loss Measurement Test

Refer to Table 2 for the pass limits for each test.

For information on the measurement algorithm for each Return Loss ENA/PNA/N1055A Measurements, see:

- "Differential Output Return Loss" on page 79
- "Common-mode Return Loss" on page 80
- "Common-mode to Differential Mode Conversion" on page 81

Differential Output Return Loss

Measurement Algorithm

1. Ensure that the PNA/ENA is physically connected and calibrated.
2. In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3. Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4. Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5. Compare the reported values with the specification to check for compliance.

Common-mode Return Loss

Measurement Algorithm

1. Ensure that the PNA/ENA is physically connected and calibrated.
2. In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3. Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4. Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5. Compare the reported values with the specification to check for compliance.

Common-mode to Differential Mode Conversion

Measurement Algorithm

1. Ensure that the PNA/ENA is physically connected and calibrated.
2. In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3. Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4. Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5. Compare the reported values with the specification to check for compliance.

6 PAM4 Module-to-Host (Module Output) Output Electrical Specifications at TP4 for OIF-CEI 56G VSR

This section provides the Methods of Implementation (MOIs) for the PAM4 OIF-CEI VSR 56G Module Output Characteristics at TP4 as specified in CEI-56G-VSR-PAM4 Implementation Agreement (Clause 16, Document: OIF2014.230.13) Section 16.3.3, Table 16-4. Measurements are made at TP4.

NOTE Ensure that the **Signaling Rate** setting in the **Configure** tab of the Compliance Test Application must match the frequency of the acquired input signal.

Module-to-Host Electrical Specifications

Table 3 Module-to-Host Electrical Specifications at TP4 (module output)

Parameter	Min. Value	Max. Value	Units	Conditions
Differential Voltage, pk-pk	-	900	mV	
Common Mode Noise, RMS	-	17.5	mV	See section 16.3.5 in the specification
Common Mode Voltage (Vcm)[1,2]	-350	2850	mV	See Notes 1, 2
Differential Return Loss (SDD22)	-	See Equation 16-1 in the specification	dB	See Note 3
Common Mode to Differential Mode Conversion (SDC22)	-	See Equation 16-3 in the specification	dB	See Note 3
Common Mode Return Loss (SCC22)	-	-2	dB	From 250 MHz to f_b GHz, See Note 3
Transition Time	9.5	-	ps	See section 16.C.4.1 in the specification
Near-end Eye Width at 10^{-6} probability (EW6)	0.265	-	UI	See section 16.3.10 in the specification, See Note 4
Near-end Eye Height at 10^{-6} probability (EH6)	70	-	mV	See section 16.3.10 in the specification, See Note 4
Far-end Eye Width at 10^{-6} probability (EW6)	0.20	-	UI	See section 16.3.10 in the specification, See Note 4
Far-end Eye Height at 10^{-6} probability (EH6)	30	-	mV	See section 16.3.10 in the specification, See Note 4
Near-end Eye Linearity	0.85	-	-	See Equation 16-14, See Note 4

Note 1: Vcm is defined in Table 1-2 General Definitions of Section 1.6 in the specification.

Note 2: Vcm is generated by the host. Specification includes effects of ground offset voltage.

Note 3: S-parameter specifications based on a differential reference impedance of 100Ω and a common mode reference impedance of 25Ω.

Note 4: Open eye is generated through the use of a reference Continuous Time Linear Equalizer (CTLE) applicable to all three PAM4 eyes (See 16.3.10.4 in the specification).

Main Voltage Measurements TP4

The PAM4 Main Voltage Measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

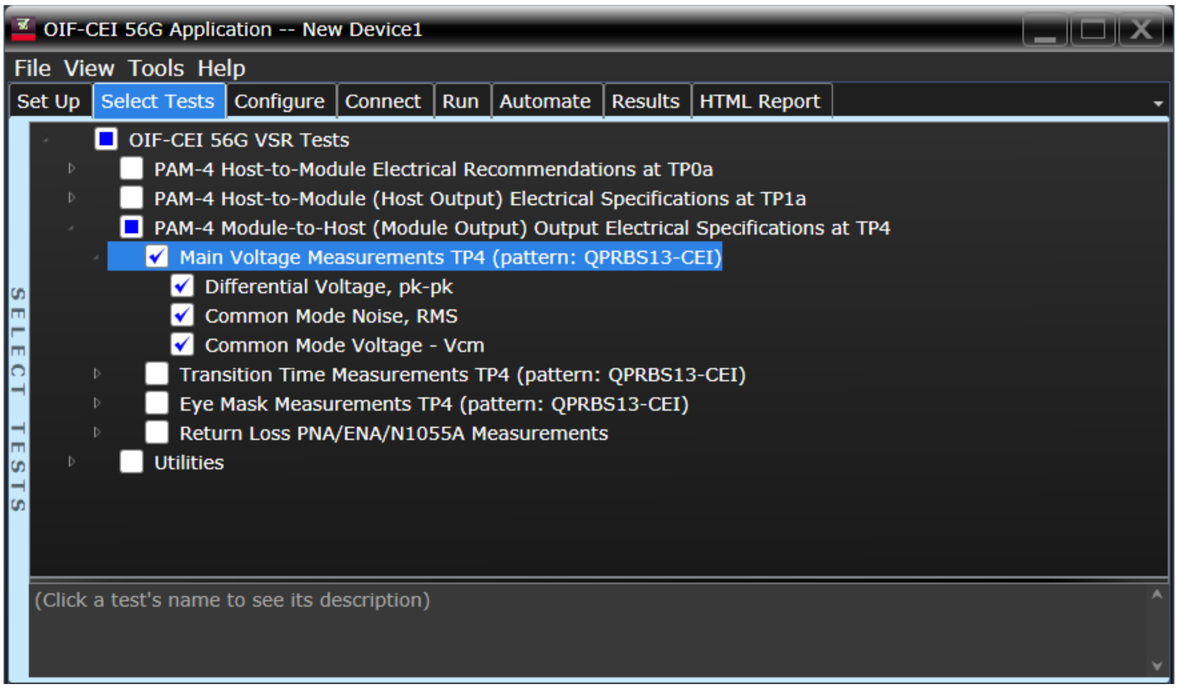


Figure 22 Selecting Main Voltage Measurement Tests

Refer to Table 3 for the pass limits for each test.

For information on the measurement algorithm for each Main Voltage Measurements TP4 (pattern: QPRBS13-CEI) tests, see:

- "Differential Voltage, pk-pk" on page 86
- "Common Mode Noise, RMS" on page 87
- "Common Mode Voltage - Vcm" on page 88

Differential Voltage, pk-pk

Test Overview The purpose of this test is to verify that the peak-to-peak voltage of the differential signal on a QPRBS13-CEI pattern is less than 900mV.

Pass Condition Refer to Table 3.

Measurement Algorithm

1 Obtain sample or acquire signal data.

2 Verify that the signal is connected, has TX enabled and has a QPRBS13-CEI pattern.

3 Measure the peak-to-peak voltage of the differential signal of DUT+ and DUT-.

4 Compare the maximum peak-to-peak voltage to 900mV.

Common Mode Noise, RMS

Test Overview

The purpose of this test is to verify that the common mode signal of the differential pair rms voltage does not exceed 17.5mV.

NOTE This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition

Refer to Table 3.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that there is a signal and that the connection is dual single-ended.
3 Measure the Common Mode Noise, RMS.

- If the Test Application is running on the DSA/DSO Z-Series Oscilloscope, the **Instrument Setup** is preset to **Real Edge**.
- If the Test Application is running on the UXR Series Oscilloscope, perform the measurement with the **Instrument Setup** set to **Channels 1 and 2**. Repeat the measurement with the Instrument Setup set to **Channels 3 and 4**.

4 Compare the voltage measurement to 17.5mV.

Common Mode Voltage - Vcm

Test Overview The purpose of this test is to verify that the common mode signal of the differential pair is between -350mV to 2850mV.

> **NOTE** This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition Refer to Table 3.

Measurement Algorithm

1 Obtain sample or acquire signal data.

2 Verify that there is a signal and that the connection is dual single-ended.

3 Measure the Common Mode Voltage.

- If the Test Application is running on the DSA/DSO Z-Series Oscilloscope, the **Instrument Setup** is preset to **Real Edge**.
- If the Test Application is running on the UXR Series Oscilloscope, perform the measurement with the **Instrument Setup** set to **Channels 1 and 2**. Repeat the measurement with the Instrument Setup set to **Channels 3 and 4**.

4 Compare the voltage measurement to the range from -350mV to 2850mV.

Transition Time Measurements TP4

The PAM4 Transition Time Measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

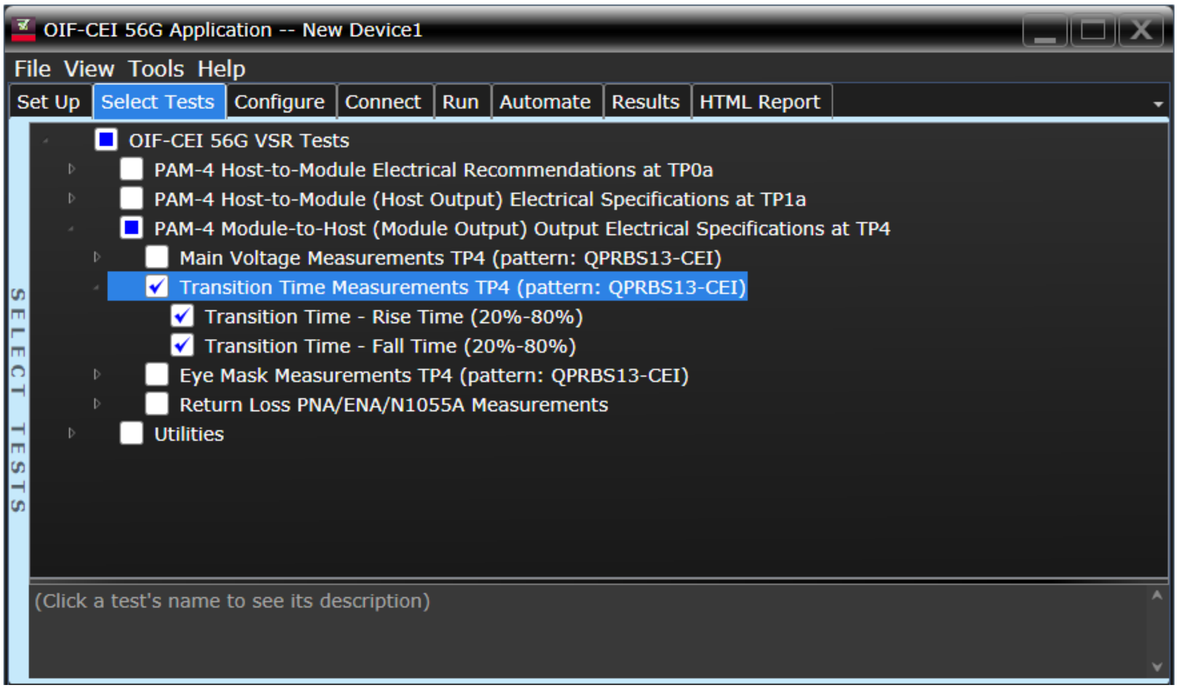


Figure 23 Selecting Transition Time Measurement Tests

Refer to Table 3 for the pass limits for each test.

For information on the measurement algorithm for each Transition Time Measurements TP4 (pattern: QPRBS13-CEI) tests, see:

- "Transition Time - Rise Time (20%-80%)" on page 90
- "Transition Time - Fall Time (20%-80%)" on page 91

Transition Time - Rise Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum rise time is 9.5ps.

Pass Condition Refer to Table 3.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is QPRBS13-CEI.
3 Find pattern 000333 for rise time.
4 Measure rise time from 20% to 80% of the signal amplitude.
5 Compare the minimum rise time with 9.5ps.

Transition Time - Fall Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum fall time is 9.5ps.

Pass Condition Refer to Table 3.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is QPRBS13-CEI.
3 Find pattern 333000 for fall time.
4 Measure fall time from 20% to 80% of the signal amplitude.
5 Compare the minimum fall time with 9.5ps.

Eye Mask Measurements TP4

The Eye Mask Measurement procedures that are described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

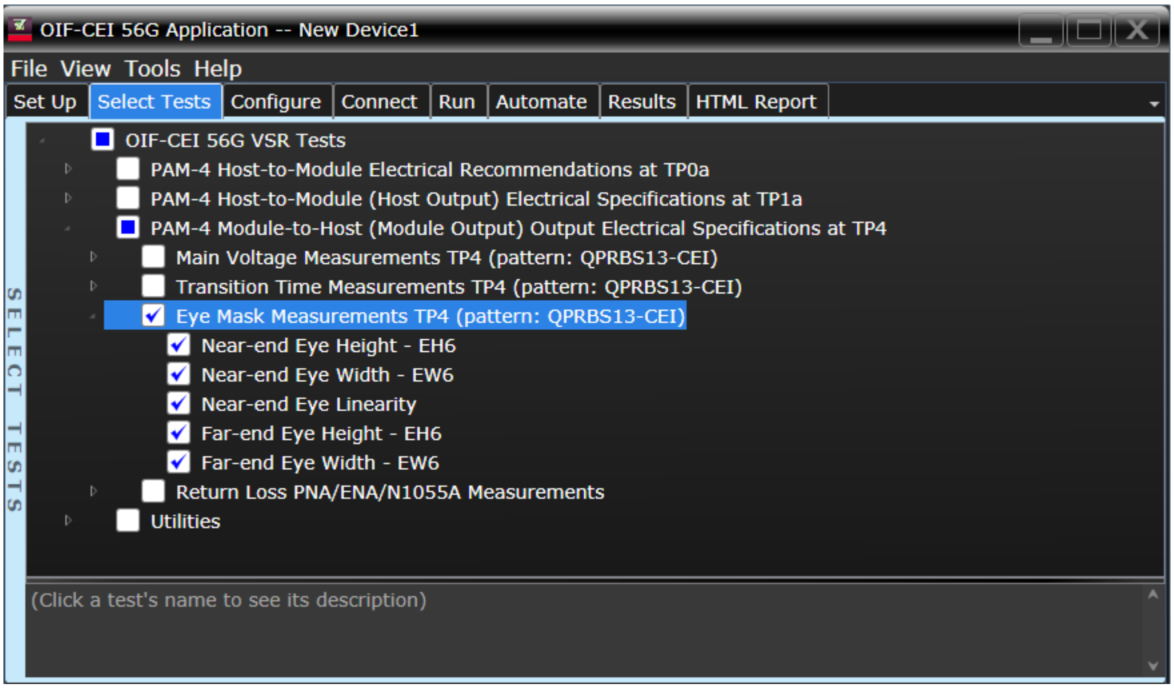


Figure 24 Selecting Eye Mask Measurement Tests

Refer to Table 3 for the pass limits for each test.

For information on the measurement algorithm for each Transition Time Measurements TP4 (pattern: QPRBS13-CEI) tests, see:

- "Near-End Eye Height - EH6" on page 93
- "Near-End Eye Width - EW6" on page 94
- "Near-end Eye Linearity" on page 95
- "Far-end Eye Height - EH6" on page 96
- "Far-end Eye Width - EW6" on page 97

Near-End Eye Height - EH6

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Near-end Eye Height is greater than 70mV. The CTLE values range from 1dB lower than the user-defined optimal CTLE to 1dB higher than the user-defined optimal CTLE.

Pass Condition Refer to Table 3.

Measurement Algorithm

1 Manually select the optimal CTLE setting in the **Use Optimized CTLE for Eye Opening** option in the **Configure** tab. The selected CTLE setting is called as 'User-defined optimal CTLE'.

2 Obtain sample or acquire signal data.

3 Set memory depth to capture the unit interval setting in the **Configure** tab. The Eye Height and Eye Width is measured at a memory depth of 1E-6.

4 On the Oscilloscope,

   a Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate 25.78125Gb/s and Loop Bandwidth to 40 MHz.

   b Set 4^{th} Order Bessel Thompson filter to 40 GHz.

5 Compare the Near-end Eye Height with 70mV. Report the resulting value.

Near-End Eye Width - EW6

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Near-end Eye Width is greater than 265mUI. The CTLE values range from 1dB lower than the user-defined optimal CTLE to 1dB higher than the user-defined optimal CTLE.

Pass Condition Refer to Table 3.

Measurement Algorithm

1 Manually select the optimal CTLE setting in the **Use Optimized CTLE for Eye Opening** option in the **Configure** tab. The selected CTLE setting is called as 'User-defined optimal CTLE'.

2 Obtain sample or acquire signal data.

3 Set memory depth to capture the unit interval setting in the **Configure** tab. The Eye Height and Eye Width is measured at a memory depth of 1E-6.

4 On the Oscilloscope

   a Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate 25.78125Gb/s and Loop Bandwidth to 40 MHz.

   b Set 4^{th} Order Bessel Thompson filter to 40 GHz.

5 Compare the Near-end Eye Width with 265mUI. Report the resulting value.

Near-end Eye Linearity

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, Eye Linearity is greater than 0.85. The CTLE values range from 1dB lower than the user-defined optimal CTLE to 1dB higher than the user-defined optimal CTLE.

Pass Condition Refer to Table 3.

Measurement Algorithm

1 Manually select the optimal CTLE setting in the **Use Optimized CTLE for Eye Opening** option in the **Configure** tab. The selected CTLE setting is called as 'User-defined optimal CTLE'.

2 Obtain sample or acquire signal data.

3 Set memory depth to capture the unit interval setting in the **Configure** tab. The Near-end Eye Linearity is measured at a memory depth of 1E-6.

4 On the Oscilloscope

  a Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate 25.78125Gb/s and Loop Bandwidth to 40 MHz.

  b Set 4^{th} Order Bessel Thompson filter to 40 GHz.

5 Calculate Eye Linearity using the equation:

Eye Linearity = [min(AVupp,AVmid,AVlow) / max(AVupp,AVmid,AVlow)]

6 Compare the Near-end Eye Linearity with 0.85. Report the resulting value.

Far-end Eye Height - EH6

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Far-end Eye Height is greater than 30mV. The CTLE values range from 1dB lower than the user-defined optimal CTLE to 1dB higher than the user-defined optimal CTLE.

Pass Condition Refer to Table 3.

Measurement Algorithm

1. Manually select the optimal CTLE setting in the **Use Optimized CTLE for Eye Opening** option in the **Configure** tab. The selected CTLE setting is called as 'User-defined optimal CTLE'.
2. Obtain sample or acquire signal data.
3. Set memory depth to capture the unit interval setting in the **Configure** tab. The Eye Height and Eye Width is measured at a memory depth of 1E-6.
4. On the Oscilloscope
   - *a* Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate 25.78125Gb/s and Loop Bandwidth to 40 MHz.
   - *b* Set 4^{th} Order Bessel Thompson filter to 40 GHz.
5. Compare the Eye Height with 30mV. Report the resulting value.

Far-end Eye Width - EW6

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Far-end Eye Width is greater than 200mUI. The CTLE values range from 1dB lower than the user-defined optimal CTLE to 1dB higher than the user-defined optimal CTLE.

Pass Condition Refer to Table 3.

Measurement Algorithm

1. Manually select the optimal CTLE setting in the **Use Optimized CTLE for Eye Opening** option in the **Configure** tab. The selected CTLE setting is called as 'User-defined optimal CTLE'.
2. Obtain sample or acquire signal data.
3. Set memory depth to capture the unit interval setting in the **Configure** tab. The Eye Height and Eye Width is measured at a memory depth of 1E-6.
4. On the Oscilloscope
   - *a* Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate 25.78125Gb/s and Loop Bandwidth to 40 MHz.
   - *b* Set 4^{th} Order Bessel Thompson filter to 40 GHz.
5. Compare the Eye Width with 200mUI. Report the resulting value.

Return Loss ENA/PNA/N1055A Measurements

The Return Loss ENA/PNA/N1055A Measurement procedures that are described in this section are performed using a Keysight Infiniium oscilloscope, PNA, ENA or N1055A and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application. The Compliance Test Application controls the PNA/ENA/N1055A to set the test limits and run the tests. You must ensure that the connected PNA/ENA/N1055A is calibrated.

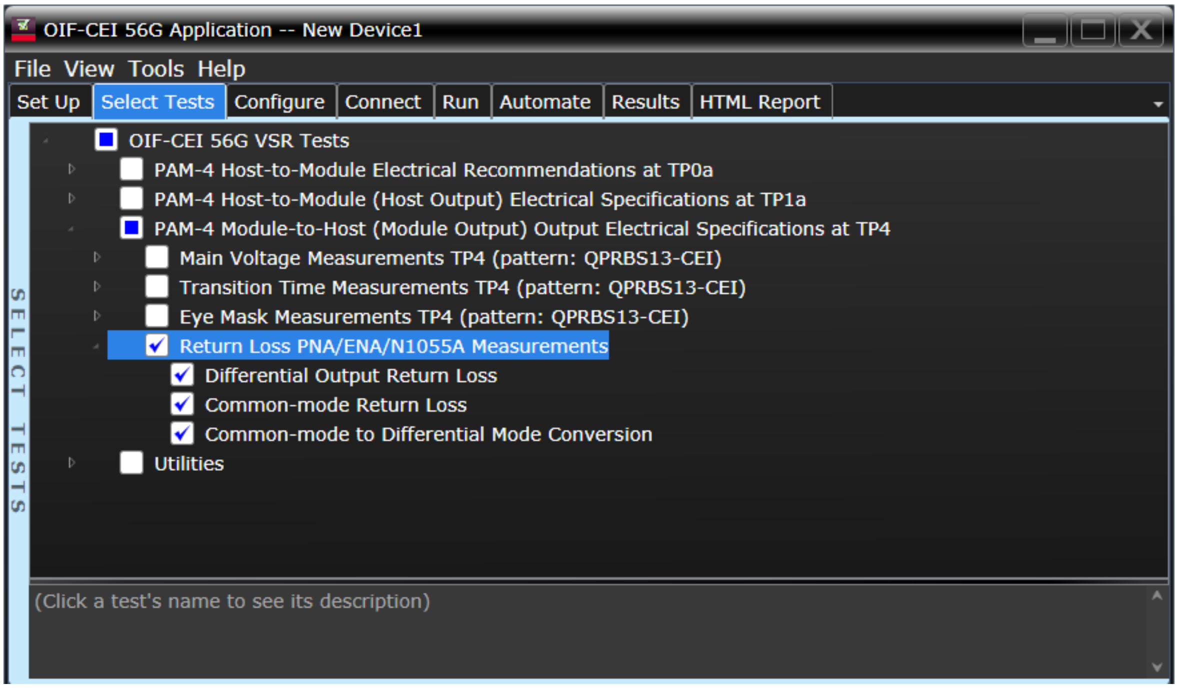


Figure 25 Selecting Return Loss Measurement Tests

Refer to Table 3 for the pass limits for each test.

For information on the measurement algorithm for each Return Loss ENA/PNA/N1055A Measurements, see:

- “Differential Output Return Loss” on page 99
- “Common-mode Return Loss” on page 100
- “Common-mode to Differential Mode Conversion” on page 101

Differential Output Return Loss

Measurement Algorithm

1. Ensure that the PNA/ENA/N1055A is physically connected and calibrated.
2. In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3. Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4. Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5. Compare the reported values with the specification to check for compliance.

Common-mode Return Loss

Measurement Algorithm

1. Ensure that the PNA/ENA/N1055A is physically connected and calibrated.
2. In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3. Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4. Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5. Compare the reported values with the specification to check for compliance.

Common-mode to Differential Mode Conversion

Measurement Algorithm

1 Ensure that the PNA/ENA/N1055A is physically connected and calibrated.
2 In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3 Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4 Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5 Compare the reported values with the specification to check for compliance.

7 PAM4 Transmitter Characteristics for OIF-CEI 56G MR

This section provides the Methods of Implementation (MOIs) for the OIF-CEI 56G PAM4 Transmitter Characteristics at compliance point T as specified in CEI-56G-MR-PAM4 Implementation Agreement (Clause 17, Document: OIF2014.245.13) Section 17.3.1, Table 17-2 and Table 17-3. Measurements are made at compliance point T.

NOTE Ensure that the **Signaling Rate** setting in the **Configure** tab of the Compliance Test Application must match the frequency of the acquired input signal.

PAM4 Transmitter Characteristics

Table 4 Transmitter Electrical Output and Output Jitter Specifications

Parameter	Symbol	Min. Value	Max. Value	Units	Conditions
Baud Rate	T_Baud	18.0	29.0	Gsym/s	
Output Differential Voltage	T_Vdiff	-	1200	mVppd	See Notes 1, 2
DC Common mode Voltage	T_Vcm	0	1.9	V	See Note 2
Output AC Common Mode Voltage	T_VcmAC	-	30	mVrms	See Notes 1, 2
Single-ended Transmitter Output Voltage	T_Vse	-0.3	1.9	V	See Notes 1, 2
Differential Output Return Loss	T_SDD22			dB	See Equation 17-4 in the specification
Common Mode Output Return Loss	T_SCC22			dB	See Equation 17-5 in the specification
Level Separation Mismatch Ratio	T_RLM	0.95	-	-	See Notes 1, 2, 3, 4
Steady-state Voltage	T_Vf	0.4	0.6	V	
Linear Fit Pulse Peak	T_Pk	0.83 x T_Vf	-	V	
Signal-to-Noise-and-Distortion-Ratio	T_SNDR	31	-	dB	
Uncorrelated Jitter (time interval from 0.005% to 99.995% of the probability distribution)	T_J_{4u}	-	0.118	UI	See Note 5
Uncorrelated jitter RMS (standard deviation of the probability distribution)	T_J_{RMS}	-	0.023	UIrms	
Even-Odd Jitter	T_EOJ	-	0.019	UIpp	

Note 1: Signals are specified as measured through a fourth-order Bessel-Thomson low-pass response with 4 MHz 3 dB bandwidth.

Note 2: Measured as described in Section 17.3.1.2 in the specification. T_Vdiff min is set by the steady-state voltage T_Vf min.

Note 3: Measured as described in Section 17.3.1.6 in the specification.

Note 4: T_RLM is defined in section 16.C.4.3 in the specification.

Note 5: Measured as described in Section 17.3.1.7 in the specification.

Jitter and Signaling Rate Measurements

The Jitter and Signaling Rate Measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

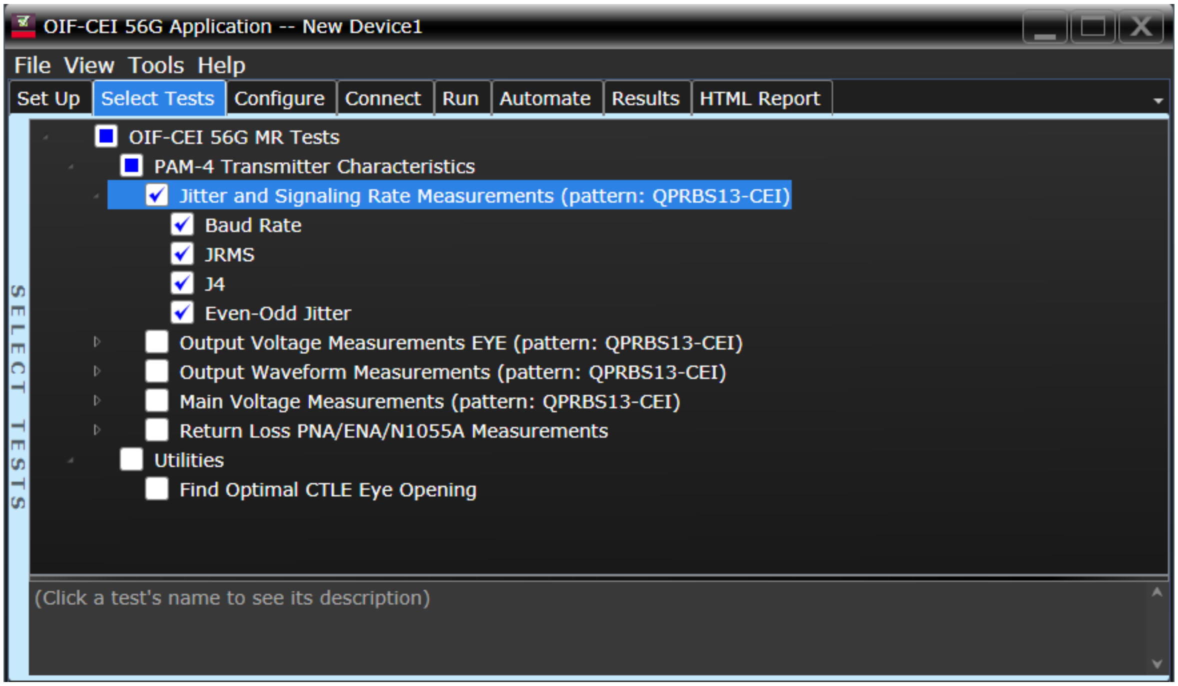


Figure 26 Selecting Jitter and Signaling Rate Measurements

Refer to Table 4 for the pass limits for each test.

For information on the measurement algorithm for each Jitter and Signaling Rate Measurements (pattern: QPRBS13-CEI) tests, see:

- "Baud Rate" on page 106
- "JRMS" on page 107
- "J4" on page 108
- "Even-Odd Jitter" on page 109

Baud Rate

Test Overview The purpose of this test is to verify that the baud rate is between 18 and 29 GBd.

Pass Condition Refer to Table 4.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Check that the signal is connected, has a bit-rate of 25.78125 Gbps and that data pattern exists (QPRBS13-CEI must be used for this test).
3 In the **Configure** tab, set **Signaling Rate** to 25.78125 Gb/s.
4 Measure minimum, maximum and mean baud rate.
5 Report minimum and maximum values.
6 Compare the baud rate value with the range between 18 and 29 GBd. Report the resulting value.

JRMS

Test Overview The purpose of this test is to verify that differential signal's JRMS is less than 0.023 UI_{RMS}. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Condition Refer to Table 4.

Measurement Algorithm

1 Obtain sample or acquire signal data. Set acquisition depth to five times the length of the QPRBS13-CEI pattern.

NOTE

For DSO-Z Series Oscilloscopes, connections must be established between Data+ to Channel 1R and Data- to Channel 3R to measure the defined 12 edges.

For UXR Series Oscilloscopes, connections must be established between Data+ to Channel 1 and Data- to Channel 2 to measure the defined 12 edges.

Irrespective of the Oscilloscope used, the signal must be of QPRBS13-CEI pattern.

2 In the **Configure** tab, set the value for the Signaling Rate as that of the Symbol Rate of the acquired signal.

3 On the Oscilloscope,

a Set Clock Recovery to OJTF First Order PLL with Nominal Data Rate (25.78125 Gbps) and Loop Bandwidth to 4 MHz.

b Using PAM4 jitter measurements, at least 10,000 QPRBS13-CEI patterns are captured to collect the measurement data of 12 edges.

c Set 4^{th} Order Bessel Thompson filter to 40 GHz.

NOTE

This measurement can run for a duration of 8-10 minutes.

4 Compare and report the JRMS value to the respective maximum specification.

J4

Test Overview The purpose of this test is to verify that differential signal's J4 is less than 0.118 UI. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Condition Refer to Table 4.

Measurement Algorithm

1 Obtain sample or acquire signal data. Set acquisition depth to five times the length of the QPRBS13-CEI pattern.

NOTE

For DSO-Z Series Oscilloscopes, connections must be established between Data+ to Channel 1R and Data- to Channel 3R to measure the defined 12 edges.

For UXR Series Oscilloscopes, connections must be established between Data+ to Channel 1 and Data- to Channel 2 to measure the defined 12 edges.

Irrespective of the Oscilloscope used, the signal must be of QPRBS13-CEI pattern.

2 In the **Configure** tab, set the value for the Signaling Rate as that of the Symbol Rate of the acquired signal.

3 On the Oscilloscope,

   a Set Clock Recovery to OJTF First Order PLL with Nominal Data Rate (25.78125 Gbps) and Loop Bandwidth to 4 MHz.

   b Using PAM4 jitter measurements, at least 10,000 QPRBS13-CEI patterns are captured to collect the measurement data of 12 edges.

   c Set 4^{th} Order Bessel Thompson filter to 40 GHz.

NOTE

This measurement can run for a duration of 8-10 minutes.

4 Compare and report the J4 value to the respective maximum specification.

Even-Odd Jitter

Test Overview The purpose of this test is to verify that differential signal's Even-Odd Jitter is less than 0.019 UIpp. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Condition Refer to Table 4.

Measurement Algorithm

1 Obtain sample or acquire signal data. Set acquisition depth to five times the length of the QPRBS13-CEI pattern.

NOTE

For DSO-Z Series Oscilloscopes, connections must be established between Data+ to Channel 1R and Data- to Channel 3R to measure the defined 12 edges.

For UXR Series Oscilloscopes, connections must be established between Data+ to Channel 1 and Data- to Channel 2 to measure the defined 12 edges.

Irrespective of the Oscilloscope used, the signal must be of QPRBS13-CEI pattern.

2 In the **Configure** tab, set the value for the Signaling Rate as that of the Symbol Rate of the acquired signal.

3 On the Oscilloscope,

  a Set Clock Recovery to OJTF First Order PLL with Nominal Data Rate (25.78125 Gbps) and Loop Bandwidth to 4 MHz.

  b Using PAM4 jitter measurements, at least 10,000 QPRBS13-CEI patterns are captured to collect the measurement data of 12 edges.

  c Set 4^{th} Order Bessel Thompson filter to 40 GHz.

NOTE

This measurement can run for a duration of 8-10 minutes.

4 Compare and report the Even-Odd Jitter value to the respective maximum specification.

Output Voltage Measurements EYE

The Output Voltage Measurement EYE procedures for a signal with QPRBS13-CEI pattern that are described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

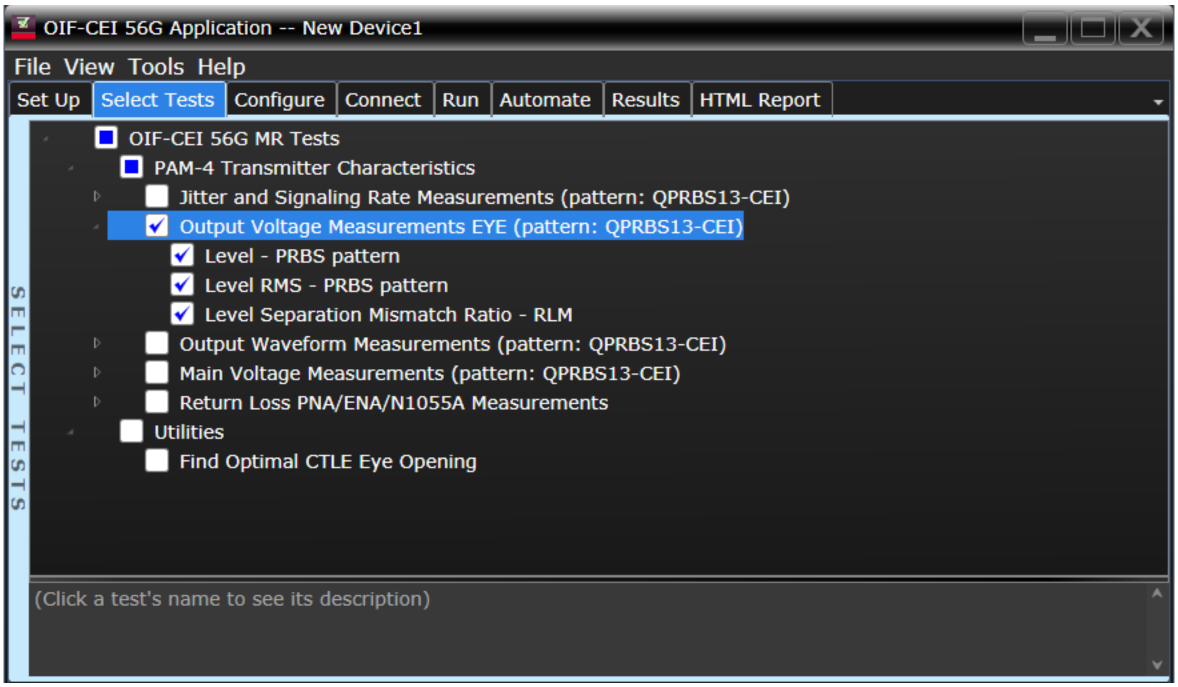


Figure 27 Selecting Output Voltage Measurements EYE Tests

Refer to Table 4 for the pass limits for each test.

For information on the measurement algorithm for each Output Voltage Measurements EYE (pattern: QPRBS13-CEI) tests, see:

- “Level - PRBS pattern” on page 111
- “Level RMS - PRBS pattern” on page 112
- “Level Separation Mismatch Ratio - RLM” on page 113

NOTE The tests Level - PRBS pattern and Level RMS - PRBS pattern are considered as “Information-Only” tests and cannot be used for compliance validation.

Level - PRBS pattern

Test Overview The purpose of this test is to obtain the mean voltage of each level of the signal with QPRBS13-CEI pattern.

Pass Condition Not applicable as the test result is considered as “Information Only”.

Measurement Algorithm

1. Check that signal is connected and proper data pattern exists (QPRBS13-CEI pattern must be used for this test).
2. V_{-1}, $V_{-1/3}$, $V_{+1/3}$ and V_{+1} are the mean signal levels of the symbols corresponding to the PAM4 symbol levels -1, -1/3, +1/3 and +1 respectively.
3. The mean voltage level V_{mid} is defined as

$$V_{mid} = (V_{-1} + V_{+1}) / 2$$

4. Report this value for information-only purpose.

Level RMS - PRBS pattern

Test Overview The purpose of this test is to obtain the of the RMS level of the signal with QPRBS13-CEI pattern.

Pass Condition Not applicable as the test result is considered as "Information Only".

Measurement Algorithm

1 Run the Level - PRBS Pattern test as a prerequisite to this test.
2 The minimum signal level RMS is calculated.
3 Report this value for information-only purpose.

Level Separation Mismatch Ratio - RLM

Test Overview The purpose of this test is to obtain the of the Separation Mismatch Ratio level (RLM) of the signal with QPRBS13-CEI pattern.

Pass Condition Refer to Table 4.

Measurement Algorithm

1. Run the Level - PRBS Pattern as a prerequisite to this test to calculate the mid-range level.
2. The mean signal levels are normalized so that V_{-1} corresponds to -1, $V_{-1/3}$ to -ES1, $V_{+1/3}$ to ES2 and V_{+1} to 1.
3. ES1 and ES2 are calculated using the following equations, respectively:

$$ES1 = (V_{-1/3} - V_{mid}) / (V_{-1} - V_{mid})$$

$$ES2 = (V_{+1/3} - V_{mid}) / (V_{+1} - V_{mid})$$

4. The level separation mismatch ratio R_{LM} is defined as:

$$R_{LM} = \min [(3 \times ES1), (3 \times ES2), (2 - 3 \times ES1), (2 - 3 \times ES2)]$$

5. Compare the resulting value with 0.95.

Output Waveform Measurements

The Transmitter Output Waveform Measurement procedures for Transition Time that are described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

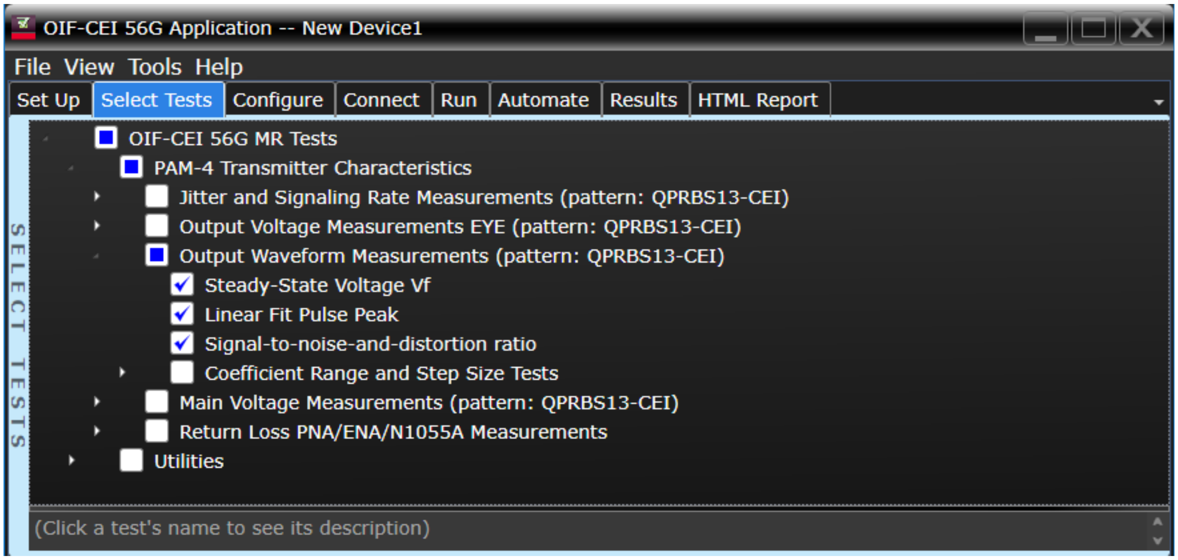


Figure 28 Selecting Output Waveform Measurements

Refer to Table 4 for the pass limits for each test.

For information on the measurement algorithm for each Output Waveform Measurements (pattern: QPRBS13-CEI) tests, see:

- "Steady State Voltage Vf" on page 115
- "Linear Fit Pulse Peak" on page 116
- "Signal-to-noise-and-distortion ratio" on page 117

Steady State Voltage V_f

Test Overview The purpose of this test is to verify that the Steady State Voltage Vf is within the range from 0.4V to 0.6V.

Pass Condition Refer to Table 4.

Measurement Algorithm

1 Check that signal is connected and proper data pattern exists (QPRBS13-CEI must be used for this test).

2 Enable (set to ON) pattern averaging to capture QPRBS13-CEI pattern at 32 points per UI for 16 averages.

3 The Steady State Voltage Vf is calculated. The resulting value is the sum of columns of p(k)/M. $N_p = 12$, $D_p = 2$.

4 Report the result.

Linear Fit Pulse Peak

Test Overview The purpose of this test is to verify the Linear Fit Pulse Peak is greater than 0.83 x T_Vf.

Pass Condition Refer to Table 4.

Measurement Algorithm

1. Check that signal is connected and proper data pattern exists (QPRBS13-CEI must be used for this test).
2. Enable (set to ON) pattern averaging to capture QPRBS13-CEI pattern at 32 points per UI for 16 averages.
3. The Linear Fit Pulse Peak is calculated. The resulting value is the sum of columns of p(k). N_p = 12, D_p = 2.
4. Report the result.

Signal-to-noise-and-distortion ratio

Test Overview The purpose of this test is to verify that the Signal-to-noise-and-distortion ratio (SNDR) is greater than 31dB.

Pass Condition Refer to Table 4.

Measurement Algorithm

1 Calculate SNDR using measurements from Level RMS - PRBS pattern test and the error calculated from Linear Fit Pulse Peak test.

2 Compare and report the value of SNDR with 31dB.

Coefficient Range and Step Size Tests

Test Overview The purpose of this test is to measure the Normalized Amplitude and Step Size values at Coefficients c(-1), c(0) and c(1).

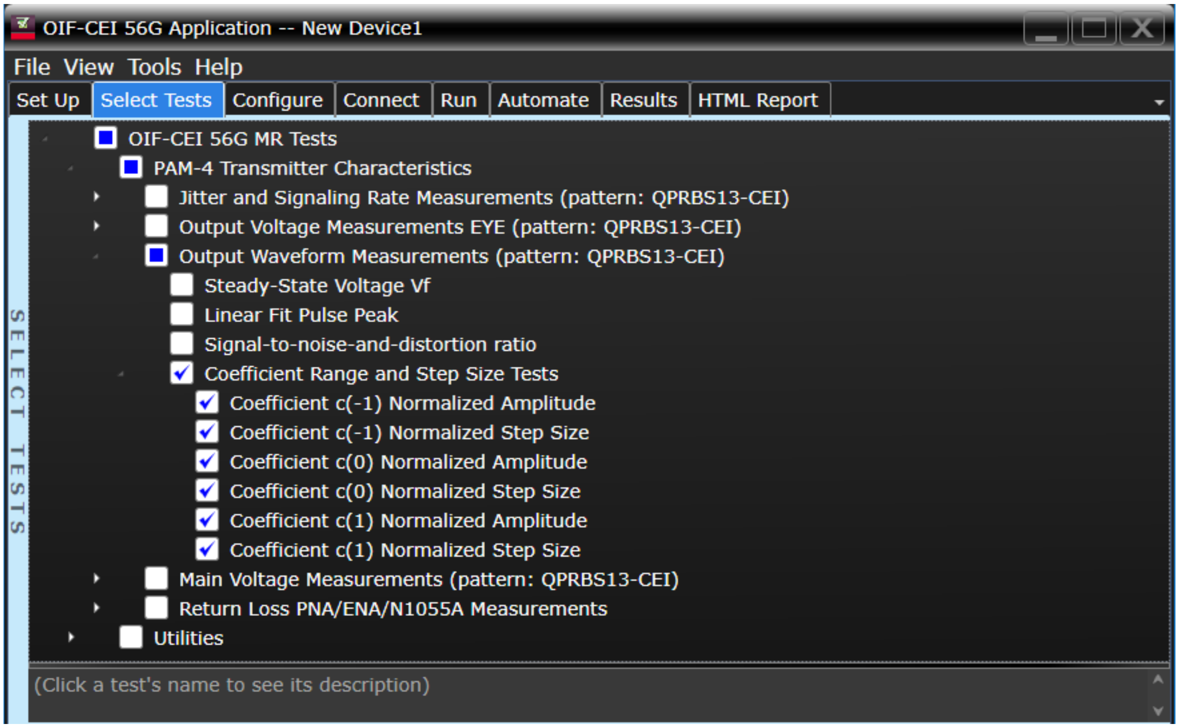


Figure 29 Selecting Coefficient Range and Step Size Tests

Pass Condition Refer to *Table 17-4* of the *OIF-CEI 56G MR specification* document.

Measurement Algorithm

1 Configure the Preset signal.
2 Enable (set to ON) pattern averaging to capture QPRBS13-CEI pattern at 32 points per UI for 16 averages.
3 Calculate linear fit p(k) of signal pattern captured in the previous step. Calculate Rm and w.
4 Set the first step.
5 Enable (set to ON) pattern averaging to capture QPRBS13-CEI pattern at 32 points per UI for 16 averages.
6 For the Dw and Nw values set in Configure tab of the Test Application, calculate qi of the signal configured in step 4 and multiply it by w calculated in step 3.
7 The coefficient values from qi are step 0.
8 Request the next coefficient step.
9 Repeat steps 5-7 to get the next coefficient values.
10 Loop through each step (7-9) requesting the next coefficient steps.
11 Calculate the amplitude and coefficient differences for each step and report each step.
12 Report the resulting values.

Main Voltage Measurements

The PAM4 Main Voltage measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

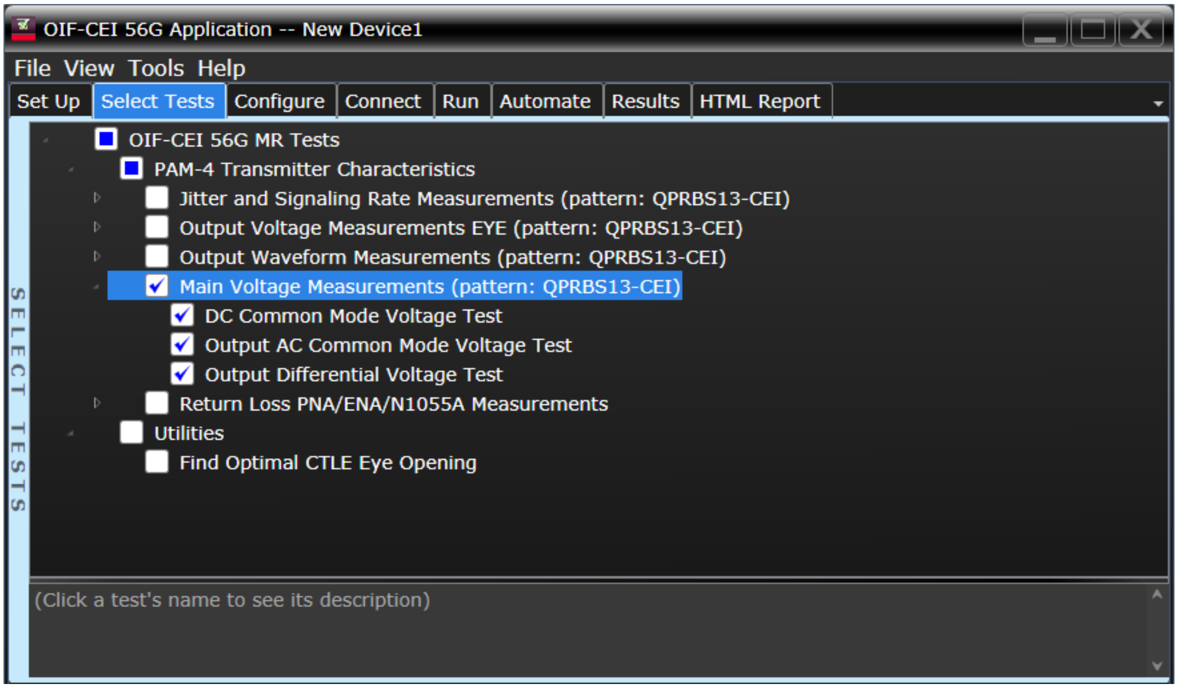


Figure 30 Selecting Main Voltage Measurements

Refer to Table 4 for the pass limits for each test.

For information on the measurement algorithm for each Main Voltage Measurements (pattern: QPRBS13-CEI) tests, see:

- "DC Common Mode Voltage Test" on page 120
- "Output AC Common Mode Voltage Test" on page 121
- "Output Differential Voltage Test" on page 122

DC Common Mode Voltage Test

Test Overview The purpose of this test is to verify that the common mode signal of the differential pair is between 0V to 1.9V.

> **NOTE** This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition Refer to Table 4.

Measurement Algorithm

1 Obtain sample or acquire signal data.

2 Verify that there is a signal and that the connection is dual single-ended.

3 Measure the DC Common Mode Output voltage.

- If the Test Application is running on the DSA/DSO Z-Series Oscilloscope, the **Instrument Setup** is preset to **Real Edge**.
- If the Test Application is running on the UXR Series Oscilloscope, perform the measurement with the **Instrument Setup** set to **Channels 1 and 2**. Repeat the measurement with the Instrument Setup set to **Channels 3 and 4**.

4 Compare the voltage measurement to the range from 0V to 1.9V.

Output AC Common Mode Voltage Test

Test Overview The purpose of this test is to verify that the Output AC Common Mode Voltage test is less than 30mVrms.

NOTE This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition Refer to Table 4.

Measurement Algorithm

1. Obtain sample or acquire signal data.
2. Verify that there is a signal and that the connection is dual single-ended.
3. Measure the Output AC Common Mode Voltage.
   - If the Test Application is running on the DSA/DSO Z-Series Oscilloscope, the **Instrument Setup** is preset to **Real Edge**.
   - If the Test Application is running on the UXR Series Oscilloscope, perform the measurement with the **Instrument Setup** set to **Channels 1 and 2**. Repeat the measurement with the Instrument Setup set to **Channels 3 and 4**.
4. Compare the voltage measurement to 30mV.

Output Differential Voltage Test

Test Overview The purpose of this test is to verify that the peak-to-peak output voltage of the differential signal on a QPRBS13-CEI pattern is less than 1200mVppd.

Pass Condition Refer to Table 4.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is connected, has TX enabled and has a QPRBS13-CEI pattern.
3 Measure the peak-to-peak output voltage of the differential signal of DUT+ and DUT-.
4 Compare the maximum peak-to-peak output differential voltage to 1200mV.

Return Loss PNA/ENA/N1055A Measurements

The Return Loss ENA/PNA/N1055A Measurement procedures that are described in this section are performed using a Keysight Infiniium oscilloscope, PNA, ENA or N1055A and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application. The Compliance Test Application controls the PNA/ENA/N1055A to set the test limits and run the tests. You must ensure that the connected PNA/ENA/N1055A is calibrated.

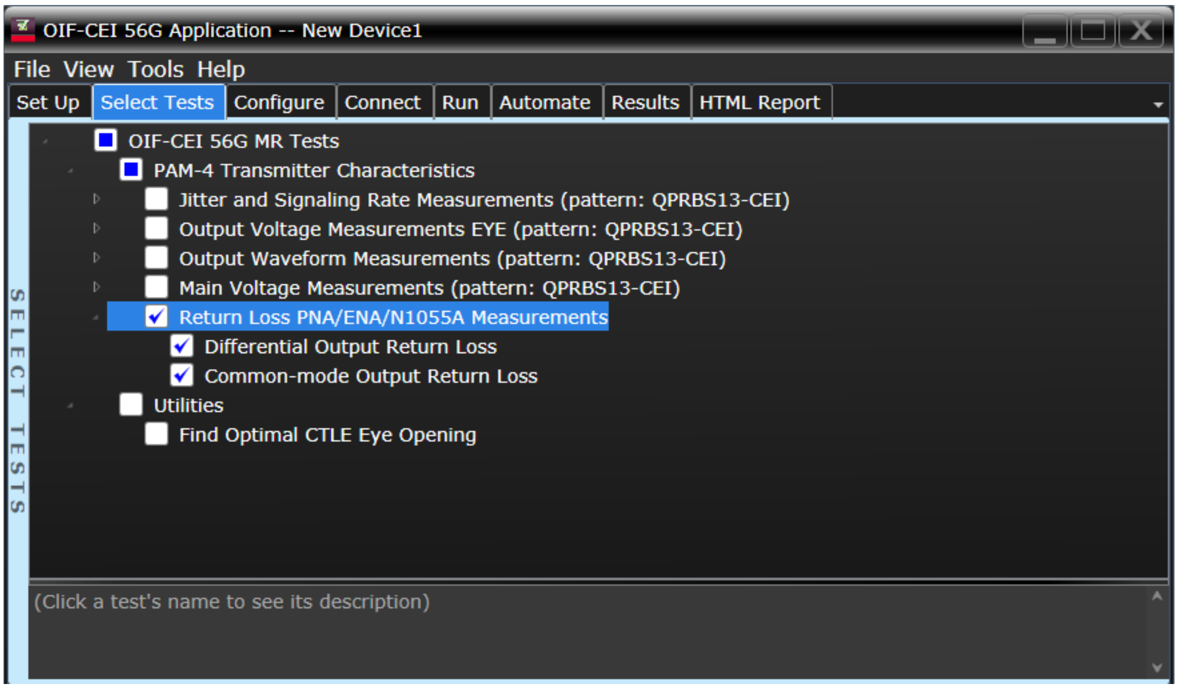


Figure 31 Selecting Return Loss Measurement Tests

Refer to Table 4 for the pass limits for each test.

For information on the measurement algorithm for each Return Loss ENA/PNA/N1055A Measurements, see:

- "Differential Output Return Loss" on page 124
- "Common-mode Output Return Loss" on page 125

Differential Output Return Loss

Measurement Algorithm

1. Ensure that the PNA/ENA/N1055A is physically connected and calibrated.
2. In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3. Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4. Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5. Compare the reported values with the specification to check for compliance.

Common-mode Output Return Loss

Measurement Algorithm

1. Ensure that the PNA/ENA/N1055A is physically connected and calibrated.
2. In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3. Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4. Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5. Compare the reported values with the specification to check for compliance.

8 PAM4 Transmitter Characteristics for OIF-CEI 56G LR

This section provides the Methods of Implementation (MOIs) for the OIF-CEI 56G PAM4 Transmitter Electrical Characteristics at compliance point T as specified in CEI-56G-LR-PAM4 Implementation Agreement (Clause 21, Document: OIF2014.380.09) Section 21.3.1, Table 21-2 and Table 21-3. Measurements are made at compliance point T.

NOTE Ensure that the **Signaling Rate** setting in the **Configure** tab of the Compliance Test Application must match the frequency of the acquired input signal.

PAM4 Transmitter Characteristics

Table 5 Transmitter Electrical Output and Output Jitter Specifications

Parameter	Symbol	Min. Value	Max. Value	Units	Conditions
Baud Rate	T_Baud	18.0	29.0	Gsym/s	
Output Differential Voltage	T_Vdiff	-	1200	mVppd	See Notes 1, 2
DC Common mode Voltage	T_Vcm	0	1.9	V	See Note 2
Output AC Common Mode Voltage	T_VcmAC	-	30	mVrms	See Notes 1, 2
Differential Output Return Loss	T_SDD22			dB	See Equation 21-4 in the specification
Common Mode Output Return Loss	T_SCC22			dB	See Equation 21-5 in the specification
Level Separation Mismatch Ratio	T_RLM	0.95	-	-	See Notes 1, 2, 3, 4
Steady-state Voltage	T_Vf	0.4	0.6	V	
Linear Fit Pulse Peak	T_Pk	0.83 x T_Vf	-	V	
Signal-to-Noise-and-Distortion-Ratio	T_SNDR	31	-	dB	
Uncorrelated Jitter (time interval from 0.005% to 99.995% of the probability distribution)	T_J_{4u}	-	0.118	UI	See Note 5
Uncorrelated jitter RMS (standard deviation of the probability distribution)	T_J_{RMS}	-	0.023	UIrms	
Even-Odd Jitter	T_EOJ	-	0.019	UIpp	

Note 1: Signals are specified as measured through a fourth-order Bessel-Thomson low-pass response with 4 MHz 3 dB bandwidth.

Note 2: Measured as described in Section 21.3.1.2 in the specification. T_Vdiff min is set by the steady-state voltage T_Vf min.

Note 3: Measured as described in Section 21.3.1.6 in the specification.

Note 4: T_RLM is defined in section 16.C.4.3 in the specification.

Note 5: Measured as described in Section 21.3.1.7 in the specification.

Jitter and Signaling Rate Measurements

The Jitter and Signaling Rate Measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

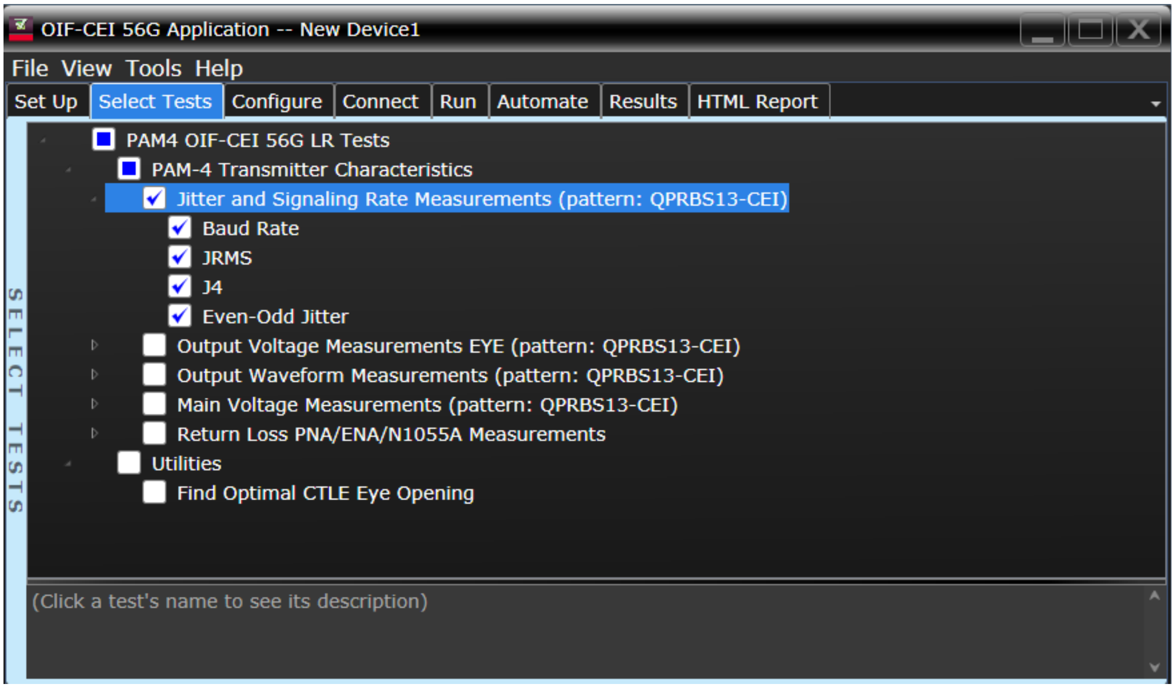


Figure 32 Selecting Jitter and Signaling Rate Measurements

Refer to Table 5 for the pass limits for each test.

For information on the measurement algorithm for each Jitter and Signaling Rate Measurements (pattern: QPRBS13-CEI) tests, see:

- “Baud Rate” on page 130
- “JRMS” on page 131
- “J4” on page 132
- “Even-Odd Jitter” on page 133

Baud Rate

Test Overview The purpose of this test is to verify that the baud rate is between 18 and 29 GBd.

Pass Condition Refer to Table 5.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Check that the signal is connected, has a bit-rate of 25.78125 Gbps and that data pattern exists (QPRBS13-CEI must be used for this test).
3 In the **Configure** tab, set **Signaling Rate** to 25.78125 Gb/s.
4 Measure minimum, maximum and mean baud rate.
5 Report minimum and maximum values.
6 Compare the baud rate value with the range between 18 and 29 GBd. Report the resulting value.

JRMS

Test Overview The purpose of this test is to verify that differential signal's JRMS is less than 0.023 UI_{RMS}. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Condition Refer to Table 5.

Measurement Algorithm

1 Obtain sample or acquire signal data. Set acquisition depth to five times the length of the QPRBS13-CEI pattern.

NOTE

For DSO-Z Series Oscilloscopes, connections must be established between Data+ to Channel 1R and Data- to Channel 3R to measure the defined 12 edges.

For UXR Series Oscilloscopes, connections must be established between Data+ to Channel 1 and Data- to Channel 2 to measure the defined 12 edges.

Irrespective of the Oscilloscope used, the signal must be of QPRBS13-CEI pattern.

2 In the **Configure** tab, set the value for the Signaling Rate as that of the Symbol Rate of the acquired signal.

3 On the Oscilloscope,

a Set Clock Recovery to OJTF First Order PLL with Nominal Data Rate (25.78125 Gbps) and Loop Bandwidth to 4 MHz.

b Using PAM4 jitter measurements, at least 10,000 QPRBS13-CEI patterns are captured to collect the measurement data of 12 edges.

c Set 4^{th} Order Bessel Thompson filter to 40 GHz.

NOTE

This measurement can run for a duration of 8-10 minutes.

4 Compare and report the JRMS value to the respective maximum specification.

J4

Test Overview The purpose of this test is to verify that differential signal's J4 is less than 0.118 UI. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Condition Refer to Table 5.

Measurement Algorithm

1 Obtain sample or acquire signal data. Set acquisition depth to five times the length of the QPRBS13-CEI pattern.

NOTE

For DSO-Z Series Oscilloscopes, connections must be established between Data+ to Channel 1R and Data- to Channel 3R to measure the defined 12 edges.

For UXR Series Oscilloscopes, connections must be established between Data+ to Channel 1 and Data- to Channel 2 to measure the defined 12 edges.

Irrespective of the Oscilloscope used, the signal must be of QPRBS13-CEI pattern.

2 In the **Configure** tab, set the value for the Signaling Rate as that of the Symbol Rate of the acquired signal.

3 On the Oscilloscope,

a Set Clock Recovery to OJTF First Order PLL with Nominal Data Rate (25.78125 Gbps) and Loop Bandwidth to 4 MHz.

b Using PAM4 jitter measurements, at least 10,000 QPRBS13-CEI patterns are captured to collect the measurement data of 12 edges.

c Set 4^{th} Order Bessel Thompson filter to 40 GHz.

NOTE

This measurement can run for a duration of 8-10 minutes.

4 Compare and report the J4 value to the respective maximum specification.

Even-Odd Jitter

Test Overview The purpose of this test is to verify that differential signal's Even-Odd Jitter is less than 0.019 UIpp. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Condition Refer to Table 5.

Measurement Algorithm

1 Obtain sample or acquire signal data. Set acquisition depth to five times the length of the QPRBS13-CEI pattern.

> **NOTE**
>
> For DSO-Z Series Oscilloscopes, connections must be established between Data+ to Channel 1R and Data- to Channel 3R to measure the defined 12 edges.
>
> For UXR Series Oscilloscopes, connections must be established between Data+ to Channel 1 and Data- to Channel 2 to measure the defined 12 edges.
>
> Irrespective of the Oscilloscope used, the signal must be of QPRBS13-CEI pattern.

2 In the **Configure** tab, set the value for the Signaling Rate as that of the Symbol Rate of the acquired signal.

3 On the Oscilloscope,

   a Set Clock Recovery to OJTF First Order PLL with Nominal Data Rate (25.78125 Gbps) and Loop Bandwidth to 4 MHz.

   b Using PAM4 jitter measurements, at least 10,000 QPRBS13-CEI patterns are captured to collect the measurement data of 12 edges.

   c Set 4^{th} Order Bessel Thompson filter to 40 GHz.

> **NOTE**
>
> This measurement can run for a duration of 8-10 minutes.

4 Compare and report the Even-Odd Jitter value to the respective maximum specification.

Output Voltage Measurements EYE

The Transmitter Output Voltage Measurement procedures for a signal with QPRBS13-CEI pattern that are described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

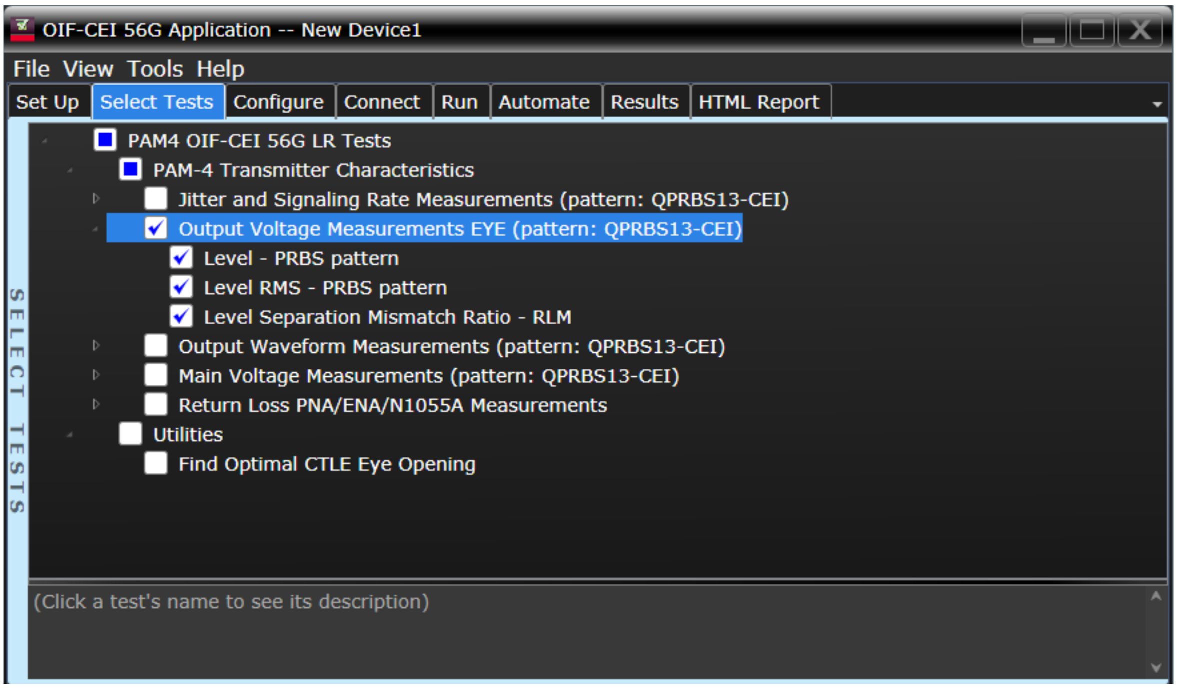


Figure 33 Selecting Output Voltage Measurements EYE Tests

Refer to Table 5 for the pass limits for each test.

For information on the measurement algorithm for each Output Voltage Measurements EYE (pattern: QPRBS13-CEI) tests, see:

- "Level - PRBS Pattern" on page 135
- "Level RMS - PRBS Pattern" on page 136
- "Level Separation Mismatch Ratio - RLM" on page 137

NOTE The tests Level - PRBS pattern and Level RMS - PRBS pattern are considered as "Information-Only" tests and cannot be used for compliance validation.

Level - PRBS Pattern

Test Overview The purpose of this test is to obtain the mean voltage of each level of the signal with QPRBS13-CEI pattern.

Pass Condition Not applicable as the test result is considered as “Information Only”.

Measurement Algorithm

1. Check that signal is connected and proper data pattern exists (QPRBS13-CEI pattern must be used for this test).
2. V_{-1}, $V_{-1/3}$, $V_{+1/3}$ and V_{+1} are the mean signal levels of the symbols corresponding to the PAM4 symbol levels -1, -1/3, +1/3 and +1 respectively.
3. The mean voltage level V_{mid} is defined as

$$V_{mid} = (V_{-1} + V_{+1}) / 2$$

4. Report this value for information-only purpose.

Level RMS - PRBS Pattern

Test Overview The purpose of this test is to obtain the of the RMS level of the signal with QPRBS13-CEI pattern.

Pass Condition Not applicable as the test result is considered as “Information Only”.

Measurement Algorithm

1 Run the Level - PRBS Pattern test as a prerequisite to this test.
2 The minimum signal level RMS is calculated.
3 Report this value for information-only purpose.

Level Separation Mismatch Ratio - RLM

Test Overview The purpose of this test is to obtain the of the Separation Mismatch Ratio level (RLM) of the signal with QPRBS13-CEI pattern.

Pass Condition Refer to Table 5.

Measurement Algorithm

1 Run the Level - PRBS Pattern as a prerequisite to this test to calculate the mid-range level.

2 The mean signal levels are normalized so that V_{-1} corresponds to -1, $V_{-1/3}$ to -ES1, $V_{+1/3}$ to ES2 and V_{+1} to 1.

3 ES1 and ES2 are calculated using the following equations, respectively:

$$ES1 = (V_{-1/3} - V_{mid}) / (V_{-1} - V_{mid})$$

$$ES2 = (V_{+1/3} - V_{mid}) / (V_{+1} - V_{mid})$$

4 The level separation mismatch ratio R_{LM} is defined as:

$$R_{LM} = \min [(3 \times ES1), (3 \times ES2), (2 - 3 \times ES1), (2 - 3 \times ES2)]$$

5 Compare the resulting value with 0.95.

Output Waveform Measurements

The Output Waveform Measurement procedures that are described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

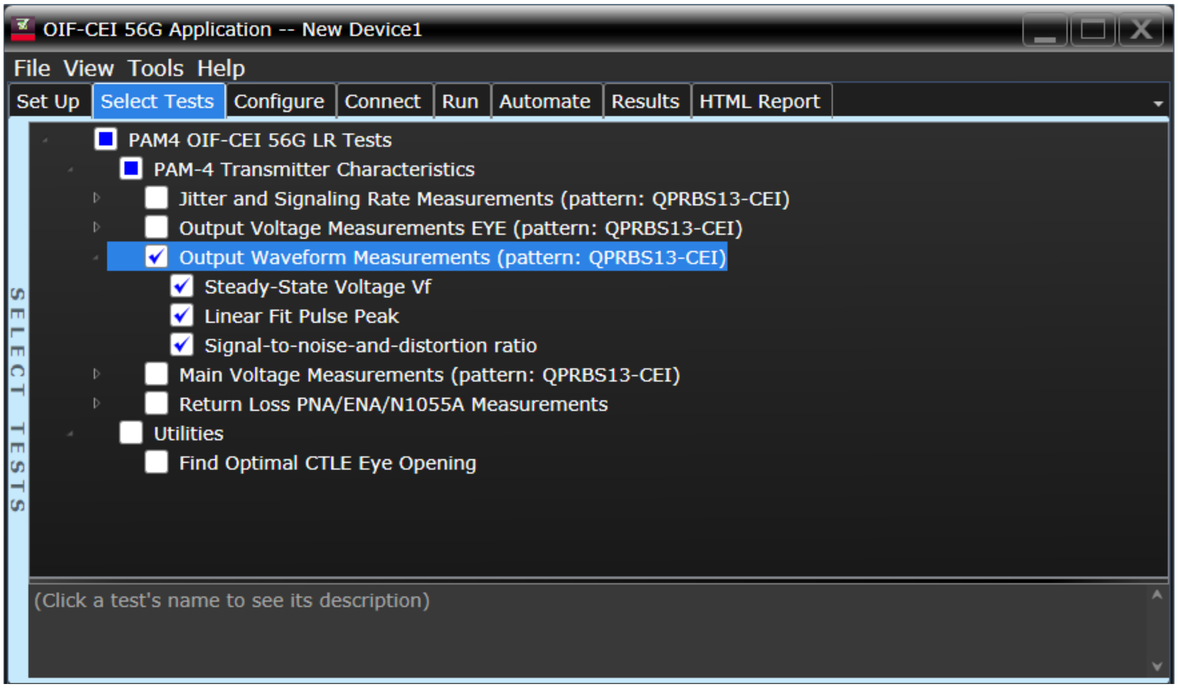


Figure 34 Selecting Output Waveform Measurements

Refer to Table 5 for the pass limits for each test.

For information on the measurement algorithm for each Output Waveform Measurements (pattern: QPRBS13-CEI) tests, see:

- “Steady State Voltage Vf” on page 139
- “Linear Fit Pulse Peak” on page 140
- “Signal-to-noise-and-distortion ratio” on page 141

Steady State Voltage V_f

Test Overview The purpose of this test is to verify that the Steady State Voltage Vf is within the range from 0.4V to 0.6V.

Pass Condition Refer to Table 5.

Measurement Algorithm

1. Check that signal is connected and proper data pattern exists (QPRBS13-CEI must be used for this test).
2. Enable (set to ON) pattern averaging to capture QPRBS13-CEI pattern at 32 points per UI for 16 averages.
3. The Steady State Voltage Vf is calculated. The resulting value is the sum of columns of p(k)/M. $N_p = 12$, $D_p = 2$.
4. Report the result.

Linear Fit Pulse Peak

Test Overview The purpose of this test is to verify the Linear Fit Pulse Peak is greater than 0.83 x T_Vf.

Pass Condition Refer to Table 5.

Measurement Algorithm

1 Check that signal is connected and proper data pattern exists (QPRBS13-CEI must be used for this test).

2 Enable (set to ON) pattern averaging to capture QPRBS13-CEI pattern at 32 points per UI for 16 averages.

3 The Linear Fit Pulse Peak is calculated. The resulting value is the sum of columns of p(k). $N_p = 12$, $D_p = 2$.

4 Report the result.

Signal-to-noise-and-distortion ratio

Test Overview The purpose of this test is to verify that the Signal-to-noise-and-distortion ratio (SNDR) is greater than 31dB.

Pass Condition Refer to Table 5.

Measurement Algorithm

1 Calculate SNDR using measurements from Level RMS - PRBS pattern test and the error calculated from Linear Fit Pulse Peak test.

2 Compare and report the value of SNDR with 31dB.

Main Voltage Measurements

The PAM4 Main Voltage measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

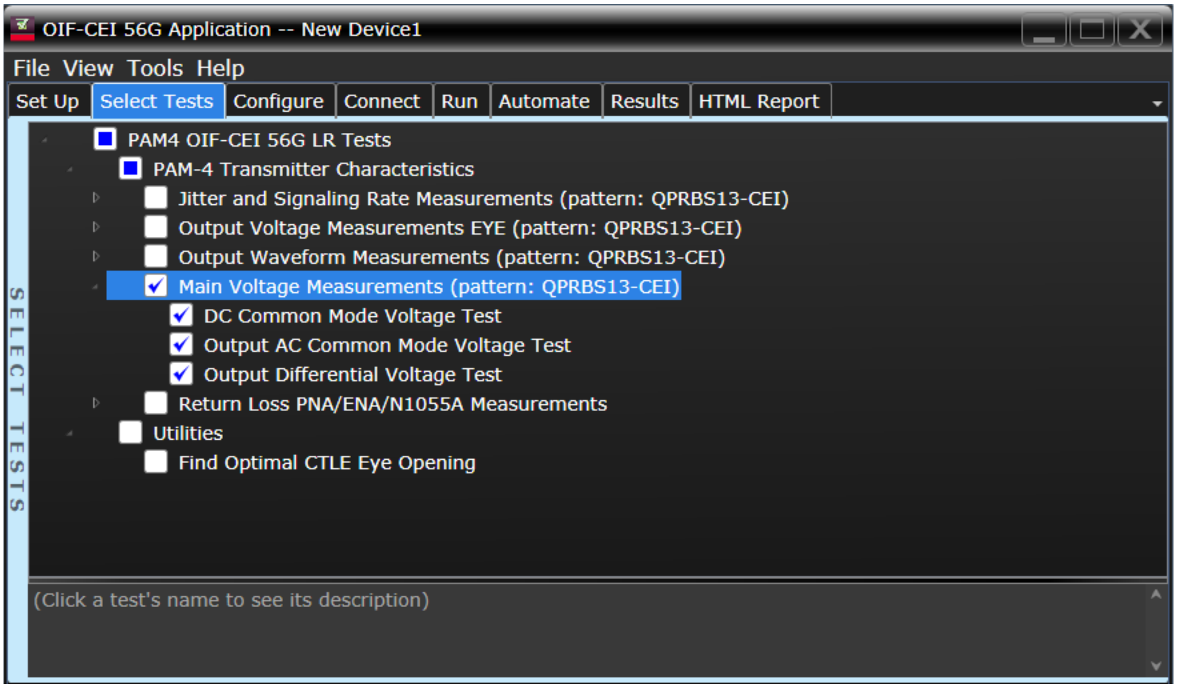


Figure 35 Selecting Main Voltage Measurements

Refer to Table 5 for the pass limits for each test.

For information on the measurement algorithm for each Main Voltage Measurements (pattern: QPRBS13-CEI) tests, see:

- "DC Common Mode Voltage Test" on page 143
- "Output AC Common Mode Voltage Test" on page 144
- "Output Differential Voltage Test" on page 145

DC Common Mode Voltage Test

Test Overview The purpose of this test is to verify that the common mode signal of the differential pair is between 0V to 1.9V.

> **NOTE** This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition Refer to Table 5.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that there is a signal and that the connection is dual single-ended.
3 Measure the DC Common Mode Output voltage.

- If the Test Application is running on the DSA/DSO Z-Series Oscilloscope, the **Instrument Setup** is preset to **Real Edge**.
- If the Test Application is running on the UXR Series Oscilloscope, perform the measurement with the **Instrument Setup** set to **Channels 1 and 2**. Repeat the measurement with the Instrument Setup set to **Channels 3 and 4**.

4 Compare the voltage measurement to the range from 0V to 1.9V.

Output AC Common Mode Voltage Test

Test Overview The purpose of this test is to verify that the Output AC Common Mode Voltage test is less than 30mVrms.

NOTE This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition Refer to Table 5.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that there is a signal and that the connection is dual single-ended.
3 Measure the Output AC Common Mode Voltage.

- If the Test Application is running on the DSA/DSO Z-Series Oscilloscope, the **Instrument Setup** is preset to **Real Edge**.
- If the Test Application is running on the UXR Series Oscilloscope, perform the measurement with the **Instrument Setup** set to **Channels 1 and 2**. Repeat the measurement with the Instrument Setup set to **Channels 3 and 4**.

4 Compare the voltage measurement to 30mV.

Output Differential Voltage Test

Test Overview The purpose of this test is to verify that the peak-to-peak output voltage of the differential signal on a QPRBS13-CEI pattern is less than 1200mVppd.

Pass Condition Refer to Table 5.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is connected, has TX enabled and has a QPRBS13-CEI pattern.
3 Measure the peak-to-peak output voltage of the differential signal of DUT+ and DUT-.
4 Compare the maximum peak-to-peak output differential voltage to 1200mV.

Return Loss PNA/ENA/N1055A Measurements

The Return Loss ENA/PNA Measurement procedures that are described in this section are performed using a Keysight Infiniium oscilloscope, PNA, ENA or N1055A and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application. The Compliance Test Application controls the PNA/ENA/N1055A to set the test limits and run the tests. You must ensure that the connected PNA/ENA/N1055A is calibrated.

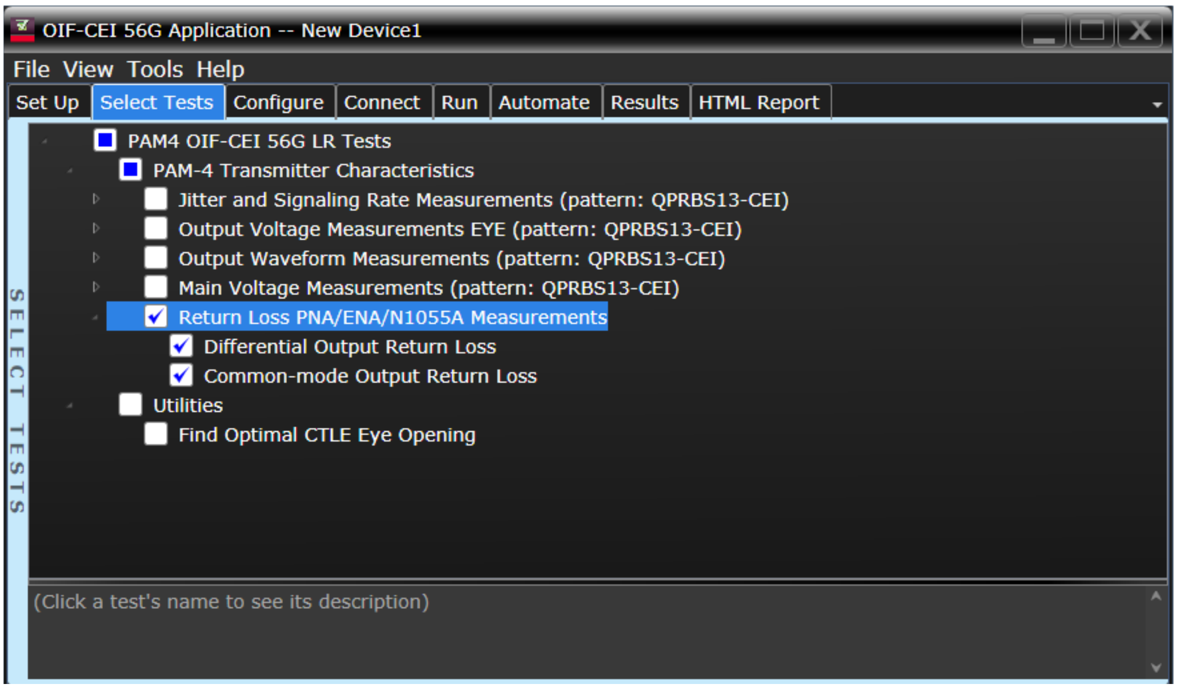


Figure 36 Selecting Return Loss Measurement Tests

Refer to Table 5 for the pass limits for each test.

For information on the measurement algorithm for each Return Loss ENA/PNA/N1055A Measurements, see:

- "Differential Output Return Loss" on page 147
- "Common-mode Output Return Loss" on page 148

Differential Output Return Loss

Measurement Algorithm

1 Ensure that the PNA/ENA/N1055A is physically connected and calibrated.
2 In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3 Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4 Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5 Compare the reported values with the specification to check for compliance.

Common-mode Output Return Loss

Measurement Algorithm

1 Ensure that the PNA/ENA/N1055A is physically connected and calibrated.
2 In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3 Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4 Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5 Compare the reported values with the specification to check for compliance.

9 NRZ Host-to-Module Electrical Recommendations at TP0a for OIF-CEI 56G VSR

This section provides the Methods of Implementation (MOIs) for the NRZ OIF-CEI VSR 56G Transmitter Characteristics at TP0a as specified in CEI-56G-VSR-NRZ Implementation Agreement (Clause 15, Document: OIF2014.277.09) Appendix 15.B.1.1, Table 15-9. Measurements are made at TP0a.

NOTE Ensure that the **Signaling Rate** setting in the **Configure** tab of the Compliance Test Application must match the frequency of the acquired input signal.

Host-to-Module transmitter output Electrical Recommendations

Table 6 Host-to-Module Electrical Recommendations at TP0a

Parameter	Symbol	Min. Value	Max. Value	Units	Conditions
Differential Voltage, pk-pk	T_Vdiff	600	-	mV	PRBS31 pattern, Emphasis Off, Note 1
Common Mode Voltage	T_Vcm	-300	2800	mV	Note 2
Differential Output Return Loss	T_SDD22	-	See section 20.3.3.2 in the specification	dB	
Transition Time: 20% to 80%	T_tr, T_tf	5	-	ps	Emphasis Off, 2 dB CTLE
Common Mode Noise, RMS	T_Ncm	-	12	mV	See section 12.3 in the specification
Uncorrelated Unbounded Gaussian jitter	T_UUGJ	-	0.15	UI	
Uncorrelated Bounded high probability jitter including EOJ	T_UBHPJ	-	0.15	UI	Note 4
Even Odd Jitter	T_EOJ	-	0.035	UI	
Total Jitter	T_TJ	-	0.28	UI	Note 3

Note 1: Maximum voltage is limited by specifications at TP1a. Minimum voltage can be lower for low loss channels.

Note 2: Load type 0 with minimum T_Vdiff, AC-Coupling or floating load.

Note 3: T_TJ includes all of the jitter components measured without any transmit equalization. A 2 dB CTLE can be used to achieve this specification. (See section 15.3.11.3 of the specification). For jitter test parameters, refer to section 12.1 in the specification, except use a CRU tracking bandwidth of f_b/5156.

Note 4: Measured with any value of transmitter equalization. See Section 12.1 in the specification.

Jitter and Signaling Rate Measurements TP0a

The Jitter and Signaling Rate Measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

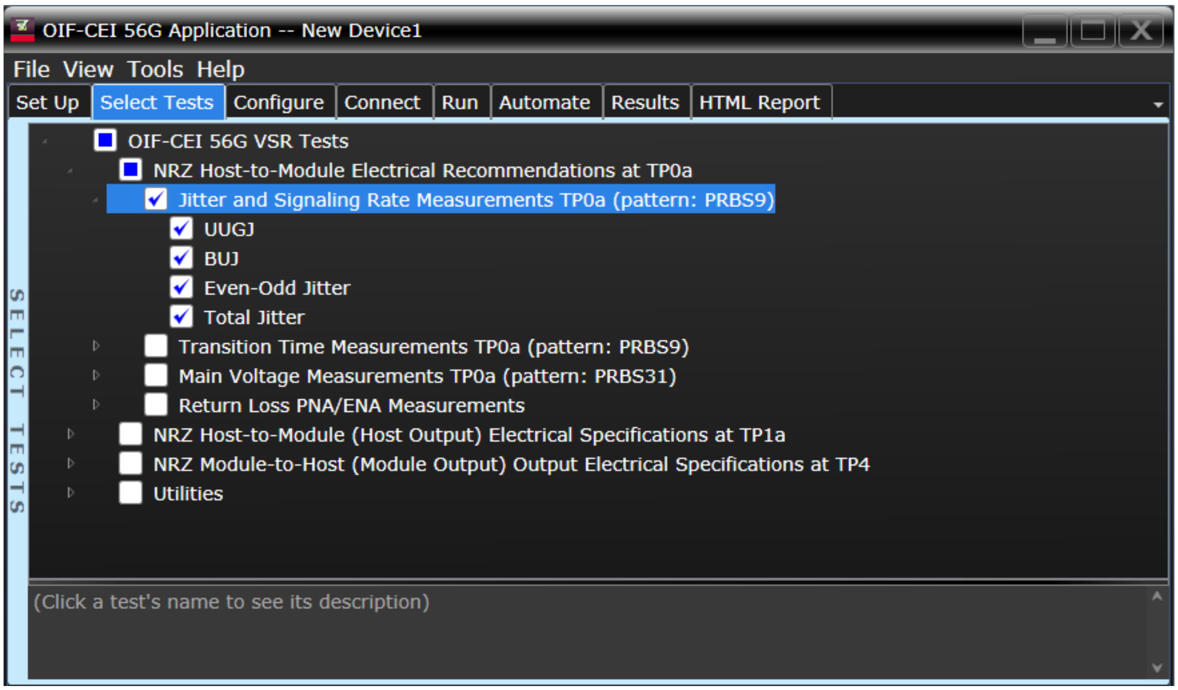


Figure 37 Selecting Jitter and Signaling Rate Measurement Tests

Refer to Table 6 for the pass limits for each test.

For information on the measurement algorithm for each Jitter and Signaling Rate Measurements TP0a (pattern: PRBS9) tests, see:

- “UUGJ” on page 152
- “BUJ” on page 153
- “Even-Odd Jitter” on page 154
- “Total Jitter” on page 155

UUGJ

Test Overview The purpose of this test is to verify that differential signal's UUGJ is less than 0.15 UI. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Condition Refer to Table 6.

Measurement Algorithm

1 Obtain sample or acquire signal data. Set acquisition depth to five times the length of the PRBS9 pattern.

NOTE

For DSO-Z Series Oscilloscopes, connections must be established between Data+ to Channel 1R and Data- to Channel 3R to measure the defined 12 edges.

For UXR Series Oscilloscopes, connections must be established between Data+ to Channel 1 and Data- to Channel 2 to measure the defined 12 edges.

Irrespective of the Oscilloscope used, the signal must be of PRBS9 pattern.

2 In the **Configure** tab, set the value for the Signaling Rate as that of the Symbol Rate of the acquired signal.

3 On the Oscilloscope,

a Set Clock Recovery to OJTF First Order PLL with Nominal Data Rate (25.78125 Gbps) and Loop Bandwidth to 4 MHz.

b Using PAM4 jitter measurements, at least 10,000 PRBS9 patterns are captured to collect the measurement data of 12 edges.

c Set 4^{th} Order Bessel Thompson filter to 40 GHz.

NOTE

This measurement can run for a duration of 8-10 minutes.

4 Compare and report the UUGJ value to the respective maximum specification.

BUJ

Test Overview The purpose of this test is to verify that differential signal's BUJ is less than 0.15 UI. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Condition Refer to Table 6.

Measurement Algorithm

1 Obtain sample or acquire signal data. Set acquisition depth to five times the length of the PRBS9 pattern.

NOTE

For DSO-Z Series Oscilloscopes, connections must be established between Data+ to Channel 1R and Data- to Channel 3R to measure the defined 12 edges.

For UXR Series Oscilloscopes, connections must be established between Data+ to Channel 1 and Data- to Channel 2 to measure the defined 12 edges.

Irrespective of the Oscilloscope used, the signal must be of PRBS9 pattern.

2 In the **Configure** tab, set the value for the Signaling Rate as that of the Symbol Rate of the acquired signal.

3 On the Oscilloscope,

a Set Clock Recovery to OJTF First Order PLL with Nominal Data Rate (25.78125 Gbps) and Loop Bandwidth to 4 MHz.

b Using PAM4 jitter measurements, at least 10,000 PRBS9 patterns are captured to collect the measurement data of 12 edges.

c Set 4^{th} Order Bessel Thompson filter to 40 GHz.

NOTE

This measurement can run for a duration of 8-10 minutes.

4 Compare and report the BUJ value to the respective maximum specification.

Even-Odd Jitter

Test Overview The purpose of this test is to verify that differential signal's Even-Odd Jitter is less than 0.035 UI. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Condition Refer to Table 6.

Measurement Algorithm

1 Obtain sample or acquire signal data. Set acquisition depth to five times the length of the PRBS9 pattern.

NOTE

For DSO-Z Series Oscilloscopes, connections must be established between Data+ to Channel 1R and Data- to Channel 3R to measure the defined 12 edges.

For UXR Series Oscilloscopes, connections must be established between Data+ to Channel 1 and Data- to Channel 2 to measure the defined 12 edges.

Irrespective of the Oscilloscope used, the signal must be of PRBS9 pattern.

2 In the **Configure** tab, set the value for the Signaling Rate as that of the Symbol Rate of the acquired signal.

3 On the Oscilloscope,

a Set Clock Recovery to OJTF First Order PLL with Nominal Data Rate (25.78125 Gbps) and Loop Bandwidth to 4 MHz.

b Using PAM4 jitter measurements, at least 10,000 PRBS9 patterns are captured to collect the measurement data of 12 edges.

c Set 4^{th} Order Bessel Thompson filter to 40 GHz.

NOTE

This measurement can run for a duration of 8-10 minutes.

4 Compare and report the Even-Odd Jitter value to the respective maximum specification.

Total Jitter

Test Overview The purpose of this test is to verify that differential signal's Total Jitter is less than 0.28 UI. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Condition Refer to Table 6.

Measurement Algorithm

1 Obtain sample or acquire signal data. Set acquisition depth to five times the length of the PRBS9 pattern.

NOTE

For DSO-Z Series Oscilloscopes, connections must be established between Data+ to Channel 1R and Data- to Channel 3R to measure the defined 12 edges.

For UXR Series Oscilloscopes, connections must be established between Data+ to Channel 1 and Data- to Channel 2 to measure the defined 12 edges.

Irrespective of the Oscilloscope used, the signal must be of PRBS9 pattern.

2 In the **Configure** tab, set the value for the Signaling Rate as that of the Symbol Rate of the acquired signal.

3 On the Oscilloscope,

a Set Clock Recovery to OJTF First Order PLL with Nominal Data Rate (25.78125 Gbps) and Loop Bandwidth to 4 MHz.

b Using PAM4 jitter measurements, at least 10,000 PRBS9 patterns are captured to collect the measurement data of 12 edges.

c Set 4^{th} Order Bessel Thompson filter to 40 GHz.

NOTE

This measurement can run for a duration of 8-10 minutes.

4 Compare and report the Total Jitter value to the respective maximum specification.

Transition Time Measurements TP0a

The NRZ Transition Time Measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

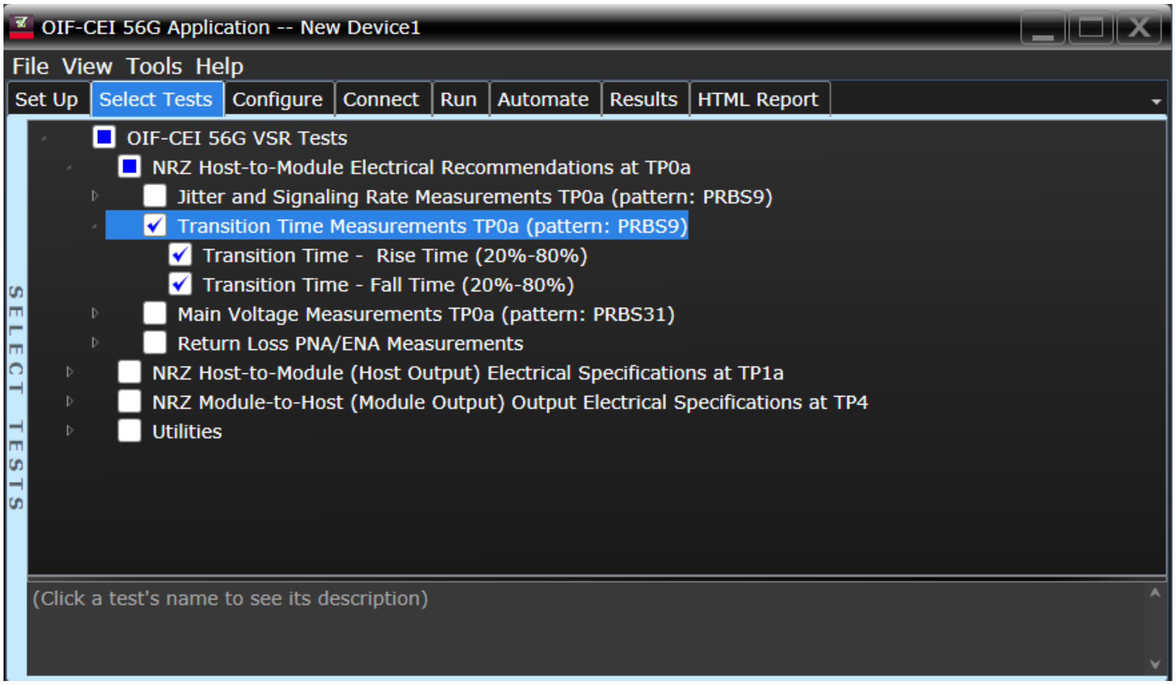


Figure 38 Selecting Transition Time Measurement Tests

Refer to Table 6 for the pass limits for each test.

For information on the measurement algorithm for each Transition Time Measurements TP0a (pattern: PRBS9) tests, see:

- “Transition Time - Rise Time (20%-80%)” on page 157
- “Transition Time - Fall Time (20%-80%)” on page 158

Transition Time - Rise Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum rise time is 7.5ps.

Pass Condition Refer to Table 6.

Measurement Algorithm

1. Obtain sample or acquire signal data.
2. Verify that the signal is PRBS9.
3. Find pattern 000333 for rise time.
4. Measure rise time from 20% to 80% of the signal amplitude.
5. Compare the minimum rise time with 7.5ps.

Transition Time - Fall Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum fall time is 7.5ps.

Pass Condition Refer to Table 6.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is PRBS9.
3 Find pattern 333000 for fall time.
4 Measure fall time from 20% to 80% of the signal amplitude.
5 Compare the minimum fall time with 7.5ps.

Main Voltage Measurements TP0a

The NRZ Main Voltage measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

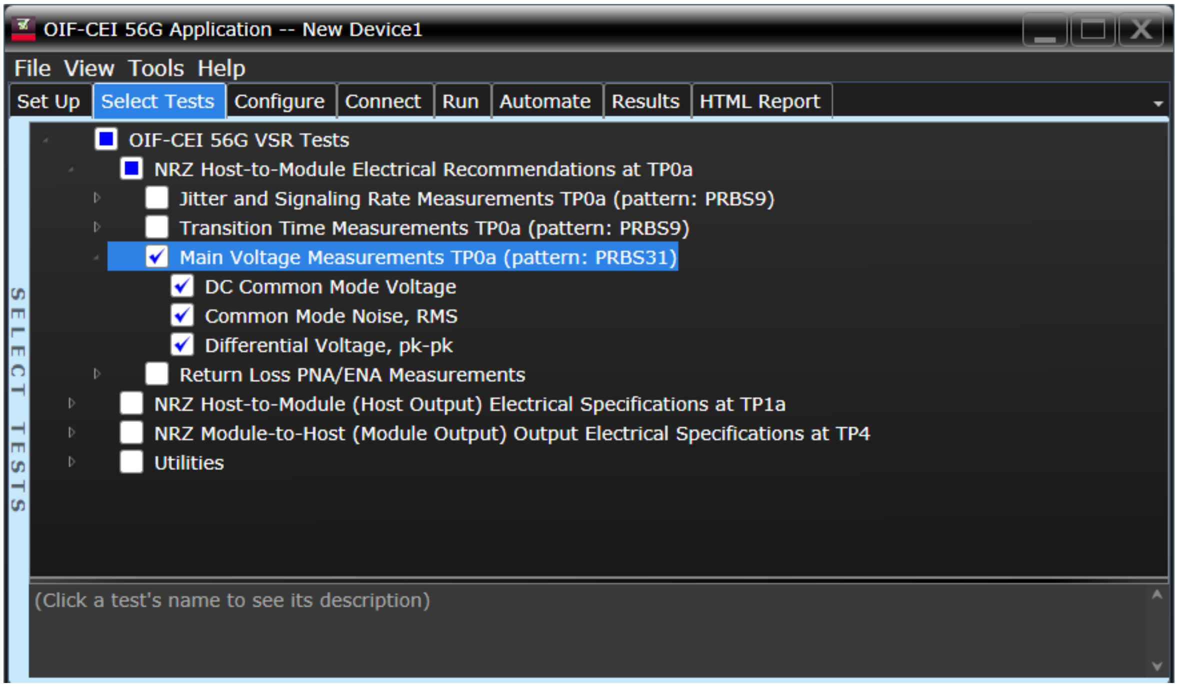


Figure 39 Selecting Main Voltage Measurement Tests

Refer to Table 6 for the pass limits for each test.

For information on the measurement algorithm for each Main Voltage Measurements TP0a (pattern: PRBS31) tests, see:

- "DC Common Mode Voltage" on page 160
- "Common Mode Noise, RMS" on page 161
- "Differential Voltage, pk-pk" on page 162

DC Common Mode Voltage

Test Overview The purpose of this test is to verify that the common mode signal of the differential pair is between -300mV to 2800mV.

NOTE This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition Refer to Table 6.

Measurement Algorithm

1 Obtain sample or acquire signal data.

2 Verify that there is a signal and that the connection is dual single-ended.

3 Measure the DC Common Mode Output voltage.

- If the Test Application is running on the DSA/DSO Z-Series Oscilloscope, the **Instrument Setup** is preset to **Real Edge**.
- If the Test Application is running on the UXR Series Oscilloscope, perform the measurement with the **Instrument Setup** set to **Channels 1 and 2**. Repeat the measurement with the Instrument Setup set to **Channels 3 and 4**.

4 Compare the voltage measurement to the range from -300mV to 2800mV.

Common Mode Noise, RMS

Test Overview The purpose of this test is to verify that the common mode signal of the differential pair rms voltage does not exceed 12mV.

NOTE This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition Refer to Table 6.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that there is a signal and that the connection is dual single-ended.
3 Measure the Common Mode Noise, RMS.

- If the Test Application is running on the DSA/DSO Z-Series Oscilloscope, the **Instrument Setup** is preset to **Real Edge**.
- If the Test Application is running on the UXR Series Oscilloscope, perform the measurement with the **Instrument Setup** set to **Channels 1 and 2**. Repeat the measurement with the Instrument Setup set to **Channels 3 and 4**.

4 Compare the voltage measurement to 12mV.

Differential Voltage, pk-pk

Test Overview The purpose of this test is to verify that the peak-to-peak voltage of the differential signal on a PRBS31 pattern is greater than 600mV.

Pass Condition Refer to Table 6.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is connected, has TX enabled and has a PRBS31 pattern.
3 Measure the peak-to-peak voltage of the differential signal of DUT+ and DUT-.
4 Compare the maximum peak-to-peak voltage to 600mV.

Return Loss ENA/PNA Measurements

The Return Loss ENA/PNA Measurement procedures that are described in this section are performed using a Keysight Infiniium oscilloscope, PNA or ENA and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application. The Compliance Test Application controls the PNA/ENA to set the test limits and run the tests. You must ensure that the connected PNA/ENA is calibrated.

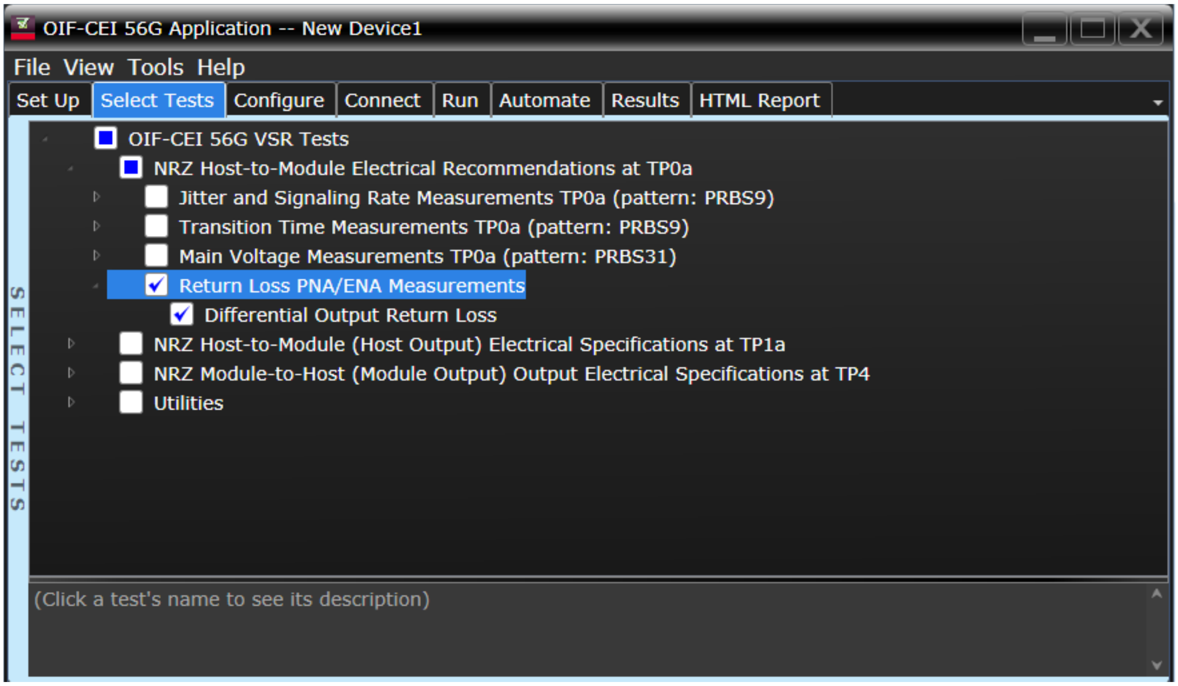


Figure 40 Selecting Return Loss Measurement Tests

Refer to Table 6 for the pass limits for each test.

For information on the measurement algorithm for each Return Loss ENA/PNA Measurements, see:

- "Differential Output Return Loss" on page 164

Differential Output Return Loss

Measurement Algorithm

1. Ensure that the PNA/ENA is physically connected and calibrated.
2. In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3. Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4. Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss. Compare the reported values with the specification to check for compliance.

10 NRZ Host-to-Module (Host Output) Electrical Specifications at TP1a for OIF-CEI 56G VSR

This section provides the Methods of Implementation (MOIs) for the NRZ OIF-CEI VSR 56G Host Output Characteristics at TP1a as specified in CEI-56G-VSR-NRZ Implementation Agreement (Clause 15, Document: OIF2014.277.09) Section 15.3.2, Table 15-1. Measurements are made at TP1a (host output).

NOTE Ensure that the **Signaling Rate** setting in the **Configure** tab of the Compliance Test Application must match the frequency of the acquired input signal.

Host-to-Module Electrical Specifications

Table 7 Host-to-Module Electrical Specifications at TP1a (host output)

Parameter	Min. Value	Max. Value	Units	Conditions
Differential Voltage pk-pk	-	900	mV	
Common Mode Noise RMS	-	25	mV	See section 15.3.5 in the specification
Common Mode Voltage - Vcm	-0.3	2.8	V	Referred to host ground
Differential Return Loss (SDD22)	-	See Equation 15-1 in the specification	dB	See section 15.3.7 in the specification
Common Mode to Differential Mode Conversion (SDC22)	-	See Equation 15-3 in the specification	dB	See section 15.3.8 in the specification
Common Mode Return Loss (SCC22)	-	-2	dB	From 250 MHz to $(3/4)f_b$ GHz, See section 15.3.9 in the specification
Transition Time: 20% to 80%	9	-	ps	See section 15.3.10 in the specification
Eye Width at 10^{-15} probability (EW15)	0.35	-	UI	See section 15.3.11 in the specification and Note 1
Eye Height at 10^{-15} probability (EH15)	50	-	mV	See section 15.3.11 in the specification and Note 1

Note 1: Open eye is generated through the use of a reference Continuous Time Linear Equalizer (CTLE) for Type A and both a CTLE and a single tap Decision Feedback Equalizer (DFE) for Type B.

Main Voltage Measurements TP1a

The NRZ Main Voltage measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

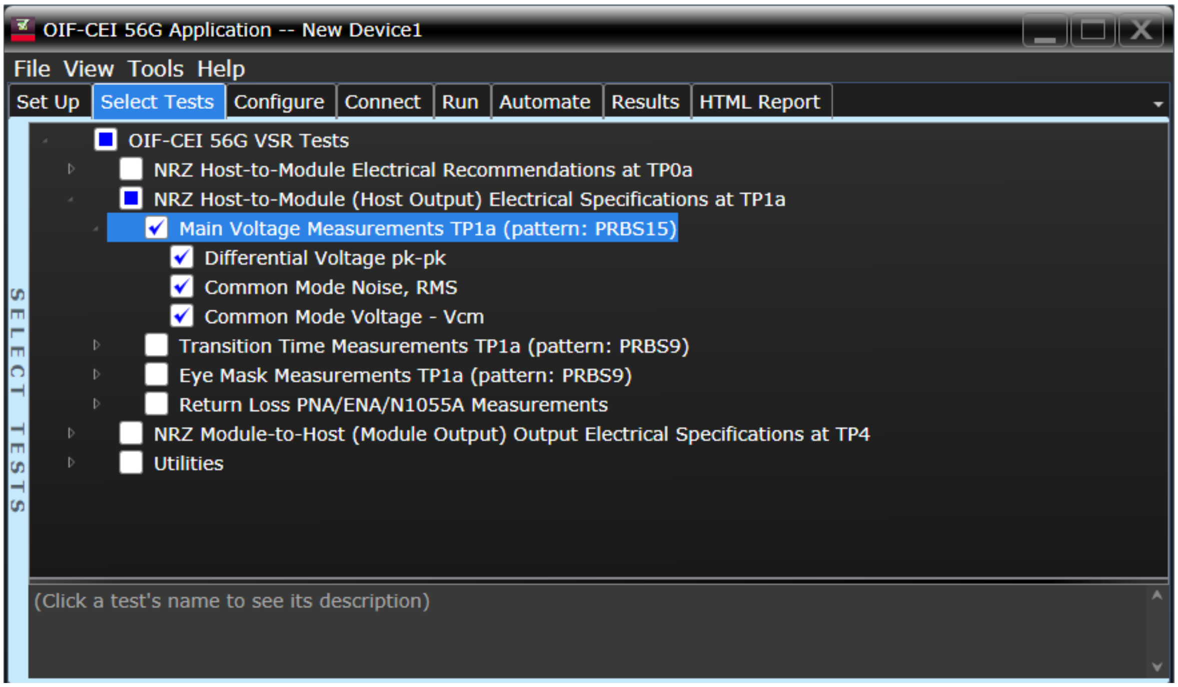


Figure 41 Selecting Main Voltage Measurement Tests

Refer to Table 7 for the pass limits for each test.

For information on the measurement algorithm for each Main Voltage Measurements TP1a (pattern: PRBS15) tests, see:

- "Differential Voltage pk-pk" on page 168
- "Common Mode Noise, RMS" on page 169
- "Common Mode Voltage - Vcm" on page 170

Differential Voltage pk-pk

Test Overview The purpose of this test is to verify that the peak-to-peak voltage of the differential signal on a PRBS15 pattern is less than 900mV.

Pass Condition Refer to Table 7.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is connected, has TX enabled and has a PRBS15 pattern.
3 Measure the peak-to-peak voltage of the differential signal of DUT+ and DUT-.
4 Compare the maximum peak-to-peak voltage to 900mV.

Common Mode Noise, RMS

Test Overview The purpose of this test is to verify that the common mode signal of the differential pair rms voltage does not exceed 25mV.

NOTE This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition Refer to Table 7.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that there is a signal and that the connection is dual single-ended.
3 Measure the Common Mode Noise, RMS.

- If the Test Application is running on the DSA/DSO Z-Series Oscilloscope, the **Instrument Setup** is preset to **Real Edge**.
- If the Test Application is running on the UXR Series Oscilloscope, perform the measurement with the **Instrument Setup** set to **Channels 1 and 2**. Repeat the measurement with the Instrument Setup set to **Channels 3 and 4**.

4 Compare the voltage measurement to 25mV.

Common Mode Voltage - V_{cm}

Test Overview The purpose of this test is to verify that the common mode signal of the differential pair is between -0.3V to 2.8V.

NOTE This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition Refer to Table 7.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that there is a signal and that the connection is dual single-ended.
3 Measure the Common Mode Voltage.

- If the Test Application is running on the DSA/DSO Z-Series Oscilloscope, the **Instrument Setup** is preset to **Real Edge**.
- If the Test Application is running on the UXR Series Oscilloscope, perform the measurement with the **Instrument Setup** set to **Channels 1 and 2**. Repeat the measurement with the Instrument Setup set to **Channels 3 and 4**.

4 Compare the voltage measurement to the range from -0.3V to 2.8V.

Transition Time Measurements TP1a

The NRZ Transition Time Measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

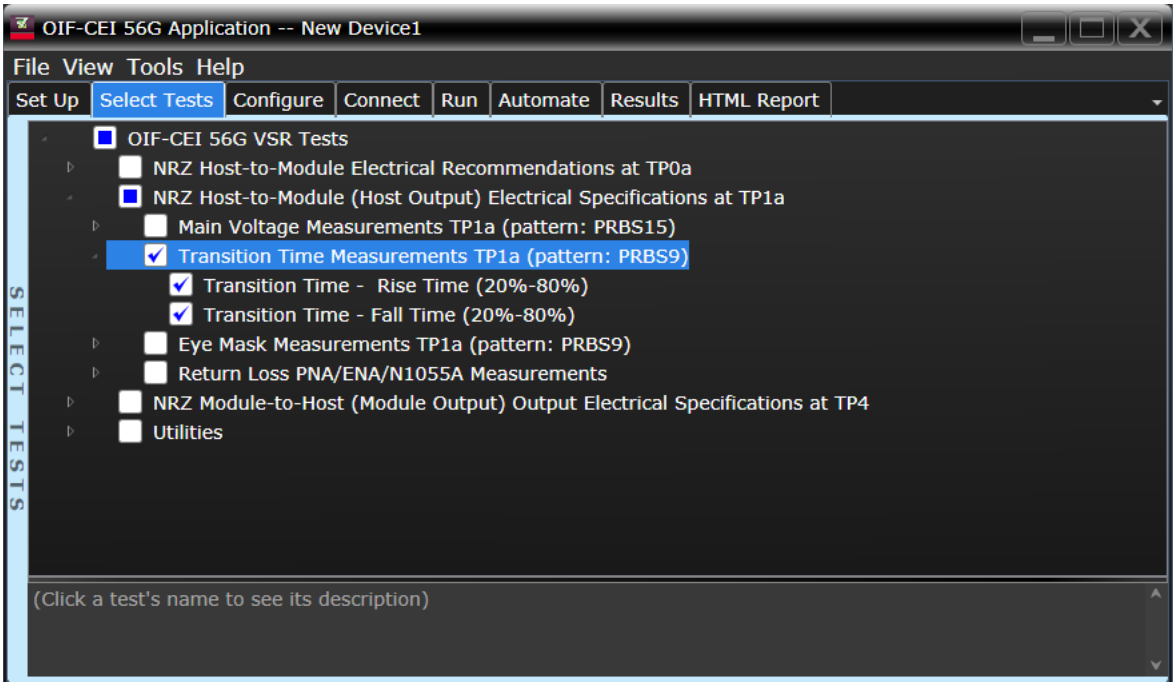


Figure 42 Selecting Transition Time Measurement Tests

Refer to Table 7 for the pass limits for each test.

For information on the measurement algorithm for each Transition Time Measurements TP1a (pattern: PRBS9) tests, see:

- "Transition Time - Rise Time (20%-80%)" on page 172
- "Transition Time - Fall Time (20%-80%)" on page 173

Transition Time - Rise Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum rise time is 9ps.

Pass Condition Refer to Table 7.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is PRBS9.
3 Find pattern 000333 for rise time.
4 Measure rise time from 20% to 80% of the signal amplitude.
5 Compare the minimum rise time with 9ps.

Transition Time - Fall Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum fall time is 9ps.

Pass Condition Refer to Table 7.

Measurement Algorithm

1. Obtain sample or acquire signal data.
2. Verify that the signal is PRBS9.
3. Find pattern 333000 for fall time.
4. Measure fall time from 20% to 80% of the signal amplitude.
5. Compare the minimum fall time with 9ps.

Eye Mask Measurements TP1a

The Eye Mask Measurement procedures that are described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

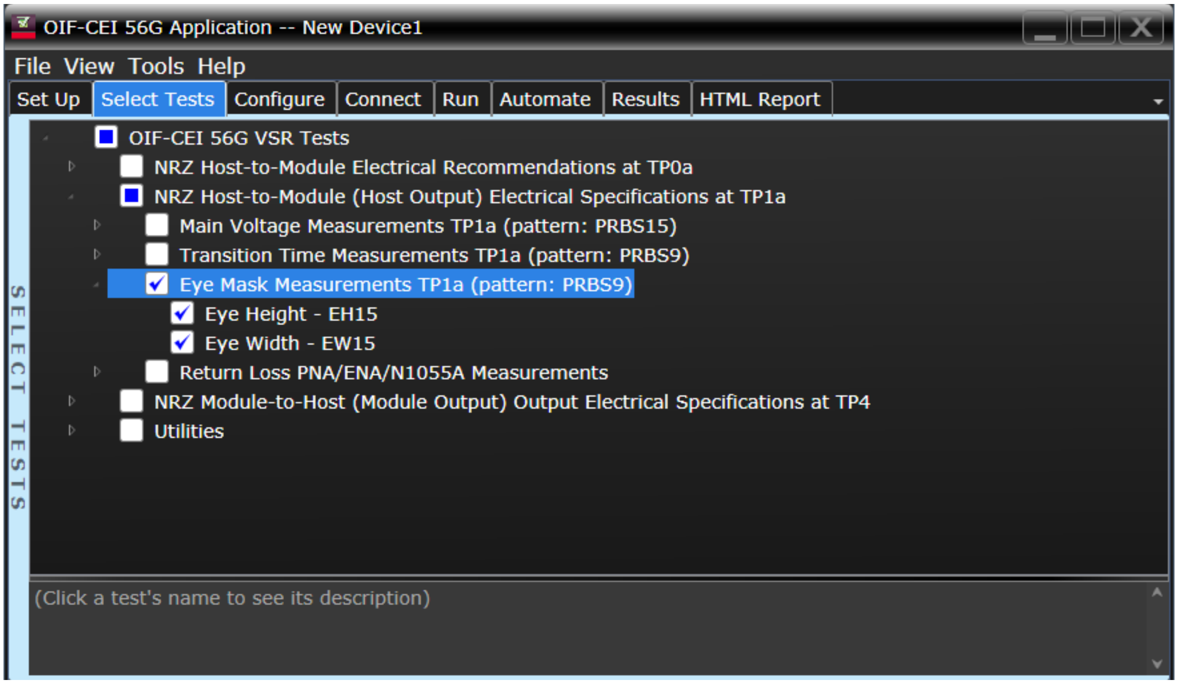


Figure 43 Selecting Eye Mask Measurement Tests

Refer to Table 7 for the pass limits for each test.

For information on the measurement algorithm for each Eye Mask Measurements TP1a (pattern: PRBS9) tests, see:

- "Eye Height - EH15" on page 175
- "Eye Width - EW15" on page 176

Eye Height - EH15

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Eye Height is greater than 50mV. The CTLE values range from 1dB lower than the user-defined optimal CTLE to 1dB higher than the user-defined optimal CTLE.

Pass Conditions Refer to Table 7.

Measurement Algorithm

1. Manually select the optimal CTLE setting in the **Use Optimized CTLE for Eye Opening** option in the **Configure** tab. The selected CTLE setting is called as ‘User-defined optimal CTLE’.
2. Obtain sample or acquire signal data.
3. Set memory depth to capture the unit interval setting in the **Configure** tab. The Eye Height and Eye Width is measured at a memory depth of 1E-6.
4. On the Oscilloscope
   - *a* Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate 25.78125Gb/s and Loop Bandwidth to 40 MHz.
   - *b* Set 4^{th} Order Bessel Thompson filter to 40 GHz.
5. Compare the Eye Height with 50mV. Report the resulting value.

Eye Width - EW15

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Eye Width is greater than 0.35UI. The CTLE values range from 1dB lower than the user-defined optimal CTLE to 1dB higher than the user-defined optimal CTLE.

Pass Conditions Refer to Table 7.

Measurement Algorithm

1 Manually select the optimal CTLE setting in the **Use Optimized CTLE for Eye Opening** option in the **Configure** tab. The selected CTLE setting is called as ‘User-defined optimal CTLE’.

2 Obtain sample or acquire signal data.

3 Set memory depth to capture the unit interval setting in the **Configure** tab. The Eye Height and Eye Width is measured at a memory depth of 1E-6.

4 On the Oscilloscope

   a Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate 25.78125Gb/s and Loop Bandwidth to 40 MHz.

   b Set 4^{th} Order Bessel Thompson filter to 40 GHz.

5 Compare the Eye Width with 0.35UI. Report the resulting value.

Return Loss ENA/PNA/N1055A Measurements

The Return Loss ENA/PNA/N1055A Measurement procedures that are described in this section are performed using a Keysight Infiniium oscilloscope, PNA, ENA or N1055A and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application. The Compliance Test Application controls the PNA/ENA/N1055A to set the test limits and run the tests. You must ensure that the connected PNA/ENA/N1055A is calibrated.

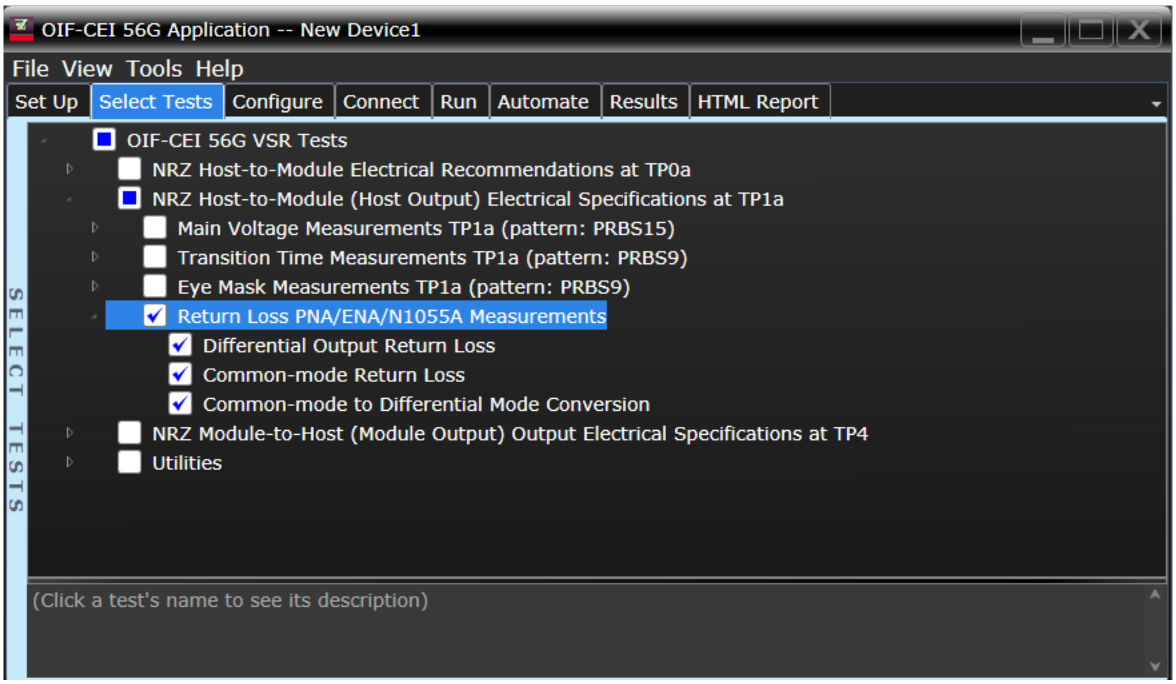


Figure 44 Selecting Return Loss Measurement Test

Refer to Table 7 for the pass limits for each test.

For information on the measurement algorithm for each Return Loss ENA/PNA/N1055A Measurements, see:

- "Differential Output Return Loss" on page 178
- "Common-mode Return Loss" on page 179
- "Common-mode to Differential Mode Conversion" on page 180

Differential Output Return Loss

Measurement Algorithm

1. Ensure that the PNA/ENA/N1055A is physically connected and calibrated.
2. In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3. Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4. Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5. Compare the reported values with the specification to check for compliance.

Common-mode Return Loss

Measurement Algorithm

1 Ensure that the PNA/ENA/N1055A is physically connected and calibrated.
2 In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3 Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4 Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5 Compare the reported values with the specification to check for compliance.

Common-mode to Differential Mode Conversion

1. Ensure that the PNA/ENA is physically connected and calibrated.
2. In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3. Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4. Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5. Compare the reported values with the specification to check for compliance.

11 NRZ Module-to-Host (Module Output) Output Electrical Specifications at TP4 for OIF-CEI 56G VSR

This section provides the Methods of Implementation (MOIs) for the NRZ Module Output Characteristics at TP4 as specified in CEI-56G-VSR-NRZ Implementation Agreement (Clause 15, Document: OIF2014.277.09) Section 15.3.3, Table 15-4. Measurements are made at TP4.

NOTE Ensure that the **Signaling Rate** setting in the **Configure** tab of the Compliance Test Application must match the frequency of the acquired input signal.

Module-to-Host Electrical Specifications

Table 8 Module-to-Host Electrical Specifications at TP4 (module output)

Parameter	Min. Value	Max. Value	Units	Conditions
Differential Voltage, pk-pk	-	900	mV	
Common Mode Noise, RMS	-	25	mV	See section 15.3.5 in the specification
Common Mode Voltage (Vcm)	-350	2850	mV	Note 1
Differential Return Loss (SDD22)	-	See Equation 15-1 in the specification	dB	See section 15.3.7 in the specification
Common Mode to Differential Mode Conversion (SDC22)	-	See Equation 15-3 in the specification	dB	See section 15.3.8 in the specification
Common Mode Return Loss (SCC22)	-	-2	dB	From 250 MHz to (3/4)f_b GHz, See section 15.3.9 in the specification
Transition Time: 20% to 80%	9	-	ps	See section 15.3.10 in the specification
Vertical Eye Closure (VEC)	-	5.5	dB	See section 15.3.11.1.1 in the specification
Eye Width at 10^{-15} probability (EW15)	0.57	-	UI	See section 15.3.11 in the specification
Eye Height at 10^{-15} probability (EH15)	200	-	mV	See section 15.3.11 in the specification

Note 1: Vcm is generated by the host. Specification includes effects of ground offset voltage.

Main Voltage Measurements TP4

The NRZ Main Voltage measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

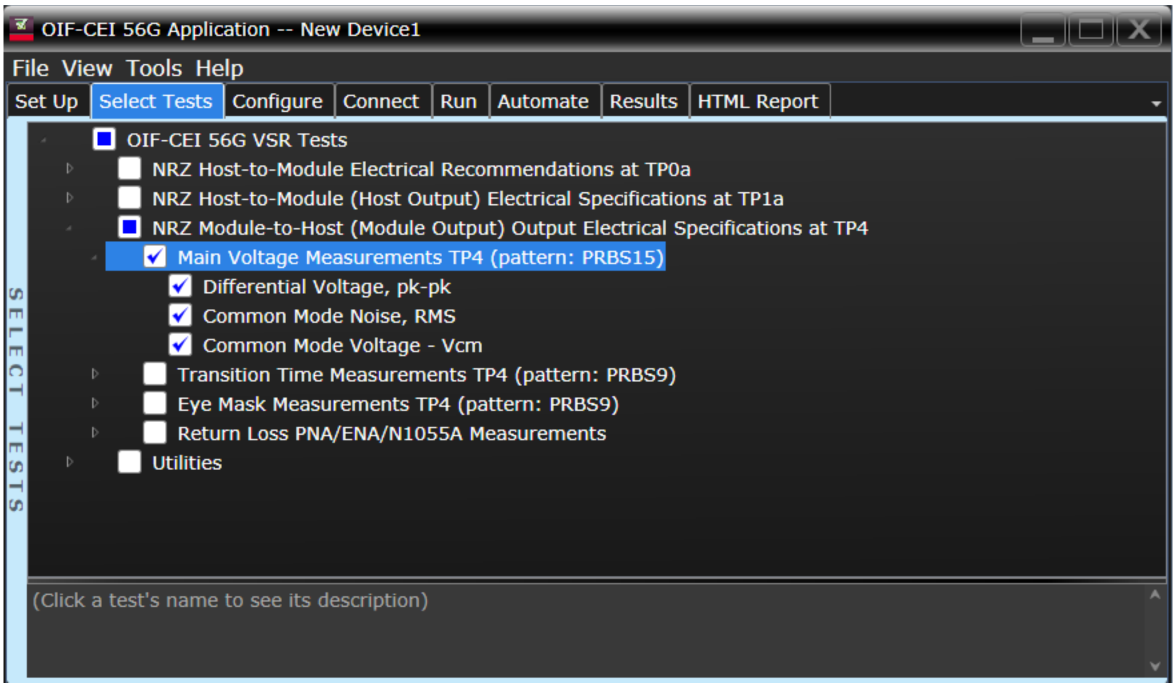


Figure 45 Selecting Main Voltage Measurement Tests

Refer to Table 8 for the pass limits for each test.

For information on the measurement algorithm for each Main Voltage Measurements TP4 (pattern: PRBS15) tests, see:

- “Differential Voltage, pk-pk” on page 184
- “Common Mode Noise, RMS” on page 185
- “Common Mode Voltage - Vcm” on page 186

Differential Voltage, pk-pk

Test Overview The purpose of this test is to verify that the peak-to-peak voltage of the differential signal on a PRBS15 pattern is less than 900mV.

Pass Condition Refer to Table 8.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is connected, has TX enabled and has a PRBS15 pattern.
3 Measure the peak-to-peak voltage of the differential signal of DUT+ and DUT-.
4 Compare the maximum peak-to-peak voltage to 900mV.

Common Mode Noise, RMS

Test Overview The purpose of this test is to verify that the common mode signal of the differential pair rms voltage does not exceed 25mV.

> **NOTE** This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition Refer to Table 8.

Measurement Algorithm

1. Obtain sample or acquire signal data.
2. Verify that there is a signal and that the connection is dual single-ended.
3. Measure the Common Mode Noise, RMS for Real Edge.
4. Repeat step 3 for Channels 1 and 2 & Channels 3 and 4.
5. Compare the voltage measurement to 25mV.

Common Mode Voltage - V_{cm}

Test Overview The purpose of this test is to verify that the common mode signal of the differential pair is between -350mV to 2850mV.

> **NOTE** This measurement can be done only with dual single-ended connection but not with a differential probing connection.

Pass Condition Refer to Table 8.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that there is a signal and that the connection is dual single-ended.
3 Measure the Common Mode Voltage for Real Edge.
4 Repeat step 3 for Channels 1 and 2 & Channels 3 and 4.
5 Compare the voltage measurement to the range from -350mV to 2850mV.

Transition Time Measurements TP4

The NRZ Transition Time Measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

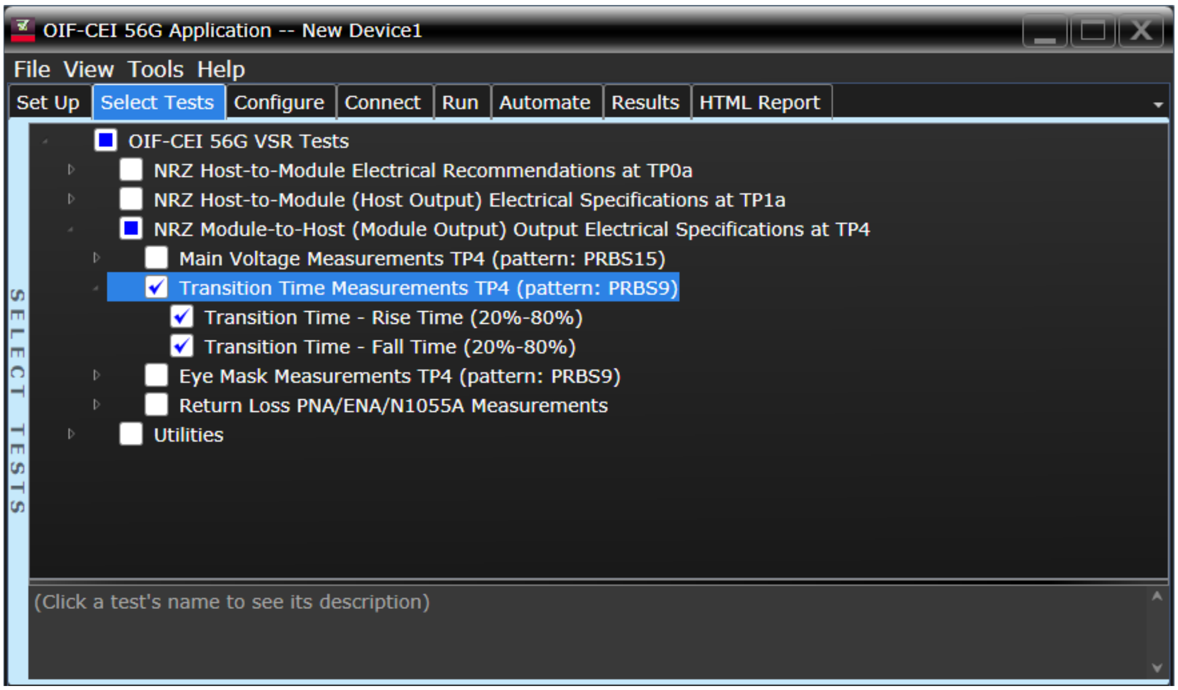


Figure 46 Selecting Transition Time Measurement Tests

Refer to Table 8 for the pass limits for each test.

For information on the measurement algorithm for each Transition Time Measurements TP4 (pattern: PRBS9) tests, see:

- "Transition Time - Rise Time (20%-80%)" on page 188
- "Transition Time - Fall Time (20%-80%)" on page 189

Transition Time - Rise Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum rise time is 9ps.

Pass Condition Refer to Table 8.

Measurement Algorithm

1. Obtain sample or acquire signal data.
2. Verify that the signal is PRBS9.
3. Find pattern 000333 for rise time.
4. Measure rise time from 20% to 80% of the signal amplitude.
5. Compare the minimum rise time with 9ps.

Transition Time - Fall Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum fall time is 9ps.

Pass Condition Refer to Table 8.

Measurement Algorithm

1. Obtain sample or acquire signal data.
2. Verify that the signal is PRBS9.
3. Find pattern 333000 for fall time.
4. Measure fall time from 20% to 80% of the signal amplitude.
5. Compare the minimum fall time with 9ps.

Eye Mask Measurements TP4

The Eye Mask Measurement procedures that are described in this section are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

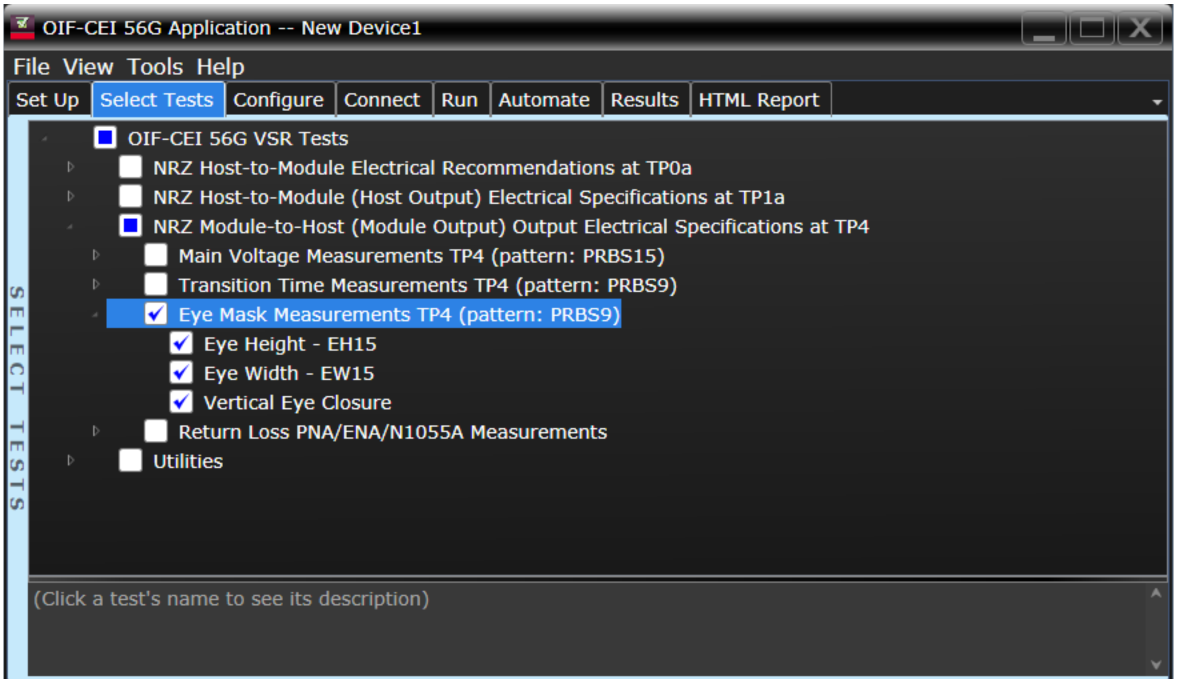


Figure 47 Selecting Eye Mask Measurement Tests

Refer to Table 8 for the pass limits for each test.

For information on the measurement algorithm for each Eye Mask Measurements TP4 (pattern: PRBS9) tests, see:

- "Eye Height - EH15" on page 191
- "Eye Width - EW15" on page 192
- "Vertical Eye Closure" on page 193

Eye Height - EH15

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Eye Height is greater than 200mV. The CTLE values range from 1dB lower than the user-defined optimal CTLE to 1dB higher than the user-defined optimal CTLE.

Pass Conditions Refer to Table 8.

Measurement Algorithm

1 Manually select the optimal CTLE setting in the **Use Optimized CTLE for Eye Opening** option in the **Configure** tab. The selected CTLE setting is called as 'User-defined optimal CTLE'.

2 Obtain sample or acquire signal data.

3 Set memory depth to capture the unit interval setting in the **Configure** tab. The Eye Height and Eye Width is measured at a memory depth of 1E-6.

4 On the Oscilloscope

   a Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate 25.78125Gb/s and Loop Bandwidth to 40 MHz.

   b Set 4^{th} Order Bessel Thompson filter to 40 GHz.

5 Compare the Eye Height with 200mV. Report the resulting value.

Eye Width - EW15

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Eye Width is greater than 0.57UI. The CTLE values range from 1dB lower than the user-defined optimal CTLE to 1dB higher than the user-defined optimal CTLE.

Pass Conditions Refer to Table 8.

Measurement Algorithm

1. Manually select the optimal CTLE setting in the **Use Optimized CTLE for Eye Opening** option in the **Configure** tab. The selected CTLE setting is called as 'User-defined optimal CTLE'.
2. Obtain sample or acquire signal data.
3. Set memory depth to capture the unit interval setting in the **Configure** tab. The Eye Height and Eye Width is measured at a memory depth of 1E-6.
4. On the Oscilloscope
   a Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate 25.78125Gb/s and Loop Bandwidth to 40 MHz.
   b Set 4^{th} Order Bessel Thompson filter to 40 GHz.
5. Compare the Eye Width with 0.57UI. Report the resulting value.

Vertical Eye Closure

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, Vertical Eye Closure at EH15 (1E-15) is less than 5.5 dB. The CTLE values range from 1dB lower than the user-defined optimal CTLE to 1dB higher than the user-defined optimal CTLE.

Pass Condition Refer to Table 8.

Measurement Algorithm

1 Manually select the optimal CTLE setting in the **Use Optimized CTLE for Eye Opening** option in the **Configure** tab. The selected CTLE setting is called as 'User-defined optimal CTLE'.

2 Obtain sample or acquire signal data.

3 Set memory depth to capture the unit interval setting in the **Configure** tab. The Near-end Eye Linearity is measured at a memory depth of 1E-6.

4 On the Oscilloscope

a Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate 25.78125Gb/s and Loop Bandwidth to 40 MHz.

b Set 4^{th} Order Bessel Thompson filter to 40 GHz.

5 Measure Eye Height at 1E-15 (EH15) to obtain Vupp, Vmid and Vlow.

6 Measure each eye amplitude to obtain AVupp, AVmid, and AVlow.

7 Measure and calculate AV as the mean value of logic 1 minus the mean value of logic 0 at the central 5% of the eye.

8 Calculate Vertical Eye Closure (VEC) using the equation:

$$VEC = 20 \times \log\{\min[(AVupp/Vupp),(AVmid/Vmid),(AVlow/Vlow)]\}$$

9 Compare the resulting value of VEC with 5.5 dB.

Return Loss ENA/PNA/N1055A Measurements

The Return Loss ENA/PNA/N1055A Measurement procedures that are described in this section are performed using a Keysight Infiniium oscilloscope, PNA, ENA or N1055A, and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application. The Compliance Test Application controls the PNA/ENA/N1055A to set the test limits and run the tests. You must ensure that the connected PNA/ENA/N1055A is calibrated.

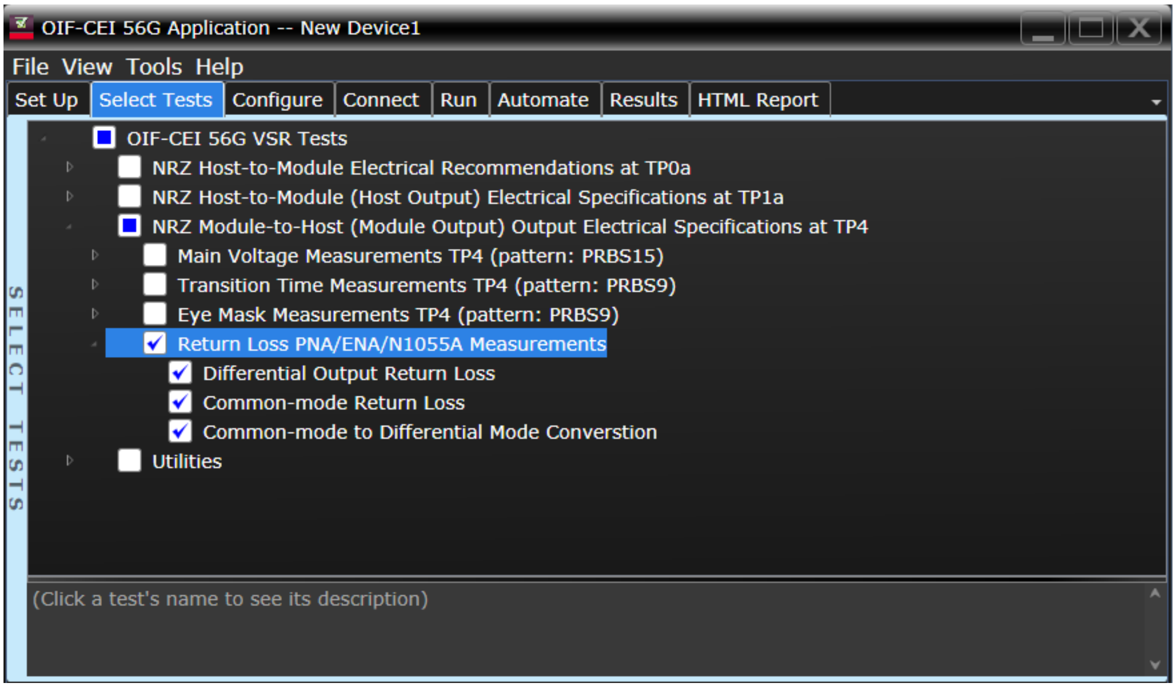


Figure 48 Selecting Return Loss Measurement Tests

Refer to Table 8 for the pass limits for each test.

For information on the measurement algorithm for each Return Loss ENA/PNA/N1055A Measurements, see:

- “Differential Output Return Loss” on page 195
- “Common-mode Return Loss” on page 196
- “Common-mode to Differential Mode Conversion” on page 197

Differential Output Return Loss

Measurement Algorithm

1. Ensure that the PNA/ENA/N1055A is physically connected and calibrated.
2. In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3. Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4. Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5. Compare the reported values with the specification to check for compliance.

Common-mode Return Loss

Measurement Algorithm

1 Ensure that the PNA/ENA/N1055A is physically connected and calibrated.
2 In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3 Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4 Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5 Compare the reported values with the specification to check for compliance.

Common-mode to Differential Mode Conversion

Measurement Algorithm

1. Ensure that the PNA/ENA/N1055A is physically connected and calibrated.
2. In the **Set Up** tab of the Compliance Test Application, click **Connect PNA** or **Connect ENA** to establish connectivity to the connected equipment.
3. Click the **Select Tests** tab and check the tests to measure the Return Loss Measurements.
4. Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the return loss.
5. Compare the reported values with the specification to check for compliance.

12 Utilities

This section provides the Methods of Implementation (MOIs) for the Utilities available for each combination of Standard Option and Signal Type to find the optimal CTLE Eye Opening.

NOTE Ensure that the **Signaling Rate** setting in the **Configure** tab of the Compliance Test Application must match the frequency of the acquired input signal.

PAM4 OIF-CEI 56G VSR Utilities

The procedure described in this section to find Optimal CTLE Eye Opening are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

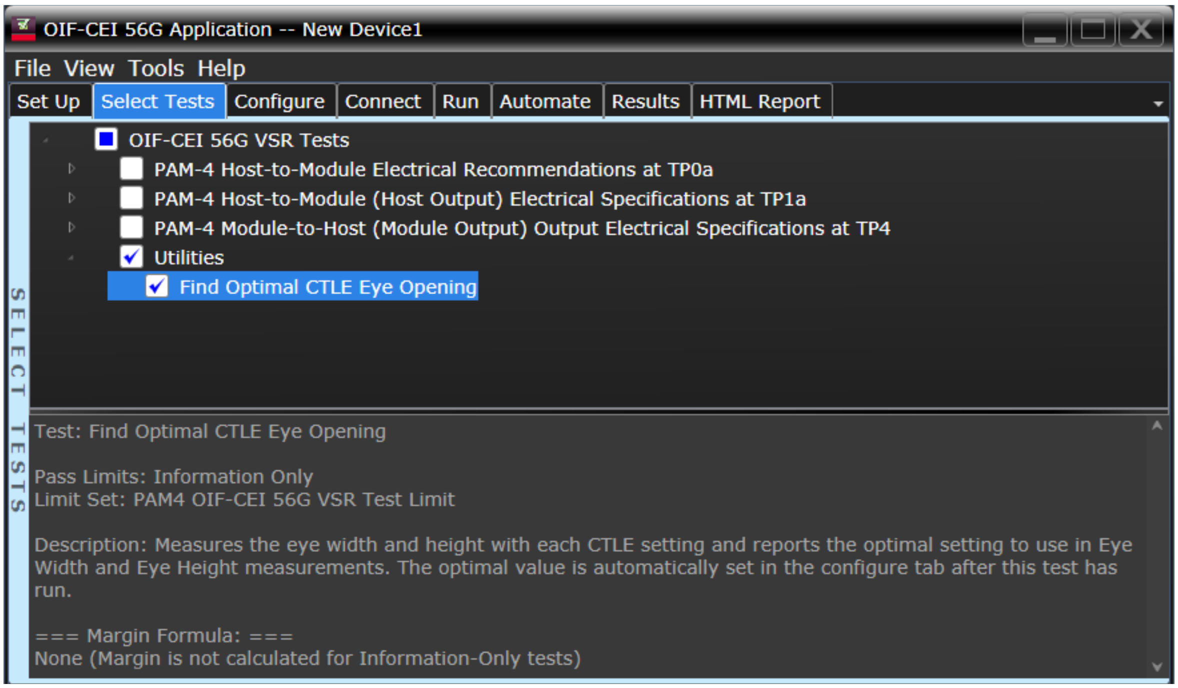
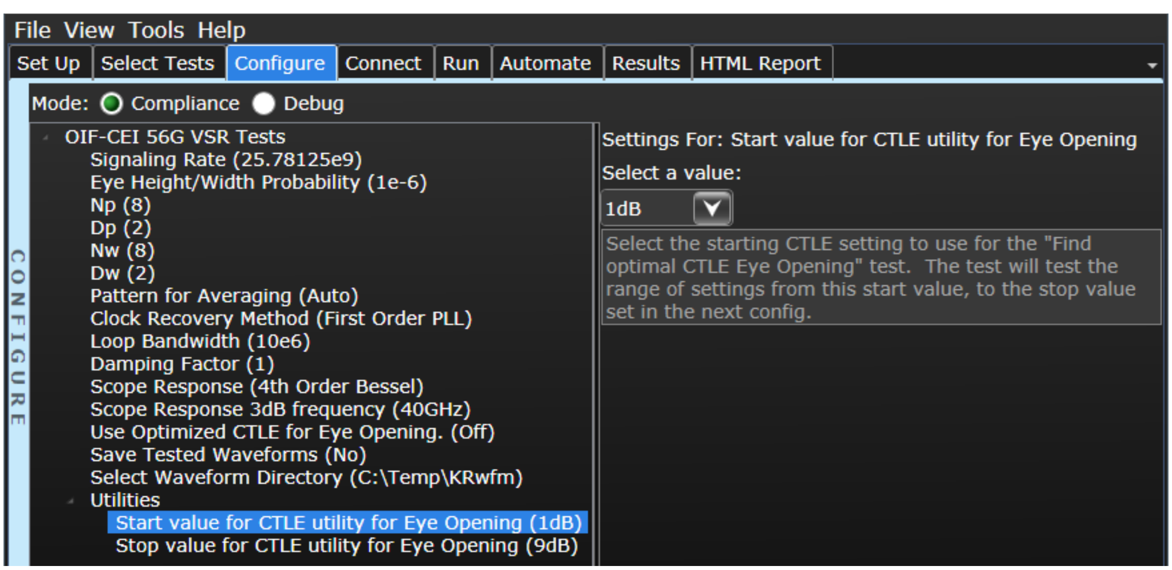


Figure 49 Selecting Utilities under OIF-CEI 56G VSR Tests for PAM4 signals

Test Overview The purpose of this test is to loop through CTLE settings to find the optimal CTLE setting for the largest area of the Eye.

Measurement Algorithm

1 Set the CTLE value to match the value set for the option **Start value for CTLE utility for Eye Opening** in the **Configure** tab.



2 Obtain or acquire signal data.

3 Set memory depth to capture 1 million UI.

4 On the Oscilloscope, Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate and Loop Bandwidth. Set 4th Order Bessel Thompson filter to 40 GHz.

5 Measure Eye Height and Eye Width.

6 Calculate area of the center eye using the formula EH1*EW1.

7 Repeat the previous steps for each CTLE setting until the CTLE value attains the value set for the option **Stop value for CTLE utility for Eye Opening** in the **Configure** tab.

8 Report the CTLE setting with the largest eye area. The Application automatically changes the configured CTLE setting to the optimal value.

PAM4 OIF-CEI 56G MR Utilities

The procedure described in this section to find Optimal CTLE Eye Opening are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

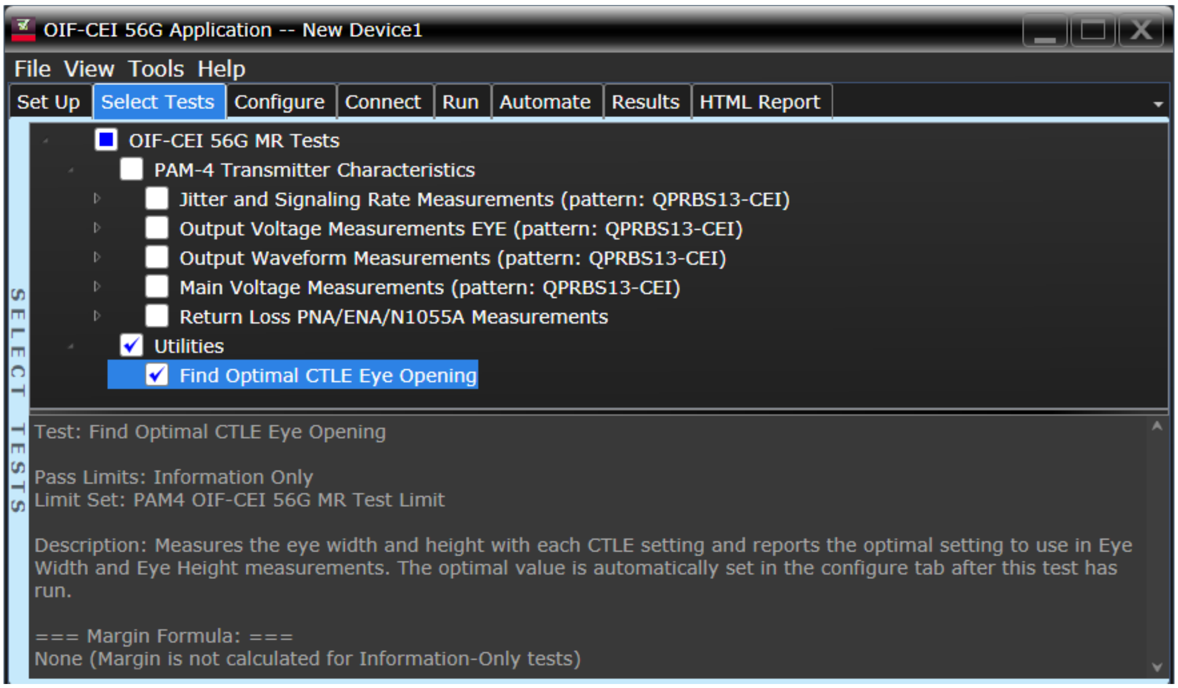
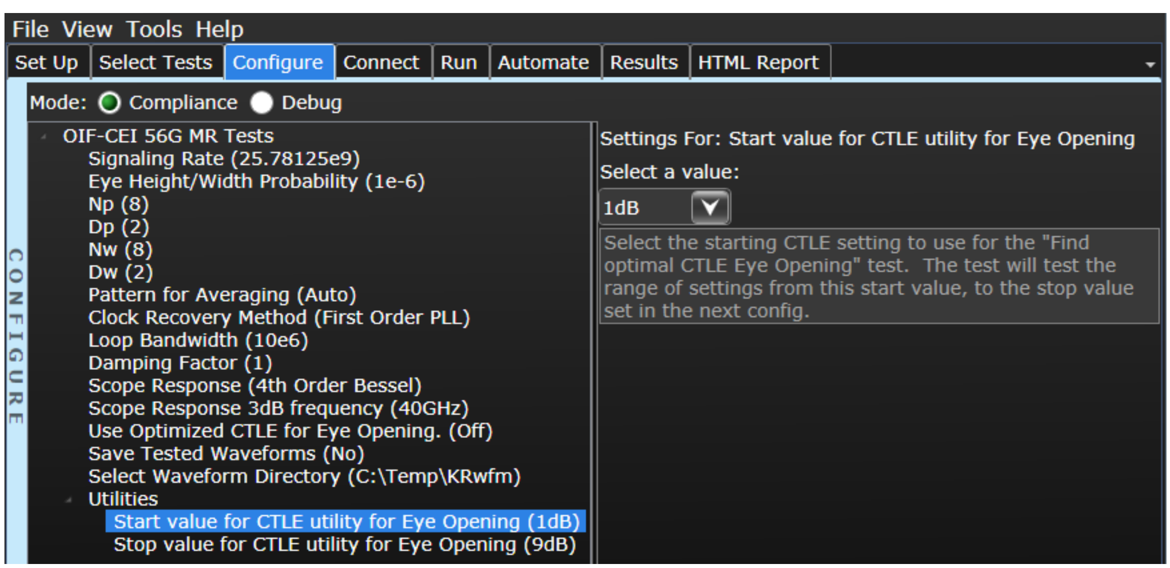


Figure 50 Selecting Utilities under OIF-CEI 56G MR Tests for PAM4 signals

Test Overview The purpose of this test is to loop through CTLE settings to find the optimal CTLE setting for the largest area of the Eye.

Measurement Algorithm

1 Set the CTLE value to match the value set for the option **Start value for CTLE utility for Eye Opening** in the **Configure** tab.



2 Obtain or acquire signal data.

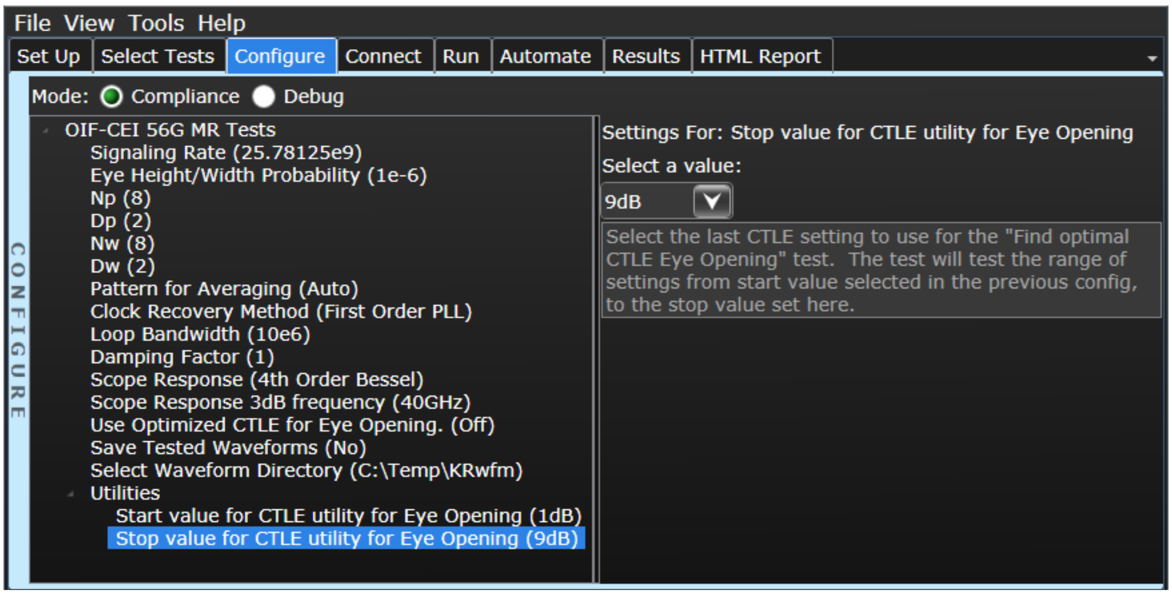
3 Set memory depth to capture 1 million UI.

4 On the Oscilloscope, Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate and Loop Bandwidth. Set 4th Order Bessel Thompson filter to 40 GHz.

5 Measure Eye Height and Eye Width.

6 Calculate area of the center eye using the formula EH1*EW1.

7 Repeat the previous steps for each CTLE setting until the CTLE value attains the value set for the option **Stop value for CTLE utility for Eye Opening** in the **Configure** tab.



8 Report the CTLE setting with the largest eye area. The Application automatically changes the configured CTLE setting to the optimal value.

PAM4 OIF-CEI 56G LR Utilities

The procedure described in this section to find Optimal CTLE Eye Opening are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

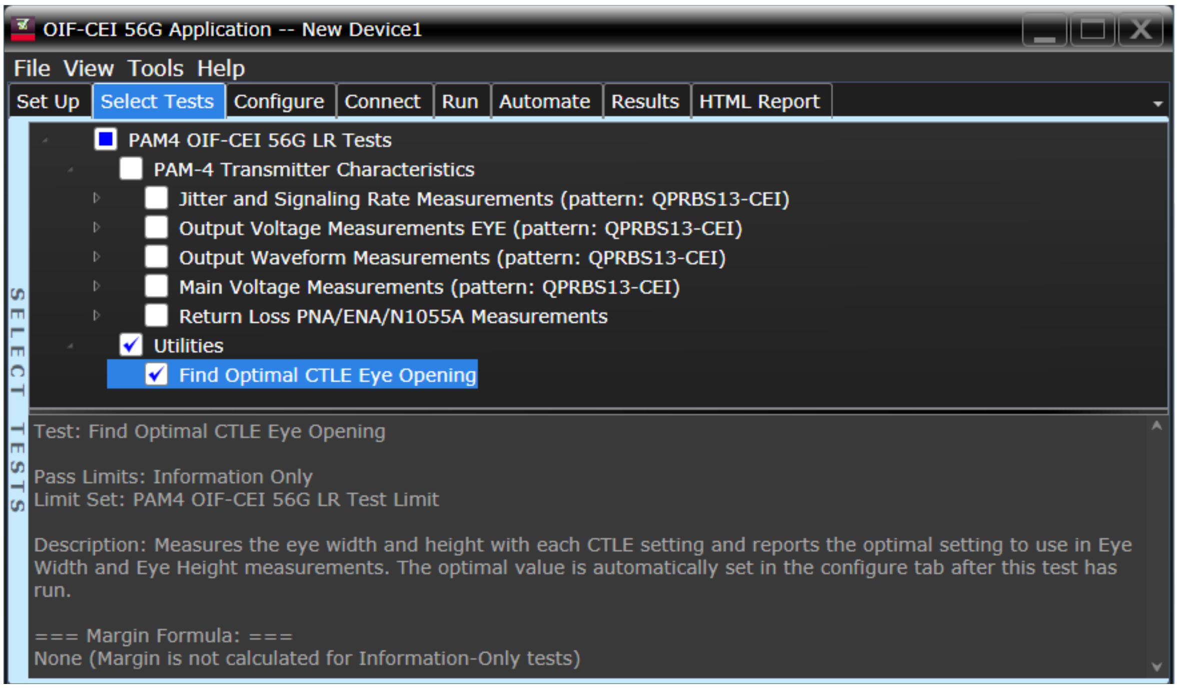
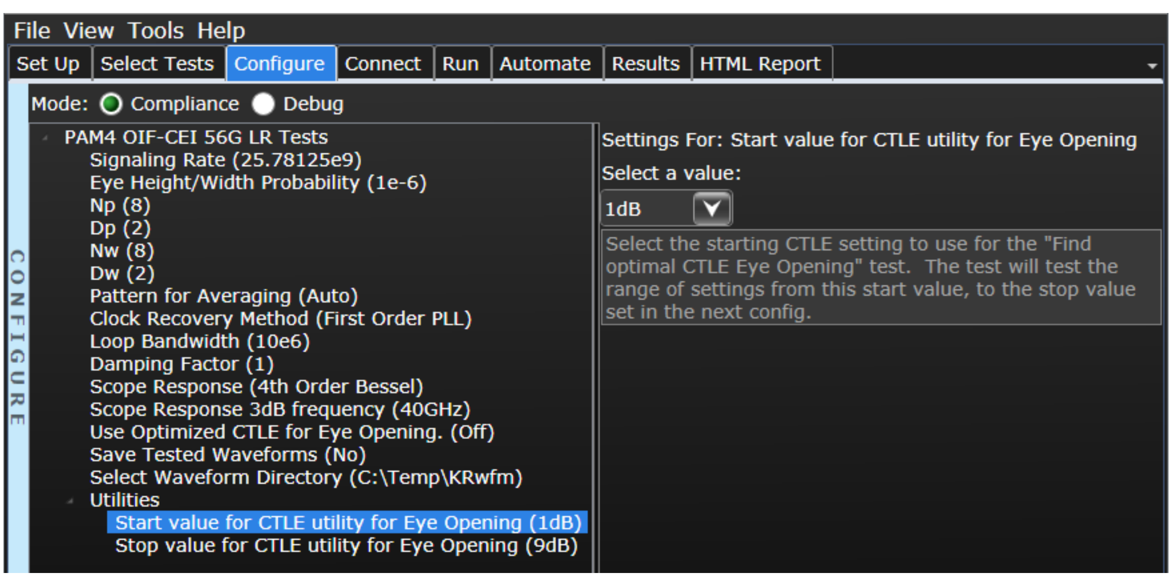


Figure 51 Selecting Utilities under OIF-CEI 56G LR Tests for PAM4 signals

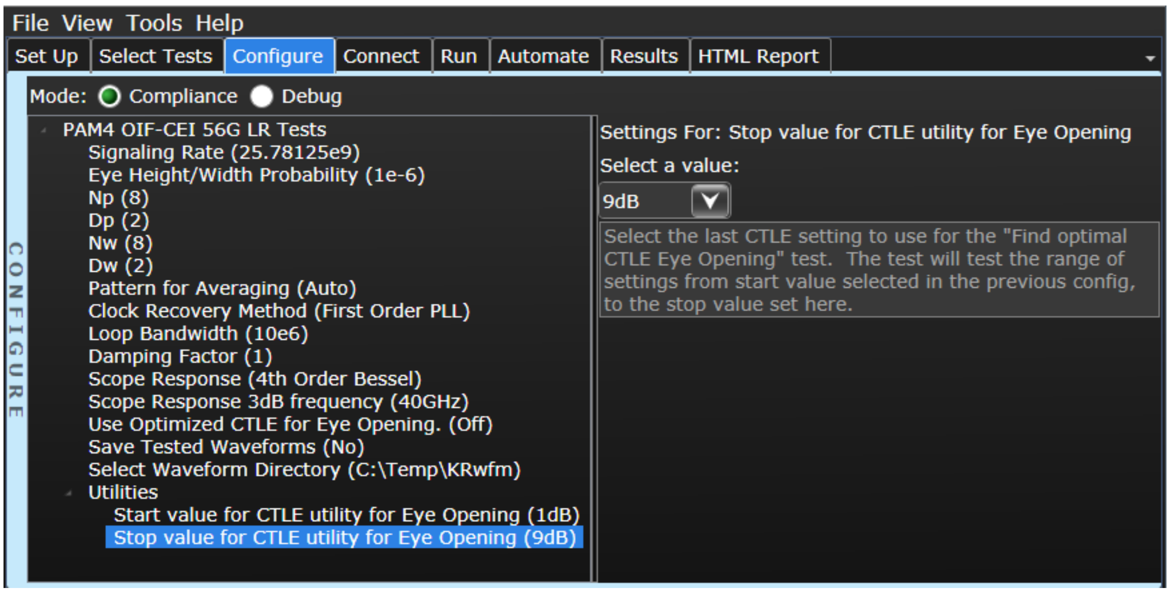
Test Overview The purpose of this test is to loop through CTLE settings to find the optimal CTLE setting for the largest area of the Eye.

Measurement Algorithm

1 Set the CTLE value to match the value set for the option **Start value for CTLE utility for Eye Opening** in the **Configure** tab.



2 Obtain or acquire signal data.
3 Set memory depth to capture 1 million UI.
4 On the Oscilloscope, Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate and Loop Bandwidth. Set 4th Order Bessel Thompson filter to 40 GHz.
5 Measure Eye Height and Eye Width.
6 Calculate area of the center eye using the formula EH1*EW1.
7 Repeat the previous steps for each CTLE setting until the CTLE value attains the value set for the option **Stop value for CTLE utility for Eye Opening** in the **Configure** tab.



8 Report the CTLE setting with the largest eye area. The Application automatically changes the configured CTLE setting to the optimal value.

NRZ OIF-CEI 56G VSR Utilities

The procedure described in this section to find Optimal CTLE Eye Opening are performed using a Keysight Infiniium oscilloscope and the D9010CEIC OIF-CEI 56G VSR/MR/LR Test Application.

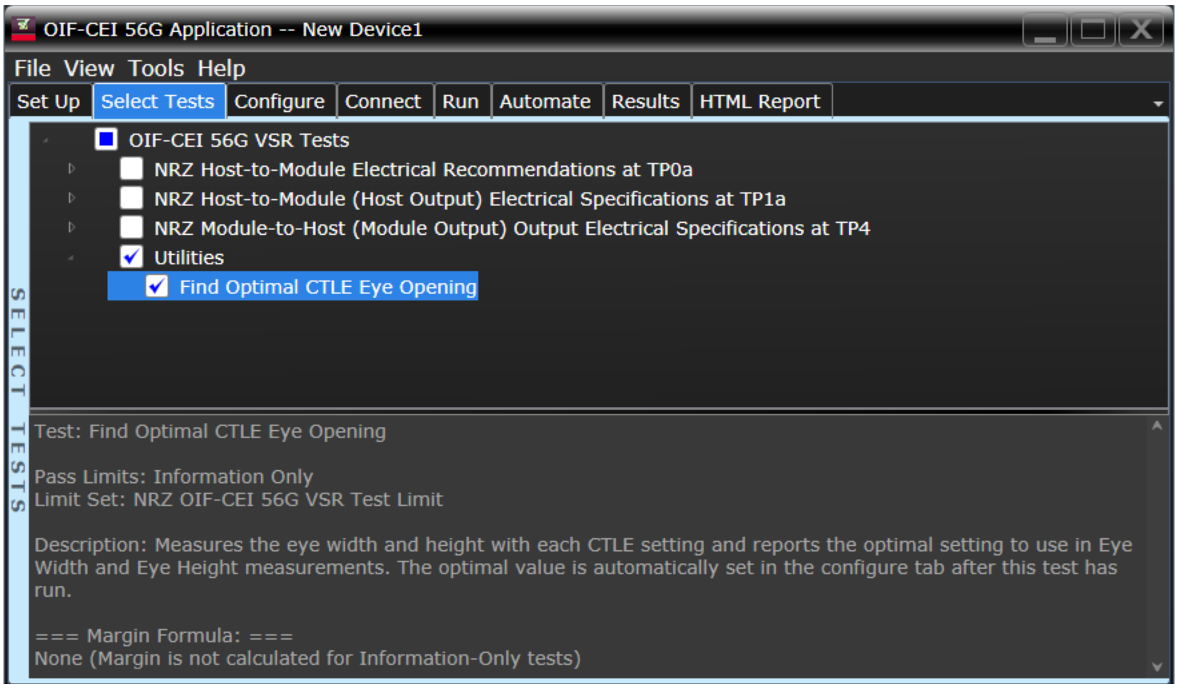
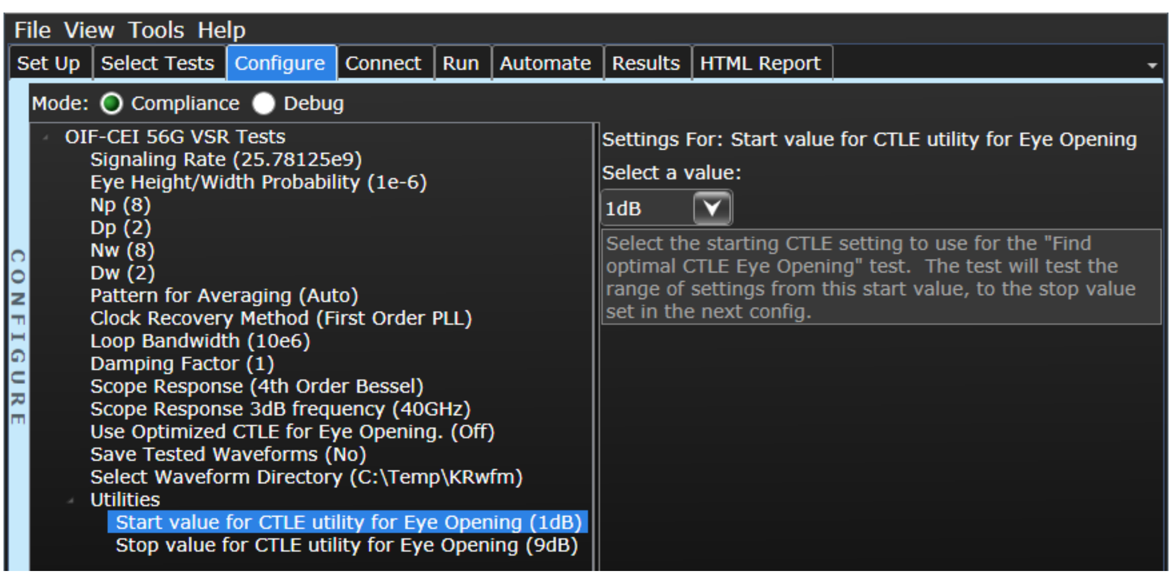


Figure 52 Selecting Utilities under OIF-CEI 56G VSR Tests for NRZ signals

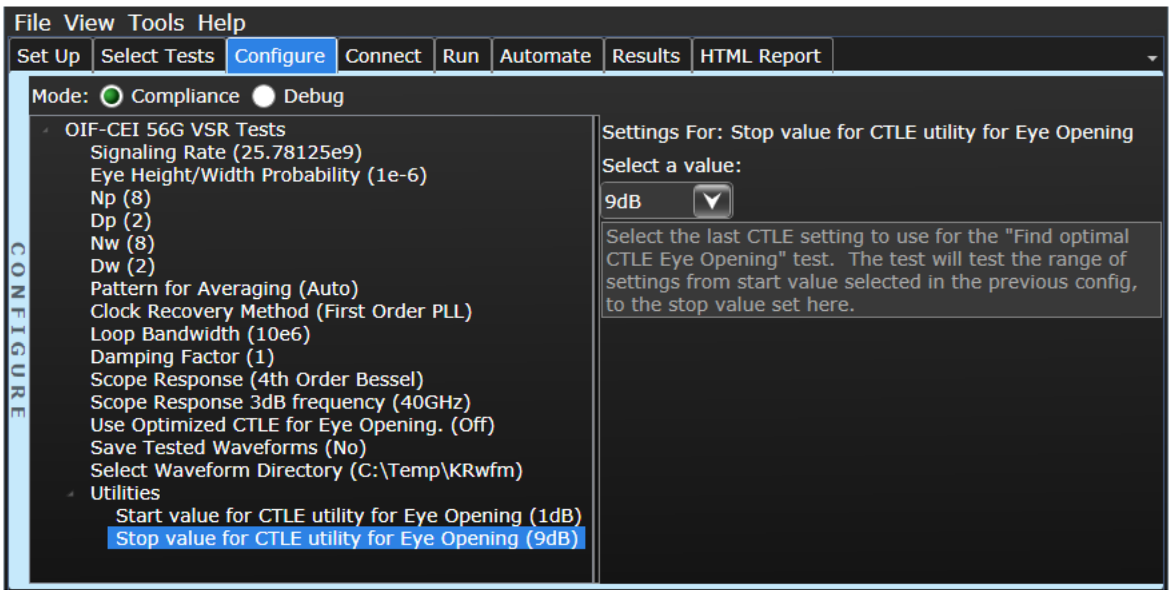
Test Overview The purpose of this test is to loop through CTLE settings to find the optimal CTLE setting for the largest area of the Eye.

Measurement Algorithm

1 Set the CTLE value to match the value set for the option **Start value for CTLE utility for Eye Opening** in the **Configure** tab.



2 Obtain or acquire signal data.
3 Set memory depth to capture 1 million UI.
4 On the Oscilloscope, Clock Recovery is set to OJTF First Order PLL with Nominal Data Rate and Loop Bandwidth. Set 4th Order Bessel Thompson filter to 40 GHz.
5 Measure Eye Height and Eye Width.
6 Calculate area of the eye using the formula EH*EW.
7 Repeat the previous steps for each CTLE setting until the CTLE value attains the value set for the option **Stop value for CTLE utility for Eye Opening** in the **Configure** tab.



8 Report the CTLE setting with the largest eye area. The Application automatically changes the configured CTLE setting to the optimal value.

13 Debug Mode

Debug mode can be selected to make enable the ability to change jitter measurement options. In the **Configure** tab, select the **Debug** radio button. This will add the following options:

- **Rj Bandwidth** — Choose the Rj Filter. Options are Narrow (Pink) or Wide (White). This changes the amount of DC jitter in the Rj measurement.
- **Jitter Pattern Length** — Choose Periodic or Arbitrary. Periodic is used for data patterns that are periodic and repeat through the scope memory. Arbitrary is used for random data patterns or long data patterns (for example, PRBS31) that do not repeat through the scope memory. If Arbitrary is selected, set the ISI filters.
- **ISI Filter Lead** — When using Arbitrary mode for the Jitter Pattern Length, set the Leading ISI filter coefficient. To help select the correct ISI filter, see Application Note 1574: Choosing the ISI Filter Size for EZJIT Plus Arbitrary Data Jitter Analysis (at www.keysight.com, literature part number 5989-4974EN).
- **ISI Filter Lag** — When using Arbitrary mode for the Jitter Pattern Length, set the Lagging ISI filter coefficient. Again, to help select the correct ISI filter, see Application Note 1574: Choosing the ISI Filter Size for EZJIT Plus Arbitrary Data Jitter Analysis.

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