N109256CB CEI 56G Compliance Application

KEYSIGHT

METHODS OF IMPLEMENTATION

Notices

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CAUTION

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WARNING

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

CEI 56G Compliance Test Application—At a Glance

The Keysight N109256CB CEI 56G Compliance 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 CEI 56G Compliance 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.
- Allows you to determine the number of trials for each test.
- Provides detailed information of each test that has been run. The result of several worst trials can be displayed at any one time.
- Creates a printable HTML report of the tests that have been run. This report includes pass/fail limits, margin analysis, and screen shots.

Supported Equipment and Software

In order to run the OIF-CEI automated tests, the following equipment and software are supported:

- N109256CB CEI 56G Compliance Test Application software and license
- 2.92-inch cables
- N1000A/86100D Infiniium DCA-X Wide-Bandwidth Oscilloscope Mainframe
  - N1010A FlexDCA Software (For the minimum version of N1010A FlexDCA oscilloscope software, see the N109256CB release notes)
  - N1046A 75/85/100 GHz 1/2/4 Port Remote Sampling Heads for the 86100D DCA-X
  - N1045A 60 GHz 2/4 Port Electrical Remote Sampling Head
  - N1055A 35/50 GHz 2/4 Port TDR/TDT Remote Sampling Head
  - 86108B/N1060A Precision Waveform Analyzer
  - N1040A Dual Electrical Channel Module
- N1076A/B, N1077A/N1078A Optical/Electrical Clock Recovery
- Keysight N109X-Series DCA-M Sampling Oscilloscopes (with different electrical capability)
  - N1092C DCA-M Sampling Oscilloscope (One Optical and Two Electrical Channels)
  - N1094A DCA-M Sampling Oscilloscope (Two Electrical Channels)
  - N1094B DCA-M Sampling Oscilloscope (Four Electrical Channels)

For more information, refer to the Data Sheet.

Contents

1 Installing the N109256CB CEI 56G Compliance Test Application

If you purchased the N109256CB Compliance Test Application separate from your Infiniium DCA-X/M Wide-Bandwidth Oscilloscope, you must install the software and license key.

Installing the Software

1 Make sure you have the minimum version of Infiniium oscilloscope software (see the N109256CB release notes) by selecting **Help > About Infiniium...** from the main menu.
2 To obtain the N109256CB Compliance Test Application, go to Keysight website: http://www.keysight.com/find/N109256CB.
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.

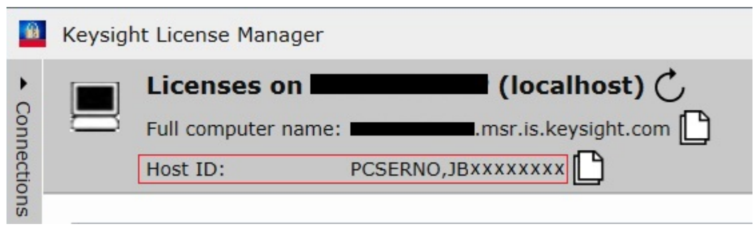


Figure 1 Viewing the Host ID information in Keysight License Manager 5

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.

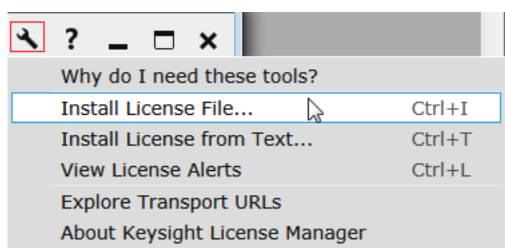


Figure 2 Configuration menu options to install licenses on Keysight License Manager 5

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.

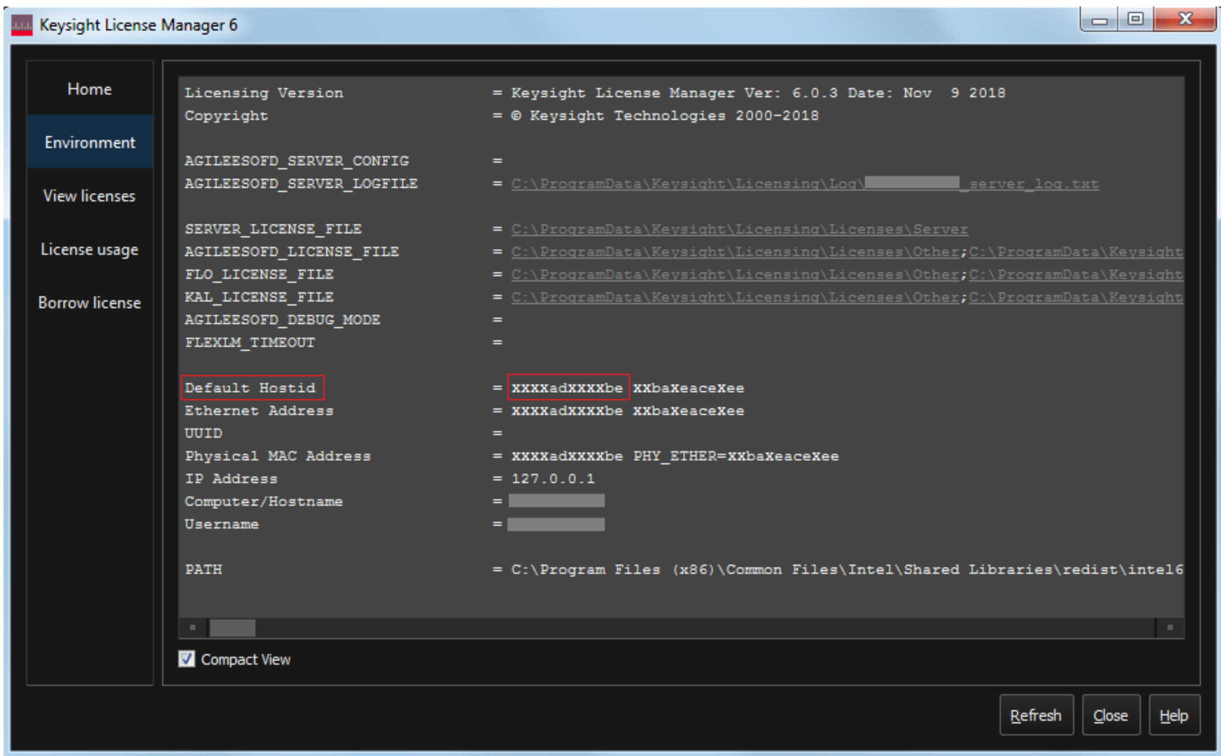


Figure 3 Viewing the Host ID information in Keysight License Manager 6

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.

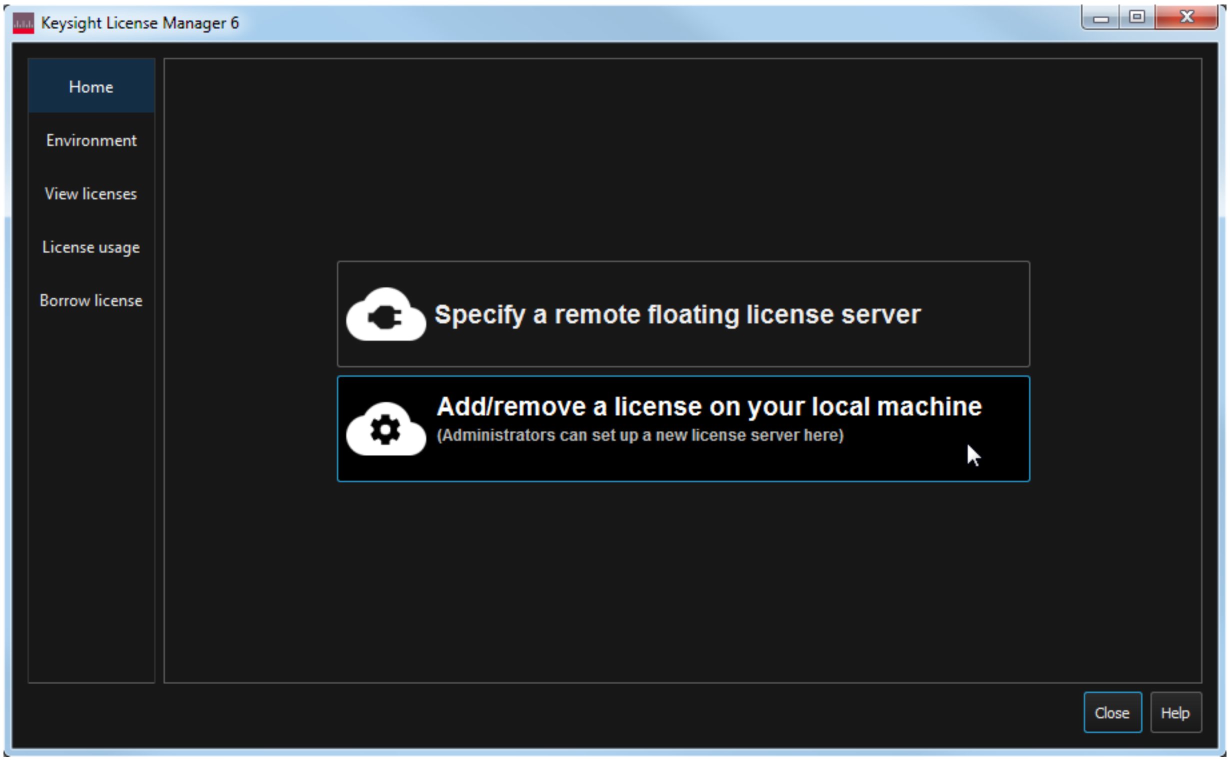


Figure 4 Home menu options to install licenses on Keysight License Manager 6

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

2 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 N109256CB CEI56G Compliance Test Application and perform the measurements.

Calibrating the Oscilloscope

If you haven't already calibrated the Oscilloscope, refer to the Help Manuals provided along with the Oscilloscope being used for testing.

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 Compliance Test Application

1 Ensure that the Device Under Test (DUT) is operating and set to desired test modes.

2 To start the Compliance Test Application, from the FlexDCA N1000-Series System Software's main menu, select **Apps > Automated Test Apps > N109256CB OIF-CEI 56G VSR/MR/LR Test App**.

The Keysight N109256CB CEI 56G Compliance Test Application appears.

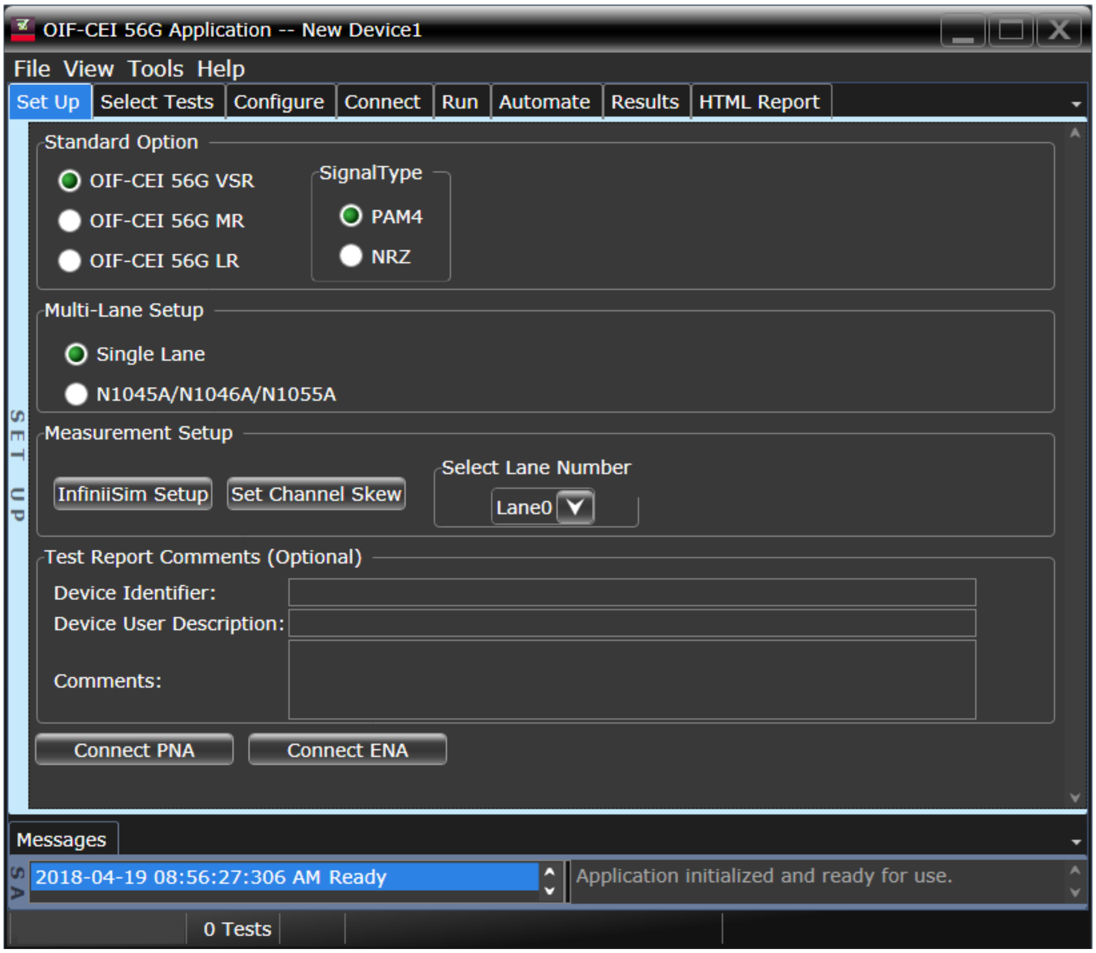


Figure 5 The N109256CB OIF CEI 56G Compliance Test Application default window

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

Table 1 **Task flow under various tabs**

Tab Name	Task flow
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. Select either **Single Lane** if the signal is being tested using one lane or select **N1045A/N1046A/N1055A** for multi-lane signal testing. Set up InfiniiSim with the **InfiniiSim Setup** button. With the **Set Channel Skew** button, the channels can be visually adjusted and skewed. 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, Number of UI to test, scope bandwidth, 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.

Configuring Test App for test runs

This section provides the primary steps that you must perform to run one or more compliance tests on the DUT, which is connected to Oscilloscope.

1 In the **Set Up** tab (shown in Figure 5), 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 Table 1 on page 20.

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 CEI 56G Compliance Test Application sets optimum values for each configuration parameter.

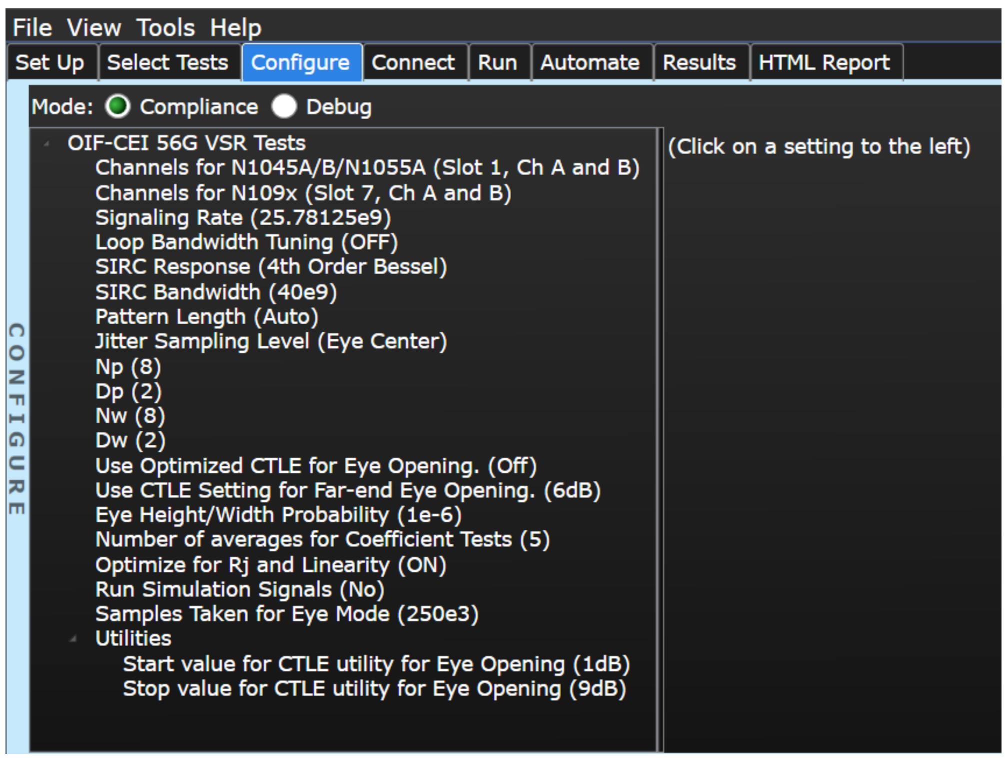


Figure 6 Configure tab in the CEI 56G Compliance Test Application

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 Compliance Test Application that the required hardware setup is complete. The connection diagram for most of the tests matches the one shown in Figure 7. However, it is a good practice to verify the connection diagram and instructions displayed under this tab. The Compliance 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.

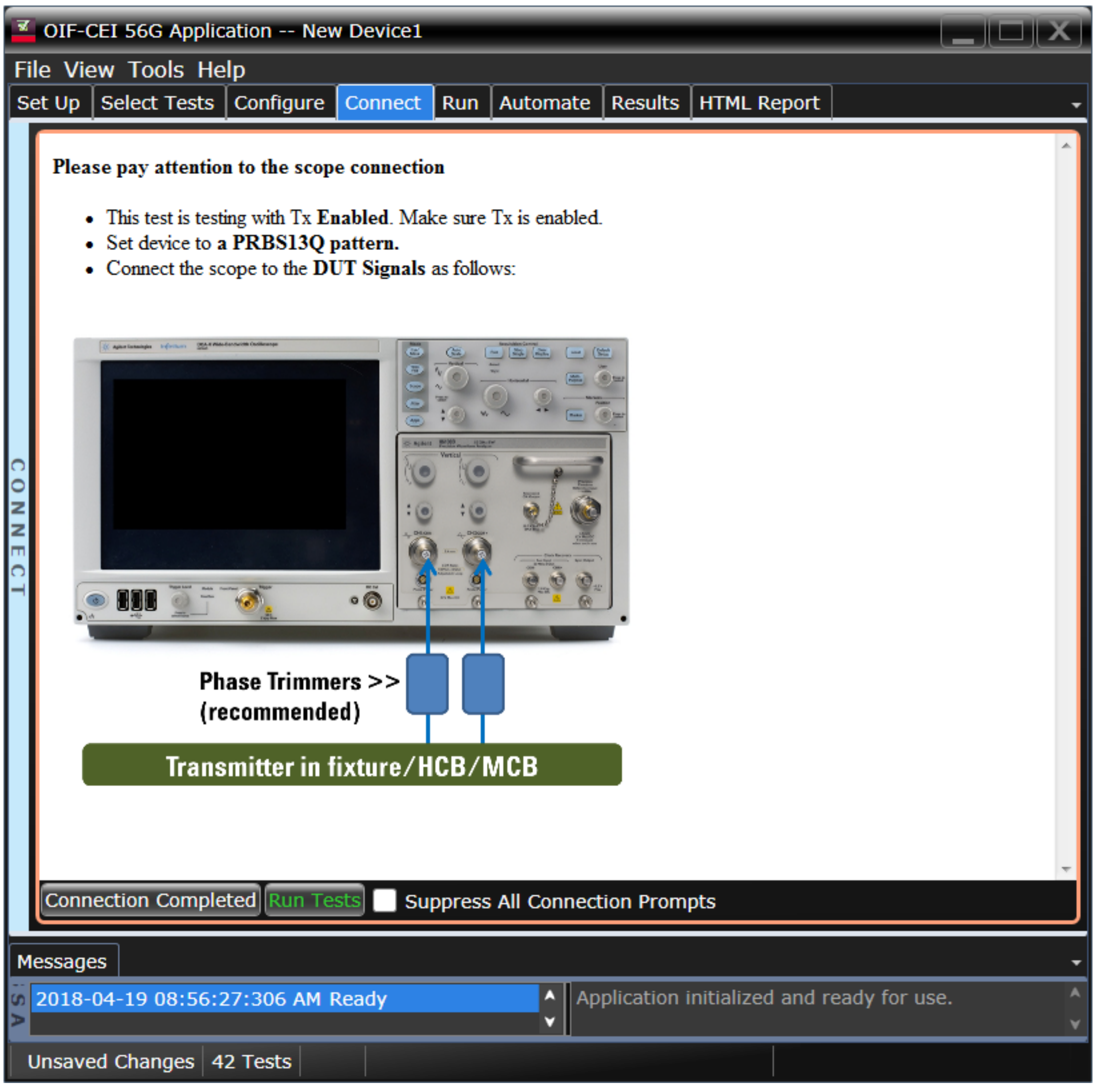


Figure 7 Connect tab in the CEI 56G Compliance Test Application

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.

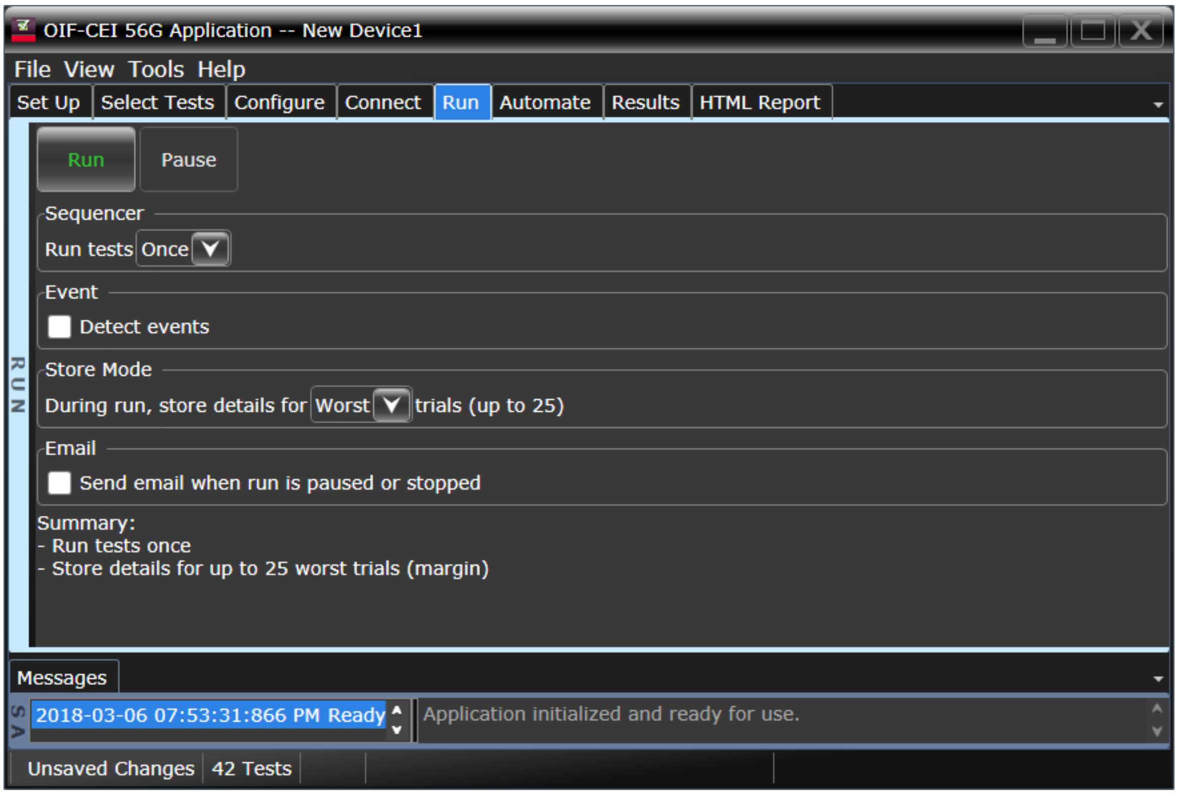


Figure 8 Run tab in CEI 56G Compliance Test Application

7 In the **Automate** tab, you may optionally configure automation scripts to perform specific actions/sequences within the Compliance 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 Compliance Test Application enables exporting these results in CSV or HTML format for the purpose of analysis.

To perform a high-level analysis on each measurement data, you may upload the results to the N8844A Data Analytics Web Services Software. Refer to "Exporting Measurement Results to Repository" on page 24 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.

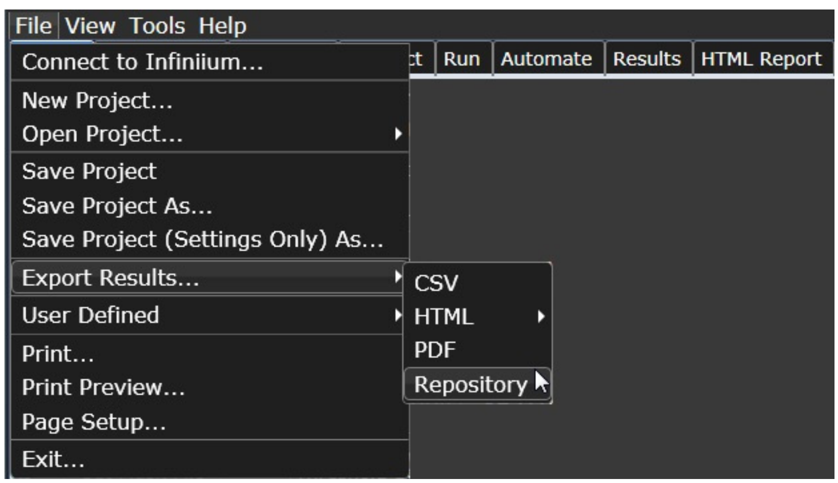
Not only can remote users with an active Internet connection access these Datasets and the corresponding test results on the Web Repository, but they have the option to add and delete Datasets on the Web Server. In the Upload Results To Repository feature, you can even modify the Dataset properties, 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.

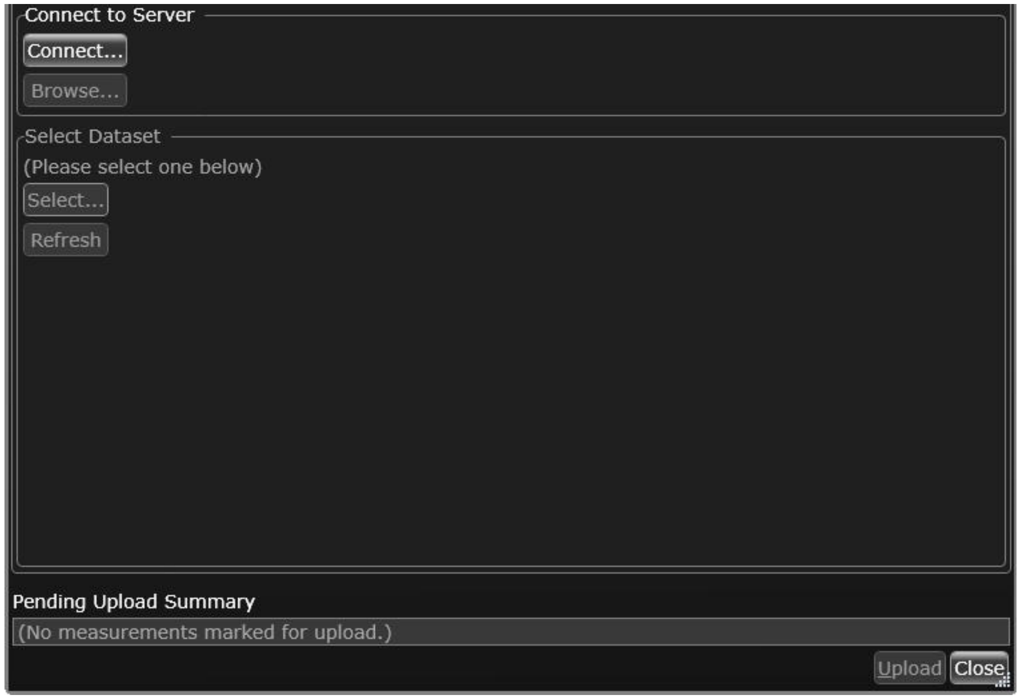
To export measurement results to the Repository after the completion of test runs,

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



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

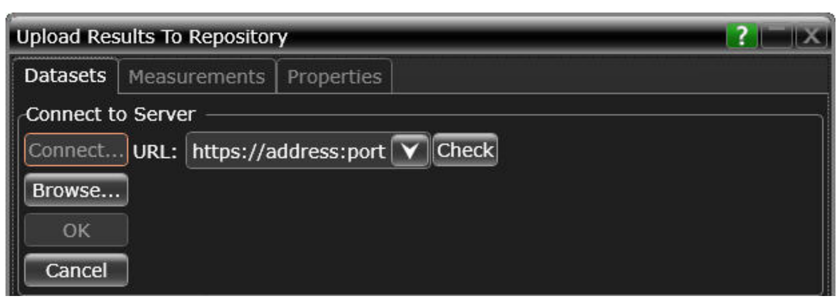
2 In the **Connect to Server** pane of the **Datasets** tab, click **Connect...** to login to the Dataset Repository server.



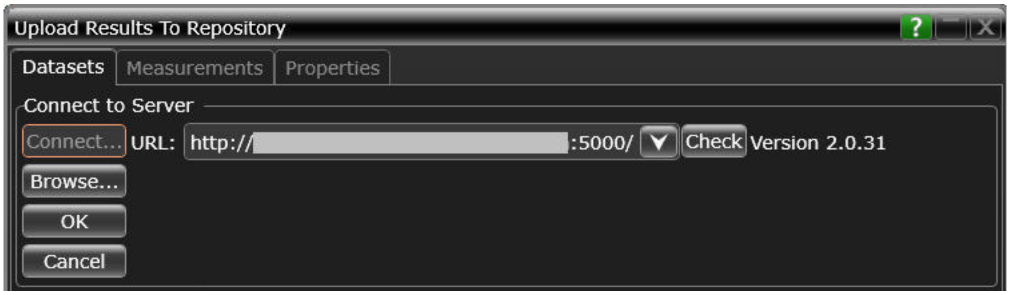
3 In the **URL:** drop-down text field that appears, replace the default text with the actual IP address or the URL along with the port number, if applicable.

   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.

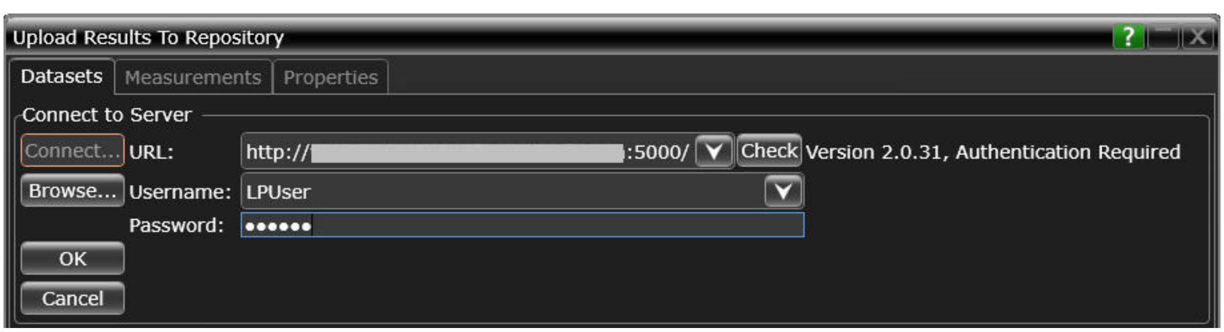


- For unrestricted access to the Repository
  a If the server does not require authentication and the KS6800A Series Analytics service is found on the specified web address, the version information is displayed adjacent to the **Check** button.



  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.

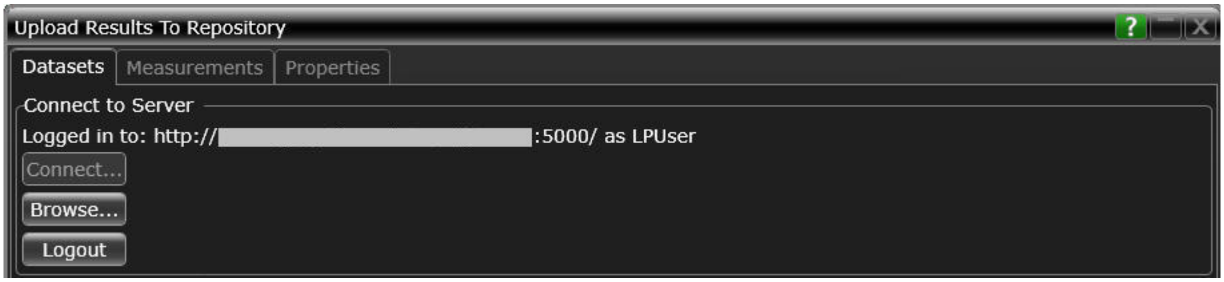
- For restricted access to the Repository
  a If service is found on the specified URL but access to the web server is restricted based on authentication, the version information is displayed along with the text Authentication Required adjacent to the **Check** button. Also, the **Username**: and **Password**: 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.

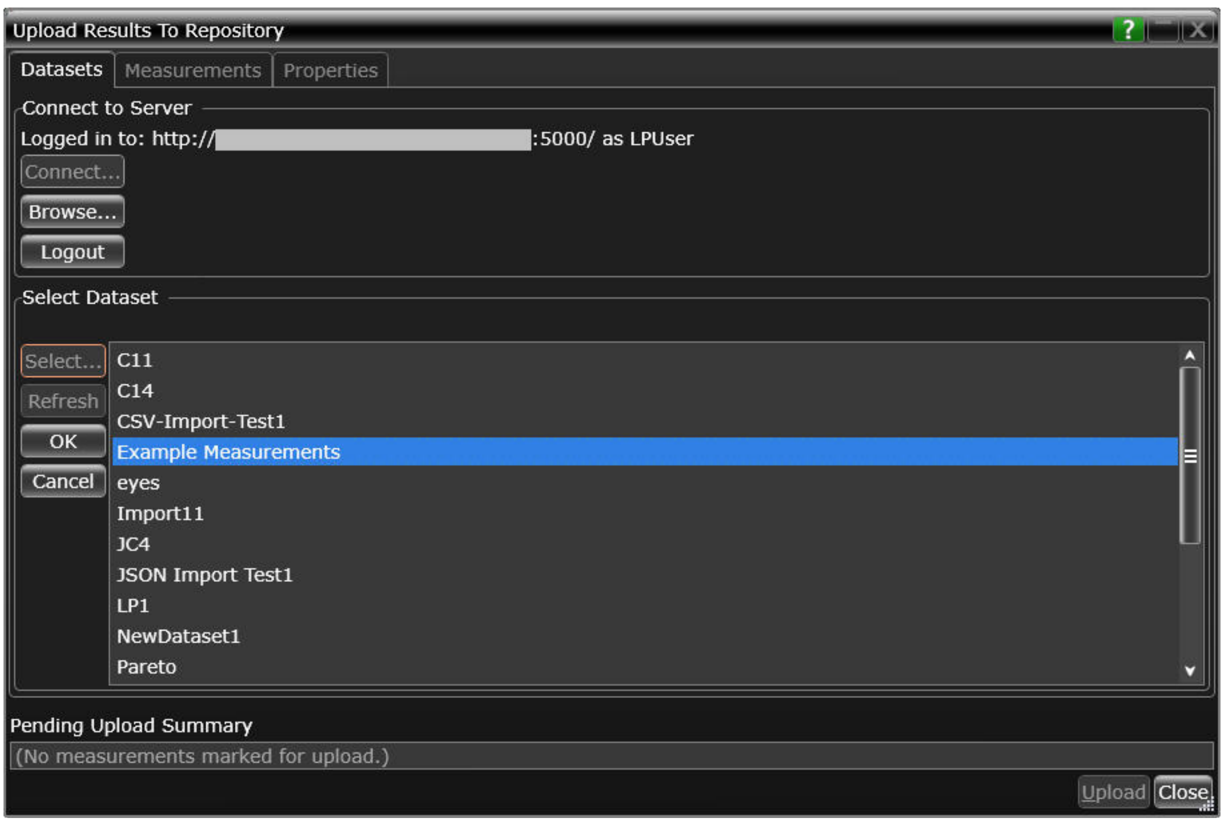
The **Connect to Server** area displays the connection status along with the username.

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

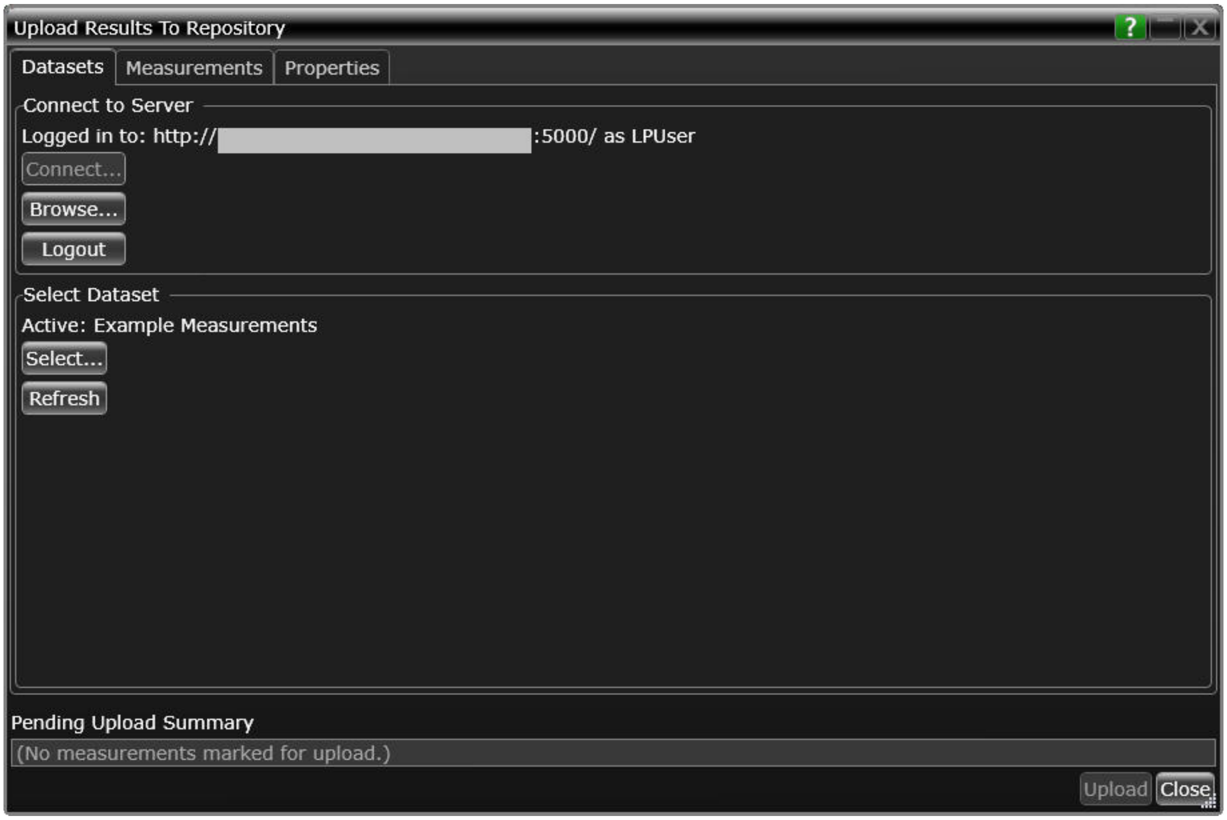


5 In the **Select Dataset** area, click **Select**... to view the list of Datasets created on the connected repository. Click **Refresh** to update the list of Datasets that appear in the Test Application's user interface.

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

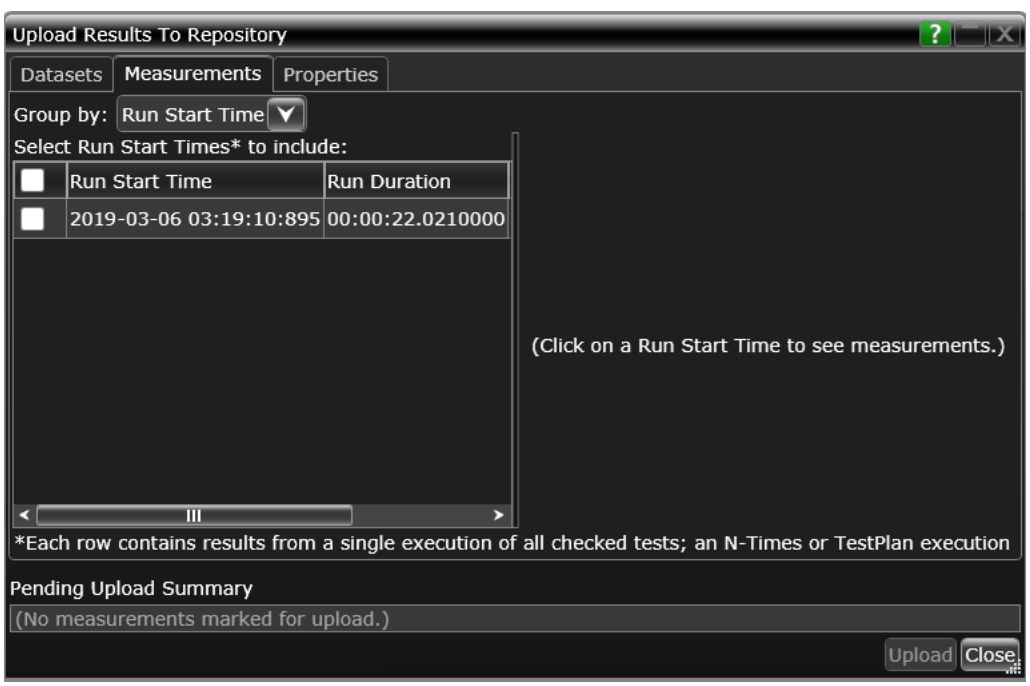


The **Select Dataset** area displays the selected Dataset as Active. The **Measurements** and **Properties** tabs are enabled after a Dataset is selected.



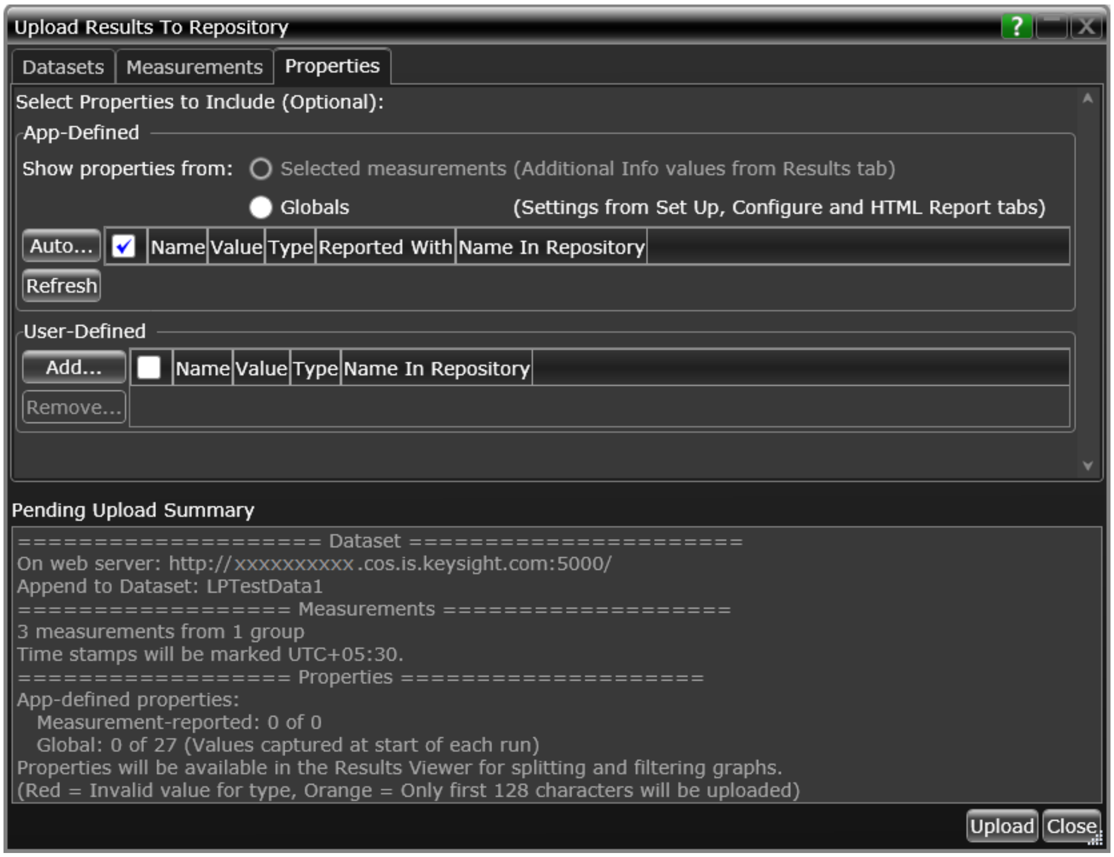
7 Click the **Measurements** tab where the test results from the last test run are displayed.

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.

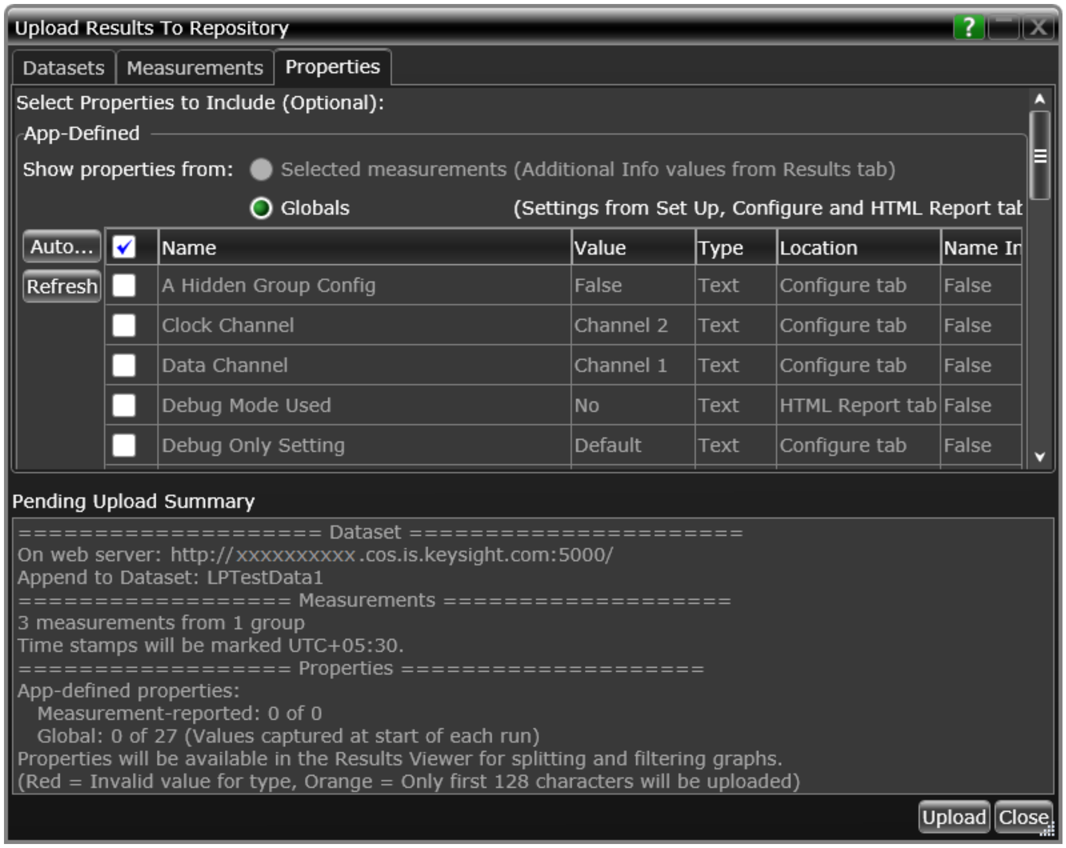


9 After selecting one or more measurements, either click **Upload** or switch to the **Properties** tab to associate one or more properties to the measurements that are being uploaded to the Web Server.

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.



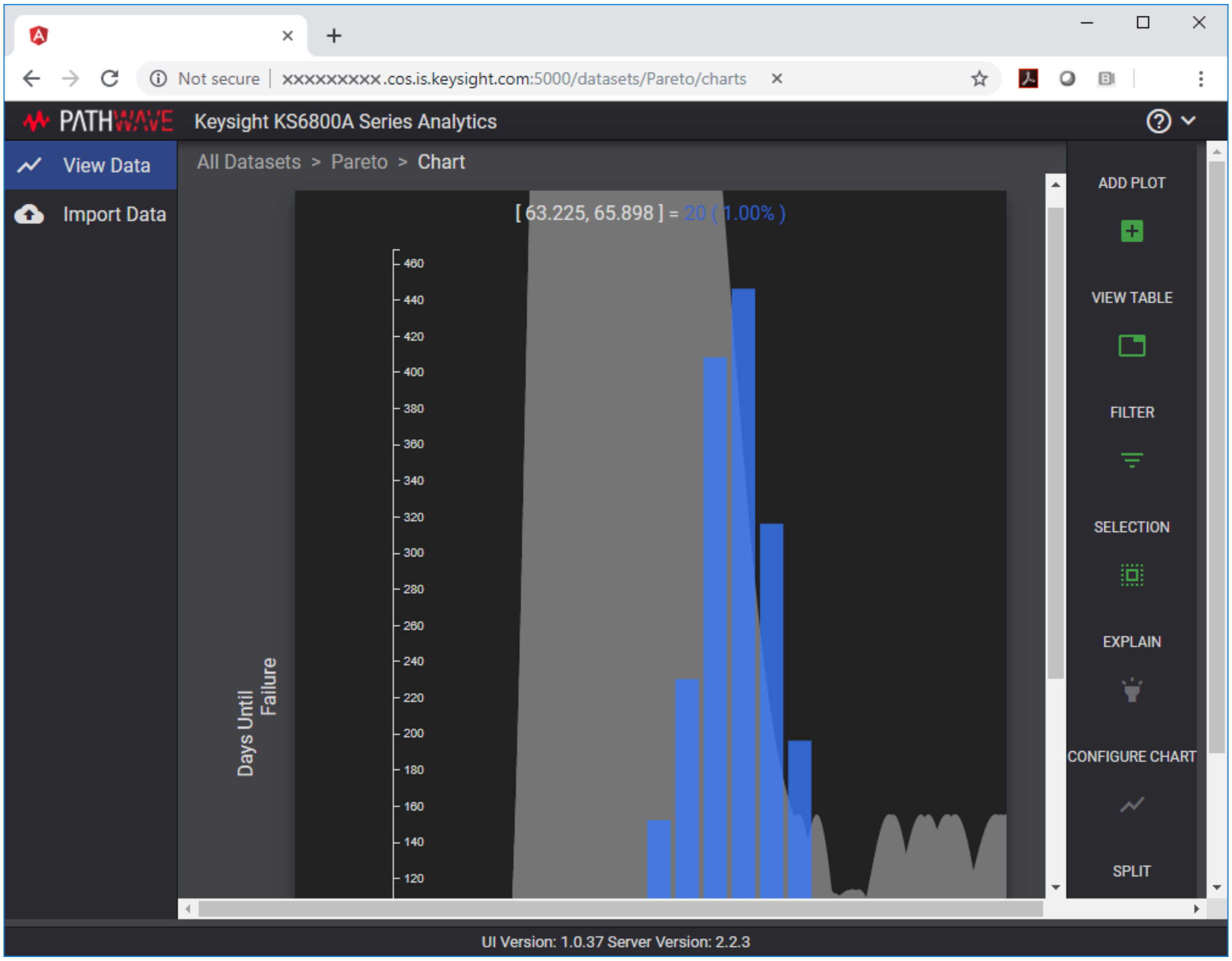
11 Click **Upload** to begin uploading measurement results.

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.

3 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.

KEYSIGHT TECHNOLOGIES

Host-to-Module transmitter output Electrical Recommendations

Table 2 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 N109256CB CEI 56G Compliance Test Application.

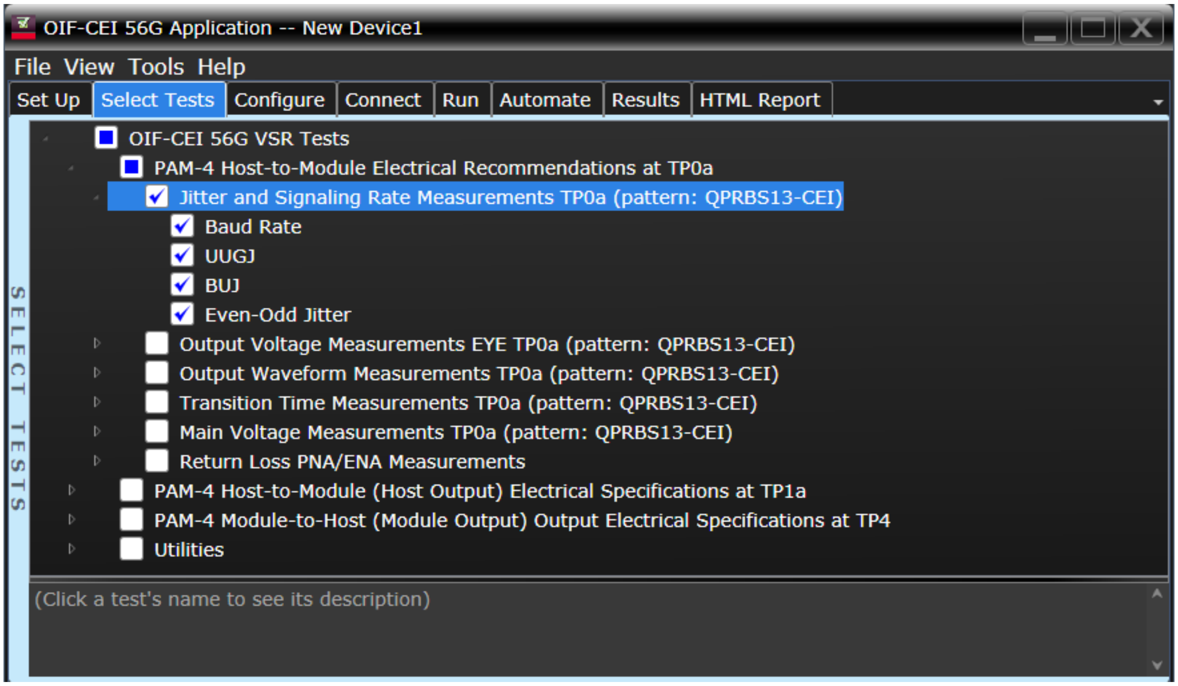


Figure 9 Selecting Jitter and Signaling Rate Measurement Tests

Refer to Table 2 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 36
- “UUGJ” on page 37
- “BUJ” on page 38
- “Even-Odd Jitter” on page 39

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 2.

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 2.

Measurement Algorithm

1 Obtain sample or acquire signal data.

NOTE **Signal must be of QPRBS13-CEI pattern and connections must be established between Data+ to Channel 1 and Data- to Channel 3 to measure the defined 12 edges.**

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 3.883 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.

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 2.

Measurement Algorithm

1 Obtain sample or acquire signal data.

NOTE

Signal must be of QPRBS13-CEI pattern and connections must be established between Data+ to Channel 1 and Data- to Channel 3 to measure the defined 12 edges.

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 3.883 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.

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 2.

Measurement Algorithm

1 Obtain sample or acquire signal data.

NOTE **Signal must be of QPRBS13-CEI pattern and connections must be established between Data+ to Channel 1 and Data- to Channel 3 to measure the defined 12 edges.**

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 3.883 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 4th Order Bessel Thompson filter to 40 GHz.

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 N109256CB CEI 56G Compliance Test Application.

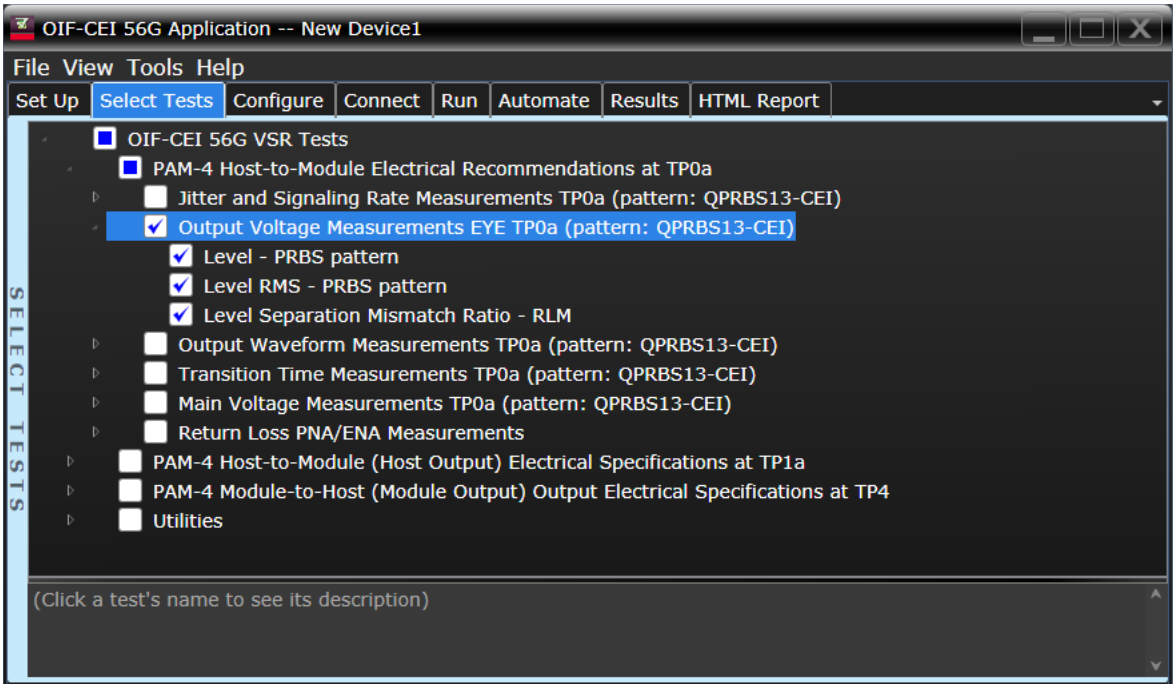


Figure 10 Selecting Output Voltage Measurements EYE Tests

Refer to Table 2 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 41
- "Level RMS - PRBS Pattern" on page 42
- "Level Separation Mismatch Ratio - RLM" on page 43

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 N109256CB CEI 56G Compliance Test Application.

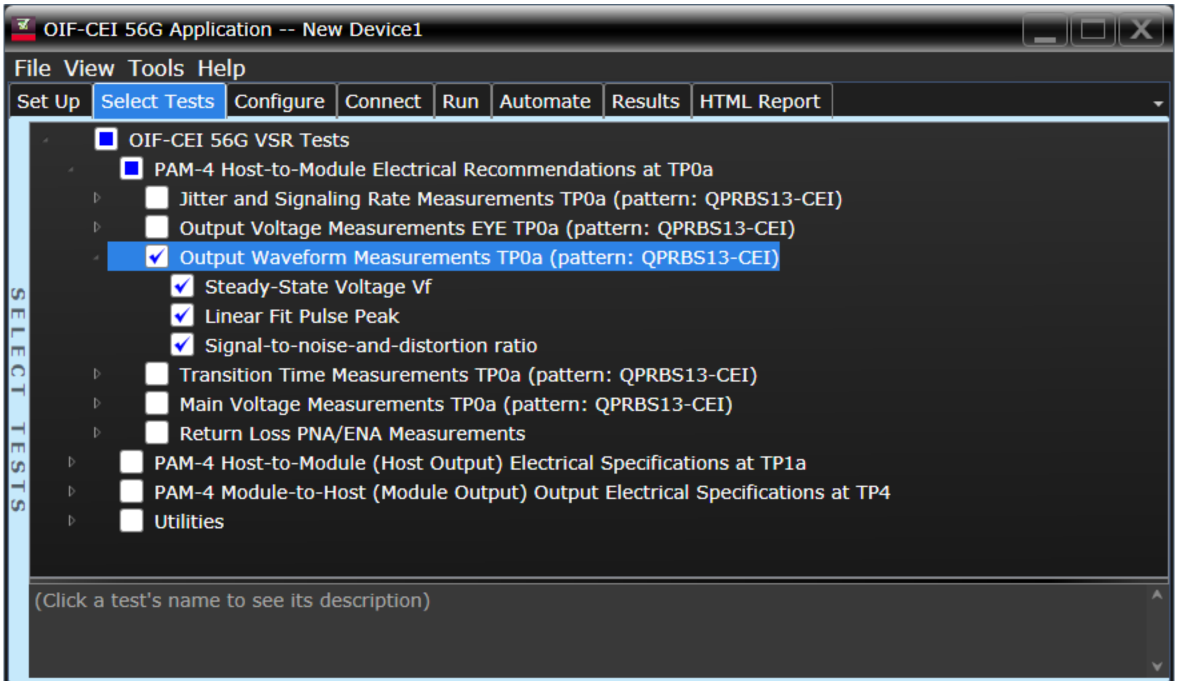


Figure 11 Selecting Output Waveform Measurements

Refer to Table 2 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 45
- “Linear Fit Pulse Peak” on page 46
- “Signal-to-noise-and-distortion ratio” on page 47

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 Set memory depth and sample rate to capture the 8191 bits of the QPRBS13-CEI pattern.

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 Set memory depth and sample rate to capture the 8191 bits of the QPRBS13-CEI pattern.

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 2.

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 N109256CB CEI 56G Compliance Test Application.

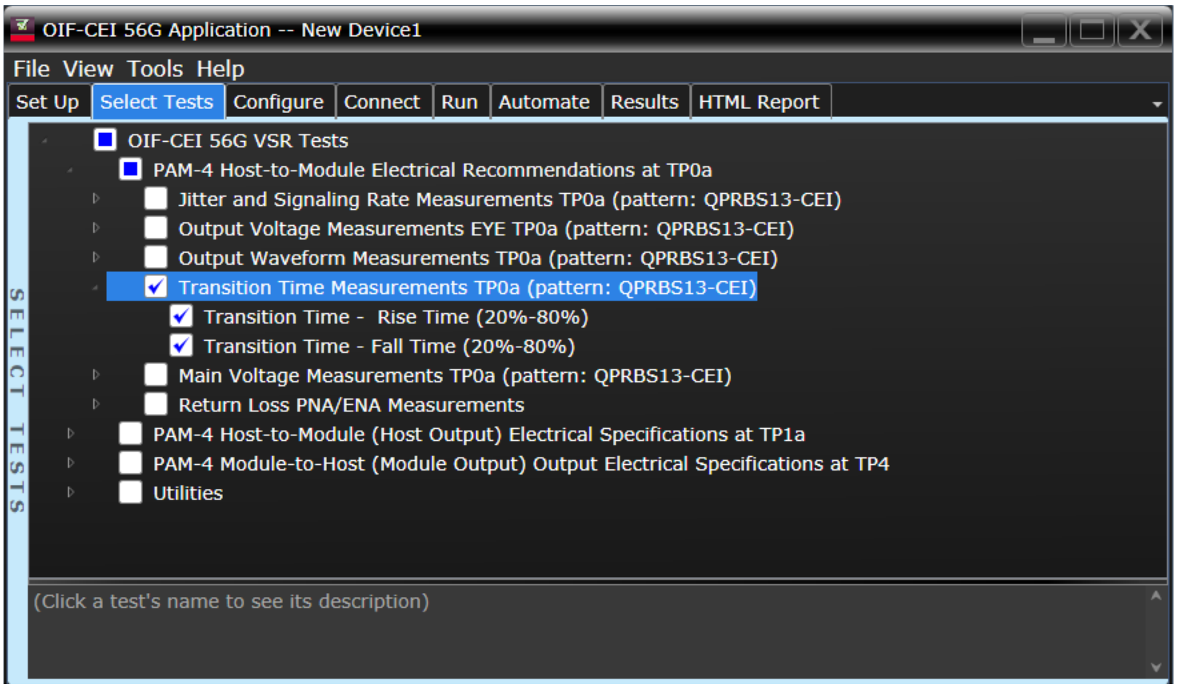


Figure 12 Selecting Transition Time Measurement Tests

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

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

- "Transition Time - Rise Time (20%-80%)" on page 49
- "Transition Time - Fall Time (20%-80%)" on page 50

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 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 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 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 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 N109256CB CEI 56G Compliance Test Application.

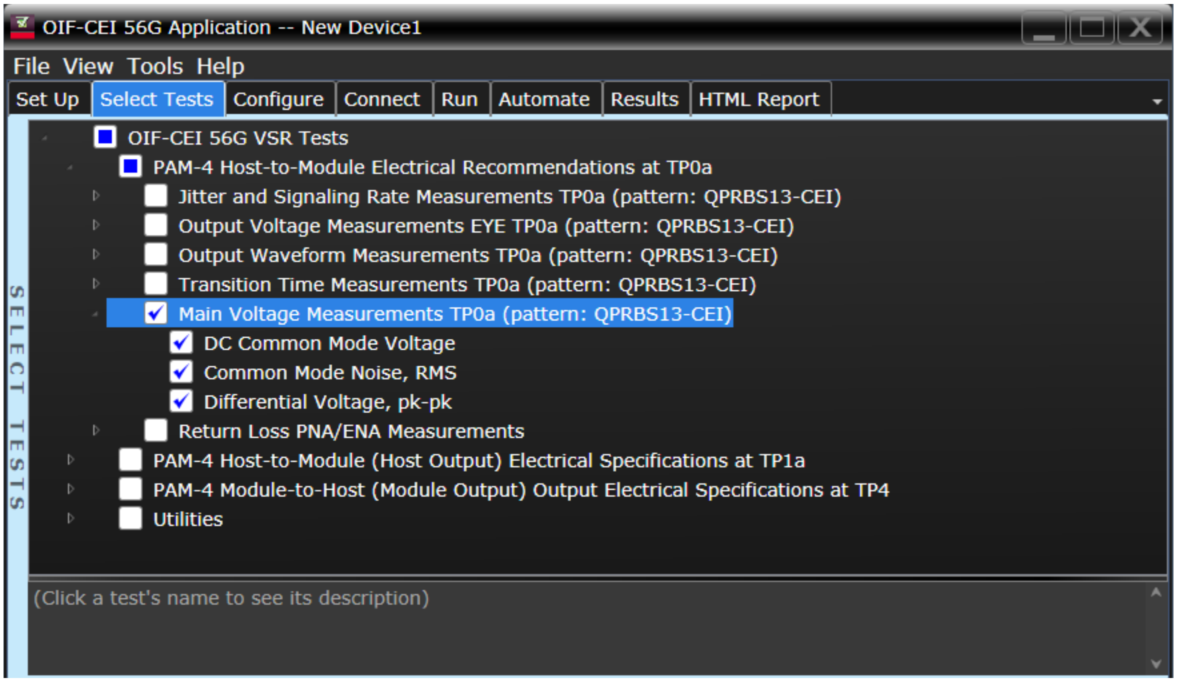


Figure 13 Selecting Main Voltage Measurement Tests

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

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

- "DC Common Mode Output Voltage" on page 52
- "Common Mode Noise, RMS" on page 53
- "Differential Voltage, pk-pk" on page 54

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 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 Set common mode signal using the common mode function.
4 Measure minimum and maximum voltage of the common mode signal.
5 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 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 Set common mode signal using the common mode function.
4 Measure RMS voltage of the common mode signal.
5 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 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 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 N109256CB CEI 56G Compliance 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.

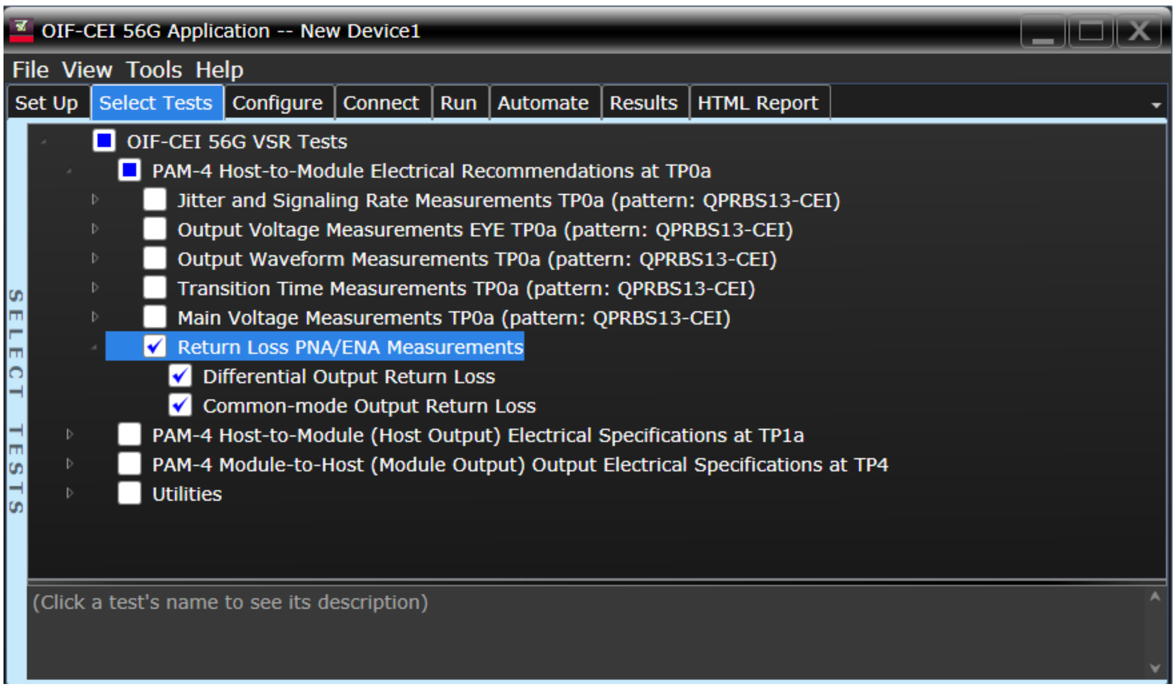


Figure 14 Selecting Return Loss Measurement Tests

Refer to Table 2 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 56
- "Common-mode Output Return Loss" on page 57

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.

4 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.

Host-to-Module Electrical Specifications

Table 3 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 N109256CB CEI 56G Compliance Test Application.

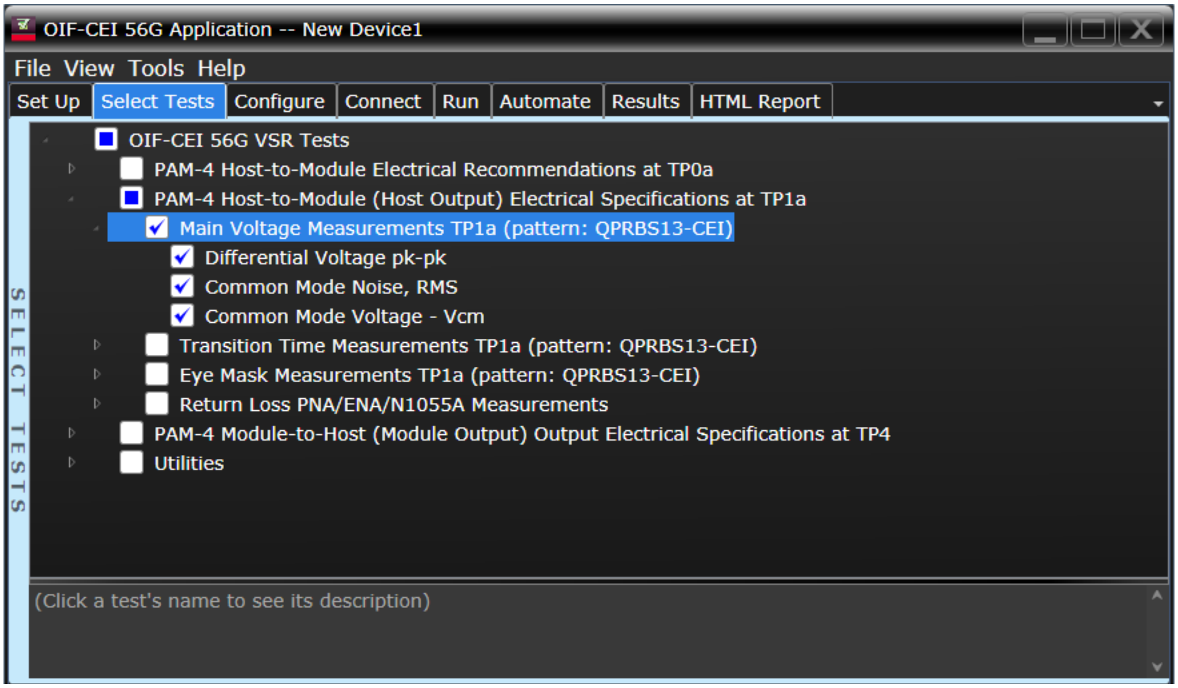


Figure 15 Selecting Main Voltage Measurement Tests

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

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

- "Differential Voltage pk-pk" on page 62
- "Common Mode Noise, RMS" on page 63
- "Common Mode Voltage - Vcm" on page 64

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 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 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 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 Set common mode signal using the common mode function.
4 Measure RMS voltage of the common mode signal.
5 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 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 Set common mode signal using the common mode function.
4 Measure minimum and maximum voltage of the common mode signal.
5 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 N109256CB CEI 56G Compliance Test Application.

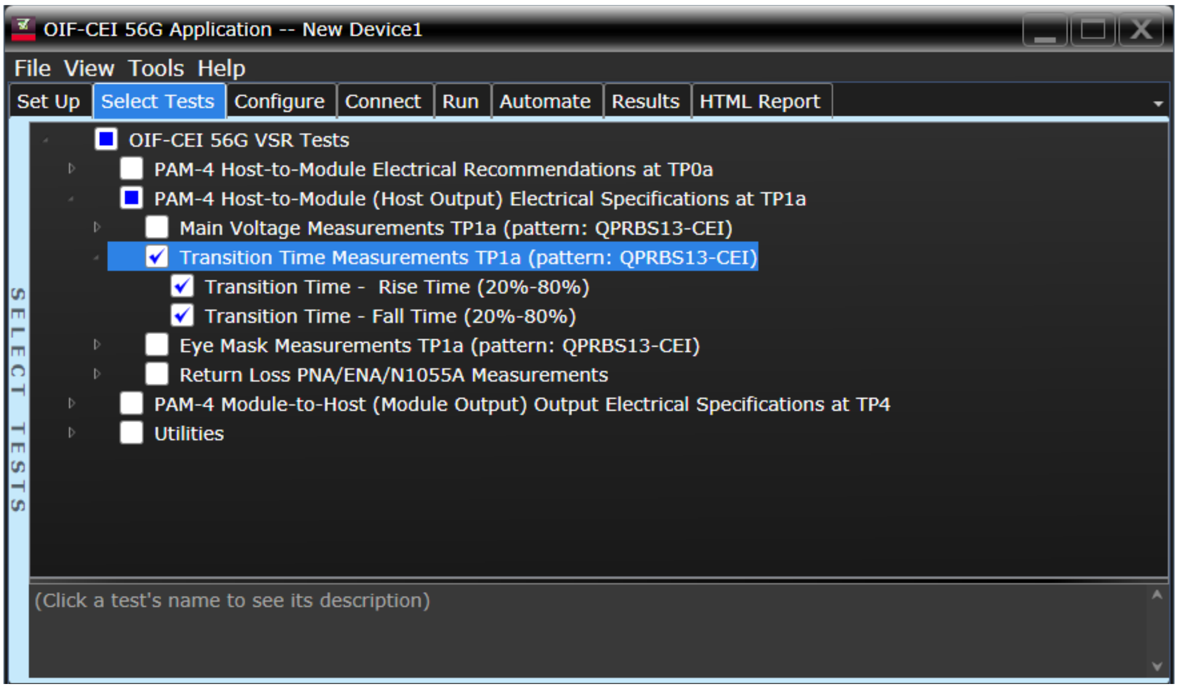


Figure 16 Selecting Transition Time Measurement Tests

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

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

- "Transition Time - Rise Time (20%-80%)" on page 66
- "Transition Time - Fall Time (20%-80%)" on page 67

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 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 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 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 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 N109256CB CEI 56G Compliance Test Application.

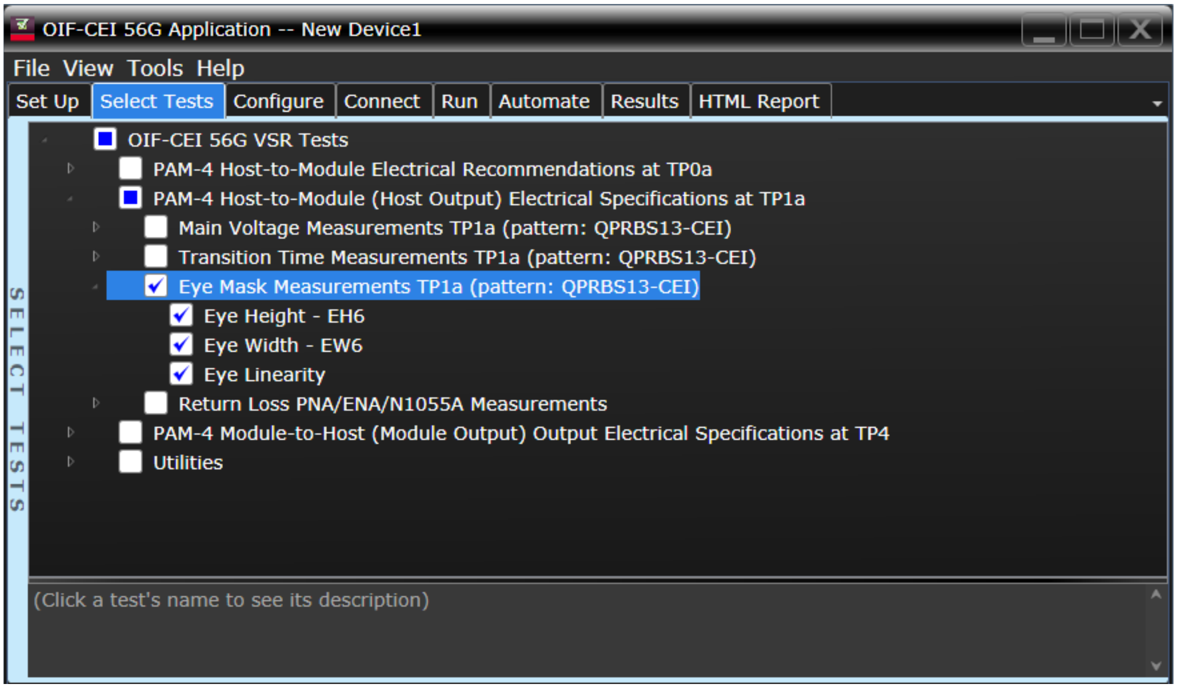


Figure 17 Selecting Eye Mask Measurement Tests

Refer to Table 3 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 69
- "Eye Width - EW6" on page 70
- "Eye Linearity" on page 71

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.

Pass Conditions Refer to Table 3.

Measurement Algorithm

1 For the optimal CTLE, you may approach in one of the following ways:
   - This setting can be characterized and automatically set by using the **Find Optimal CTLE Eye Opening** under the **Utilities** in the **Select Tests** tab.
   - Manually select the optimal CTLE setting from the **Use Optimized CTLE for Eye Opening** drop-down options 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 3.883 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.

Pass Conditions Refer to Table 3.

Measurement Algorithm

1 For the optimal CTLE, you may approach in one of the following ways:
   - This setting can be characterized and automatically set by using the **Find Optimal CTLE Eye Opening** under the **Utilities** in the **Select Tests** tab.
   - Manually select the optimal CTLE setting from the **Use Optimized CTLE for Eye Opening** drop-down options 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 3.883 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.

Pass Condition Refer to Table 3.

Measurement Algorithm

1 For the optimal CTLE, you may approach in one of the following ways:

- This setting can be characterized and automatically set by using the **Find Optimal CTLE Eye Opening** under the **Utilities** in the **Select Tests** tab.
- Manually select the optimal CTLE setting from the **Use Optimized CTLE for Eye Opening** drop-down options 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 3.883 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 N109256CB CEI 56G Compliance 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.

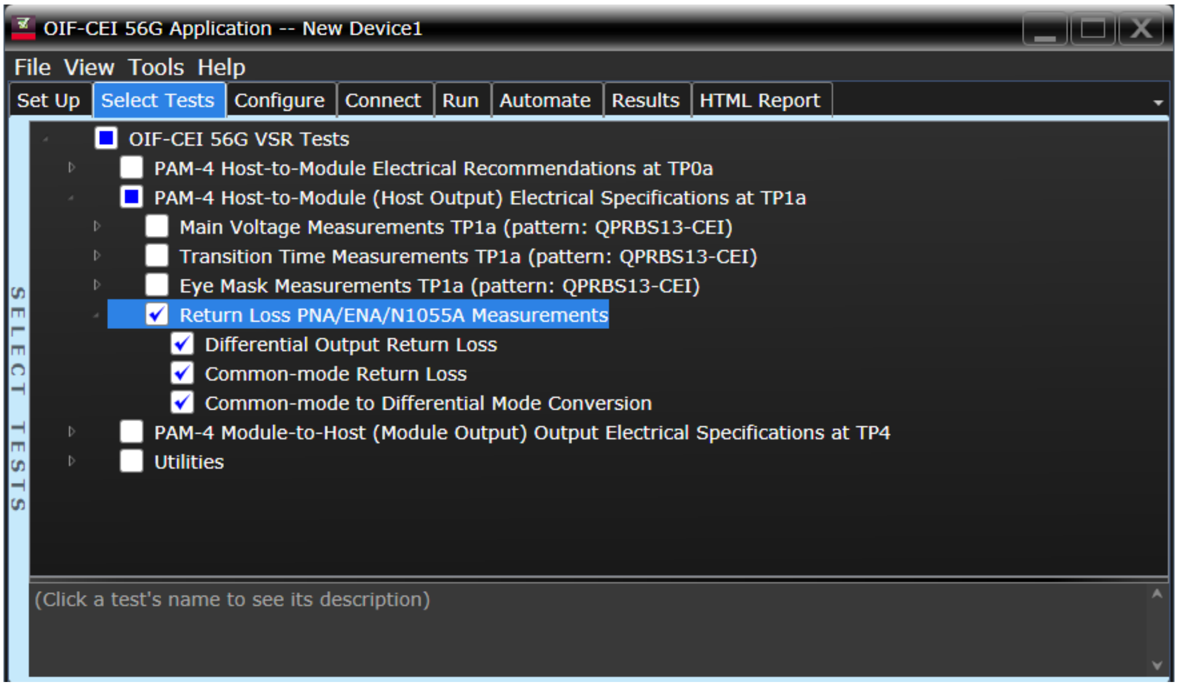


Figure 18 Selecting Return Loss Measurement Test

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 73
- “Common-mode Return Loss” on page 74
- “Common-mode to Differential Mode Conversion” on page 75

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.

5 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 4 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 N109256CB CEI 56G Compliance Test Application.

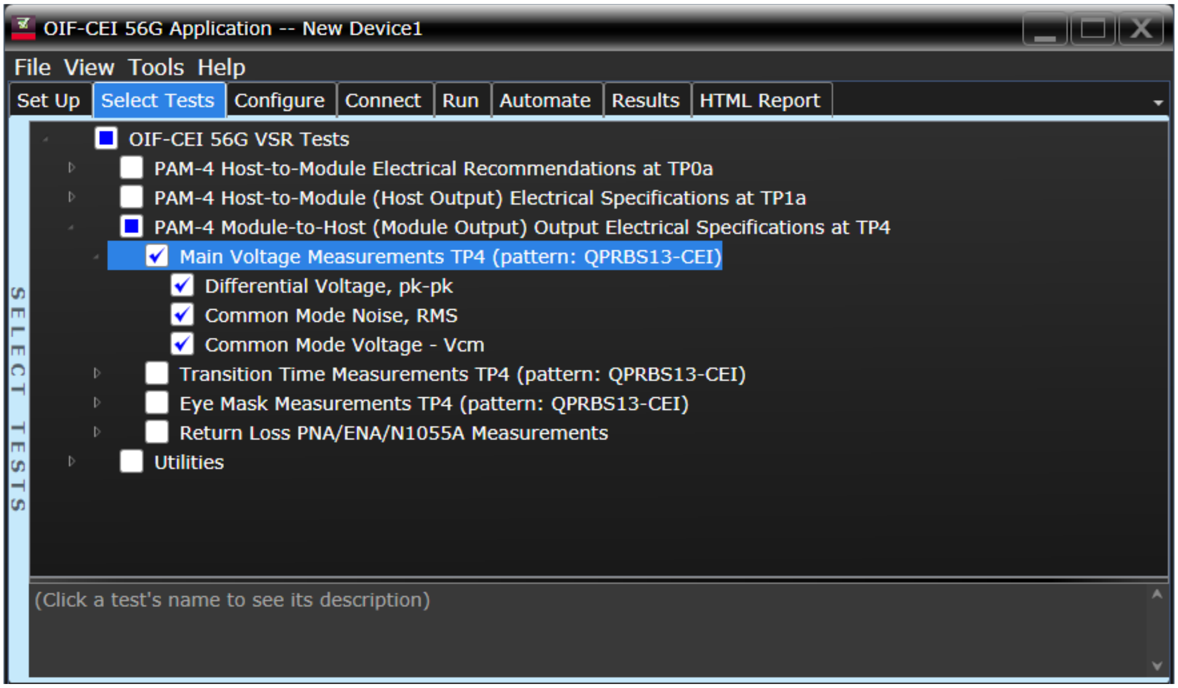


Figure 19 Selecting Main Voltage Measurement Tests

Refer to Table 4 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 80
- "Common Mode Noise, RMS" on page 81
- "Common Mode Voltage - Vcm" on page 82

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 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 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 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 Set common mode signal using the common mode function.
4 Measure RMS voltage of the common mode signal.
5 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 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 Set common mode signal using the common mode function.
4 Measure minimum and maximum voltage of the common mode signal.
5 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 N109256CB CEI 56G Compliance Test Application.

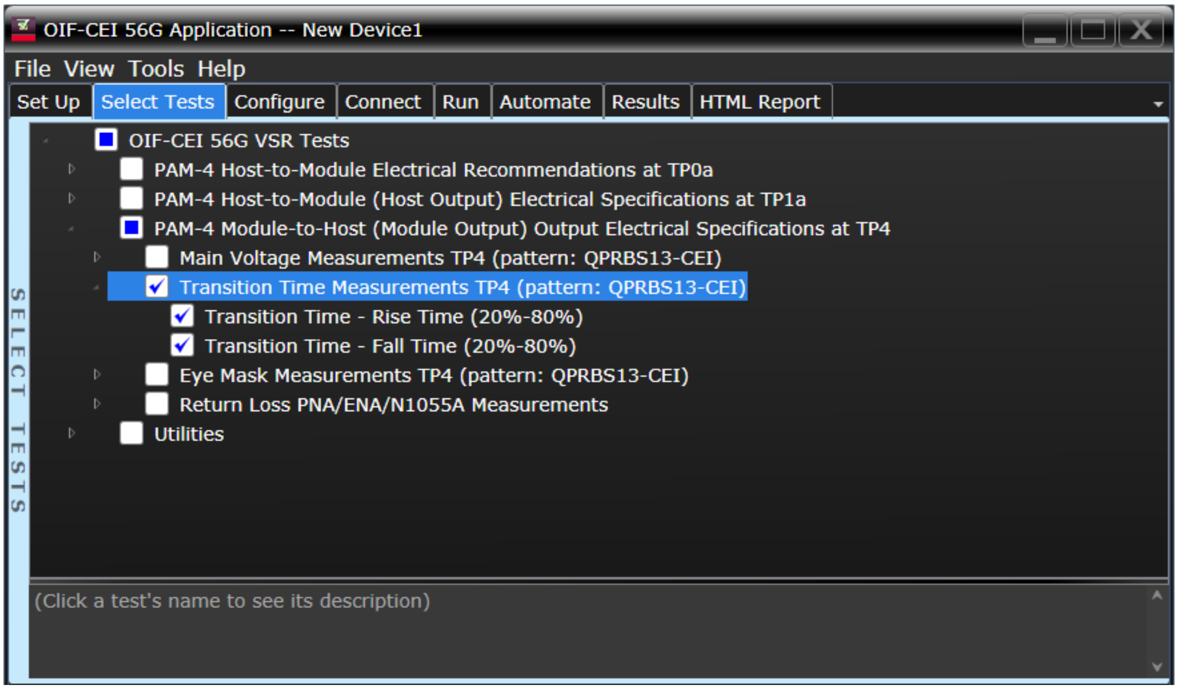


Figure 20 Selecting Transition Time Measurement Tests

Refer to Table 4 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 84
- "Transition Time - Fall Time (20%-80%)" on page 85

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 4.

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 4.

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 N109256CB CEI 56G Compliance Test Application.

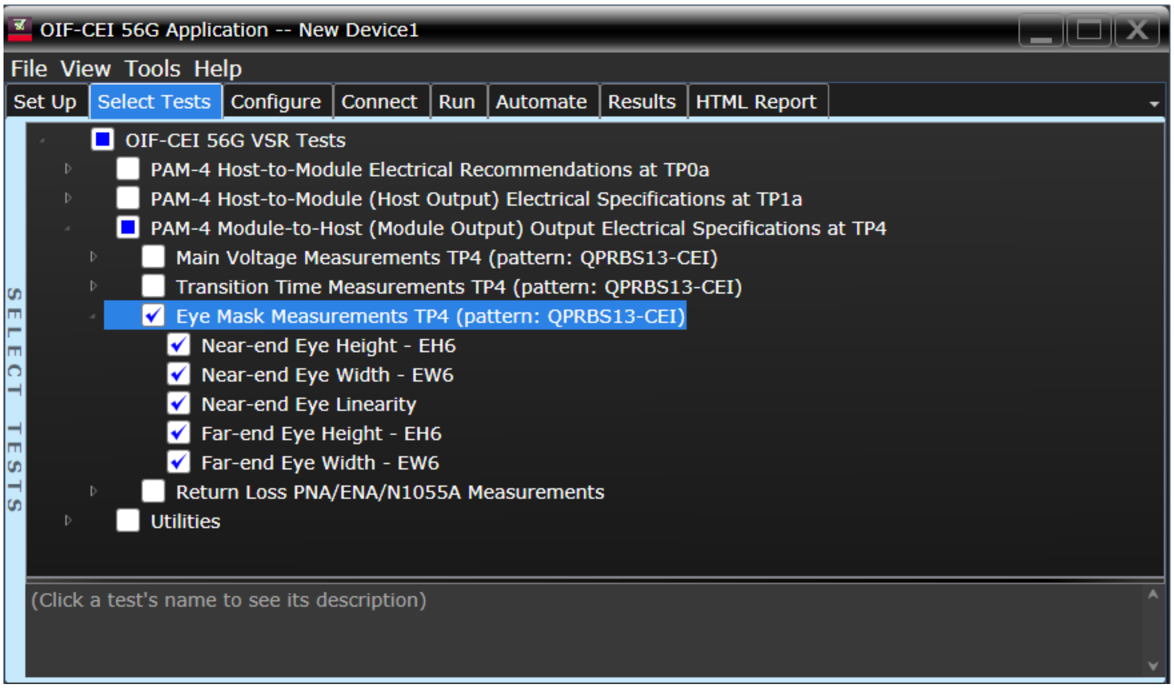


Figure 21 Selecting Eye Mask Measurement Tests

Refer to Table 4 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 87
- "Near-End Eye Width - EW6" on page 88
- "Near-end Eye Linearity" on page 89
- "Far-end Eye Height - EH6" on page 90
- "Far-end Eye Width - EW6" on page 91

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.

Pass Condition Refer to Table 4.

Measurement Algorithm

1 For the optimal CTLE, you may approach in one of the following ways:
   - This setting can be characterized and automatically set by using the **Find Optimal CTLE Eye Opening** under the **Utilities** in the **Select Tests** tab.
   - Manually select the optimal CTLE setting from the **Use Optimized CTLE for Eye Opening** drop-down options 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 3.883 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.

Pass Condition Refer to Table 4.

Measurement Algorithm

1. For the optimal CTLE, you may approach in one of the following ways:
   - This setting can be characterized and automatically set by using the **Find Optimal CTLE Eye Opening** under the **Utilities** in the **Select Tests** tab.
   - Manually select the optimal CTLE setting from the **Use Optimized CTLE for Eye Opening** drop-down options 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 3.883 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.

Pass Condition Refer to Table 4.

Measurement Algorithm

1 For the optimal CTLE, you may approach in one of the following ways:
   - This setting can be characterized and automatically set by using the **Find Optimal CTLE Eye Opening** under the **Utilities** in the **Select Tests** tab.
   - Manually select the optimal CTLE setting from the **Use Optimized CTLE for Eye Opening** drop-down options 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 3.883 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.

Pass Condition Refer to Table 4.

Measurement Algorithm

1 For the optimal CTLE, you may approach in one of the following ways:
   - This setting can be characterized and automatically set by using the **Find Optimal CTLE Eye Opening** under the **Utilities** in the **Select Tests** tab.
   - Manually select the optimal CTLE setting from the **Use Optimized CTLE for Eye Opening** drop-down options 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 3.883 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.

Pass Condition Refer to Table 4.

Measurement Algorithm

1 For the optimal CTLE, you may approach in one of the following ways:
   - This setting can be characterized and automatically set by using the **Find Optimal CTLE Eye Opening** under the **Utilities** in the **Select Tests** tab.
   - Manually select the optimal CTLE setting from the **Use Optimized CTLE for Eye Opening** drop-down options 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 3.883 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 N109256CB CEI 56G Compliance 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.

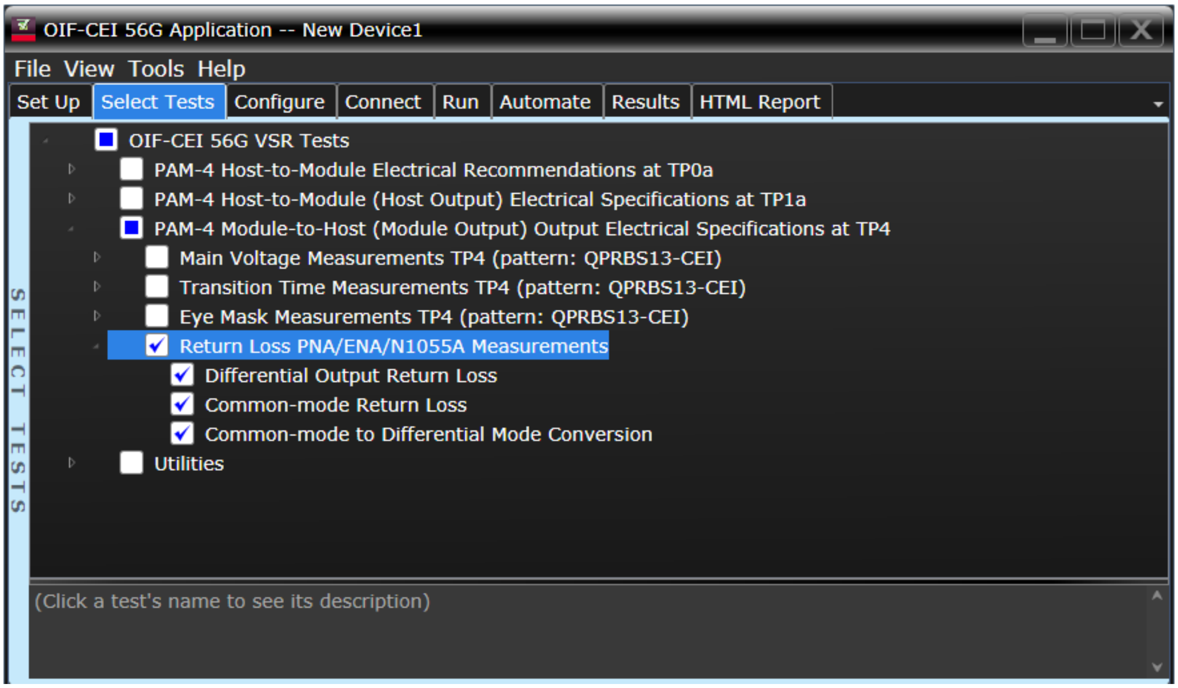


Figure 22 Selecting Return Loss Measurement Tests

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 93
- "Common-mode Return Loss" on page 94
- "Common-mode to Differential Mode Conversion" on page 95

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.

6 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 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
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 N109256CB CEI 56G Compliance Test Application.

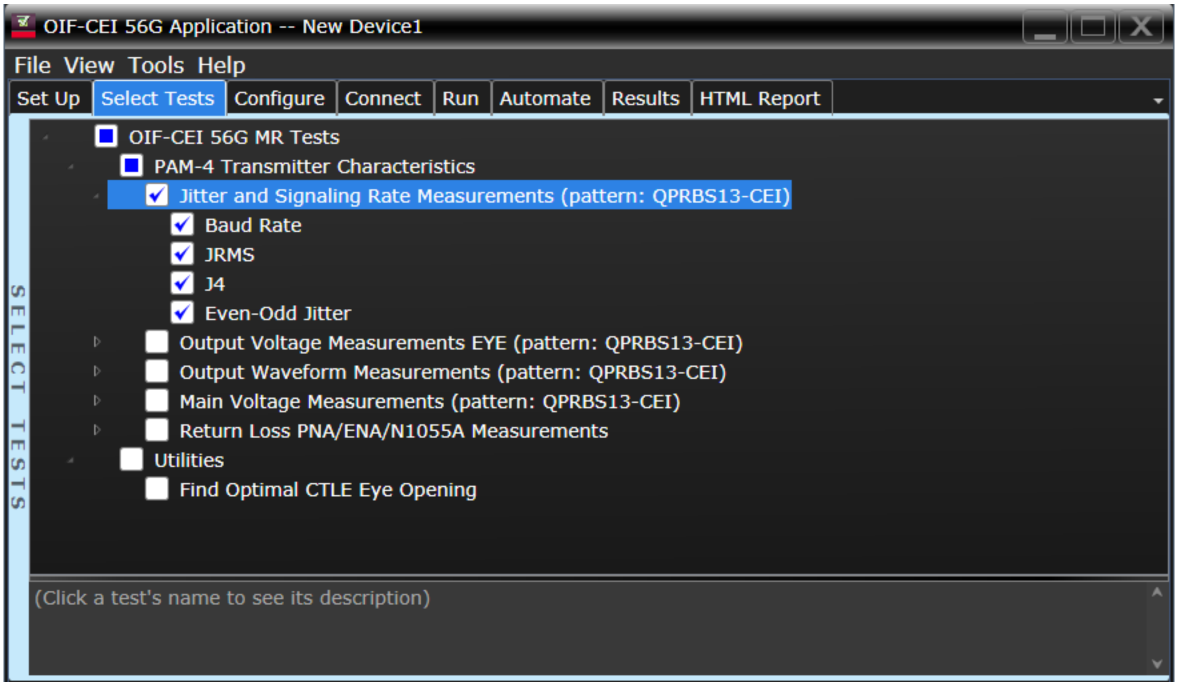


Figure 23 Selecting Jitter and Signaling Rate Measurements

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 100
- “JRMS” on page 101
- “J4” on page 102
- “Even-Odd Jitter” on page 103

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.

NOTE **Signal must be of QPRBS13-CEI pattern and connections must be established between Data+ to Channel 1 and Data- to Channel 3 to measure the defined 12 edges.**

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 3.883 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.

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.

NOTE **Signal must be of QPRBS13-CEI pattern and connections must be established between Data+ to Channel 1 and Data- to Channel 3 to measure the defined 12 edges.**

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 3.883 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.

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.

NOTE **Signal must be of QPRBS13-CEI pattern and connections must be established between Data+ to Channel 1 and Data- to Channel 3 to measure the defined 12 edges.**

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 3.883 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.

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 N109256CB CEI 56G Compliance Test Application.

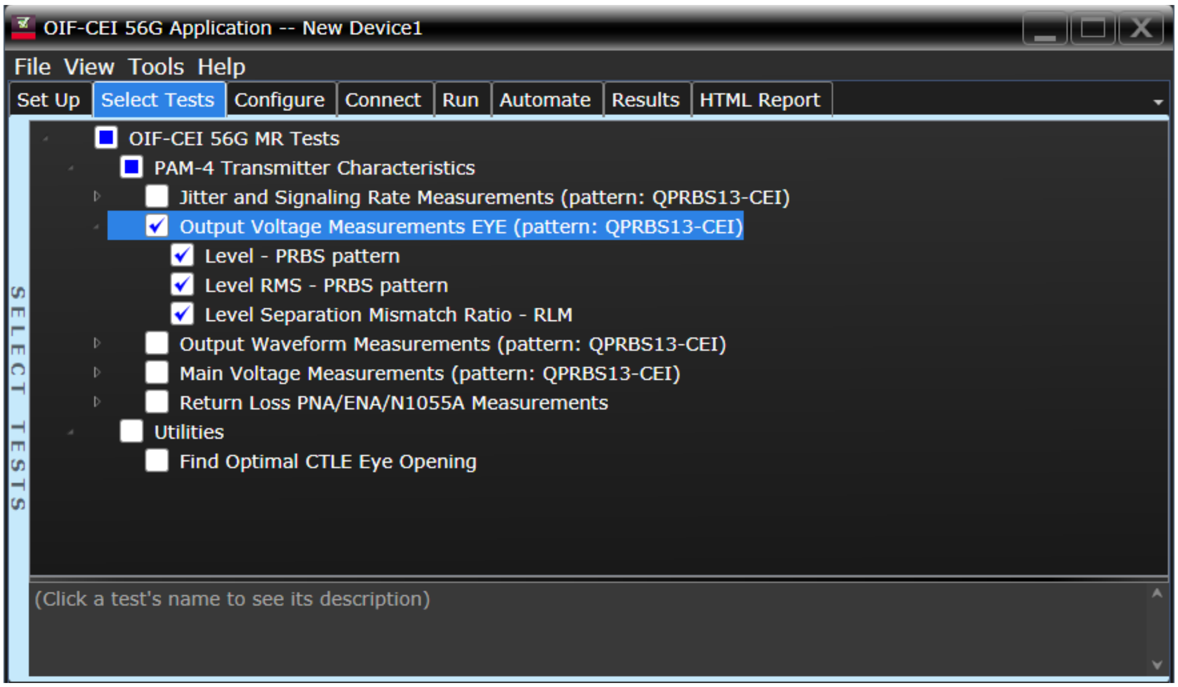


Figure 24 Selecting Output Voltage Measurements EYE Tests

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 105
- "Level RMS - PRBS pattern" on page 106
- "Level Separation Mismatch Ratio - RLM" on page 107

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 Transmitter Output Waveform Measurement procedures for Transition Time that are described in this section are performed using a Keysight Infiniium oscilloscope and the N109256CB CEI 56G Compliance Test Application.

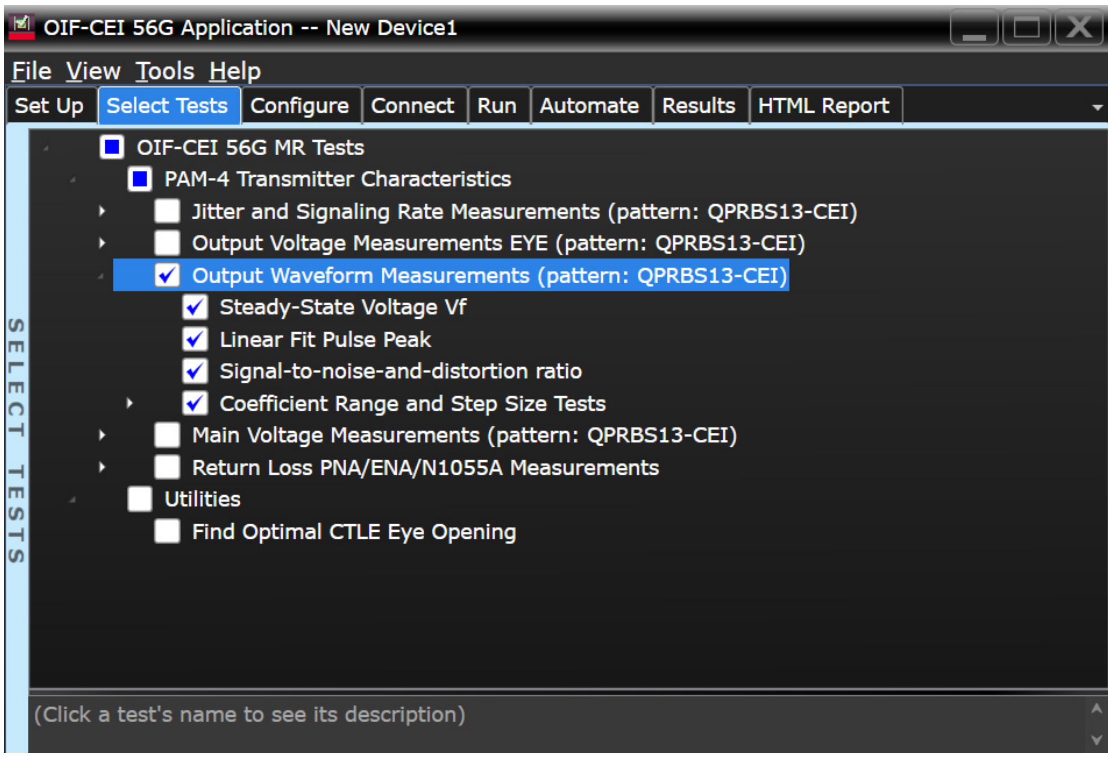


Figure 25 Selecting Output Waveform Measurements

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 109
- "Linear Fit Pulse Peak" on page 110
- "Signal-to-noise-and-distortion ratio" on page 111
- "Coefficient Range and Step Size Tests" on page 112

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. Set memory depth and sample rate to capture the 8191 bits of the QPRBS13-CEI pattern.
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 Set memory depth and sample rate to capture the 8191 bits of the QPRBS13-CEI pattern.
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.

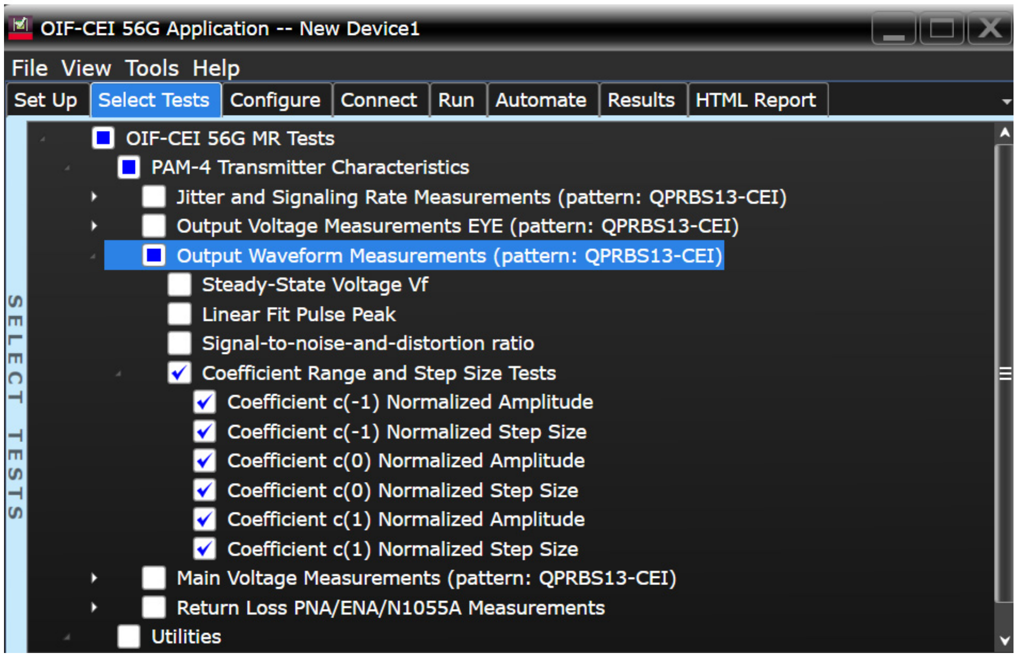
Pass Condition Refer to Table 5.

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.

Coefficient Range and Step Size Tests

Test Overview The purpose of these tests is to verify the coefficient normalized amplitude and coefficient normalized step size.



To know more about the algorithm of coefficient normalized amplitude and coefficient normalized step size tests, see:

- "Coefficient c(-1) Normalized Amplitude and Coefficient c(-1) Normalized Step Size" on page 113
- "Coefficient c(0) Normalized Amplitude and Coefficient c(0) Normalized Step Size" on page 114
- "Coefficient c(1) Normalized Amplitude and Coefficient c(1) Normalized Step Size" on page 115

Coefficient c(-1) Normalized Amplitude and Coefficient c(-1) Normalized Step Size

Test Overview The purpose of the Coefficient c(-1) Normalized Amplitude test is to verify that the normalized amplitude of each step is between -15% to 0%. The purpose of the Coefficient c(-1) Normalized Step Size test is to verify that the normalized step size is between 0.5 and 5.

Pass Condition The calculated normalized amplitude and normalized step size are within the range.

Measurement Algorithm

1 Request Transmitter to be set to "PRESET" condition.
2 Capture full pattern of QPRBS13-CEI at 32 points per UI.
3 Calculate linear fit pulse response at "PRESET" condition as per section 17.3.1.6.1.
4 Define r(k) from "PRESET".
5 Request to change c(-1) to the first step.
6 Calculate linear fit pulse response as per section 17.3.1.6.1 Np=12 and Dp = 2.
7 Calculate coefficients c(i) as per section 17.3.1.6.1 referencing sections 11.3.1.6.2 to 11.3.1.6.5.
8 Save coefficient c(-1) as base step values.
9 Request next c(-1) step.
10 Calculate linear fit pulse response as per section 17.3.1.6.1 Np=12 and Dp = 2.
11 Calculate coefficients c(i) as per section 17.3.1.6.1 referencing sections 11.3.1.6.2 to 11.3.1.6.5.
12 Calculate the normalized amplitude as (|c(-1)| + |c(0)| + |c(1)|) * 2 * Vf
13 Calculate the normalized step as coefficient value from step 11 – coefficient value from step 7.
14 Repeat steps 9-12 for as many steps as user requests. Each of these step sizes is calculated as coefficient value from step 11 – previous coefficient value from step 11.

NOTE Normalized amplitude is just the value from step 12 for each step.

Coefficient c(0) Normalized Amplitude and Coefficient c(0) Normalized Step Size

Test Overview The purpose of the Coefficient c(0) Normalized Amplitude test is to verify that the normalized amplitude of each step is between -25% to 0%. The purpose of the Coefficient c(0) Normalized Step Size test is to verify that the normalized step size is between 0.5 and 5.

Pass Condition The calculated normalized amplitude and normalized step size are within the range.

Measurement Algorithm

1. Request Transmitter to be set to “PRESET” condition.
2. Capture full pattern of QPRBS13-CEI at 32 points per UI.
3. Calculate linear fit pulse response at “PRESET” condition as per section 17.3.1.6.1.
4. Define r(k) from “PRESET”.
5. Request to change c(0) to the first step.
6. Calculate linear fit pulse response as per section 17.3.1.6.1 Np=12 and Dp = 2.
7. Calculate coefficients c(i) as per section 17.3.1.6.1 referencing sections 11.3.1.6.2 to 11.3.1.6.5.
8. Save coefficient c(0) as base step values.
9. Request next c(0) step.
10. Calculate linear fit pulse response as per section 17.3.1.6.1 Np=12 and Dp = 2.
11. Calculate coefficients c(i) as per section 17.3.1.6.1 referencing sections 11.3.1.6.2 to 11.3.1.6.5.
12. Calculate the normalized amplitude as (|c(-1)| + |c(0)| + |c(1)|) * 2 * Vf
13. Calculate the normalized step as coefficient value from step 11 – coefficient value from step 7.
14. Repeat steps 9-12 for as many steps as user requests. Each of these step sizes is calculated as coefficient value from step 11 – previous coefficient value from step 11.

NOTE Normalized amplitude is just the value from step 12 for each step.

Coefficient c(1) Normalized Amplitude and Coefficient c(1) Normalized Step Size

Test Overview The purpose of the Coefficient c(1) Normalized Amplitude test is to verify that the normalized amplitude of each step is between 60% to 100%. The purpose of the Coefficient c(1) Normalized Step Size test is to verify that the normalized step size is between 0.5 and 5.

Pass Condition The calculated normalized amplitude and normalized step size are within the range.

Measurement Algorithm

1 Request Transmitter to be set to “PRESET” condition.
2 Capture full pattern of QPRBS13-CEI at 32 points per UI.
3 Calculate linear fit pulse response at “PRESET” condition as per section 17.3.1.6.1.
4 Define r(k) from “PRESET”.
5 Request to change c(1) to the first step.
6 Calculate linear fit pulse response as per section 17.3.1.6.1 Np=12 and Dp = 2.
7 Calculate coefficients c(i) as per section 17.3.1.6.1 referencing sections 11.3.1.6.2 to 11.3.1.6.5.
8 Save coefficient c(1) as base step values.
9 Request next c(1) step.
10 Calculate linear fit pulse response as per section 17.3.1.6.1 Np=12 and Dp = 2.
11 Calculate coefficients c(i) as per section 17.3.1.6.1 referencing sections 11.3.1.6.2 to 11.3.1.6.5.
12 Calculate the normalized amplitude as (|c(-1)| + |c(0)| + |c(1)|) * 2 * Vf
13 Calculate the normalized step as coefficient value from step 11 – coefficient value from step 7.
14 Repeat steps 9-12 for as many steps as user requests. Each of these step sizes is calculated as coefficient value from step 11 – previous coefficient value from step 11.

NOTE **Normalized amplitude is just the value from step 12 for each step.**

Main Voltage Measurements

The PAM4 Main Voltage measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the N109256CB CEI 56G Compliance Test Application.

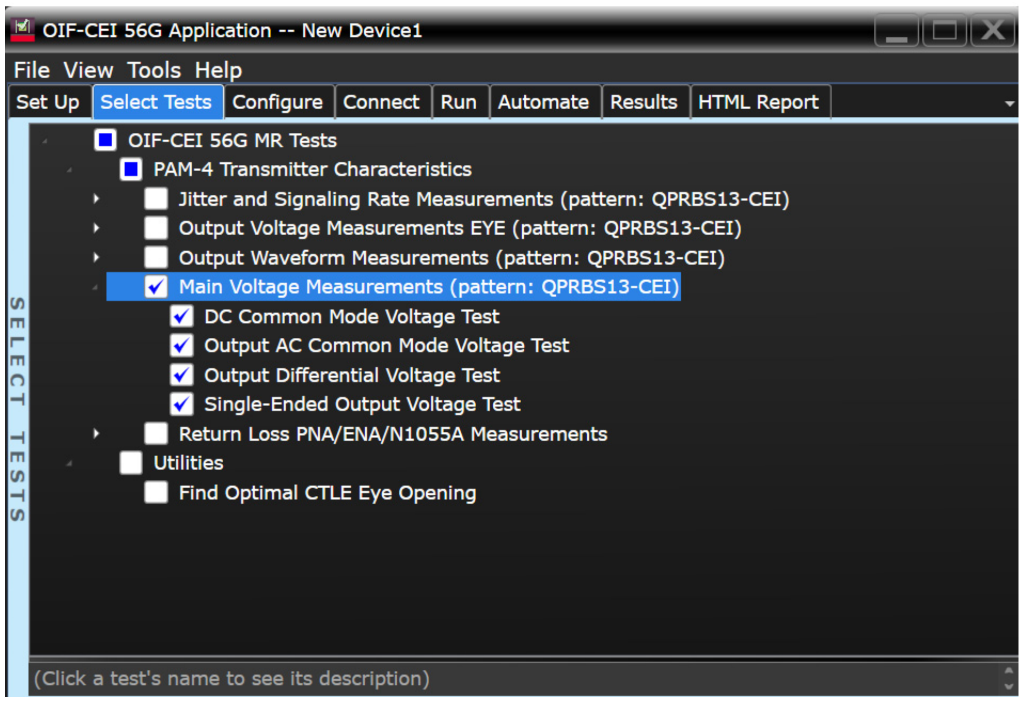


Figure 26 Selecting Main Voltage Measurements

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 117
- "Output AC Common Mode Voltage Test" on page 118
- "Output Differential Voltage Test" on page 119
- "Single-Ended Output Voltage Test" on page 120

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 Set common mode signal using the common mode function.
4 Measure minimum and maximum voltage of the common mode signal.
5 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 Set common mode signal using the common mode function.
4 Measure RMS voltage of the common mode signal.
5 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.

Single-Ended Output Voltage Test

Test Overview The purpose of this test is to verify that the minimum voltage on a single-ended signal is greater than -300mV and that the maximum voltage is less than 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 minimum and maximum voltage on each single-ended signal.
4 Compare the voltage measurements with the range between -300mV and 1.9V.

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 N109256CB CEI 56G Compliance 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.

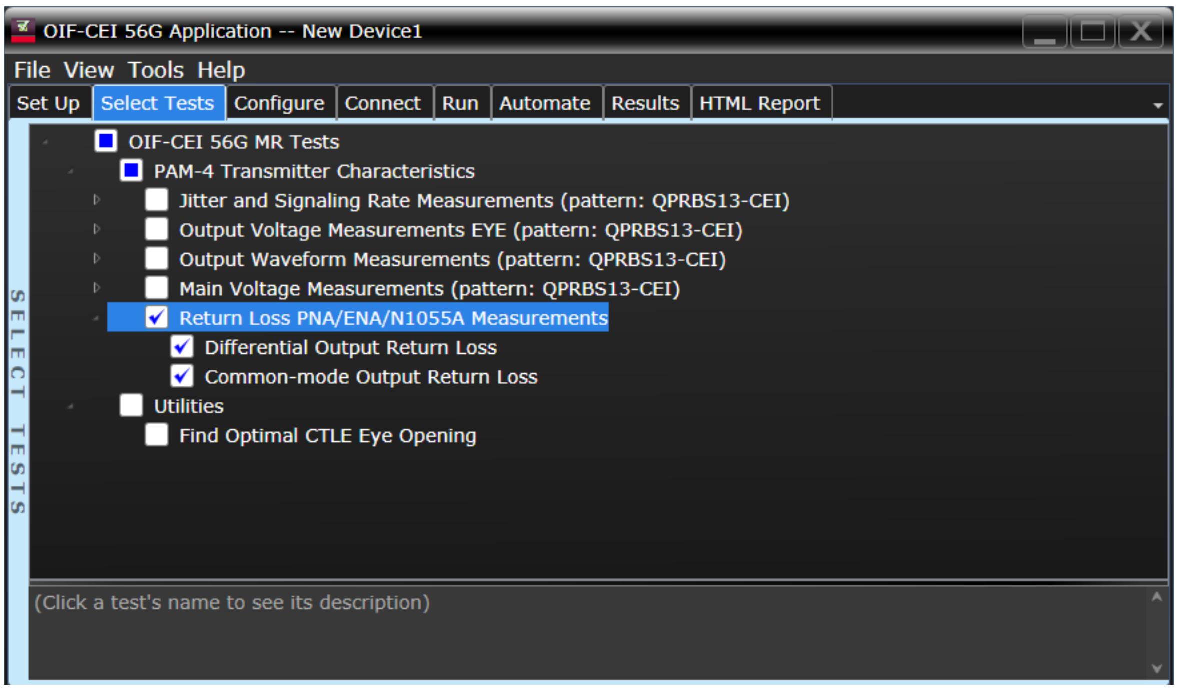


Figure 27 Selecting Return Loss Measurement Tests

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 122
- "Common-mode Output Return Loss" on page 123

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.

7 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 6 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 N109256CB CEI 56G Compliance Test Application.

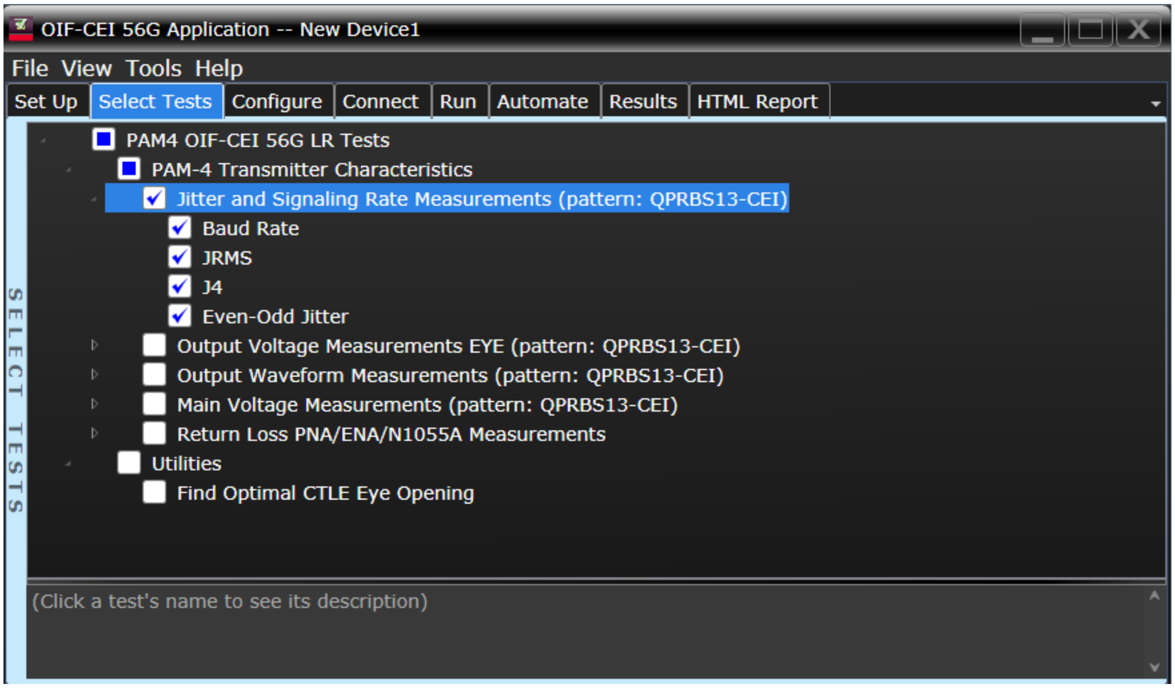


Figure 28 Selecting Jitter and Signaling Rate Measurements

Refer to Table 6 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 128
- "JRMS" on page 129
- "J4" on page 130
- "Even-Odd Jitter" on page 131

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 6.

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 6.

Measurement Algorithm

1 Obtain sample or acquire signal data.

NOTE **Signal must be of QPRBS13-CEI pattern and connections must be established between Data+ to Channel 1 and Data- to Channel 3 to measure the defined 12 edges.**

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 3.883 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.

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 6.

Measurement Algorithm

1 Obtain sample or acquire signal data.

NOTE **Signal must be of QPRBS13-CEI pattern and connections must be established between Data+ to Channel 1 and Data- to Channel 3 to measure the defined 12 edges.**

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 3.883 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.

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 6.

Measurement Algorithm

1 Obtain sample or acquire signal data.

NOTE

Signal must be of QPRBS13-CEI pattern and connections must be established between Data+ to Channel 1 and Data- to Channel 3 to measure the defined 12 edges.

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 3.883 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.

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 N109256CB CEI 56G Compliance Test Application.

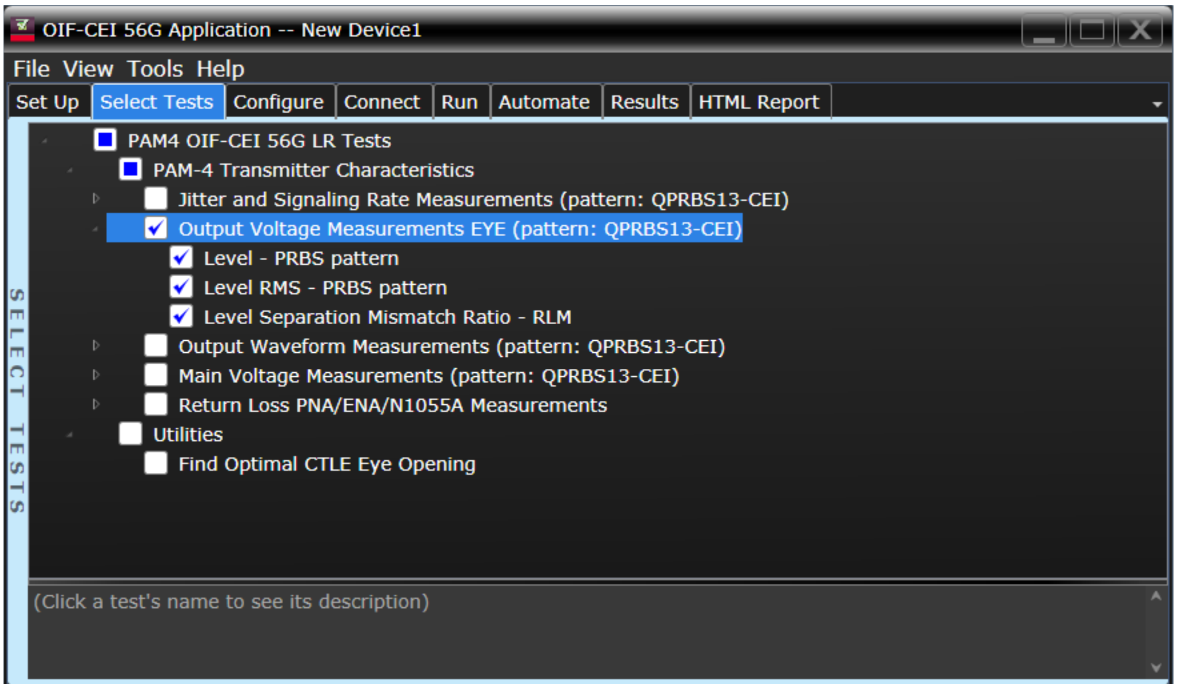


Figure 29 Selecting Output Voltage Measurements EYE Tests

Refer to Table 6 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 133
- “Level RMS - PRBS Pattern” on page 134
- “Level Separation Mismatch Ratio - RLM” on page 135

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 6.

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 N109256CB CEI 56G Compliance Test Application.

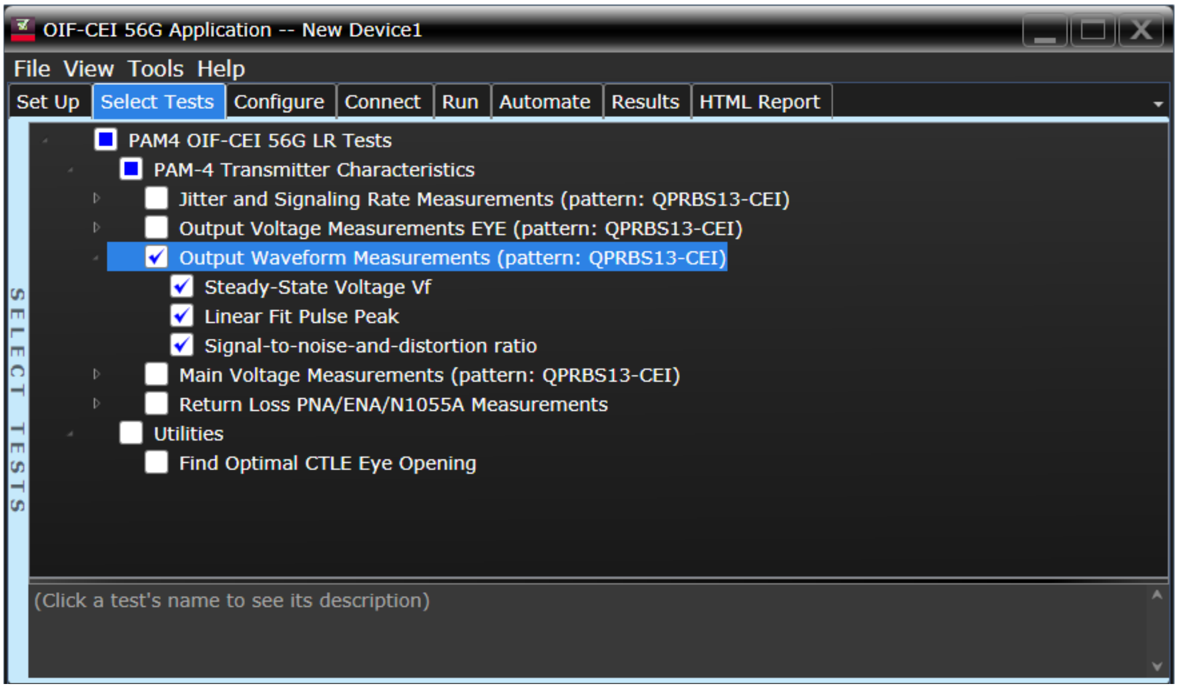


Figure 30 Selecting Output Waveform Measurements

Refer to Table 6 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 137
- "Linear Fit Pulse Peak" on page 138
- "Signal-to-noise-and-distortion ratio" on page 139

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 6.

Measurement Algorithm

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

2 Set memory depth and sample rate to capture the 8191 bits of the QPRBS13-CEI pattern.

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 6.

Measurement Algorithm

1 Check that signal is connected and proper data pattern exists (QPRBS13-CEI must be used for this test).
2 Set memory depth and sample rate to capture the 8191 bits of the QPRBS13-CEI pattern.
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.

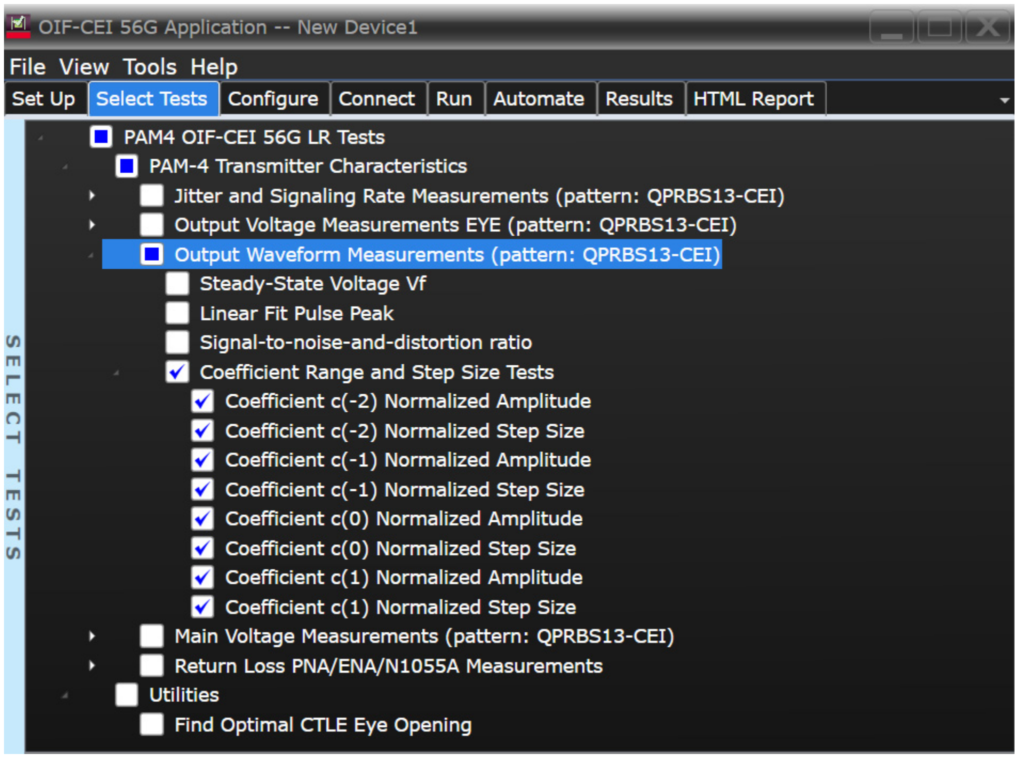
Pass Condition Refer to Table 6.

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 these tests is to verify the coefficient normalized amplitude and coefficient normalized step size.



To know more about the algorithm of coefficient normalized amplitude and coefficient normalized step size tests, see:

- "Coefficient c(-1) Normalized Amplitude and Coefficient c(-1) Normalized Step Size" on page 142
- "Coefficient c(0) Normalized Amplitude and Coefficient c(0) Normalized Step Size" on page 143
- "Coefficient c(1) Normalized Amplitude and Coefficient c(1) Normalized Step Size" on page 144

Coefficient c(-2) Normalized Amplitude and **Coefficient c(-2) Normalized Step Size**

Test Overview The purpose of the Coefficient c(-2) Normalized Amplitude test is to verify that the normalized amplitude of each step is between 0% to 10%. The purpose of the Coefficient c(-2) Normalized Step Size test is to verify that the normalized step size is between 0.5 and 2.5.

Pass Condition The calculated normalized amplitude and normalized step size are within the range.

Measurement Algorithm

1 Request Transmitter to be set to “PRESET” condition.
2 Capture full pattern of QPRBS13-CEI at 32 points per UI.
3 Calculate linear fit pulse response at “PRESET” condition as per section 21.3.1.6.1.
4 Define r(k) from “PRESET”.
5 Request to change c(-2) to the first step.
6 Calculate linear fit pulse response as per section 21.3.1.6.1 Np=12 and Dp = 2.
7 Calculate coefficients c(i) as per section 21.3.1.6.1 referencing sections 11.3.1.6.2 to 11.3.1.6.5.
8 Save coefficient c(-2) as base step values.
9 Request next c(-2) step.
10 Calculate linear fit pulse response as per section 21.3.1.6.1 Np=12 and Dp = 2.
11 Calculate coefficients c(i) as per section 21.3.1.6.1 referencing sections 11.3.1.6.2 to 11.3.1.6.5.
12 Calculate the normalized amplitude as (|c(-1)| + |c(0)| + |c(1)|) * 2 * Vf
13 Calculate the normalized step as coefficient value from step 11 – coefficient value from step 7.
14 Repeat steps 9-12 for as many steps as user requests. Each of these step sizes is calculated as coefficient value from step 11 – previous coefficient value from step 11.

NOTE **Normalized amplitude is just the value from step 12 for each step.**

Coefficient c(-1) Normalized Amplitude and Coefficient c(-1) Normalized Step Size

Test Overview The purpose of the Coefficient c(-1) Normalized Amplitude test is to verify that the normalized amplitude of each step is between -28% to 0%. The purpose of the Coefficient c(-1) Normalized Step Size test is to verify that the normalized step size is between 0.5 and 2.5.

Pass Condition The calculated normalized amplitude and normalized step size are within the range.

Measurement Algorithm

1 Request Transmitter to be set to “PRESET” condition.
2 Capture full pattern of QPRBS13-CEI at 32 points per UI.
3 Calculate linear fit pulse response at “PRESET” condition as per section 21.3.1.6.1.
4 Define r(k) from “PRESET”.
5 Request to change c(-1) to the first step.
6 Calculate linear fit pulse response as per section 21.3.1.6.1 Np=12 and Dp = 2.
7 Calculate coefficients c(i) as per section 21.3.1.6.1 referencing sections 11.3.1.6.2 to 11.3.1.6.5.
8 Save coefficient c(-1) as base step values.
9 Request next c(-1) step.
10 Calculate linear fit pulse response as per section 21.3.1.6.1 Np=12 and Dp = 2.
11 Calculate coefficients c(i) as per section 21.3.1.6.1 referencing sections 11.3.1.6.2 to 11.3.1.6.5.
12 Calculate the normalized amplitude as (|c(-1)| + |c(0)| + |c(1)|) * 2 * Vf
13 Calculate the normalized step as coefficient value from step 11 – coefficient value from step 7.
14 Repeat steps 9-12 for as many steps as user requests. Each of these step sizes is calculated as coefficient value from step 11 – previous coefficient value from step 11.

NOTE Normalized amplitude is just the value from step 12 for each step.

Coefficient c(0) Normalized Amplitude and Coefficient c(0) Normalized Step Size

Test Overview The purpose of the Coefficient c(0) Normalized Amplitude test is to verify that the normalized amplitude of each step is between -28% to 0%. The purpose of the Coefficient c(0) Normalized Step Size test is to verify that the normalized step size is between 0.5 and 2.5.

Pass Condition The calculated normalized amplitude and normalized step size are within the range.

Measurement Algorithm

1. Request Transmitter to be set to "PRESET" condition.
2. Capture full pattern of QPRBS13-CEI at 32 points per UI.
3. Calculate linear fit pulse response at "PRESET" condition as per section 21.3.1.6.1.
4. Define r(k) from "PRESET".
5. Request to change c(0) to the first step.
6. Calculate linear fit pulse response as per section 21.3.1.6.1 Np=12 and Dp = 2.
7. Calculate coefficients c(i) as per section 21.3.1.6.1 referencing sections 11.3.1.6.2 to 11.3.1.6.5.
8. Save coefficient c(0) as base step values.
9. Request next c(0) step.
10. Calculate linear fit pulse response as per section 21.3.1.6.1 Np=12 and Dp = 2.
11. Calculate coefficients c(i) as per section 21.3.1.6.1 referencing sections 11.3.1.6.2 to 11.3.1.6.5.
12. Calculate the normalized amplitude as (|c(-1)| + |c(0)| + |c(1)|) * 2 * Vf
13. Calculate the normalized step as coefficient value from step 11 – coefficient value from step 7.
14. Repeat steps 9-12 for as many steps as user requests. Each of these step sizes is calculated as coefficient value from step 11 – previous coefficient value from step 11.

NOTE Normalized amplitude is just the value from step 12 for each step.

Coefficient c(1) Normalized Amplitude and Coefficient c(1) Normalized Step Size

Test Overview The purpose of the Coefficient c(1) Normalized Amplitude test is to verify that the normalized amplitude of each step is between 60% to 100%. The purpose of the Coefficient c(1) Normalized Step Size test is to verify that the normalized step size is between 0.5 and 2.5.

Pass Condition The calculated normalized amplitude and normalized step size are within the range.

Measurement Algorithm

1 Request Transmitter to be set to “PRESET” condition.
2 Capture full pattern of QPRBS13-CEI at 32 points per UI.
3 Calculate linear fit pulse response at “PRESET” condition as per section 21.3.1.6.1.
4 Define r(k) from “PRESET”.
5 Request to change c(1) to the first step.
6 Calculate linear fit pulse response as per section 21.3.1.6.1 Np=12 and Dp = 2.
7 Calculate coefficients c(i) as per section 21.3.1.6.1 referencing sections 11.3.1.6.2 to 11.3.1.6.5.
8 Save coefficient c(1) as base step values.
9 Request next c(1) step.
10 Calculate linear fit pulse response as per section 21.3.1.6.1 Np=12 and Dp = 2.
11 Calculate coefficients c(i) as per section 21.3.1.6.1 referencing sections 11.3.1.6.2 to 11.3.1.6.5.
12 Calculate the normalized amplitude as (|c(-1)| + |c(0)| + |c(1)|) * 2 * Vf
13 Calculate the normalized step as coefficient value from step 11 – coefficient value from step 7.
14 Repeat steps 9-12 for as many steps as user requests. Each of these step sizes is calculated as coefficient value from step 11 – previous coefficient value from step 11.

NOTE Normalized amplitude is just the value from step 12 for each step.

Main Voltage Measurements

The PAM4 Main Voltage measurement procedures described in this section are performed using a Keysight Infiniium oscilloscope and the N109256CB CEI 56G Compliance Test Application.

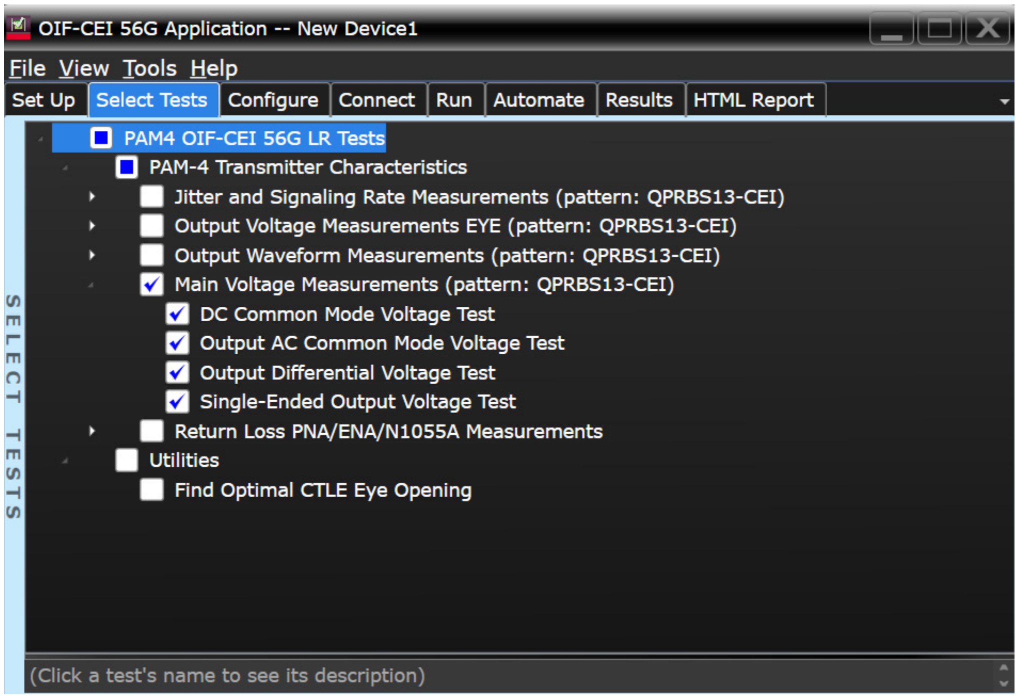


Figure 31 Selecting Main Voltage Measurements

Refer to Table 6 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 146
- "Output AC Common Mode Voltage Test" on page 147
- "Output Differential Voltage Test" on page 148
- "Single-Ended Output Voltage Test" on page 149

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 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 Set common mode signal using the common mode function.
4 Measure minimum and maximum voltage of the common mode signal.
5 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 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 Set common mode signal using the common mode function.
4 Measure RMS voltage of the common mode signal.
5 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 6.

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.

Single-Ended Output Voltage Test

Test Overview The purpose of this test is to verify that the minimum voltage on a single-ended signal is greater than -300mV and that the maximum voltage is less than 1.9V.

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

Pass Condition -300 mV <= Single-Ended Output Voltage <= 1.900 V

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 minimum and maximum voltage on each single-ended signal.
4 Compare the voltage measurements with the range between -300mV and 1.9V.

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 N109256CB CEI 56G Compliance 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.

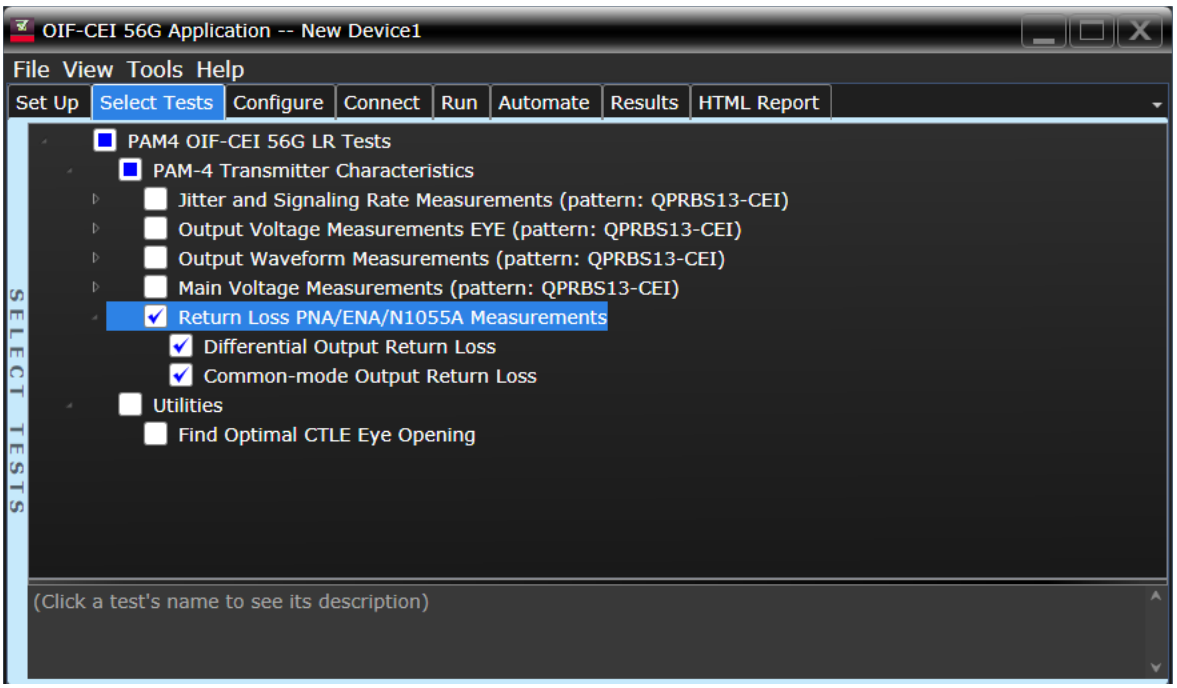


Figure 32 Selecting Return Loss Measurement Tests

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

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

- "Differential Output Return Loss" on page 151
- "Common-mode Output Return Loss" on page 152

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 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 7 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 N109256CB CEI 56G Compliance Test Application.

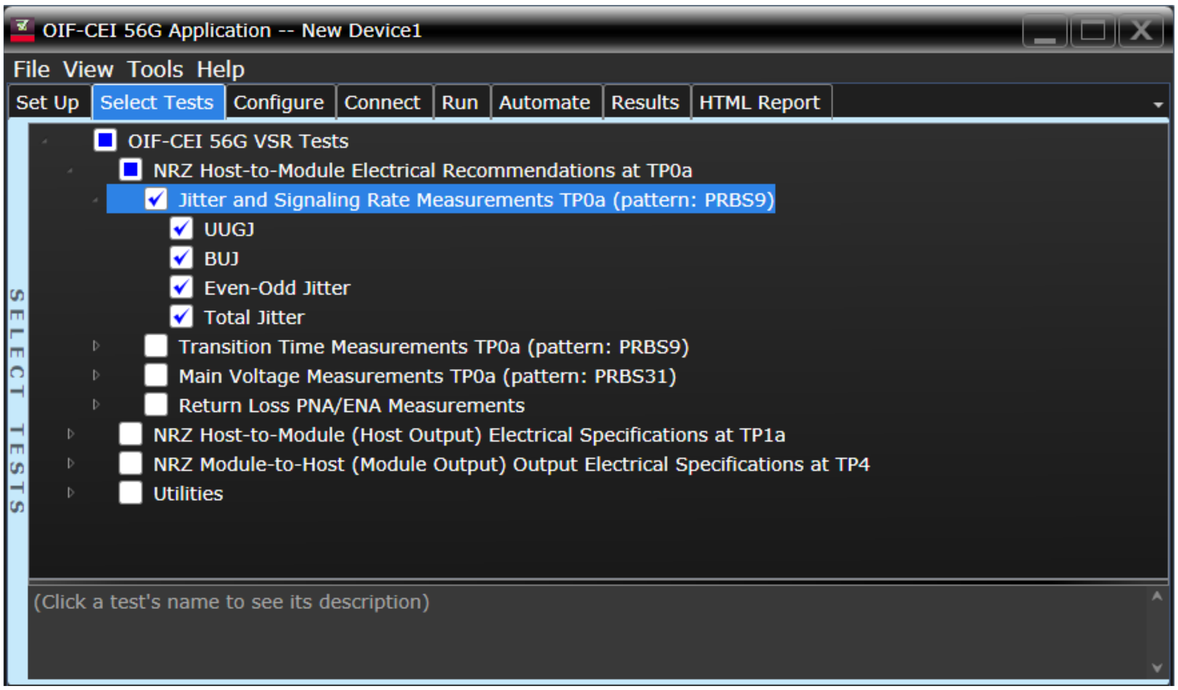


Figure 33 Selecting Jitter and Signaling Rate Measurement Tests

Refer to Table 7 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 156
- "BUJ" on page 157
- "Even-Odd Jitter" on page 158
- "Total Jitter" on page 159

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 7.

Measurement Algorithm

1 Obtain sample or acquire signal data.

NOTE **Signal must be of PRBS9 pattern and connections must be established between Data+ to Channel 1 and Data- to Channel 3 to measure the defined 12 edges.**

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 5 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.

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 7.

Measurement Algorithm

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

NOTE **Signal must be of PRBS9 pattern and connections must be established between Data+ to Channel 1 and Data- to Channel 3 to measure the defined 12 edges.**

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 5 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.

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 7.

Measurement Algorithm

1 Obtain sample or acquire signal data.

NOTE **Signal must be of PRBS9 pattern and connections must be established between Data+ to Channel 1 and Data- to Channel 3 to measure the defined 12 edges.**

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 5 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.

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 7.

Measurement Algorithm

1 Obtain sample or acquire signal data.

NOTE **Signal must be of PRBS9 pattern and connections must be established between Data+ to Channel 1 and Data- to Channel 3 to measure the defined 12 edges.**

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 5 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.

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 N109256CB CEI 56G Compliance Test Application.

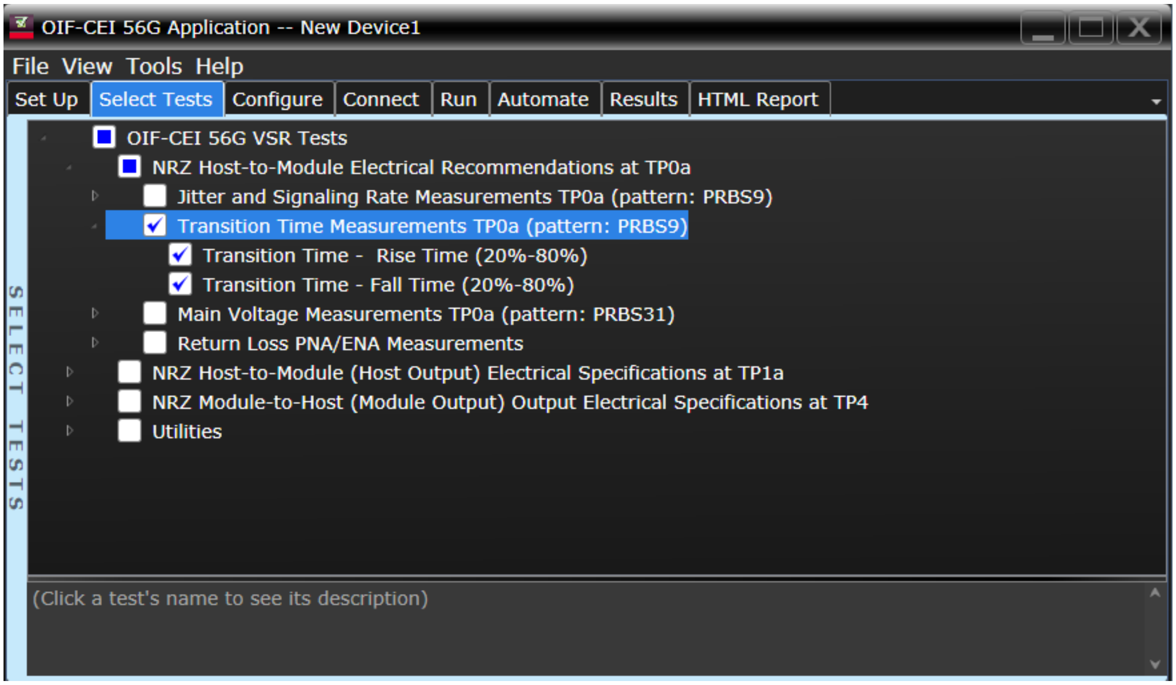


Figure 34 Selecting Transition Time Measurement Tests

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

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

- "Transition Time - Rise Time (20%-80%)" on page 161
- "Transition Time - Fall Time (20%-80%)" on page 162

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 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 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 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 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 N109256CB CEI 56G Compliance Test Application.

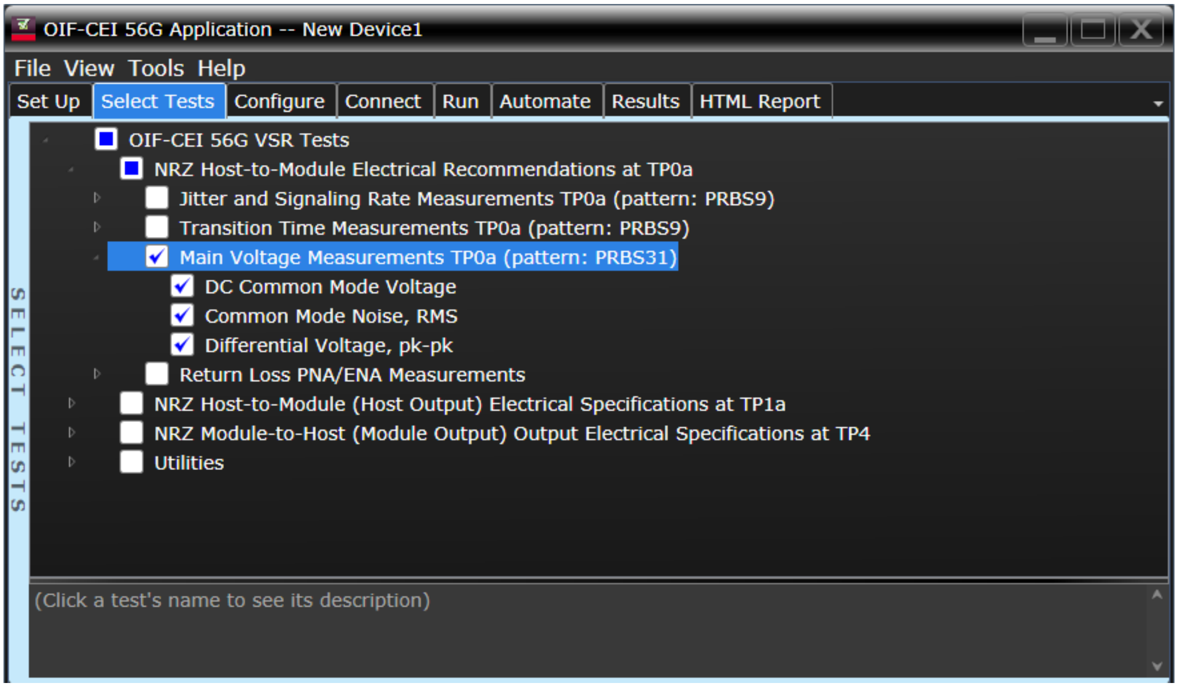


Figure 35 Selecting Main Voltage Measurement Tests

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

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

- "DC Common Mode Voltage" on page 164
- "Common Mode Noise, RMS" on page 165
- "Differential Voltage, pk-pk" on page 166

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 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 Set common mode signal using the common mode function.
4 Measure minimum and maximum voltage of the common mode signal.
5 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 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 Set common mode signal using the common mode function.
4 Measure RMS voltage of the common mode signal.
5 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 7.

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 N109256CB CEI 56G Compliance 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.

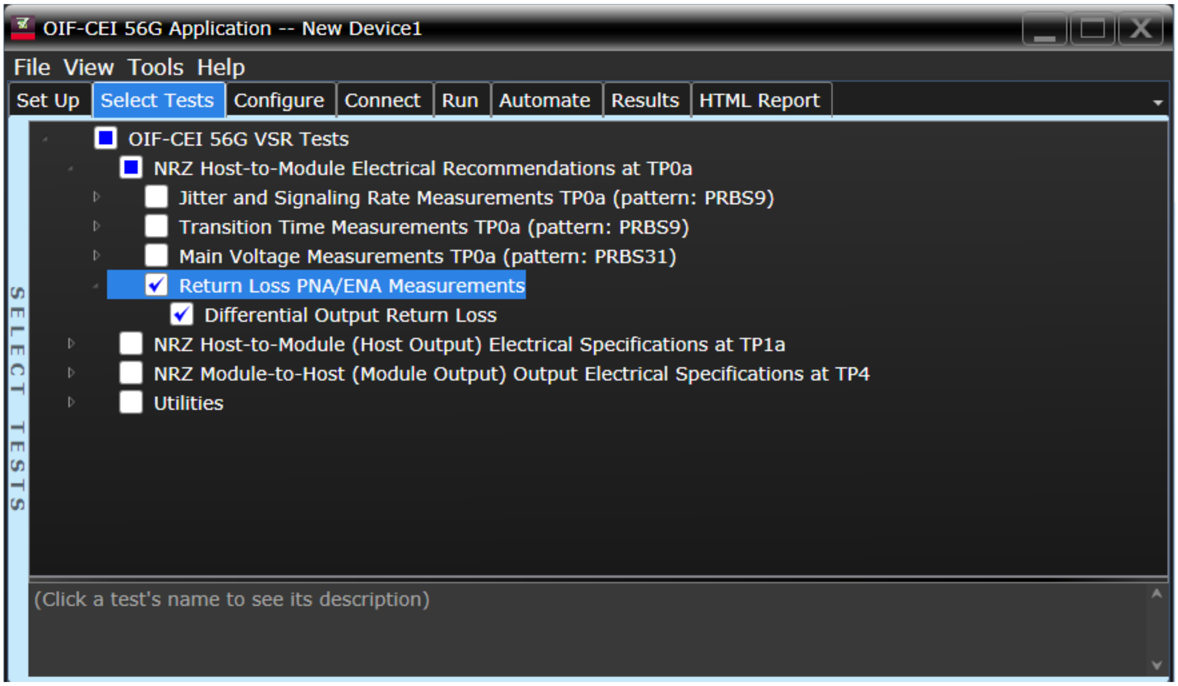


Figure 36 Selecting Return Loss Measurement Tests

Refer to Table 7 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 168

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.

9 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 8 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 N109256CB CEI 56G Compliance Test Application.

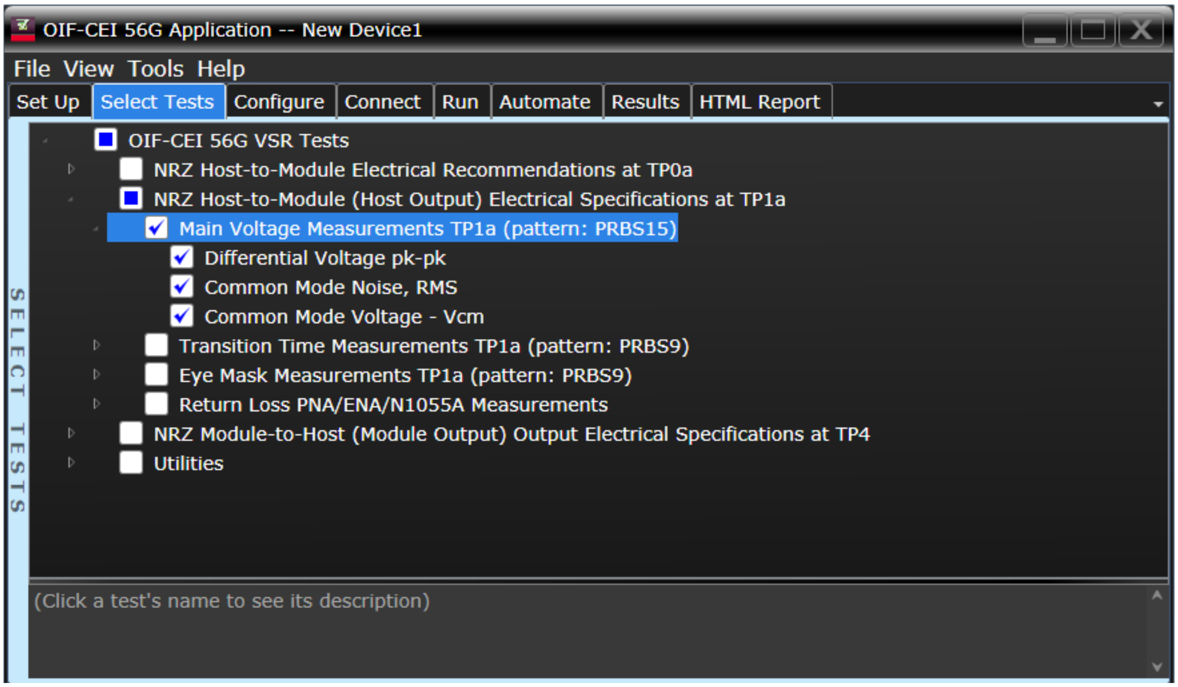


Figure 37 Selecting Main Voltage Measurement Tests

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

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

- "Differential Voltage pk-pk" on page 172
- "Common Mode Noise, RMS" on page 173
- "Common Mode Voltage - Vcm" on page 174

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 Set common mode signal using the common mode function.
4 Measure RMS voltage of the common mode signal.
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 -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 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 Set common mode signal using the common mode function.
4 Measure minimum and maximum voltage of the common mode signal.
5 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 N109256CB CEI 56G Compliance Test Application.

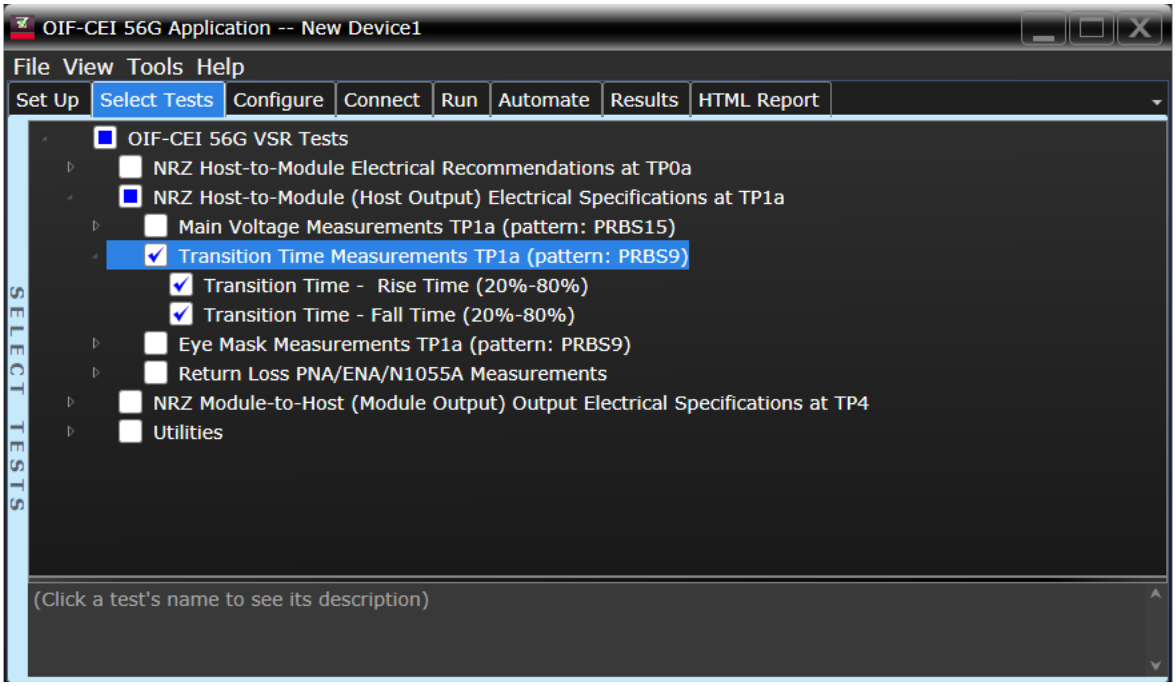


Figure 38 Selecting Transition Time Measurement Tests

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

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

- "Transition Time - Rise Time (20%-80%)" on page 176
- "Transition Time - Fall Time (20%-80%)" on page 177

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 TP1a

The Eye Mask Measurement procedures that are described in this section are performed using a Keysight Infiniium oscilloscope and the N109256CB CEI 56G Compliance Test Application.

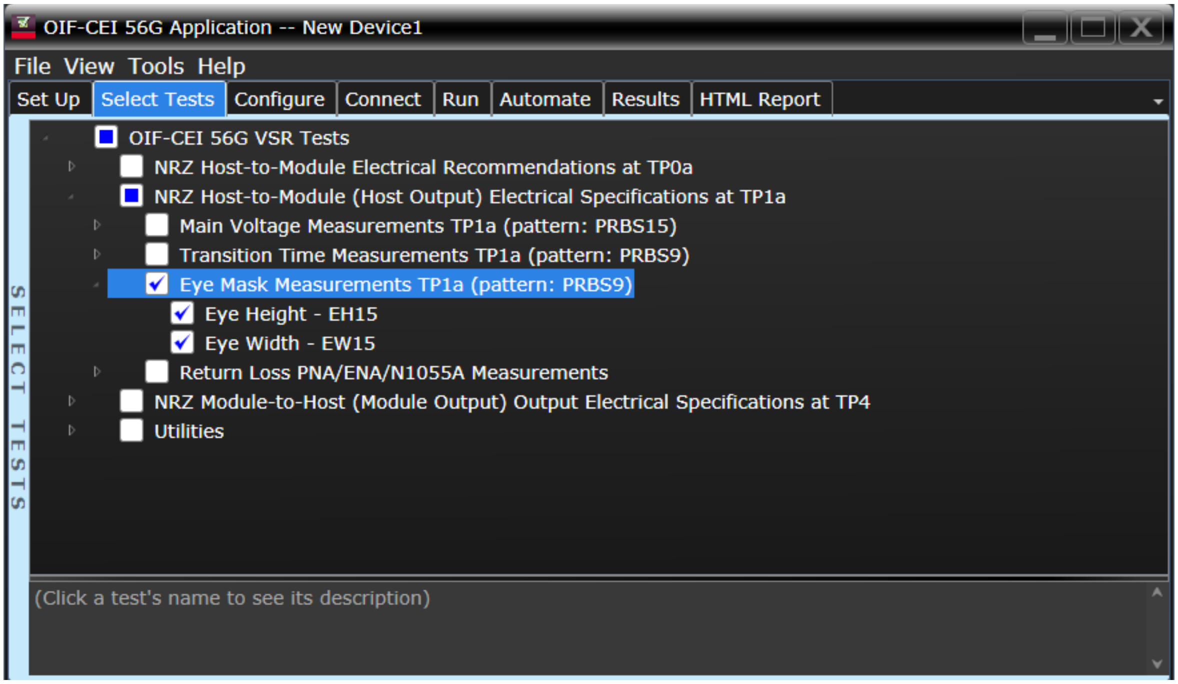


Figure 39 Selecting Eye Mask Measurement Tests

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

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

- “Eye Height - EH15” on page 179
- “Eye Width - EW15” on page 180

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.

Pass Conditions Refer to Table 8.

Measurement Algorithm

1 For the optimal CTLE, you may approach in one of the following ways:
   - This setting can be characterized and automatically set by using the **Find Optimal CTLE Eye Opening** under the **Utilities** in the **Select Tests** tab.
   - Manually select the optimal CTLE setting from the **Use Optimized CTLE for Eye Opening** drop-down options 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 5 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.

Pass Conditions Refer to Table 8.

Measurement Algorithm

1 For the optimal CTLE, you may approach in one of the following ways:
   - This setting can be characterized and automatically set by using the **Find Optimal CTLE Eye Opening** under the **Utilities** in the **Select Tests** tab.
   - Manually select the optimal CTLE setting from the **Use Optimized CTLE for Eye Opening** drop-down options 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 5 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 N109256CB CEI 56G Compliance 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.

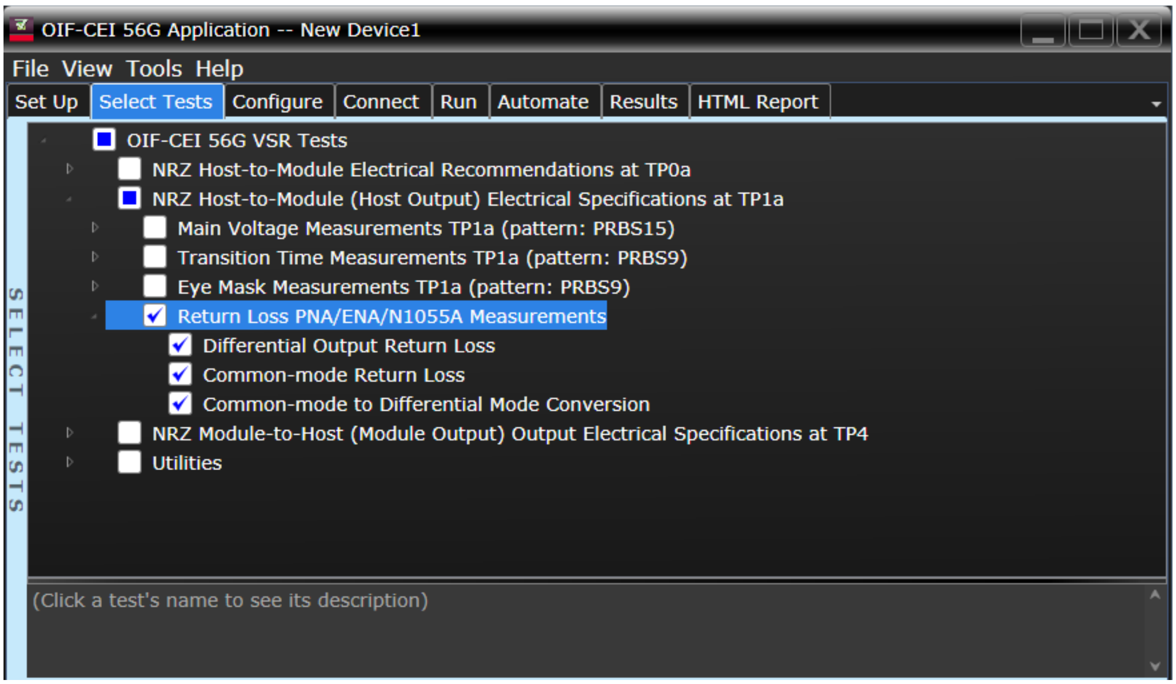


Figure 40 Selecting Return Loss Measurement Test

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 182
- "Common-mode Return Loss" on page 183
- "Common-mode to Differential Mode Conversion" on page 184

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.

10 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 9 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 N109256CB CEI 56G Compliance Test Application.

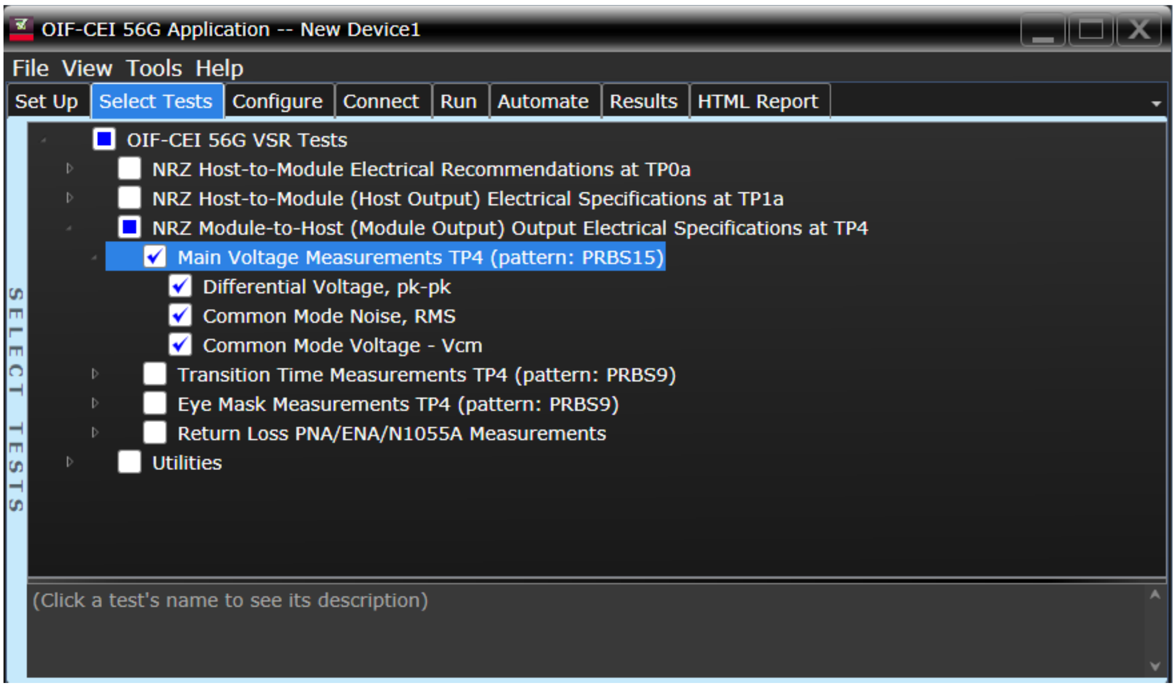


Figure 41 Selecting Main Voltage Measurement Tests

Refer to Table 9 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 188
- "Common Mode Noise, RMS" on page 189
- "Common Mode Voltage - Vcm" on page 190

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 9.

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 9.

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 Set common mode signal using the common mode function.
4 Measure RMS voltage of the common mode signal.
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 9.

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 Set common mode signal using the common mode function.
4 Measure minimum and maximum voltage of the common mode signal.
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 N109256CB CEI 56G Compliance Test Application.

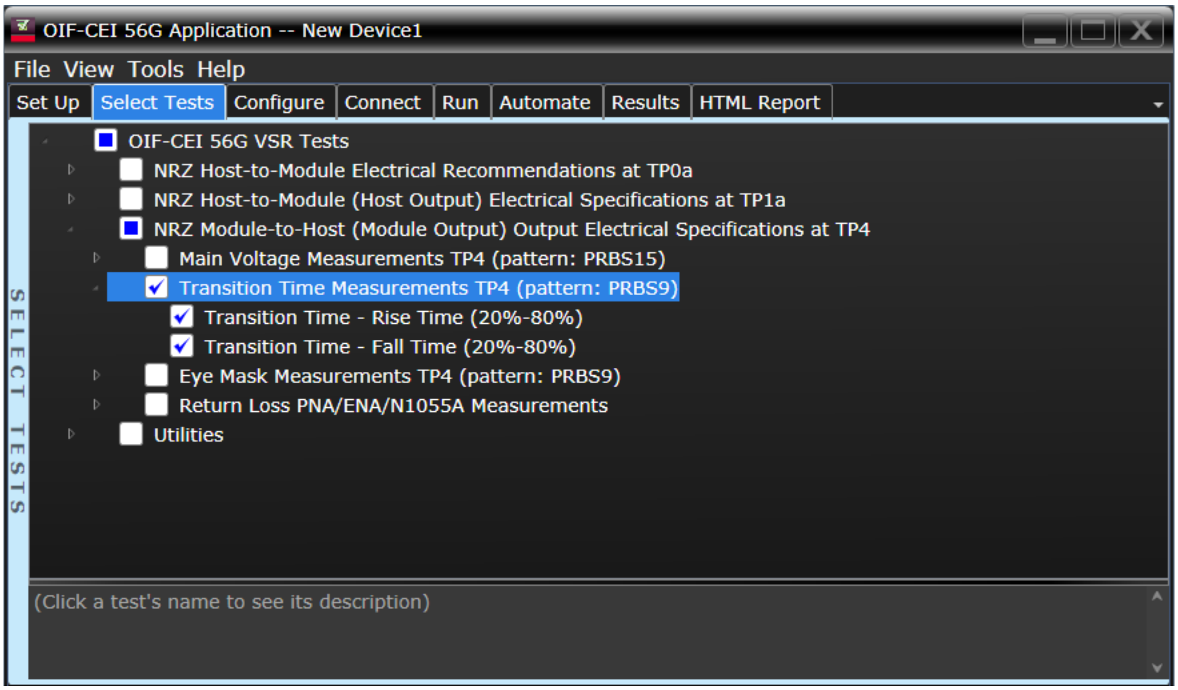


Figure 42 Selecting Transition Time Measurement Tests

Refer to Table 9 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 192
- "Transition Time - Fall Time (20%-80%)" on page 193

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 9.

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 9.

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 N109256CB CEI 56G Compliance Test Application.

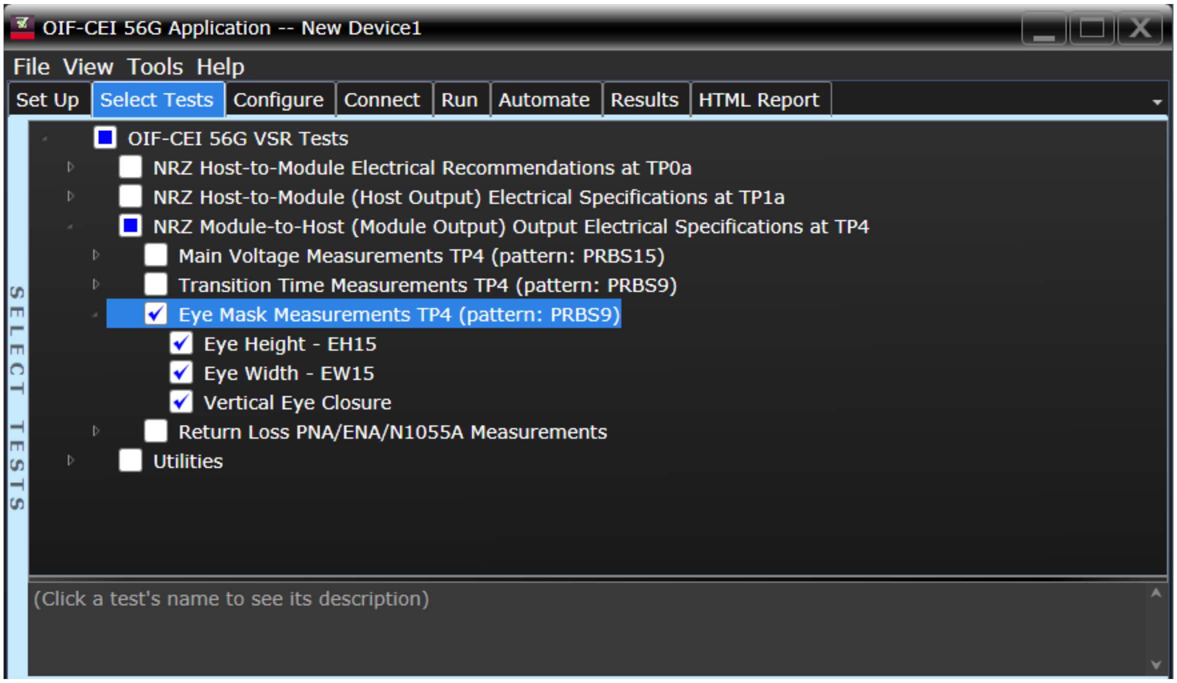


Figure 43 Selecting Eye Mask Measurement Tests

Refer to Table 9 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 195
- "Eye Width - EW15" on page 196
- "Vertical Eye Closure" on page 197

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.

Pass Conditions Refer to Table 9.

Measurement Algorithm

1 For the optimal CTLE, you may approach in one of the following ways:
   - This setting can be characterized and automatically set by using the **Find Optimal CTLE Eye Opening** under the **Utilities** in the **Select Tests** tab.
   - Manually select the optimal CTLE setting from the **Use Optimized CTLE for Eye Opening** drop-down options 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 5 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.

Pass Conditions Refer to Table 9.

Measurement Algorithm

1 For the optimal CTLE, you may approach in one of the following ways:
   - This setting can be characterized and automatically set by using the **Find Optimal CTLE Eye Opening** under the **Utilities** in the **Select Tests** tab.
   - Manually select the optimal CTLE setting from the **Use Optimized CTLE for Eye Opening** drop-down options 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 5 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 9.

Measurement Algorithm

1 For the optimal CTLE, you may approach in one of the following ways:
   - This setting can be characterized and automatically set by using the **Find Optimal CTLE Eye Opening** under the **Utilities** in the **Select Tests** tab.
   - Manually select the optimal CTLE setting from the **Use Optimized CTLE for Eye Opening** drop-down options 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 5 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 N109256CB CEI 56G Compliance 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.

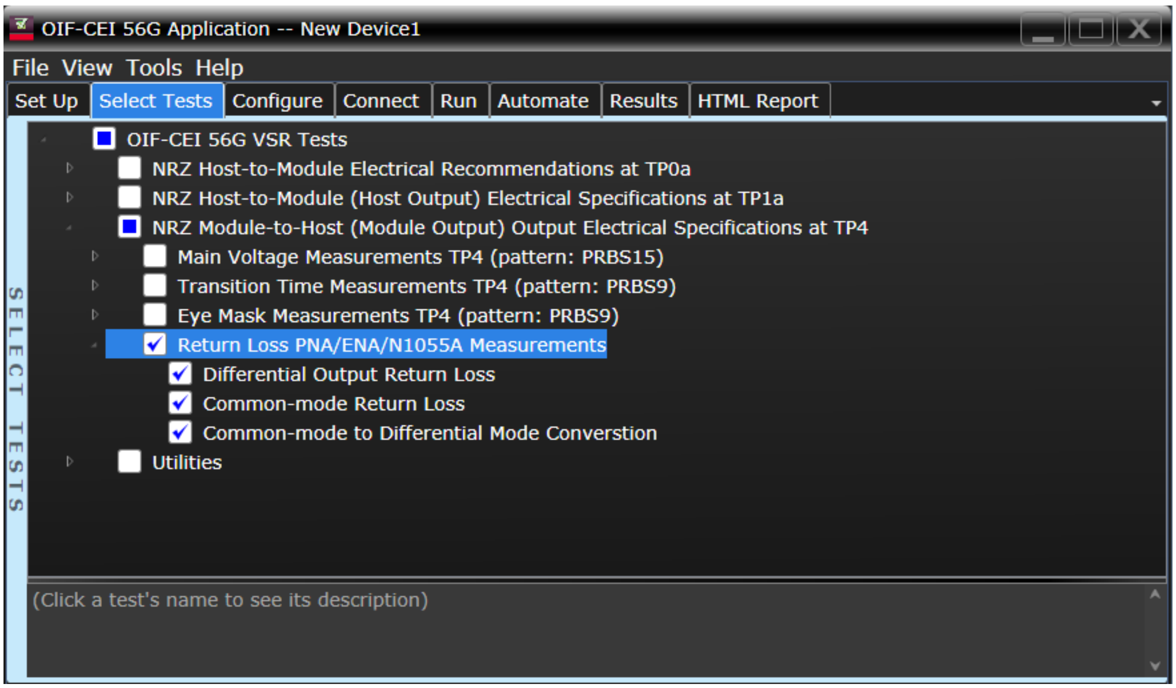


Figure 44 Selecting Return Loss Measurement Tests

Refer to Table 9 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 199
- "Common-mode Return Loss" on page 200
- "Common-mode to Differential Mode Conversion" on page 201

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.

11 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.

Run the CTLE utility tests documented in this section before running the corresponding Eye Width/Eye Height tests. The following is the general sequence of steps to be followed:

1 Run the Utility called “Find Optimal CTLE Eye Opening” to determine the correct CTLE value to use in subsequent tests, such as Eye Height and Eye Width.
Run the Utility standalone (do not run with other tests).
After running the utility, the “Use Optimized CTLE for Eye Opening” setting on the Configure tab will be set with the optimal value.
2 Deselect the Utility for subsequent tests and select the desired tests to be run.
It is recommended to group tests that use the same pattern. The tests are run in order, from top to bottom.

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 N109256CB CEI 56G Compliance Test Application.

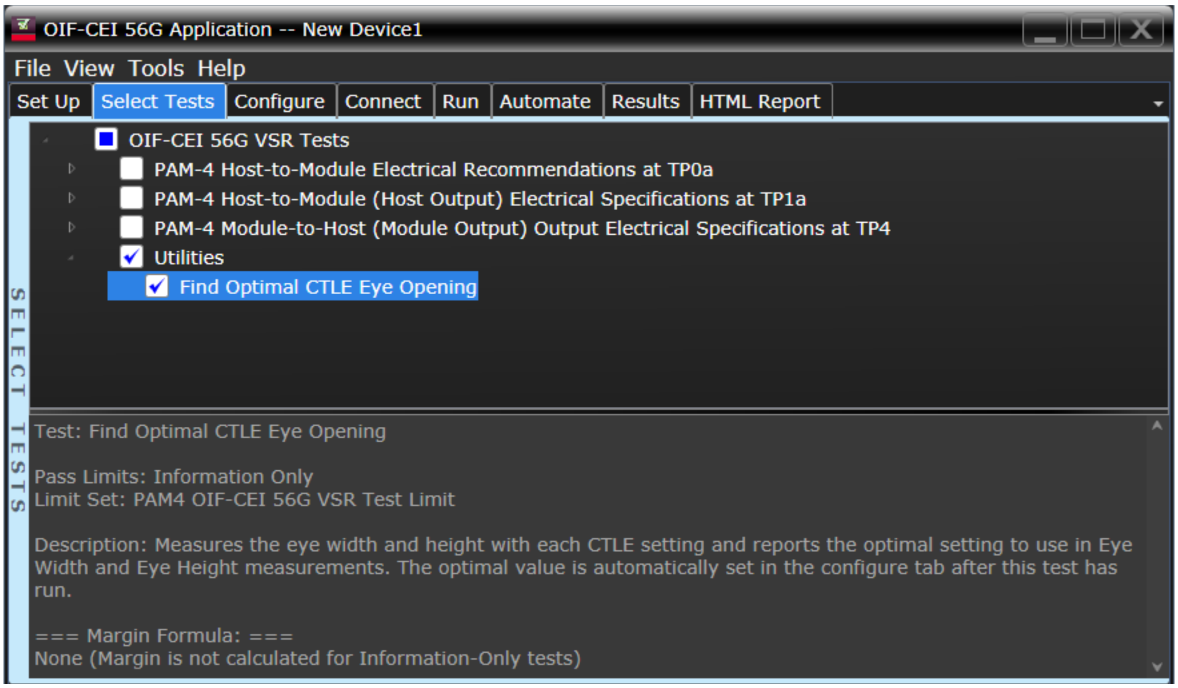
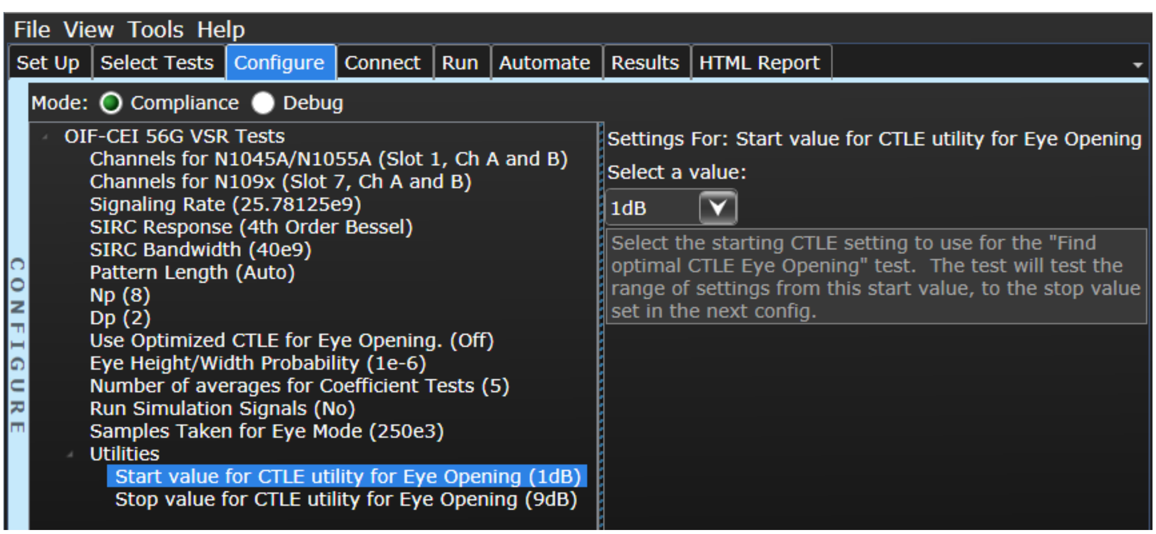


Figure 45 Selecting Utilities under OIF-CEI 56G VSR Tests for PAM4 signals

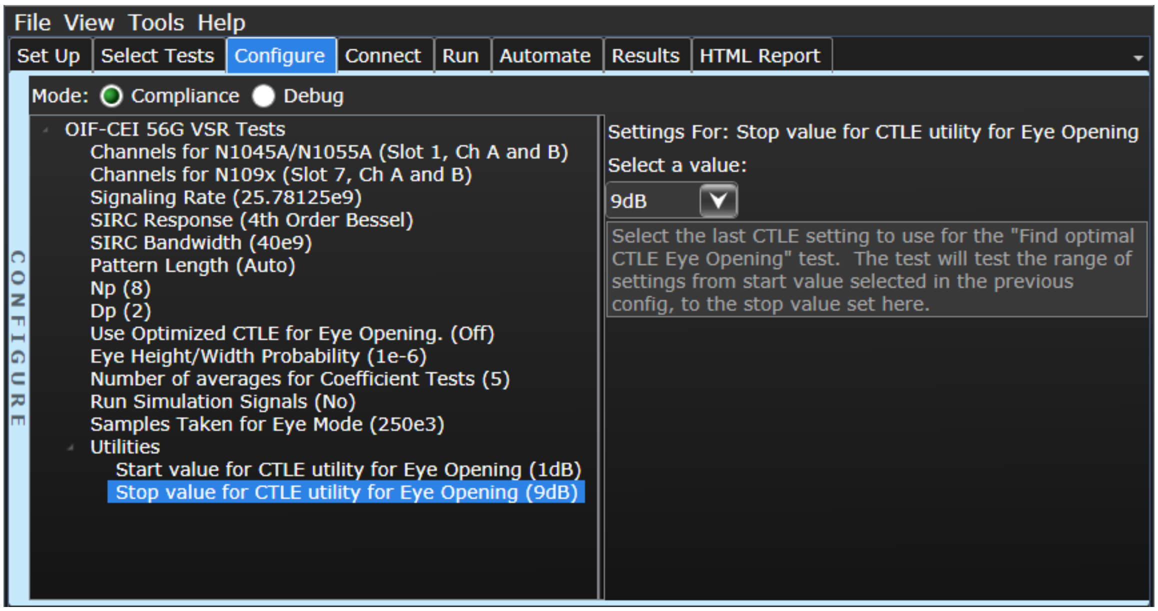
Test Overview The purpose of this test is to loop through CTLE settings to find the optimal CTLE setting for the largest area of the Eye.

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 N109256CB CEI 56G Compliance Test Application.

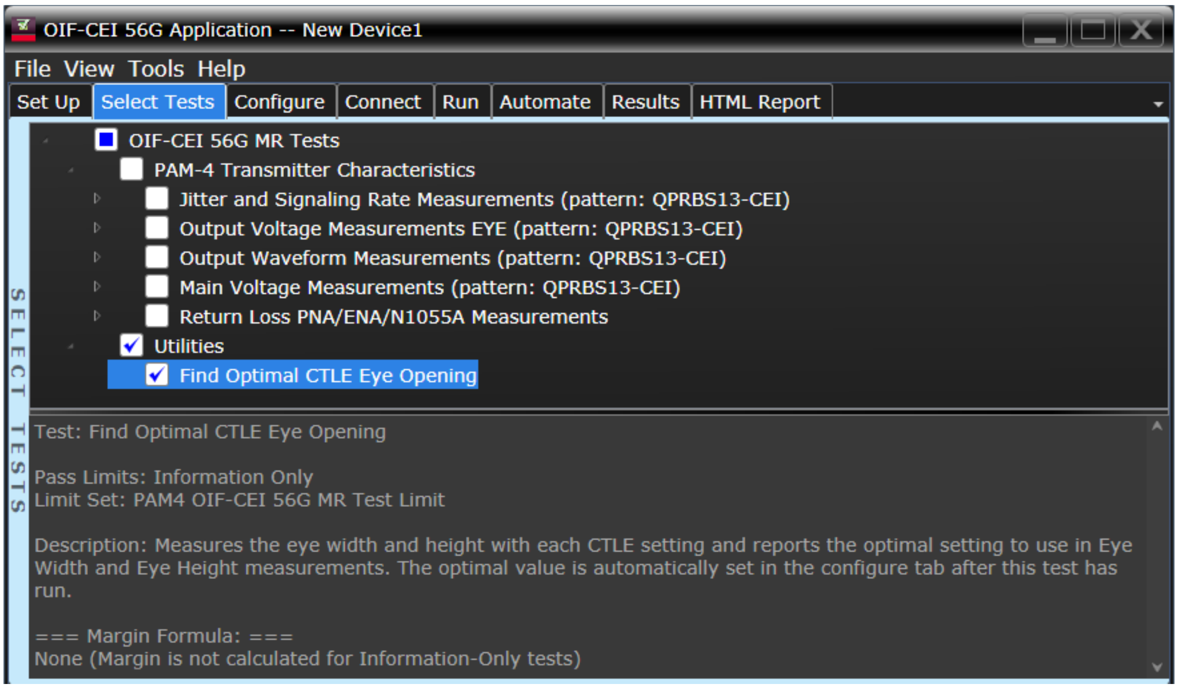


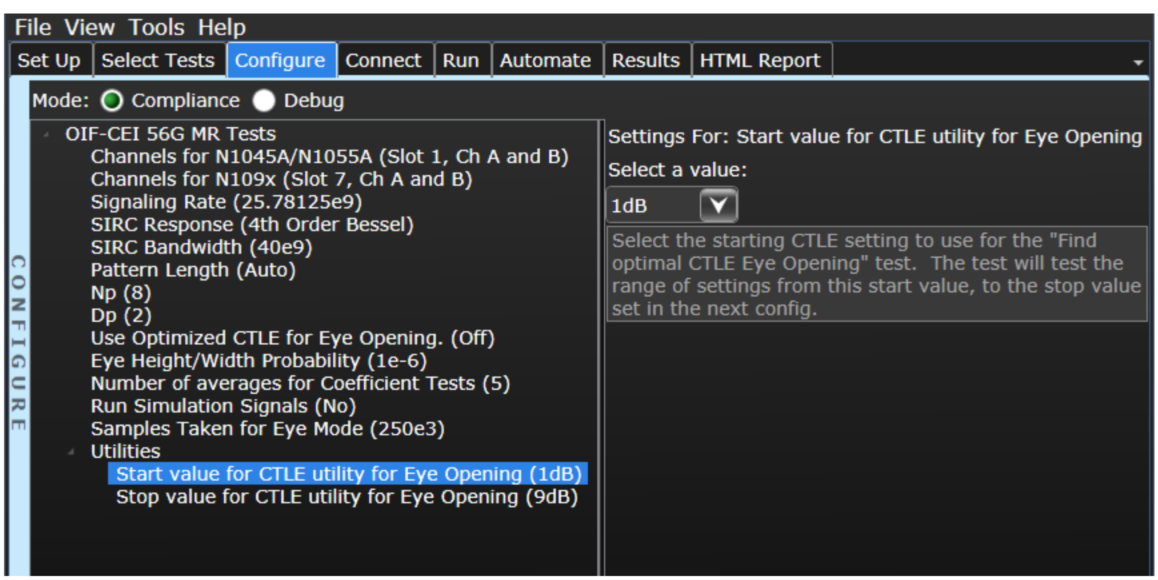
Figure 46 Selecting Utilities under OIF-CEI 56G MR Tests for PAM4 signals

Test Overview

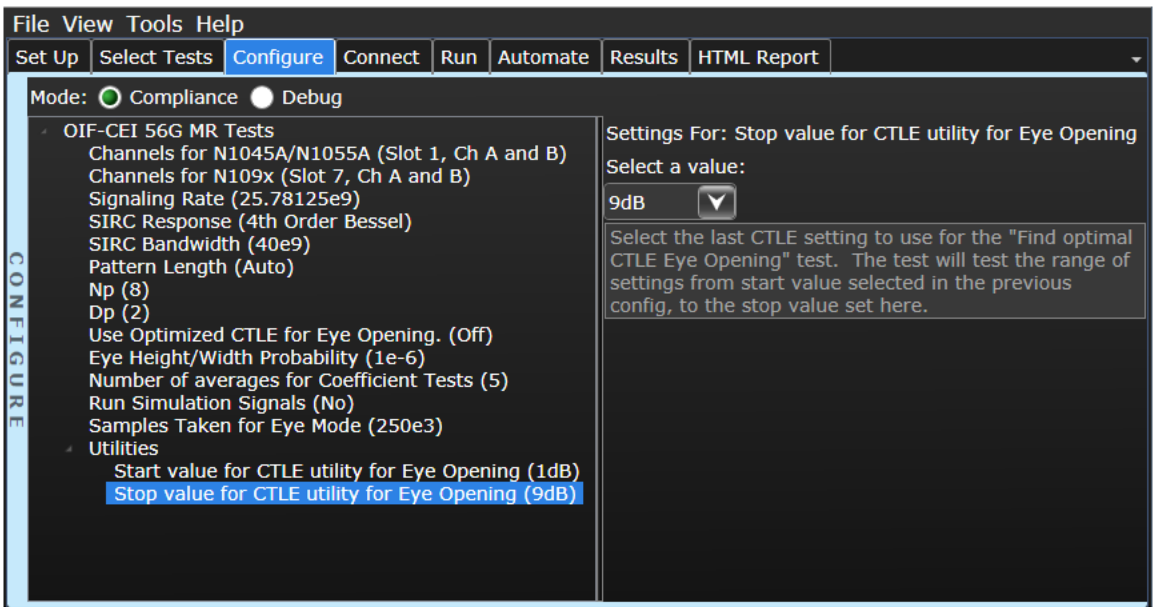
The purpose of this test is to loop through CTLE settings to find the optimal CTLE setting for the largest area of the Eye.

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 N109256CB CEI 56G Compliance Test Application.

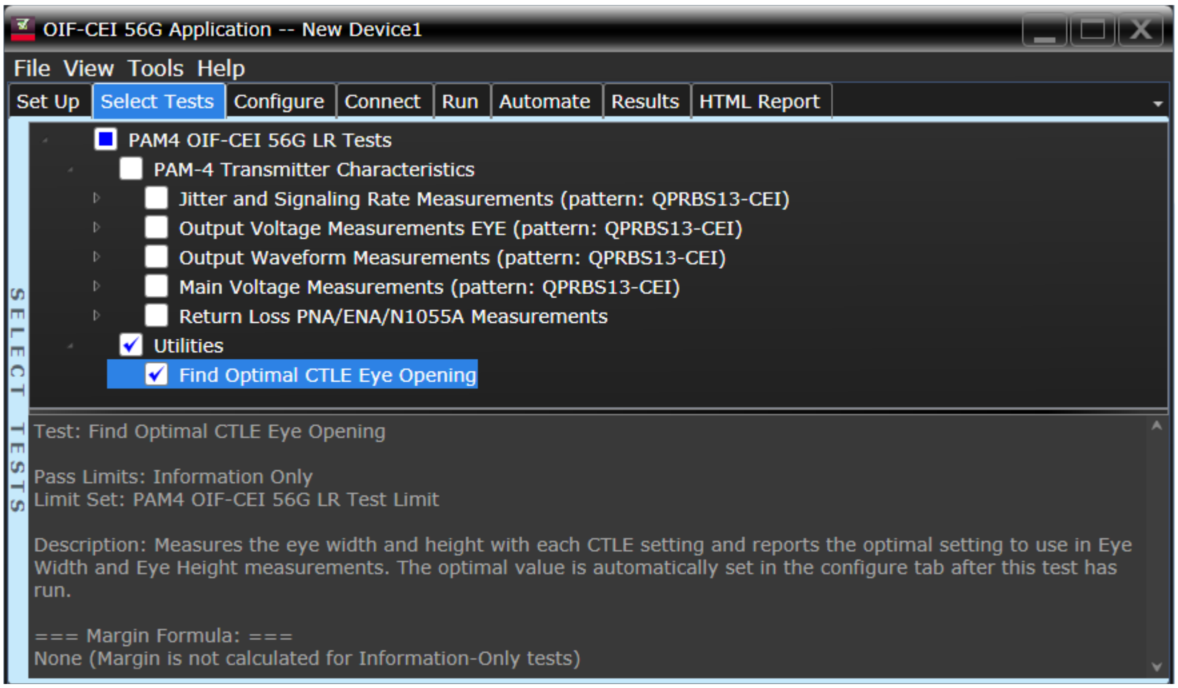
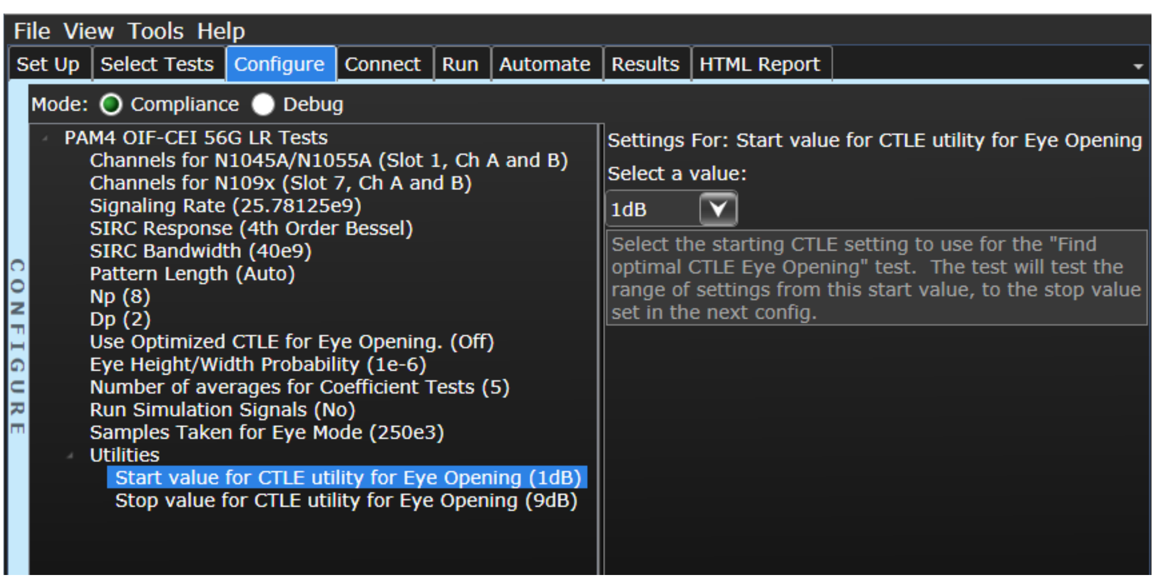


Figure 47 Selecting Utilities under OIF-CEI 56G LR Tests for PAM4 signals

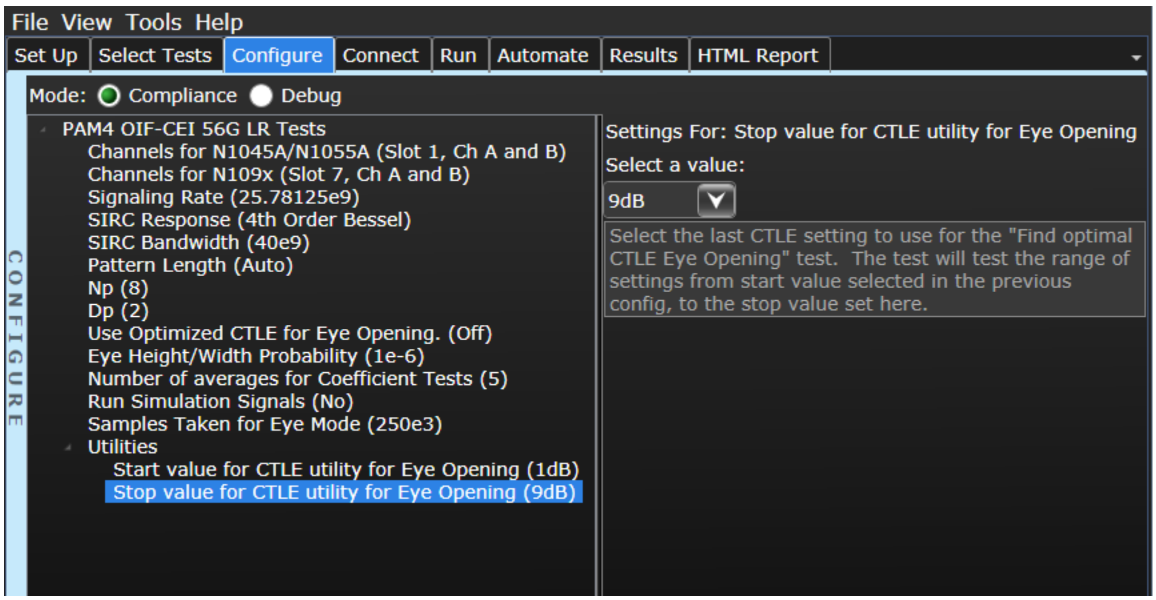
Test Overview The purpose of this test is to loop through CTLE settings to find the optimal CTLE setting for the largest area of the Eye.

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 N109256CB CEI 56G Compliance Test Application.

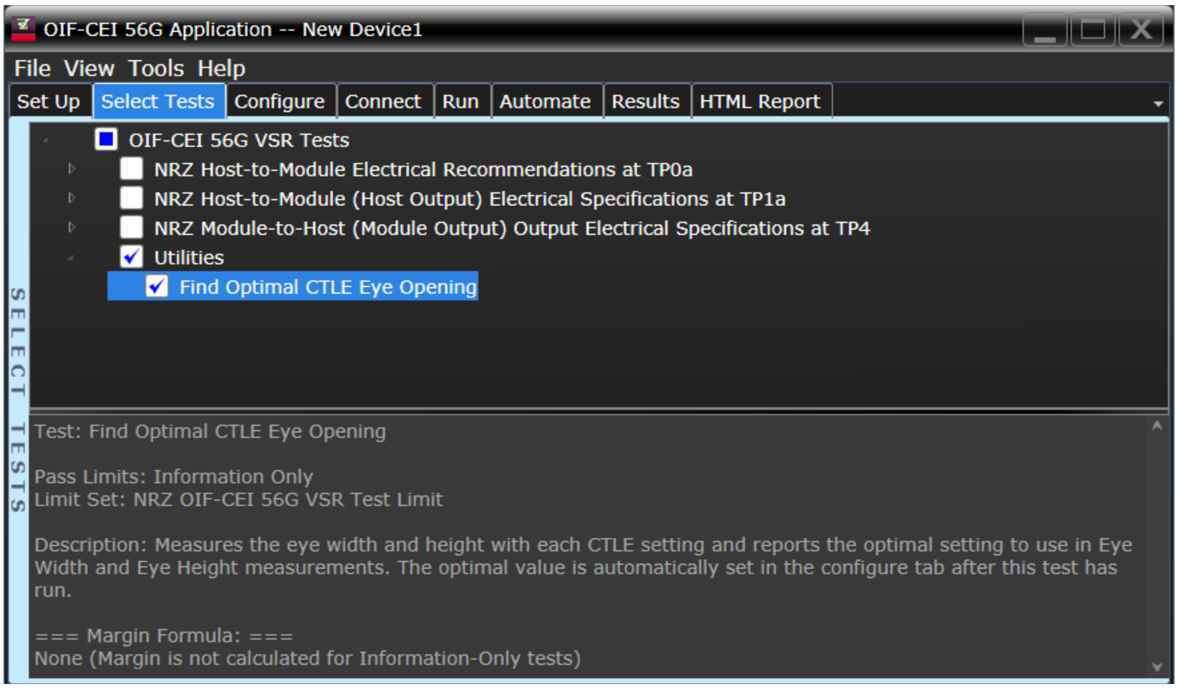
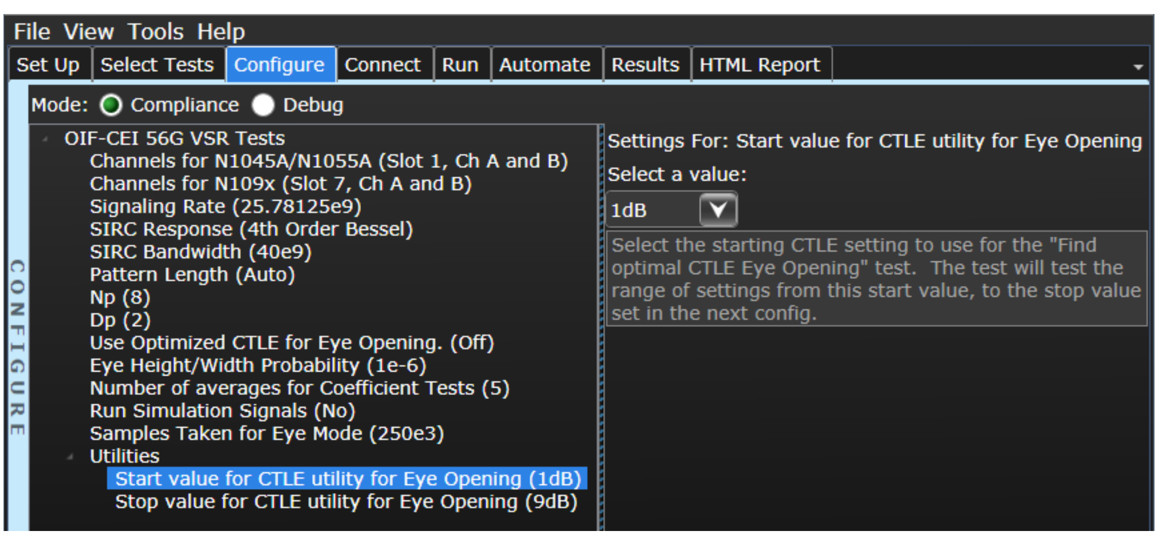


Figure 48 Selecting Utilities under OIF-CEI 56G VSR Tests for NRZ signals

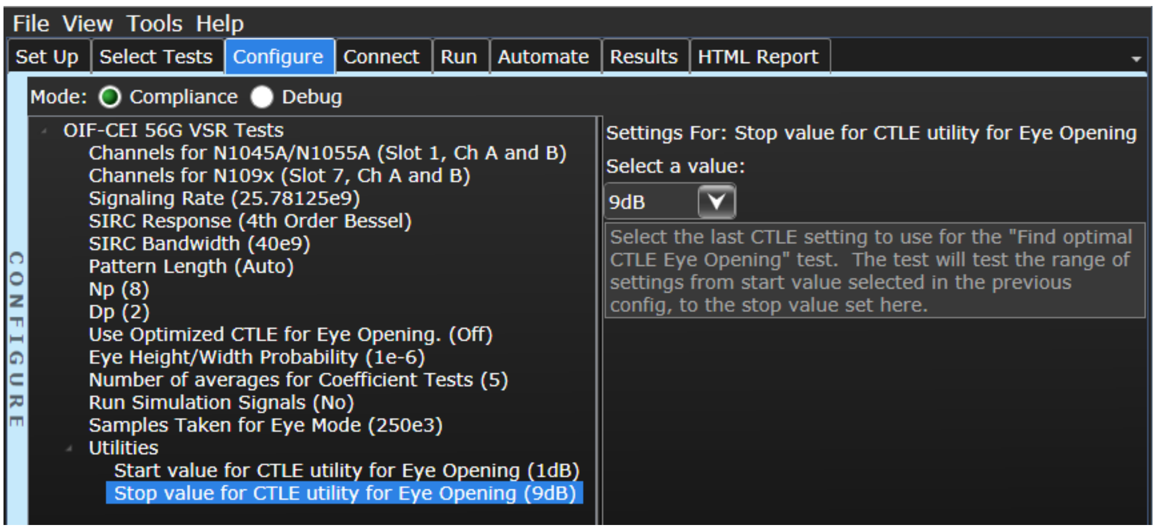
Test Overview The purpose of this test is to loop through CTLE settings to find the optimal CTLE setting for the largest area of the Eye.

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.

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