Keysight N1091BSCB 400G IEEE FlexDCA Compliance Application

KEYSIGHT TECHNOLOGIES

Methods of Implementation

Notices

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400G IEEE FlexDCA Compliance Application—At a Glance

The Keysight N1091BSCB 400G IEEE FlexDCA Compliance Application is an Ethernet test solution that covers the electrical timing parameters for PAM4 and NRZ specification (IEEE 802.3bs/IEEE 802.3cd).

The main features of the 400G IEEE FlexDCA Compliance Application are:

- Data Analytics
- IEEE802.3bs/cd, update for final release specification
- Complete coverage of specification-based chip-to-chip (C2C) and chip-to-module (C2M) tests
- Test coverage for PAM4 and NRZ signals
- Coverage of Signal-to-Noise Distortion Ratio (SNDR) and SNDR_ISI at test point TP0a
- Support for User Interactive Pulse Response

The 400G IEEE FlexDCA Compliance 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 maximum 25 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 Hardware and Software

To run the automated tests on PAM4 and NRZ signals using the 400G IEEE FlexDCA Compliance Application, you need the following hardware and software:

Hardware:

- N1000A DCA-X Wide-Bandwidth Oscilloscope Mainframe or 86100D DCA-X Wide-Bandwidth Oscilloscope Mainframe
  - N1040A Dual Electrical Channel Module for DCA-X Mainframe
  - N1045A 60 GHz 2/4 Port Electrical Remote Sampling Head
  - N1045B 60 GHz 2/4 Port Electrical Remote Sampling Head
  - N1046A 75/85/100 GHz 1/2/4 Port Remote Sampling Head
  - N1055A 35/50 GHz 2/4 Port TDR/TDT Remote Sampling Head
  - 86108B Precision Waveform Analyzer
- 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)

Software:

- N1091BSCB 400G IEEE FlexDCA Compliance Application software
- N1000A DCA-X Mainframe Software (For the minimum version of oscilloscope software, see the N1091BSCB release notes)

Licenses:

- For the required licenses for the N1091BSCB 400G IEEE FlexDCA Compliance Application, refer to the Data Sheet.

Contents

10 Utilities

1 Installing the N1091BSCB 400G IEEE FlexDCA Compliance Application

If you purchased the N1091BSCB 400G IEEE FlexDCA Compliance Application separate from your DCA oscilloscope, you must install the software and license key.

Installing the Software

1. Make sure you have the minimum version of DCA oscilloscope software (see the N1091BSCB release notes) from the **Help** menu.
2. To obtain the N1091BSCB Compliance Test Application, go to Keysight website: http://www.keysight.com/find/N1091BSCB.
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

Refer to the N1091BSCB 400G IEEE FlexDCA Compliance Application Data Sheet to know about the various licenses pertaining to N1091BSCB TX Test Automation SW Application for IEEE 802.3bs/cd and also about the other licenses that are required to unlock some additional features.

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.

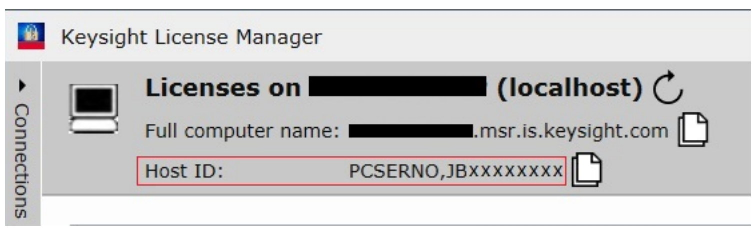


Figure 1 Viewing the Host ID information in Keysight License Manager 5

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.

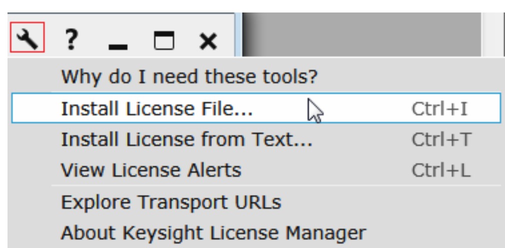


Figure 2 Configuration menu options to install licenses on Keysight License Manager 5

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.

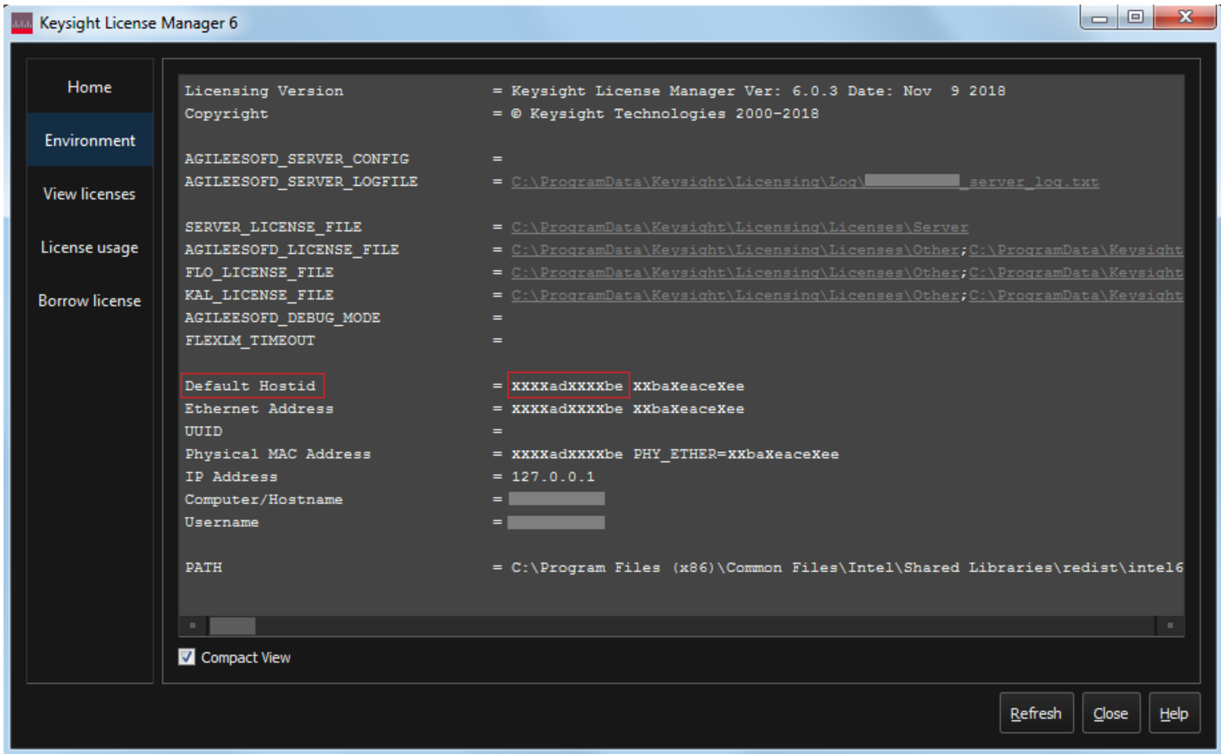


Figure 3 Viewing the Host ID information in Keysight License Manager 6

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.

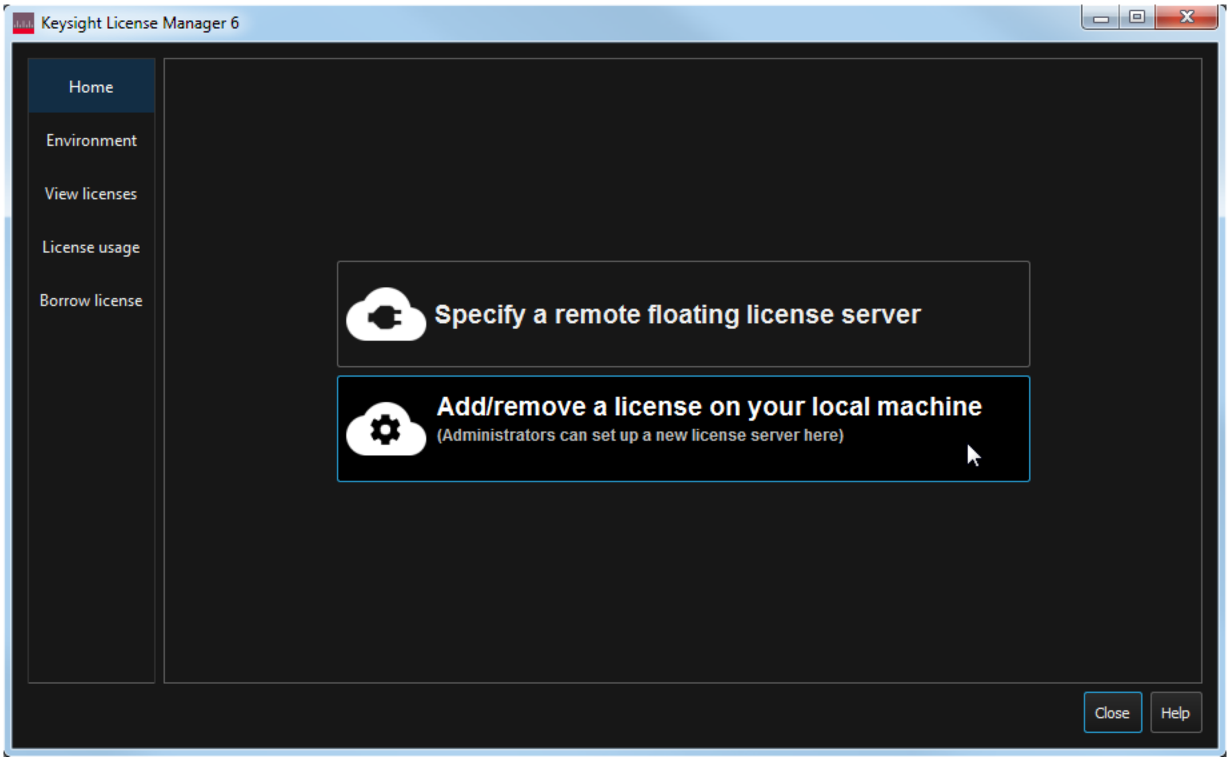


Figure 4 Home menu options to install licenses on Keysight License Manager 6

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 N1091BSCB 400G IEEE FlexDCA Compliance Application and perform the measurements.

Calibrating the Oscilloscope

If you haven't already calibrated the oscilloscope, follow the calibration instructions described within the Help manuals available with the Oscilloscope you are using.

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

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

Starting the 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 DCA oscilloscope's main menu, select **Analyze > Automated Test Apps > N1091BSCB IEEE802.3 bs/cd Test App**.

3 The Keysight N1091BSCB 400G IEEE FlexDCA Compliance Application appears.

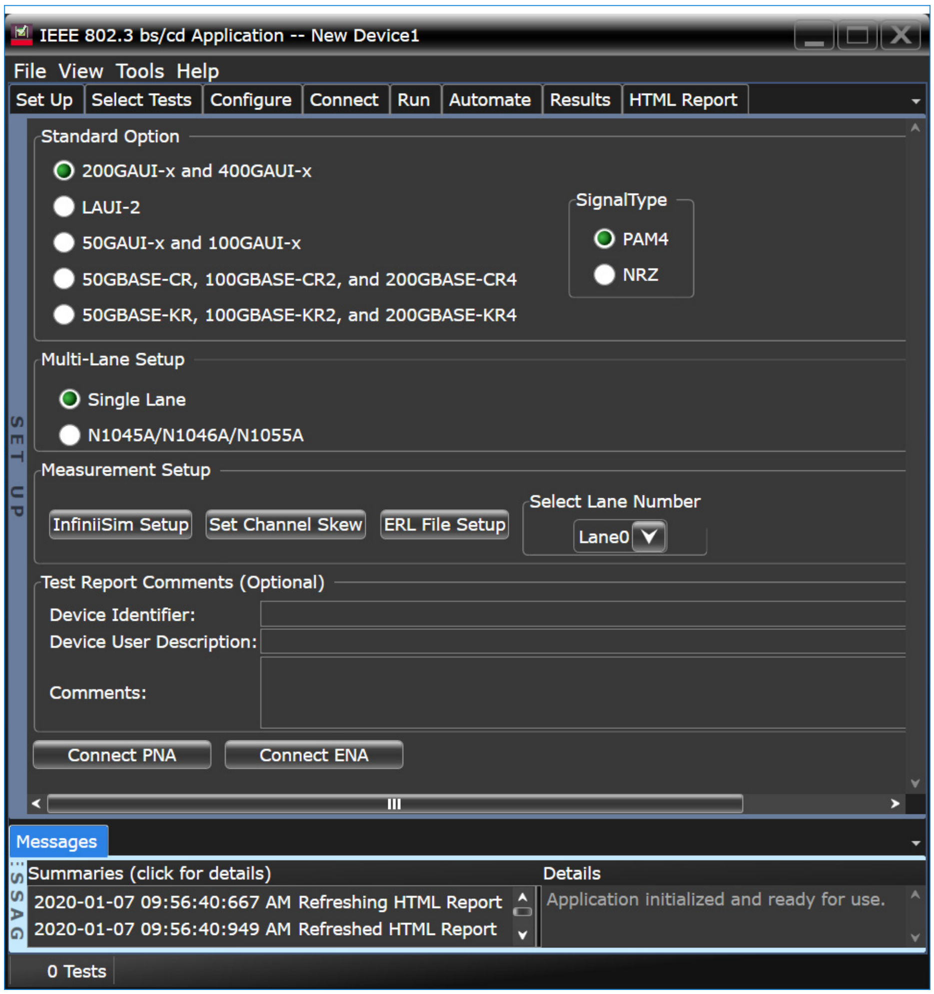


Figure 5 The N1091BSCB 400G IEEE FlexDCA Compliance Application Main window

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. With the **ERL File Setup** button, the s-parameter file for the effective return loss can be specified. 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. Table 2, Table 3 and Table 5 show a comprehensive list of the tests that are filtered in the **Select Tests** tab for each combination of **Standard Option** and **SignalType**.

2 Optionally, you may configure the rest of the settings as described in Table 1 on page 20.

3 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.

4 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 N1091BSCB 400G IEEE FlexDCA Compliance Application sets optimum values for each configuration parameter.

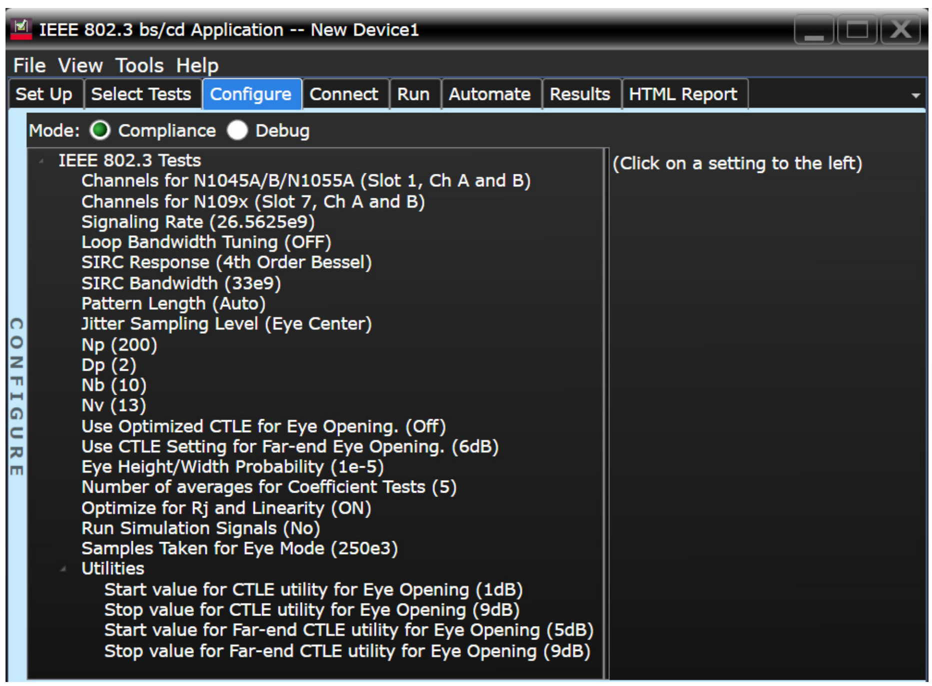


Figure 6 Configure tab in the 400G IEEE FlexDCA Compliance Application

5 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.

6 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.

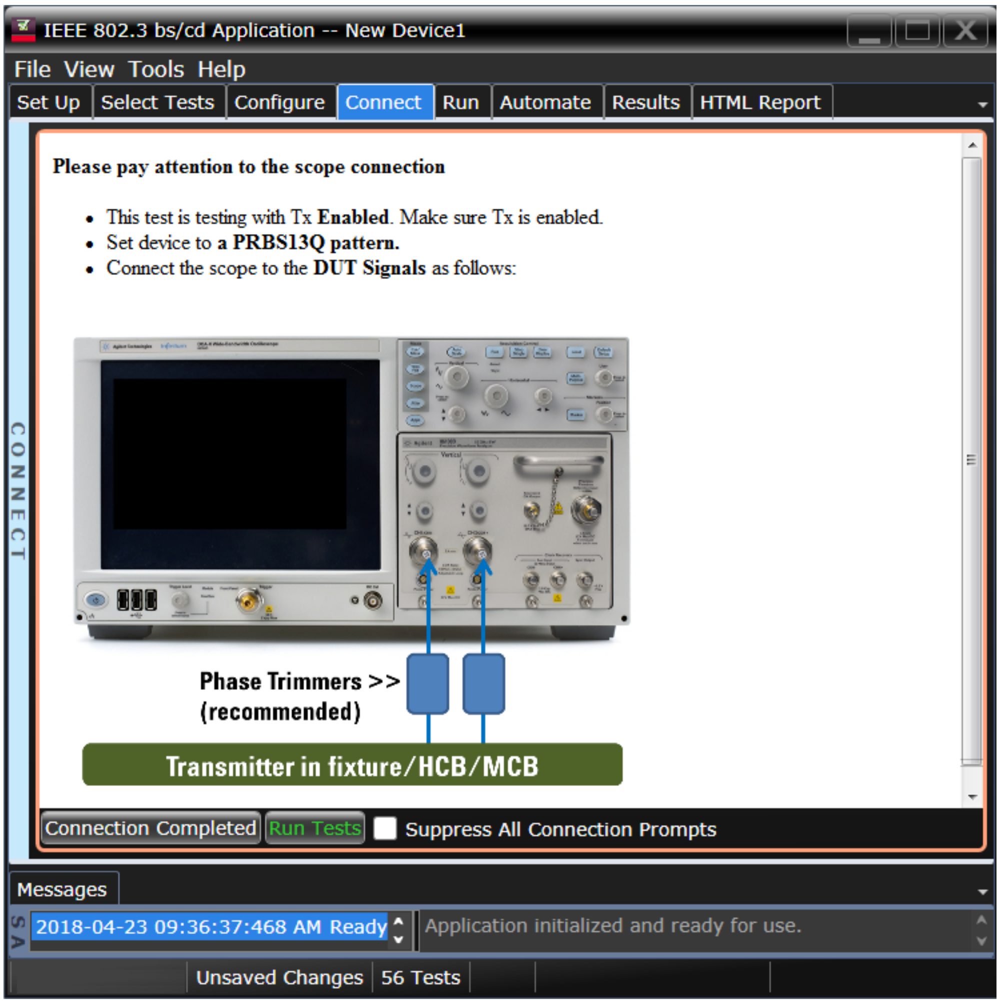


Figure 7 Connect tab in the 400G IEEE FlexDCA Compliance Application

7 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.

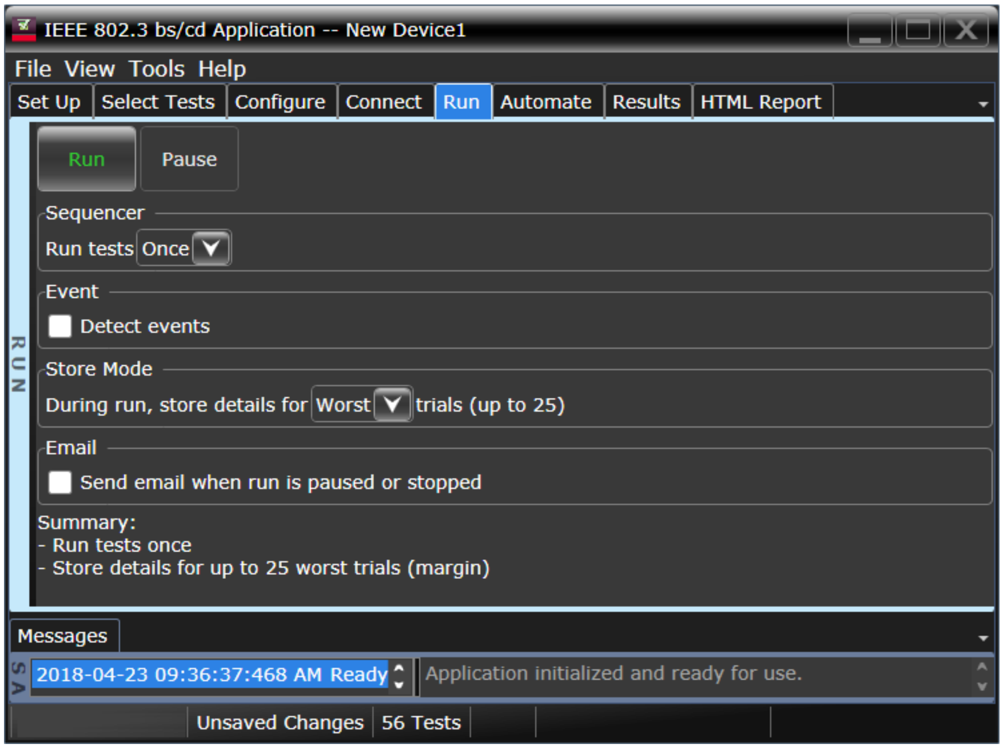


Figure 8 Run tab in the 400G IEEE FlexDCA Compliance Application

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

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

10 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 Keysight KS6800A Series Analytics 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.

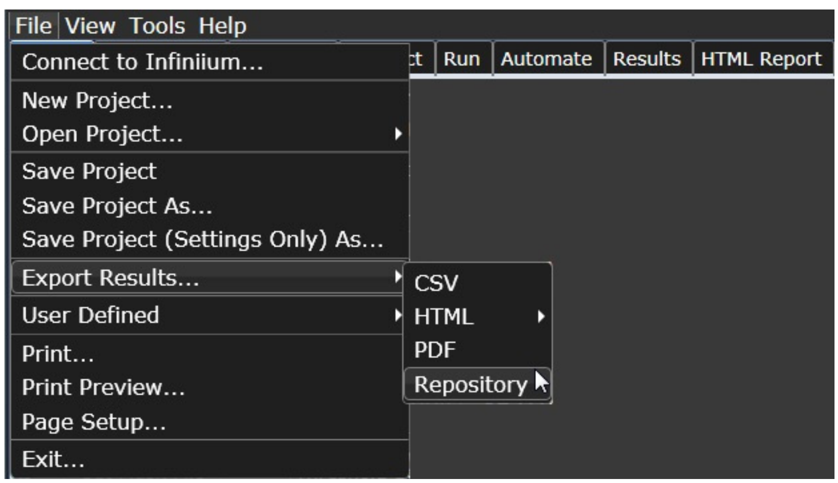
Not only can remote users with an active Internet connection access these Datasets and the corresponding test results on the Web Repository, but they have the option to add and delete Datasets on the Web Server. In the Upload Results To Repository feature, you can even modify the Dataset properties,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

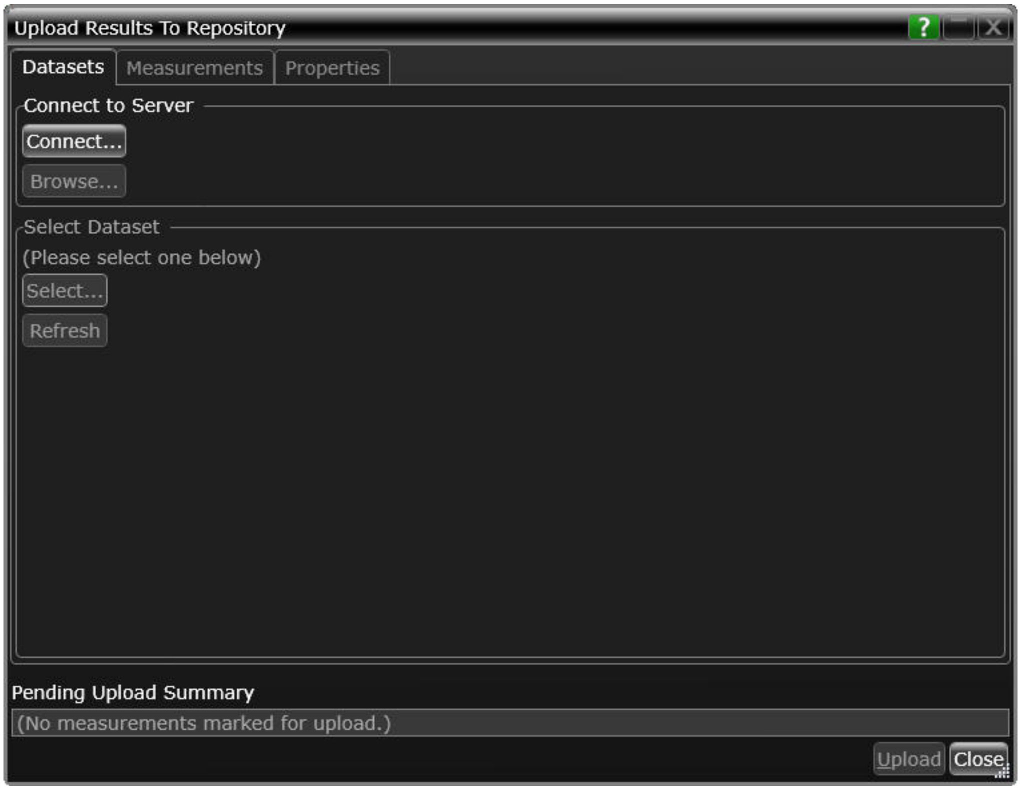
To export measurement results to the Repository after the completion of test runs,

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



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

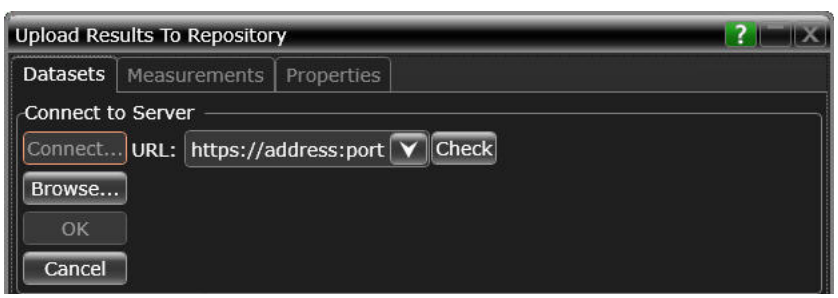
2 In the **Connect to Server** pane of the **Datasets** tab, click **Connect...** to login to the Dataset Repository server.



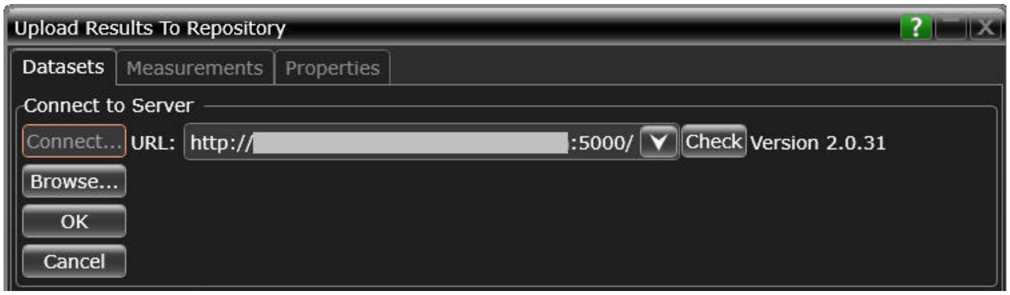
3 In the **URL:** drop-down text field that appears, replace the default text with the actual IP address or the URL along with the port number, if applicable.

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.

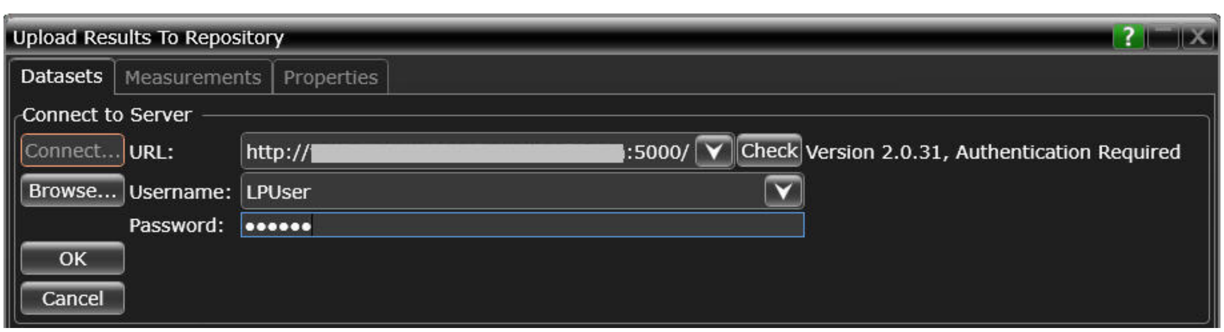


- For unrestricted access to the Repository
  - a If the server does not require authentication and the KS6800A Series Analytics service is found on the specified web address, the version information is displayed adjacent to the **Check** button.



  - 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.

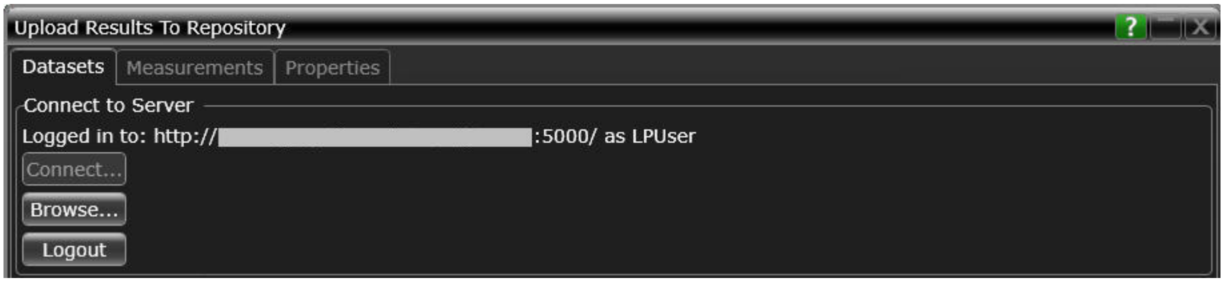
- For restricted access to the Repository
  - a If service is found on the specified URL but access to the web server is restricted based on authentication, the version information is displayed along with the text Authentication Required adjacent to the **Check** button. Also, the **Username**: and **Password**: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

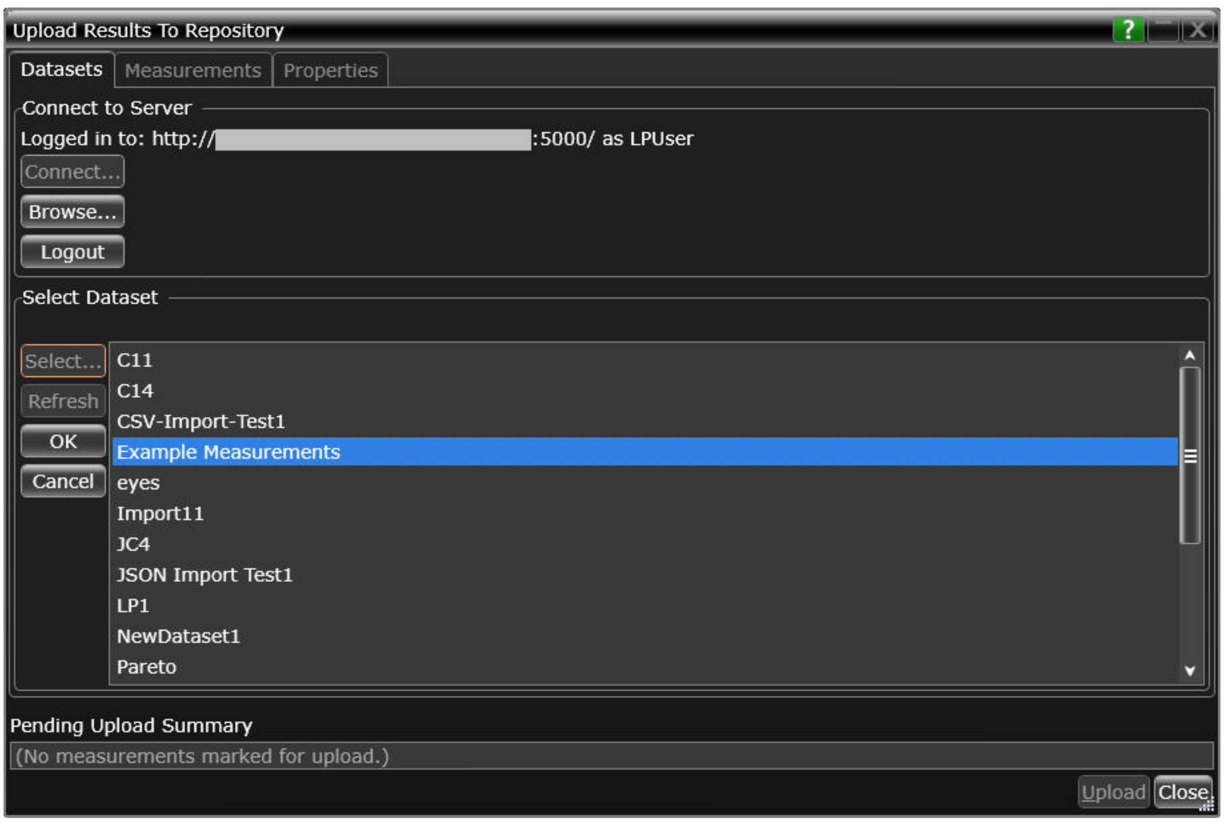
The **Connect to Server** area displays the connection status along with the username.

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

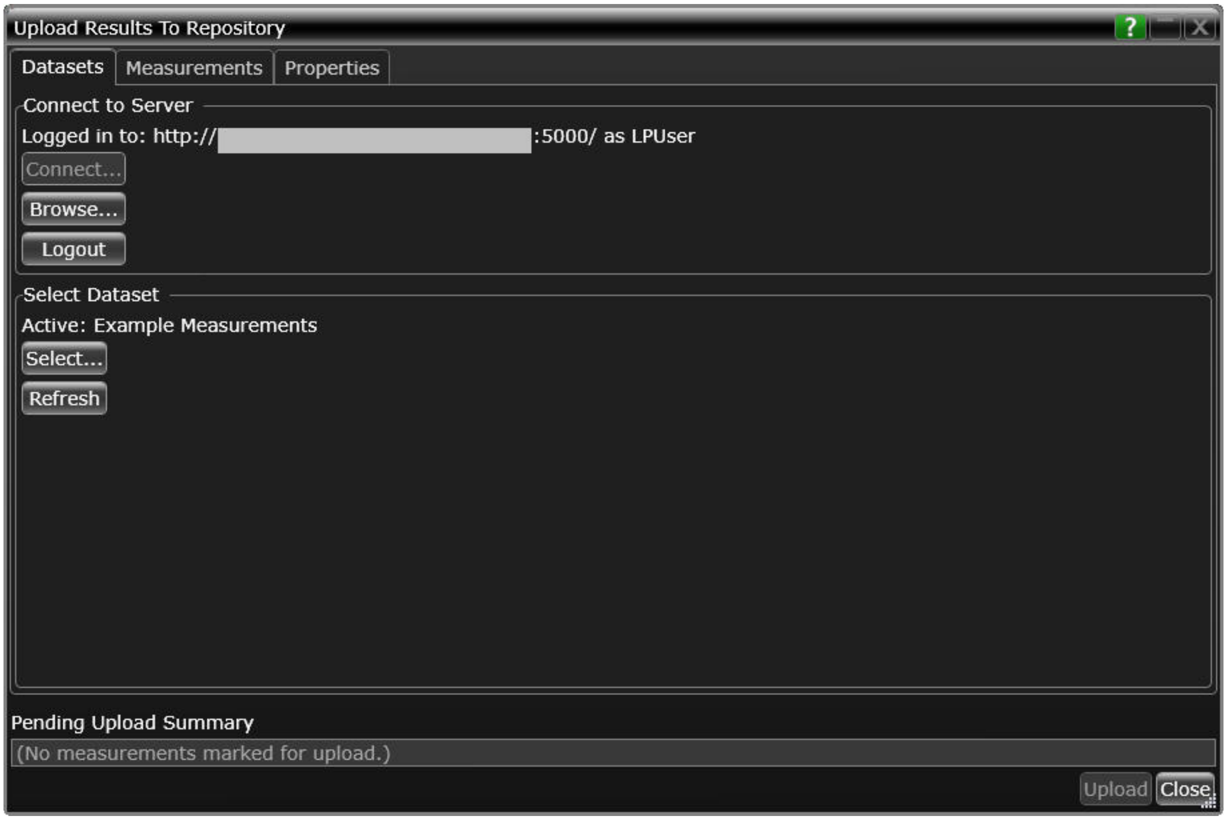


5 In the **Select Dataset** area, click **Select**... to view the list of Datasets created on the connected repository. Click **Refresh** to update the list of Datasets that appear in the Test Application's user interface.

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

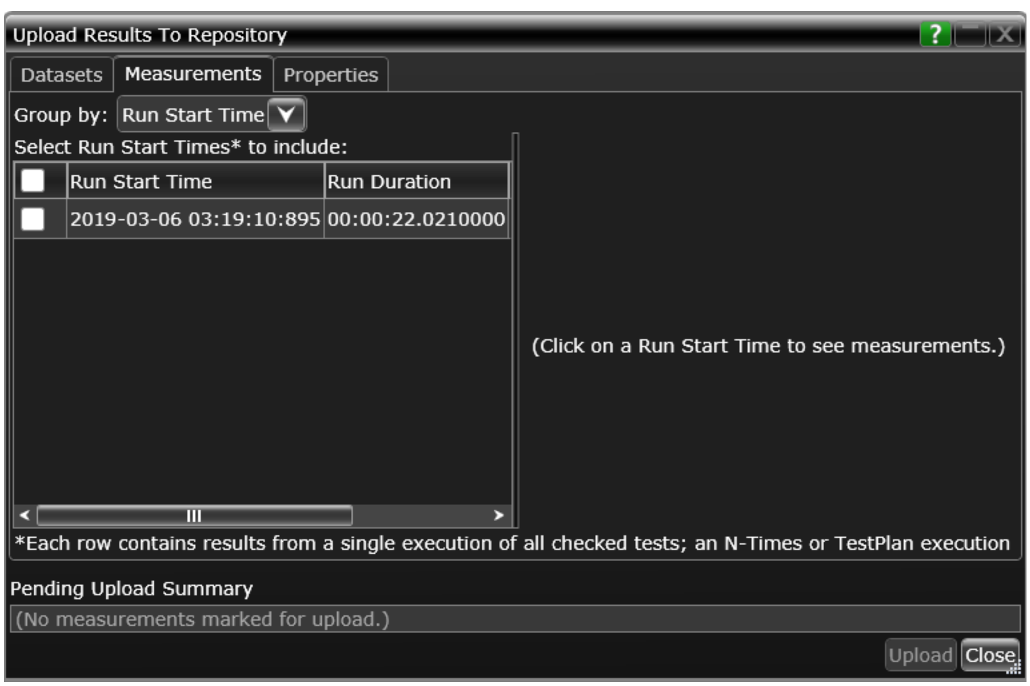


The **Select Dataset** area displays the selected Dataset as Active. The **Measurements** and **Properties** tabs are enabled after a Dataset is selected.



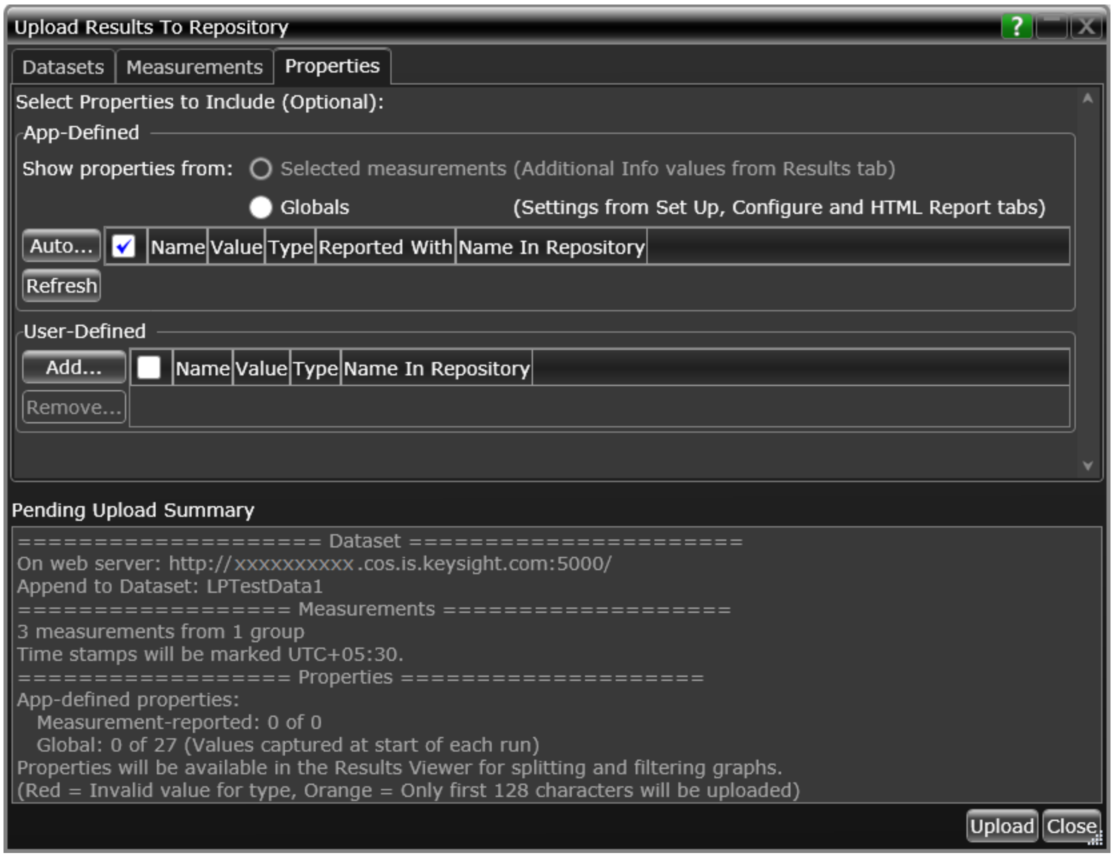
7 Click the **Measurements** tab where the test results from the last test run are displayed.

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.

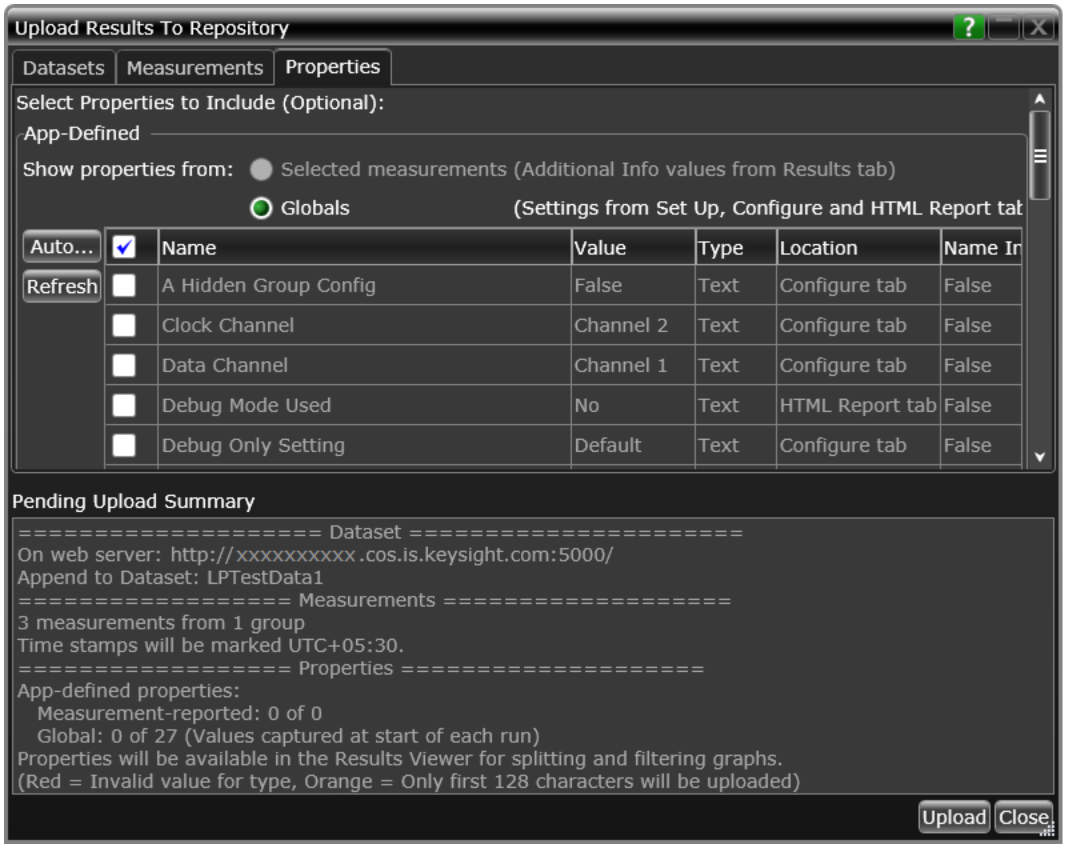


9 After selecting one or more measurements, either click **Upload** or switch to the **Properties** tab to associate one or more properties to the measurements that are being uploaded to the Web Server.

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.



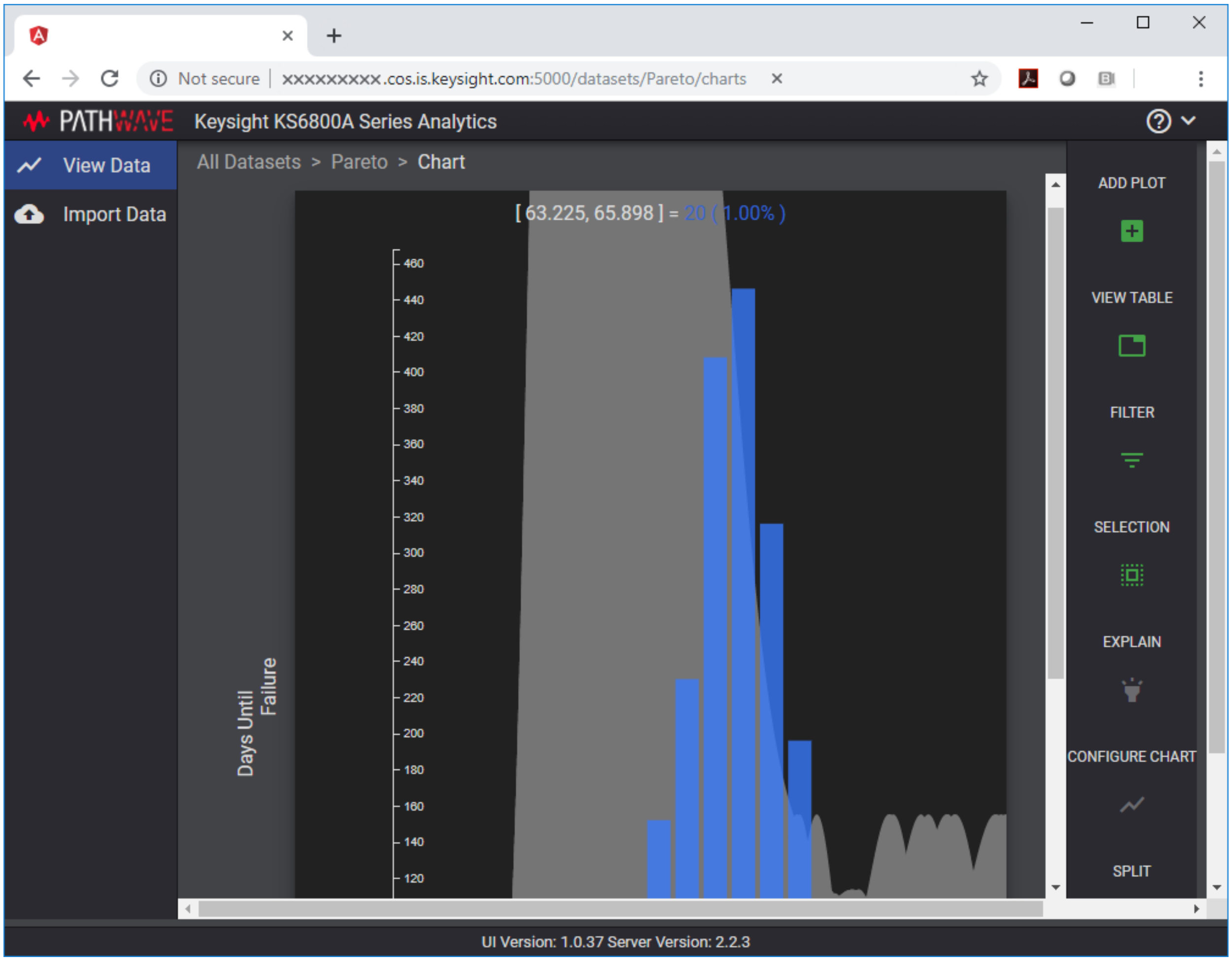
11 Click **Upload** to begin uploading measurement results.

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.

List of tests for Standard Option - Signal Type combinations

Following tables display the test list that appears under the **Select Tests** tab for each combination of **Standard Option** and **Signal Type** under the **Set Up** tab:

Table 2 Filtered test list for combinations of Standard Option and Signal Type at Test Point TP0a

Standard Option	Signal Type	Tests

▪ 200GAUI-x and 400GAUI-x
▪ 50GAUI-x and 100GAUI-x
▪ 50GBASE-KR, 100GBASE-KR2, and 200GBASE-KR4
	PAM4	PAM4 Transmitter Characteristics at TP0a
		▪ Jitter and Signaling Rate Measurements TP0a (pattern: PRBS13Q)
		  • Signaling Rate
		  • JRMS
		  • J4
		  • Even-Odd Jitter
		▪ Output Voltage Measurements EYE TP0a (pattern: PRBS13Q)
		  • Level - PRBS Pattern
		  • Level RMS - PRBS Pattern
		  • Level Separation Mismatch Ratio - RLM
		▪ Output Waveform Measurements TP0a (pattern: PRBS13Q)
		  • Steady State Voltage Vf
		  • Linear Fit Pulse Peak
		  • Signal-to-noise-and-distortion ratio
		  • SNR_ISI Tests
		  • Pre and Post Equalization Tests
		  • ERL
		  • Coefficient Initialization - Preset n
		  • abs Step Size
		▪ Main Voltage Measurements TP0a (pattern: PRBS13Q)
		  • Differential Peak-to-Peak Output Voltage Test with TX Disabled
		  • DC Common Mode Output Voltage Test
		  • AC Common Mode Output Voltage Test
		  • Differential Peak-to-Peak Output Voltage Test
		▪ Return Loss PNA/ENA Measurements
		  • Differential Output Return Loss
		  • Common-mode Output Return Loss

▪ 200GAUI-x and 400GAUI-x
▪ LAUI 2
▪ 50GAUI-x and 100GAUI-x
	NRZ	NRZ Transmitter Characteristics at TP0a
		▪ Jitter and Signaling Rate Measurements TP0a (pattern: PRBS9)
		  • Signaling Rate
		  • Even-Odd Jitter
		  • Effective bounded uncorrelated jitter
		  • Effective total uncorrelated jitter
		▪ Output Waveform Measurements TP0a (pattern: PRBS9)
		  • Steady State Voltage Vf
		  • Linear Fit Pulse Peak
		  • Signal-to-noise-and-distortion ratio
		  • Pre and Post Equalization Tests
		▪ Main Voltage Measurements TP0a (pattern: PRBS9)
		  • Differential Peak-to-Peak Output Voltage Test with TX Disabled
		  • DC Common Mode Output Voltage Test
		  • AC Common Mode Output Voltage Test
		  • Differential Peak-to-Peak Output Voltage Test
		▪ Return Loss PNA/ENA Measurements
		  • Differential Output Return Loss
		  • Common-mode Output Return Loss

Table 3 Filtered test list for combinations of Standard Option and Signal Type at Test Point TP1a

Standard Option	Signal Type	Tests

▪ 200GAUI-x and 400GAUI-x
▪ 50GAUI-x and 100GAUI-x
	PAM4	PAM4 Host Output Characteristics at TP1a
		▪ Main Voltage Measurements TP1a (pattern: PRBS13Q)
		  • Differential Peak-to-Peak Output Voltage Test with TX Disabled
		  • Differential Peak-to-Peak Output Voltage Test
		  • AC Common Mode Output Voltage Test
		  • DC Common Mode Output Voltage Test
		  • Single-ended Output Voltage Test
		▪ Transition Time Measurements TP1a (pattern: PRBS13Q)
		  • Minimum Output Rise Time (20%-80%)
		  • Minimum Output Fall Time (20%-80%)
		▪ Signaling Rate and Eye Mask Measurements TP1a (pattern: PRBS13Q)
		  • Signaling Rate
		  • Eye Height A
		  • Eye Width
		  • ESMW
		▪ Return Loss PNA/ENA Measurements
		  • Differential Output Return Loss
		  • Common-mode to Differential Output Return Loss

▪ 200GAUI-x and 400GAUI-x
▪ LAUI 2
▪ 50GAUI-x and 100GAUI-x
	NRZ	NRZ Host Output Characteristics at TP1a
		▪ Main Voltage Measurements TP1a (pattern: PRBS9)
		  • Differential Peak-to-Peak Output Voltage Test with TX Disabled
		  • Differential Peak-to-Peak Output Voltage Test
		  • AC Common Mode Output Voltage Test
		  • DC Common Mode Output Voltage Test
		  • Single-ended Output Voltage Test
		▪ Transition Time Measurements TP1a (pattern: PRBS9)
		  • Minimum Output Rise Time (20%-80%)
		  • Minimum Output Fall Time (20%-80%)
		▪ Signaling Rate and Eye Mask Measurements TP1a (pattern: PRBS9)
		  • Signaling Rate
		  • Eye Height A
		  • Eye Width
		▪ Return Loss PNA/ENA Measurements
		  • Differential Output Return Loss
		  • Common-mode to Differential Output Return Loss

Table 4 Filtered list for combinations of Standard Option and Signal Type at Test Point TP2

Standard Option	Signal Type	Tests
▪ 50GBASE-CR, 100GBASE-CR2, and 200GBASE-CR	PAM4	PAM4 Transmitter Characteristics at TP2 ▪ Jitter and Signaling Rate Measurements TP2 (pattern: PRBS13Q) • Signaling Rate • JRMS • J3u • Even-Odd Jitter ▪ Output Voltage Measurements EYE TP2 (pattern: PRBS13Q) • Level - PRBS Pattern • Level RMS - PRBS Pattern • Level Separation Mismatch Ratio - RLM ▪ Output Waveform Measurements TP2 (pattern: PRBS13Q) • Steady State Voltage Vf • Linear Fit Pulse Peak • Signal-to-noise-and-distortion ratio • ERL • Coefficient Initialization - Preset n • abs Step Size ▪ Main Voltage Measurements TP2 (pattern: PRBS13Q) • Differential Peak to Peak Output Voltage Test with TX Disabled • DC Common Mode Output Voltage Test • AC Common Mode Output Voltage Test • Differential Peak-to-Peak Output Voltage Test ▪ Return Loss PNA/ENA Measurements • Differential Output Return Loss • Common-mode Output Return Loss

Table 5 Filtered test list for combinations of Standard Option and Signal Type at Test Point TP4

Standard Option	Signal Type	Tests

▪ 200GAUI-x and 400GAUI-x
▪ 50GAUI-x and 100GAUI-x
	PAM4	PAM4 Module Output Characteristics at TP4
		▪ Main Voltage Measurements TP4 (pattern: PRBS13Q)
		  • Differential Output Voltage Test
		  • AC Common Mode Output Voltage Test
		  • DC Common Mode Voltage Test
		▪ Transition Time Measurements TP4 (pattern: PRBS13Q)
		  • Minimum Output Rise Time (20%-80%)
		  • Minimum Output Fall Time (20%-80%)
		▪ Signaling Rate and Eye Mask Measurements TP4 (pattern: PRBS13Q)
		  • Signaling Rate
		  • Near-end Eye Height
		  • Near-end Eye Width
		  • Near-end ESMW
		  • Vertical Eye Closure
		  • Far-end Eye Height
		  • Far-end Eye Width
		  • Far-end ESMW
		▪ Return Loss PNA/ENA Measurements
		  • Differential Output Return Loss
		  • Common-mode to Differential Output Return Loss

▪ 200GAUI-x and 400GAUI-x
▪ LAUI 2
▪ 50GAUI-x and 100GAUI-x
	NRZ	NRZ Module Output Characteristics at TP4
		▪ Main Voltage Measurements TP4 (pattern: PRBS9)
		  • Differential Output Voltage Test
		  • AC Common Mode Output Voltage Test
		  • DC Common Mode Voltage Test
		▪ Transition Time Measurements TP4 (pattern: PRBS9)
		  • Minimum Output Rise Time (20%-80%)
		  • Minimum Output Fall Time (20%-80%)
		▪ Signaling Rate and Eye Mask Measurements TP4 (pattern: PRBS9)
		  • Signaling Rate
		  • Near-end Eye Height
		  • Near-end Eye Width
		  • Vertical Eye Closure
		  • Far-end Eye Height
		  • Far-end Eye Width
		  • Return Loss ENA/PNA/N1055A Measurements
		▪ Return Loss PNA/ENA Measurements
		  • Differential Output Return Loss
		  • Common-mode to Differential Output Return Loss

3 PAM4 Transmitter Characteristics at TP0a

This section provides the Methods of Implementation (MOIs) for the IEEE PAM4 Transmitter Characteristics at TP0a. Measurements are made at test point 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.

C2C transmitter characteristics

PAM4 GAUI-x tests

See Table 6 for pass limits pertaining to 200GAUI-x and 400GAUI-x PAM4 tests, which are specified in IEEE P802.3bs™ /D3.5 (Draft Standard for Ethernet Amendment 10: Media Access Control Parameters, Physical Layers and Management Parameters for 200Gb/s and 400Gb/s Operation), Annex 120D.3.1, Table 120D-1.

Table 6 200GAUI-4 and 400GAUI-8 C2C transmitter characteristics at TP0a

Parameter	Reference	Value	Units
Signaling rate per lane (range)		26.5625 ± 100 ppm	GBd
Differential peak-to-peak output voltage[a] (max) Transmitter disabled Transmitter enabled	See Sec. 93.8.1.3 of the IEEE specification	 30 1200	 mV mV
Common-mode voltage[a] (max)	See Sec. 93.8.1.3 of the IEEE specification	1.9	V
Common-mode voltage[a] (min)	See Sec. 93.8.1.3 of the IEEE specification	0	V
AC common-mode output voltage[a] (max, RMS)	See Sec. 93.8.1.3 of the IEEE specification	30	mV
Differential output return loss (min)	See Sec. 120D.3.1.1 of the IEEE specification	See Equation (120D–2) of the IEEE specification	dB
Common-mode output return loss (min)	See Sec. 93.8.1.4 of the IEEE specification	See Equation (93-4) of the IEEE specification	dB
Output waveform[b] Level separation mismatch ratio RLM(min) Steady state voltage vf (max) Steady state voltage vf (min) Linear fit pulse peak (min) Pre-cursor equalization Post-cursor equalization	See Sections 120D.3.1.2 120D.3.1.4 120D.3.1.4 120D.3.1.4 120D.3.1.5 120D.3.1.5	 0.95 0.6 0.4 0.76 × vf Table 120D–2 Table 120D–3	 - V V V - -
Signal-to-noise-and-distortion ratio SNDR (min)	See Sec.120D.3.1.6 of the IEEE specification	31.5	dB
Transmitter Output residual ISI SNR_{ISI} (min)	See Sec. 120D.3.1.7 of the IEEE specification	34.8	dB
Output jitter J_{RMS} (max) J4u (max) Even-odd jitter (max)	See Sections 120D.3.1.8 120D.3.1.8 120D.3.1.8	 0.023 0.118 0.019	 UI UI UI

a. Measurement uses the method described in section 93.8.1.3 of IEEE specification with the exception that the PRBS13Q test pattern is used.

b. The state of the transmit equalizer is controlled by management interface.

For PAM4 KR Tests

A 50GBASE-KR, 100GBASE-KR2, and 200GBASE-KR4 chip-to-chip transmitter shall meet all specifications in section 137.9.2 of the IEEE specification (refer to Table 6 for limits corresponding to Table 120D-1) with the following exceptions:

- The value for the “Linear fit pulse peak (min)” is 0.75 × vf.
- The output waveform Pre-cursor equalization and Post-cursor equalization parameters are replaced by the “Transmitter output waveform” specifications detailed in section 136.9.3.1 of the IEEE specification and summarized in Table 7, which corresponds to Table 136-11.
- The differential output return loss (min) and SNR_{ISI} (min) requirements are replaced by the transmitter effective return loss (ERL) specification in section 137.9.2.1 of the IEEE P802.3cd^{TM} specification.
- The value of SNDR (min) is 32.5dB.
- The J4u limit in Table 6 does not apply. The maximum J3u is 0.106 UI (see section 136.9.3.3 of the IEEE P802.3cd^{TM} specification).

Jitter and Signaling Rate Measurements TP0a

The Jitter and Signaling Rate Measurement procedures described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

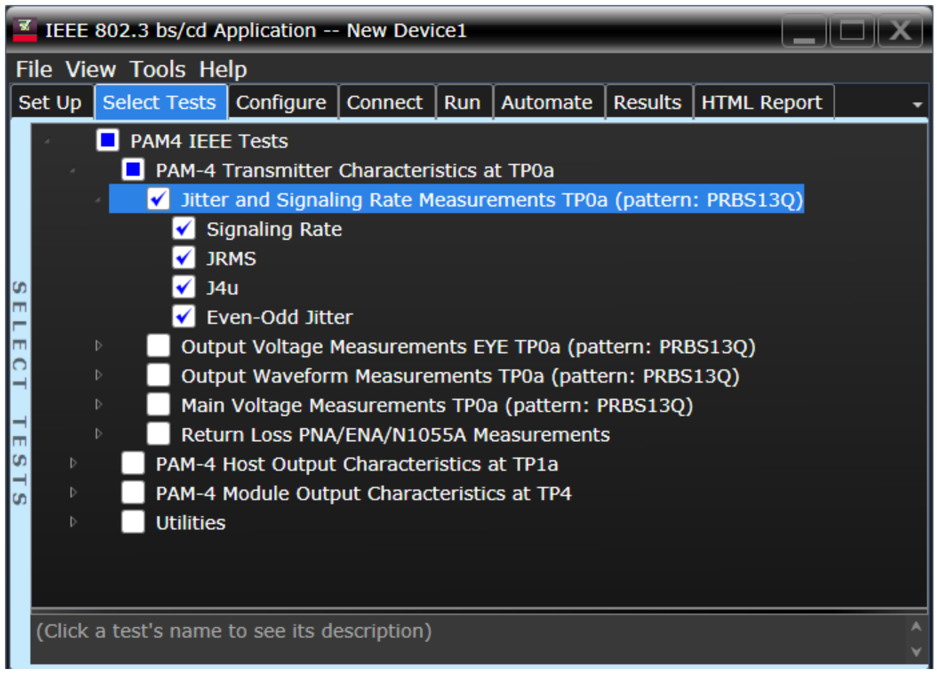


Figure 9 Selecting Jitter and Signaling Rate Measurement Tests

Refer to the section C2C transmitter characteristics for information on the pass limits for each test that is displayed for the selected standard option.

To know about the measurement algorithm for each Jitter and Signaling Rate Measurements TP0a (pattern: PRBS13Q) tests, see:

- "Signaling Rate" on page 41
- "JRMS" on page 42
- "J4" on page 43
- "Even-Odd Jitter" on page 44

Signaling Rate

Test Overview The purpose of this test is to verify that the signaling rate meets the specified standards.

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Check that the signal is connected, has a bit-rate of 53.125 GHz and that data pattern exists (PRBS13Q must be used for this test).
3 In the **Configure** tab, set **Signaling Rate** to 26.5625 Gb/s.
4 Measure minimum and maximum data rate.
5 Report minimum and maximum values.
6 Compare the mean data rate value with the specified standards. Report the resulting value.

JRMS

Test Overview The purpose of this test is to verify that differential signal's JRMS meets the specified standards. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Conditions Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1 Obtain sample or acquire signal data.

NOTE Signal must be of PRBS13Q 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 (26.5625 Gbps) and Loop Bandwidth to 4 MHz.

   b Using PAM4 jitter measurements, at least 10,000 PRBS13Q patterns are captured to collect the measurement data of 12 edges.

   c Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

4 Compare and report the JRMS value to the specified standards.

J4

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

Pass Conditions Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1 Obtain sample or acquire signal data.

NOTE Signal must be of PRBS13Q 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 (26.5625 Gbps) and Loop Bandwidth to 4 MHz.

   b Using PAM4 jitter measurements, at least 10,000 PRBS13Q patterns are captured to collect the measurement data of 12 edges.

   c Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

4 Compare and report the J4 value meets the specified standards.

Even-Odd Jitter

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

Pass Conditions Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1 Obtain sample or acquire signal data.

> **NOTE** Signal must be of PRBS13Q 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 (26.5625 Gbps) and Loop Bandwidth to 4 MHz.

   b Using PAM4 jitter measurements, at least 10,000 PRBS13Q patterns are captured to collect the measurement data of 12 edges.

   c Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

4 Compare and report the Even-Odd Jitter value to the specified standards.

Output Voltage Measurements EYE TP0a

The Output Voltage Measurement EYE procedures for a signal with PRBS13Q pattern that are described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

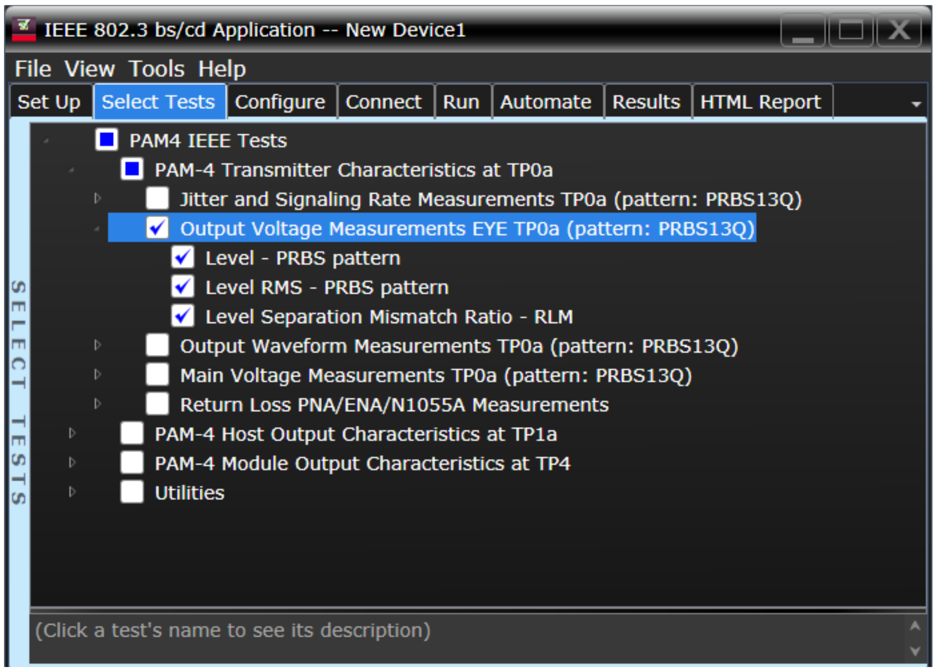


Figure 10 Selecting Output Voltage Measurements EYE Tests

Refer to the section C2C transmitter characteristics for information on the pass limits for each test that is displayed for the selected standard option.

To know about the measurement algorithm for each Output Voltage Measurements EYE TP0a (pattern: PRBS13Q) tests, see:

- “Level - PRBS Pattern” on page 46
- “Level RMS - PRBS Pattern” on page 47
- “Level Separation Mismatch Ratio - RLM” on page 48

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 PRBS13Q 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 (PRBS13Q pattern must be used for this test).

2 V_0, V_1, V_2 and V_3 are the mean signal levels of the symbols corresponding to the PAM4 symbol levels 0, 1, 2 and 3 respectively, as defined in IEEE P802.3bs™ /D3.5 (Draft Standard for Ethernet Amendment 10: Media Access Control Parameters, Physical Layers and Management Parameters for 200Gb/s and 400Gb/s Operation), Annex 120D.3.1.2. The calculation of mean signal levels is also defined in section 120D.3.1.2.1.

3 The mean level V_{mid} is defined by equation (120D-3), which is,

$$V_{mid} = (V_0 + V_3) / 2$$

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 PRBS13Q 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 IEEE P802.3bs^{TM} /D3.5 (Draft Standard for Ethernet Amendment 10: Media Access Control Parameters, Physical Layers and Management Parameters for 200Gb/s and 400Gb/s Operation), Annex 120D.3.1.2.

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 PRBS13Q pattern.

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

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_0 corresponds to -1, V_1 to -ES1, V_2 to ES2 and V_3 to 1.

3 ES1 and ES2 are calculated using equations (120D-4) and (120D-5), respectively of the IEEE P802.3bs™ /D3.5 (Draft Standard for Ethernet Amendment 10: Media Access Control Parameters, Physical Layers and Management Parameters for 200Gb/s and 400Gb/s Operation), Annex 120D.3.1.2.

$$ES1 = (V_1 - V_{mid}) / (V_0 - V_{mid})$$

$$ES2 = (V_2 - V_{mid}) / (V_3 - V_{mid})$$

4 The level separation mismatch ratio R_{LM} is defined by equation (120D-5).

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

5 Report this value for information-only purpose.

Output Waveform Measurements TP0a

The Output Waveform Measurement procedures that are described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

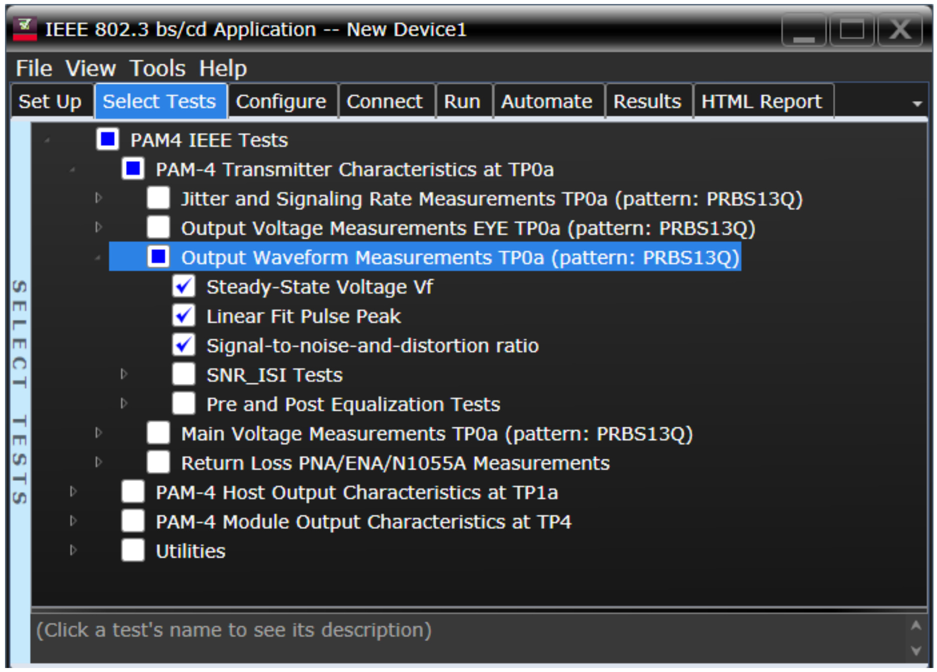


Figure 11 Selecting Transmitter Output Waveform Measurement Tests

Refer to the section C2C transmitter characteristics for information on the pass limits for each test that is displayed for the selected standard option.

To know about the measurement algorithm for each Output Waveform Measurements TP0a (pattern: PRBS13Q) tests, see:

- “Steady State Voltage Vf” on page 50
- “Linear Fit Pulse Peak” on page 51
- “Signal-to-noise-and-distortion ratio” on page 52
- “SNR_ISI Tests” on page 53
- “Pre and Post Equalization Tests” on page 54
- “ERL” on page 65
- “Coefficient Initialization - Preset n” on page 66
- “abs Step Size” on page 68

Steady State Voltage V_f

Test Overview The purpose of this test is to verify that the Steady State Voltage is between 0.4V and 0.6V.

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1. Check that signal is connected and proper data pattern exists (PRBS13Q must be used for this test).
2. Set memory depth and sample rate to capture the 8191 bits of the PRBS13Q pattern.
3. Calculate V_f 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. Compare and report the resulting value in the range between 0.4V and 0.6V.

Linear Fit Pulse Peak

Test Overview The purpose of this test is to verify that the Linear Fit Pulse meets the specified standards.

NOTE **Run the Steady-State Voltage Vf test as a prerequisite to running the Linear Fit Pulse Peak test.**

Pass Conditions Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1 Check that signal is connected and proper data pattern exists (PRBS13Q must be used for this test).

2 Set memory depth and sample rate to capture the 8191 bits of the PRBS13Q pattern.

3 Calculate Linear Fit Pulse 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 Compare the specified standards to the resulting value.

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) meets the specified standards.

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1 Calculate SNDR using measurements from Level RMS - PRBS pattern test and error from Linear Fit Pulse Peak test.
2 Compare the resulting value of SNDR to the specified standards.

SNR_ISI Tests

Test Overview The purpose of this test is to verify that the Transmitter Output residual ratio (SNR_ISI) for each value of Output Gain (in Decibels) meets the specified standards.

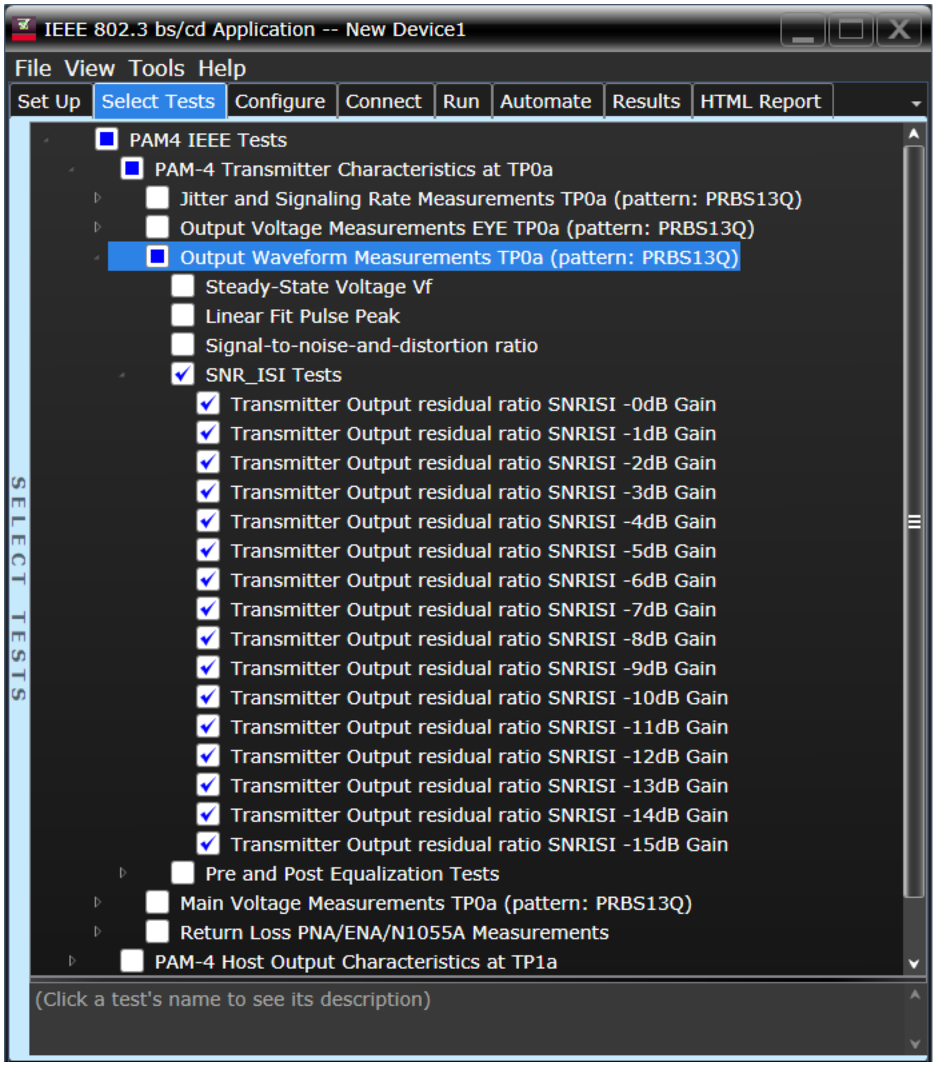


Figure 12 Selecting SNR_ISI Tests

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1 Select one or more tests that pertain to a specific Output Gain value.
2 Calculate SNRISI for each selected test using measurements from Level RMS - PRBS pattern test and error from Linear Fit Pulse Peak test.
3 Compare the resulting value to the specified standards.

Pre and Post Equalization Tests

Test Overview The purpose of this test is to verify the Pre-cursor and Post-cursor equalization ratios.

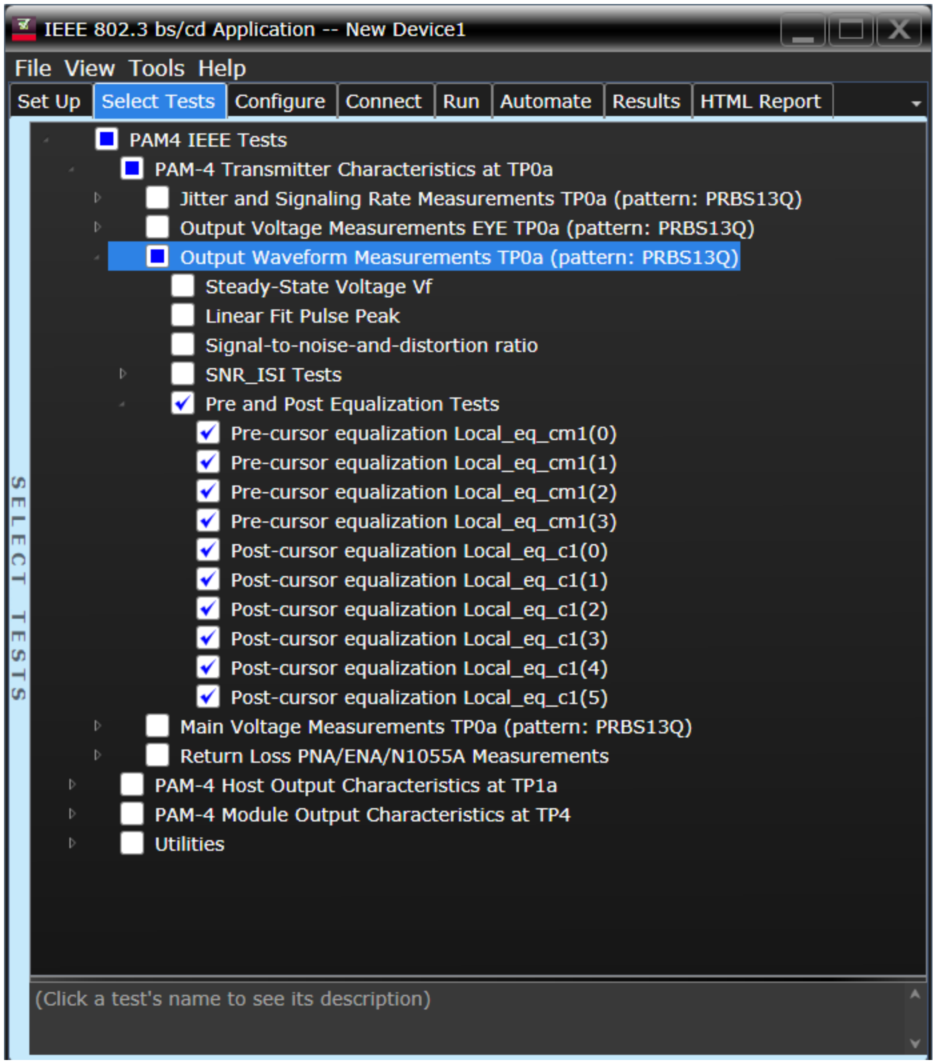


Figure 13 Selecting Pre and Post Equalization Tests

To know about the measurement algorithm for each Pre and Post Equalization Tests, see:

- "Pre-cursor equalization Local_eq_cm1(0)" on page 55
- "Pre-cursor equalization Local_eq_cm1(1)" on page 56
- "Pre-cursor equalization Local_eq_cm1(2)" on page 57
- "Pre-cursor equalization Local_eq_cm1(3)" on page 58
- "Pre-cursor equalization Local_eq_c1(0)" on page 59
- "Post-cursor equalization Local_eq_c1(1)" on page 60
- "Post-cursor equalization Local_eq_c1(2)" on page 61
- "Post-cursor equalization Local_eq_c1(3)" on page 62
- "Post-cursor equalization Local_eq_c1(4)" on page 63
- "Post-cursor equalization Local_eq_c1(5)" on page 64

Pre-cursor equalization Local_eq_cm1(0)

Test Overview The purpose of this test is to verify that the Pre-cursor equalization ratio is 0 ± 0.04.

Pass Condition When the Pre-cursor equalization with weight Local_eq_cm1 = 0, the ratio defined by C(-1) / [|C(-1)| + |C(0)| + |C(1)|} must be within 0 ± 0.04.

Measurement Algorithm

1. Request Transmitter to be set to “PRESET” condition.
2. Set memory depth to capture one full PRBS13Q pattern and scale.
3. Calculate linear fit pulse response at “PRESET” condition.
4. Define matrix Rm using equation (92-4) from IEEE 802.3.
5. Request to change the eq setting to Pre-cursor equalization with weight local_eq_cm1 = 0.
6. Calculate linear fit pulse response 85.8.3.3.5 with N_p = 200, D_p = 2. The value for ES is defined to be (|ES1| + |ES2|)/2 where ES1 and ES2 are defined in section 120D.3.1.2 of the IEEE P802.3bs^{TM} /D3.5 document.
7. Calculate coefficients using equation (92-5) from IEEE 802.3.
8. Calculate pre-cursor ratio using the equation C(-1) / [|C(-1)| + |C(0)| + |C(1)|}.
9. Compare and report the value of pre-cursor ratio with 0 ± 0.04.

Pre-cursor equalization Local_eq_cm1(1)

Test Overview The purpose of this test is to verify that the Pre-cursor equalization ratio is -0.05 ± 0.04.

Pass Condition When the Pre-cursor equalization with weight Local_eq_cm1 = 1, the ratio defined by C(-1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.05 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS13Q pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Pre-cursor equalization with weight local_eq_cm1 = 1.
6 Calculate linear fit pulse response 85.8.3.3.5 with N_p = 200, D_p = 2. The value for ES is defined to be (|ES1| + |ES2|)/2 where ES1 and ES2 are defined in section 120D.3.1.2 of the IEEE P802.3bs™ /D3.5 document.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate pre-cursor ratio using the equation C(-1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of pre-cursor ratio with -0.05 ± 0.04.

Pre-cursor equalization Local_eq_cm1(2)

Test Overview The purpose of this test is to verify that the Pre-cursor equalization ratio is -0.1 ± 0.04.

Pass Condition When the Pre-cursor equalization with weight Local_eq_cm1 = 2, the ratio defined by C(-1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.1 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS13Q pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Pre-cursor equalization with weight local_eq_cm1 = 2.
6 Calculate linear fit pulse response 85.8.3.3.5 with N_p = 200, D_p = 2. The value for ES is defined to be (|ES1| + |ES2|)/2 where ES1 and ES2 are defined in section 120D.3.1.2 of the IEEE P802.3bs^{TM} /D3.5 document.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate pre-cursor ratio using the equation C(-1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of pre-cursor ratio with -0.1 ± 0.04.

Pre-cursor equalization Local_eq_cm1(3)

Test Overview The purpose of this test is to verify that the Pre-cursor equalization ratio is -0.15 ± 0.04.

Pass Condition When the Pre-cursor equalization with weight Local_eq_cm1 = 3, the ratio defined by C(-1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.15 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS13Q pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Pre-cursor equalization with weight local_eq_cm1 = 3.
6 Calculate linear fit pulse response 85.8.3.3.5 with N_p = 200, D_p = 2. The value for ES is defined to be (|ES1| + |ES2|)/2 where ES1 and ES2 are defined in section 120D.3.1.2 of the IEEE P802.3bs™ /D3.5 document.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate pre-cursor ratio using the equation C(-1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of pre-cursor ratio with -0.15 ± 0.04.

Pre-cursor equalization Local_eq_c1(0)

Test Overview The purpose of this test is to verify that the Post-cursor equalization ratio is 0 ± 0.04.

Pass Condition When the Post-cursor equalization with weight Local_eq_c1 = 0, the ratio defined by C(1) / [|C(-1)| + |C(0)| + |C(1)|} must be within 0 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS13Q pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Post-cursor equalization with weight local_eq_c1 = 0.
6 Calculate linear fit pulse response 85.8.3.3.5 with $N_p = 200$, $D_p = 2$. The value for ES is defined to be (|ES1| + |ES2|)/2 where ES1 and ES2 are defined in section 120D.3.1.2 of the IEEE P802.3bs™ /D3.5 document.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate post-cursor ratio using the equation C(1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of post-cursor ratio with 0 ± 0.04.

Post-cursor equalization Local_eq_c1(1)

Test Overview The purpose of this test is to verify that the Post-cursor equalization ratio is -0.05 ± 0.04.

Pass Condition When the Post-cursor equalization with weight Local_eq_c1 = 1, the ratio defined by C(1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.05 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS13Q pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Post-cursor equalization with weight local_eq_c1 = 1.
6 Calculate linear fit pulse response 85.8.3.3.5 with N_p = 200, D_p = 2. The value for ES is defined to be (|ES1| + |ES2|)/2 where ES1 and ES2 are defined in section 120D.3.1.2 of the IEEE P802.3bs™ /D3.5 document.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate post-cursor ratio using the equation C(1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of post-cursor ratio with -0.05 ± 0.04.

Post-cursor equalization Local_eq_c1(2)

Test Overview The purpose of this test is to verify that the Post-cursor equalization ratio is -0.1 ± 0.04.

Pass Condition When the Post-cursor equalization with weight Local_eq_c1 = 2, the ratio defined by C(1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.1 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS13Q pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Post-cursor equalization with weight local_eq_c1 = 2.
6 Calculate linear fit pulse response 85.8.3.3.5 with N_p = 200, D_p = 2. The value for ES is defined to be (|ES1| + |ES2|)/2 where ES1 and ES2 are defined in section 120D.3.1.2 of the IEEE P802.3bs™ /D3.5 document.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate post-cursor ratio using the equation C(1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of post-cursor ratio with -0.1 ± 0.04.

Post-cursor equalization Local_eq_c1(3)

Test Overview The purpose of this test is to verify that the Post-cursor equalization ratio is -0.15 ± 0.04.

Pass Condition When the Post-cursor equalization with weight Local_eq_c1 = 3, the ratio defined by C(1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.15 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS13Q pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Post-cursor equalization with weight local_eq_c1 = 3.
6 Calculate linear fit pulse response 85.8.3.3.5 with N_p = 200, D_p = 2. The value for ES is defined to be (|ES1| + |ES2|)/2 where ES1 and ES2 are defined in section 120D.3.1.2 of the IEEE P802.3bs^{TM} /D3.5 document.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate post-cursor ratio using the equation C(1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of post-cursor ratio with -0.15 ± 0.04.

Post-cursor equalization Local_eq_c1(4)

Test Overview The purpose of this test is to verify that the Post-cursor equalization ratio is -0.2 ± 0.04.

Pass Condition When the Post-cursor equalization with weight Local_eq_c1 = 4, the ratio defined by C(1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.2 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS13Q pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Post-cursor equalization with weight local_eq_c1 = 4.
6 Calculate linear fit pulse response 85.8.3.3.5 with N_p = 200, D_p = 2. The value for ES is defined to be (|ES1| + |ES2|)/2 where ES1 and ES2 are defined in section 120D.3.1.2 of the IEEE P802.3bs^{TM} /D3.5 document.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate post-cursor ratio using the equation C(1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of post-cursor ratio with -0.2 ± 0.04.

Post-cursor equalization Local_eq_c1(5)

Test Overview The purpose of this test is to verify that the Post-cursor equalization ratio is -0.25 ± 0.04.

Pass Condition When the Post-cursor equalization with weight Local_eq_c1 = 5, the ratio defined by C(1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.25 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS13Q pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Post-cursor equalization with weight local_eq_c1 = 5.
6 Calculate linear fit pulse response 85.8.3.3.5 with N_p = 200, D_p = 2. The value for ES is defined to be (|ES1| + |ES2|)/2 where ES1 and ES2 are defined in section 120D.3.1.2 of the IEEE P802.3bs^{TM} /D3.5 document.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate post-cursor ratio using the equation C(1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of post-cursor ratio with -0.25 ± 0.04.

ERL

Test Overview The purpose of this test is to verify that the Effective Return Loss (ERL) at TP0a is greater than or equal to 15dB.

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1 In the **Set Up** tab of the Compliance Test Application, click **ERL File Setup** button to set up the s-parameter file (refer to Annex 93A.5.1 of the IEEE P802.3cd™ specification for more information about the standards defined to create the s-parameters).

2 Click the **Select Tests** tab and check the ERL test to measure the effective return loss.

3 Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the effective return loss.

4 Compare the resulting ERL value with the 15 dB.

Coefficient Initialization - Preset n

Test Overview The purpose of this test is to verify that the Coefficients meets the specified standards. These test groups consist of the following tests:

- Coefficient Initialization - Preset 1
  - Coefficient Initialization - Preset 1 for c(-1)
  - Coefficient Initialization - Preset 1 for c(0)
  - Coefficient Initialization - Preset 1 for c(1)
  - Coefficient Initialization - Preset 1 for c(-2)
- Coefficient Initialization - Preset 2
  - Coefficient Initialization - Preset 2 for c(-1)
  - Coefficient Initialization - Preset 2 for c(0)
  - Coefficient Initialization - Preset 2 for c(1)
  - Coefficient Initialization - Preset 2 for c(-2)
- Coefficient Initialization - Preset 3
  - Coefficient Initialization - Preset 3 for c(-1)
  - Coefficient Initialization - Preset 3 for c(0)
  - Coefficient Initialization - Preset 3 for c(1)
  - Coefficient Initialization - Preset 3 for c(-2)

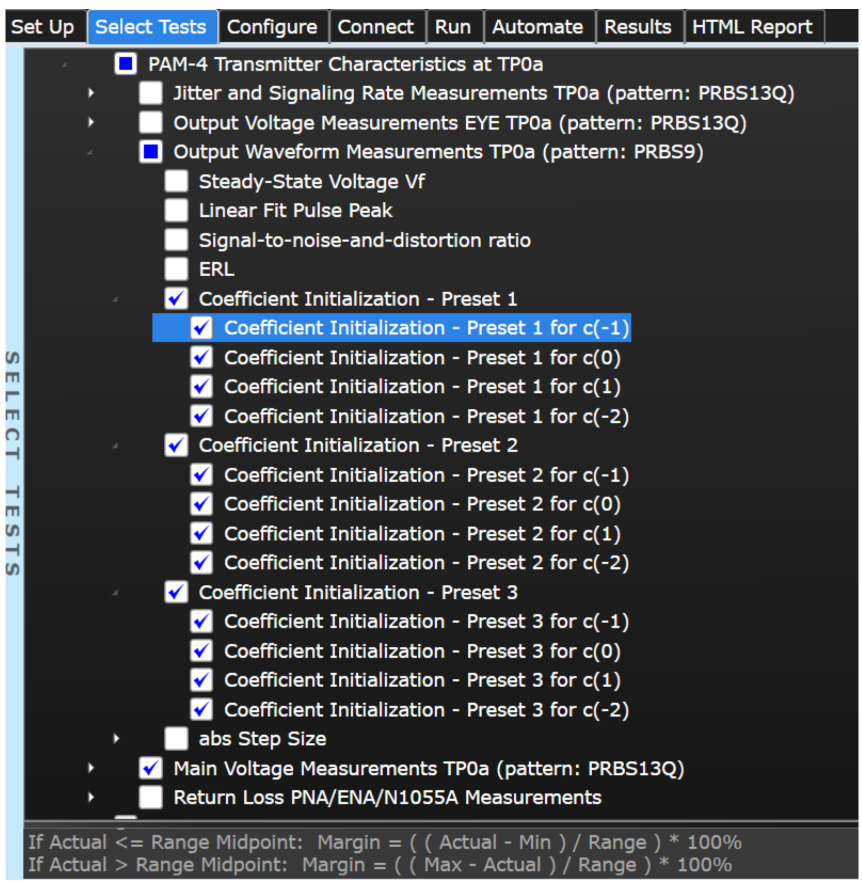


Figure 14 Selecting Coefficient Initialization - Preset n Tests

Pass Condition

Preset\Coefficient	c(-1)	c(0)	c(1)	c(-2)
Preset 1	[-0.05, 0.05]	[0.95, 1.050]	[-0.05, 0.05]	[-0.025, 0.025]
Preset 2	[-0.2, -0.1]	[0.7, 0.8]	[-0.15, -0.05]	[-0.025, 0.025]
Preset 3	[-0.3, -0.2]	[0.7, 0.8]	[-0.05, 0.05]	[-0.025, 0.025]

Measurement Algorithm

1 Request Transmitter to be set to “PRESET n” condition.
2 Capture full pattern of PRBS13Q at 32 points per UI.
3 Calculate linear fit pulse response at “PRESET” condition as per section 85.8.3.3.5.
4 Define r(m) from “PRESET” as per equation 136-1.
5 Request preset # (for each test).
6 Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 2.
7 Calculate coefficients c(i) using equation 136-2.
8 Report c(#) value from step 7.

abs Step Size

Test Overview The purpose of this test is to verify the abs Step Size.

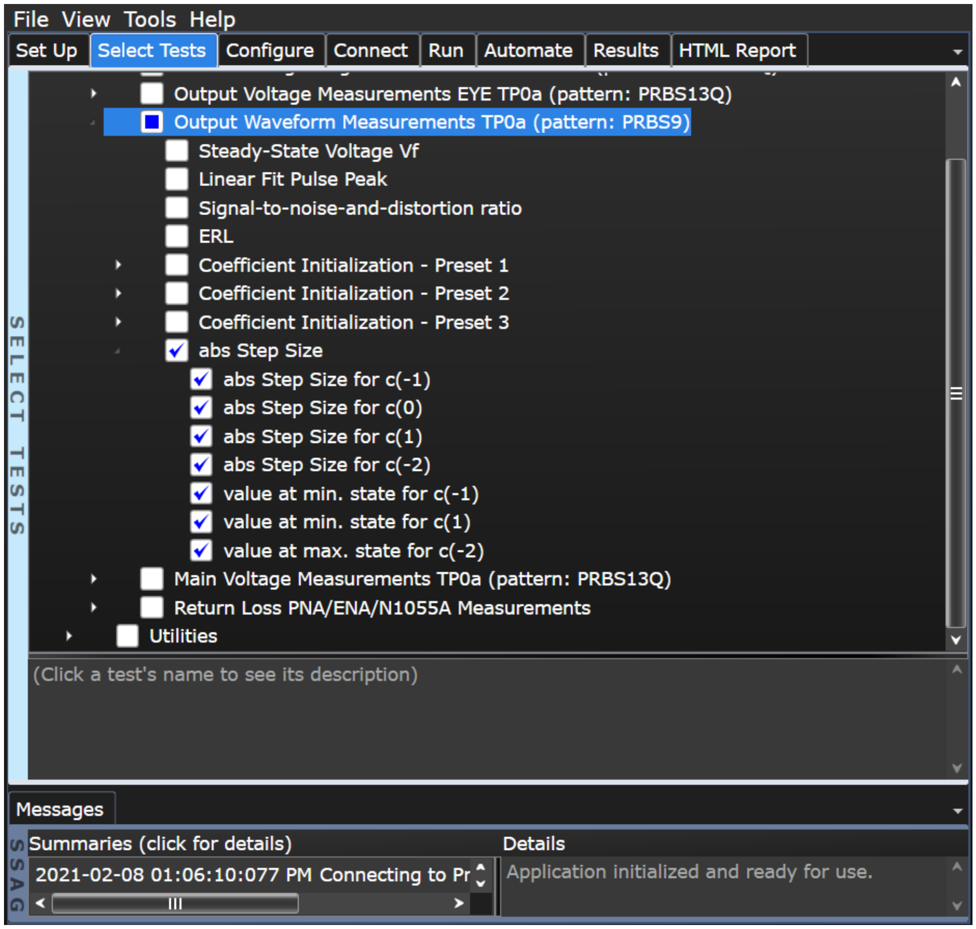


Figure 15 Selecting abs Step Size Tests

To know about the measurement algorithm for each abs Step Size test, see:

"abs Step Size for c(-1)" on page 69

"abs Step Size for c(0)" on page 70

"abs Step Size for c(1)" on page 71

"abs Step Size for c(-2)" on page 72

"value at min. state for c(-1)" on page 73

"value at min. state for c(1)" on page 74

"value at max. state for c(-2)" on page 75

abs Step Size for c(-1)

Test Overview The purpose of this test is to verify that the abs Step Size for c(-1) is within limits.

Pass Condition When abs Coefficient Step Size - c(-1) is greater than or equal to 5mV and less than or equal to 50 mV.

Measurement Algorithm

1. Request Transmitter to be set to "PRESET" condition.
2. Capture full pattern of PRBS13Q at 32 points per UI.
3. Calculate linear fit pulse response at "PRESET" condition as per section 85.8.3.3.5.
4. Define r(m) from "PRESET" as per equation 136-1.
5. Request to change c(-1) to the first step.
6. Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 3.
7. Calculate coefficients c(i) using equation 136-2.
8. Save coefficient c(-1) as base step value.
9. Request next c(-1) step.
10. Calculate linear fit pulse response as per section 85.8.3.3.5 with N_p = 200, D_p = 3.
11. Calculate coefficients c(i) using equation 136-2.
12. Calculate the step size as coefficient value from step 11 – coefficient value from step 7.
13. 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.

abs Step Size for c(0)

Test Overview The purpose of this test is to verify that the abs Step Size for c(0) is within limits.

Pass Condition When abs Coefficient Step Size - c(0) is greater than or equal to 5mV and less than or equal to 50 mV.

Measurement Algorithm

1. Request Transmitter to be set to “PRESET” condition.
2. Capture full pattern of PRBS13Q at 32 points per UI.
3. Calculate linear fit pulse response at “PRESET” condition as per section 85.8.3.3.5.
4. Define r(m) from “PRESET” as per equation 136-1.
5. Request to change c(0) to the first step.
6. Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 3.
7. Calculate coefficients c(i) using equation 136-2.
8. Save coefficient c(0) as base step value.
9. Request next c(0) step.
10. Calculate linear fit pulse response as per section 85.8.3.3.5 with N_p = 200, D_p = 3.
11. Calculate coefficients c(i) using equation 136-2.
12. Calculate the step size as coefficient value from step 11 – coefficient value from step 7.
13. 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.

abs Step Size for c(1)

Test Overview The purpose of this test is to verify that the abs Step Size for c(1) is within limits.

Pass Condition When abs Coefficient Step Size - c(1) is greater than or equal to 5mV and less than or equal to 50 mV.

Measurement Algorithm

1. Request Transmitter to be set to “PRESET” condition.
2. Capture full pattern of PRBS13Q at 32 points per UI.
3. Calculate linear fit pulse response at “PRESET” condition as per section 85.8.3.3.5.
4. Define r(m) from “PRESET” as per equation 136-1.
5. Request to change c(1) to the first step.
6. Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 3.
7. Calculate coefficients c(i) using equation 136-2.
8. Save coefficient c(1) as base step value.
9. Request next c(1) step.
10. Calculate linear fit pulse response as per section 85.8.3.3.5 with N_p = 200, D_p = 3.
11. Calculate coefficients c(i) using equation 136-2.
12. Calculate the step size as coefficient value from step 11 – coefficient value from step 7.
13. 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.

abs Step Size for c(-2)

Test Overview The purpose of this test is to verify that the abs Step Size for c(-2) is within limits.

Pass Condition When abs Coefficient Step Size - c(-2) is greater than or equal to 5mV and less than or equal to 25 mV.

Measurement Algorithm

1. Request Transmitter to be set to “PRESET” condition.
2. Capture full pattern of PRBS13Q at 32 points per UI.
3. Calculate linear fit pulse response at “PRESET” condition as per section 85.8.3.3.5.
4. Define r(m) from “PRESET” as per equation 136-1.
5. Request to change c(-2) to the first step.
6. Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 3.
7. Calculate coefficients c(i) using equation 136-2.
8. Save coefficient c(-2) as base step value.
9. Request next c(-2) step.
10. Calculate linear fit pulse response as per section 85.8.3.3.5 with N_p = 200, D_p = 3.
11. Calculate coefficients c(i) using equation 136-2.
12. Calculate the step size as coefficient value from step 11 – coefficient value from step 7.
13. 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.

value at min. state for c(-1)

Test Overview The purpose of this test is to verify that the value at min. state for c(-1) is within limits.

Pass Condition When value at min. state for c(-1) is less than or equal to -250 m.

Measurement Algorithm

1. Request Transmitter to be set to “PRESET” condition. If preset has already been calculated during trial, steps 1-4 are skipped.
2. Capture full pattern of PRBS13Q at 32 points per UI.
3. Calculate linear fit pulse response at “PRESET” condition as per section 85.8.3.3.5.
4. Define r(m) from “PRESET” as per equation 136-1.
5. Request user to set c(-3), c(-2), and c(1) to zero. Decrement both c(0) and c(-1) to their minimum value.
6. Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 2.
7. Calculate coefficients c(i) using equation 136-2.
8. Report c(-1) value from step 7.

value at min. state for c(1)

Test Overview The purpose of this test is to verify that the value at min. state for c(1) is within limits.

Pass Condition When value at min. state for c(1) is less than or equal to -250 m.

Measurement Algorithm

1 Request Transmitter to be set to “PRESET” condition. If preset has already been calculated during trial, steps 1-4 are skipped.
2 Capture full pattern of PRBS13Q at 32 points per UI.
3 Calculate linear fit pulse response at “PRESET” condition as per section 85.8.3.3.5.
4 Define r(m) from “PRESET” as per equation 136-1.
5 Request user to set c(-2), c(-1), and c(1) to zero. Decrement both c(0) and c(1) to their minimum value.
6 Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 2.
7 Calculate coefficients c(i) using equation 136-2.
8 Report c(-3) value from step 7.

value at max. state for c(-2)

Test Overview The purpose of this test is to verify that the value at max. state for c(-2) is within limits.

Pass Condition When value at max. state for c(-2) is greater than or equal to 100 m.

Measurement Algorithm

1. Request Transmitter to be set to “PRESET” condition. If preset has already been calculated during trial, steps 1-4 are skipped.
2. Capture full pattern of PRBS13Q at 32 points per UI.
3. Calculate linear fit pulse response at “PRESET” condition as per section 85.8.3.3.5.
4. Define r(m) from “PRESET” as per equation 136-1.
5. Request user to set c(-3), c(-1), and c(1) to zero. Increment both c(0) and c(-2) to their maximum value.
6. Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 2.
7. Calculate coefficients c(i) using equation 136-2.
8. Report c(-2) value from step 7.

Main Voltage Measurements TP0a

The Main Voltage measurement procedures described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

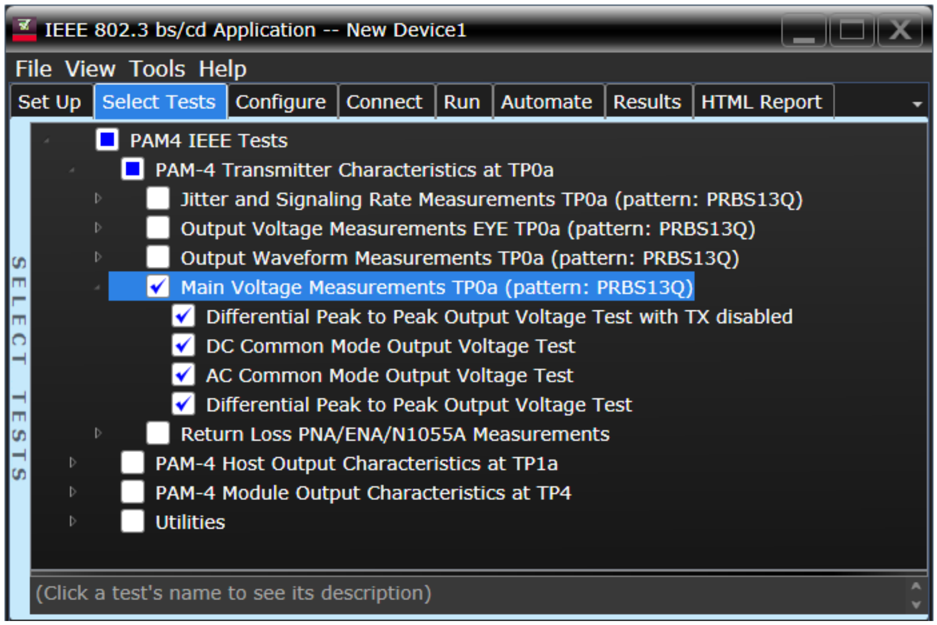


Figure 16 Selecting Main Voltage Measurement Tests

Refer to the section C2C transmitter characteristics for information on the pass limits for each test that is displayed for the selected standard option.

To know about the measurement algorithm for each Main Voltage Measurements TP0a (pattern: PRBS13Q) tests, see:

- "Differential Peak-to-Peak Output Voltage Test with TX Disabled" on page 77
- "DC Common Mode Output Voltage Test" on page 78
- "AC Common Mode Output Voltage Test" on page 79
- "Differential Peak-to-Peak Output Voltage Test" on page 80

Differential Peak-to-Peak Output Voltage Test with TX Disabled

Test Overview The purpose of this test is to verify that when TX is disabled, the peak-to-peak voltage meets the specified standards.

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1 Obtain a sample or acquire the signal data.
2 Ensure that TX is disabled on the acquired signal (no valid data transitions).
3 Measure peak-to-peak voltage of the signal.
4 Compare the maximum peak-to-peak voltage to the specified standards.

DC Common Mode Output Voltage Test

Test Overview The purpose of this test is to verify that the common mode signal meets the specified standards.

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

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

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 specified standards.

AC Common Mode Output Voltage Test

Test Overview The purpose of this test is to verify that the common mode signal meets the specified standards.

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

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

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 the specified standards.

Differential Peak-to-Peak Output Voltage Test

Test Overview The purpose of this test is to verify that the peak-to-peak voltage of the differential signal on a PRBS13Q pattern meets the specified standards.

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is connected, has TX enabled and has a PRBS13Q pattern.
3 Measure the peak-to-peak voltage of the differential signal on DUT+ and DUT-.
4 Compare the maximum peak-to-peak voltage to the specified standards.

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 DCA oscilloscope along with either a PNA, ENA or an N1055A and the N1091BSCB 400G IEEE FlexDCA Compliance 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 device is calibrated.

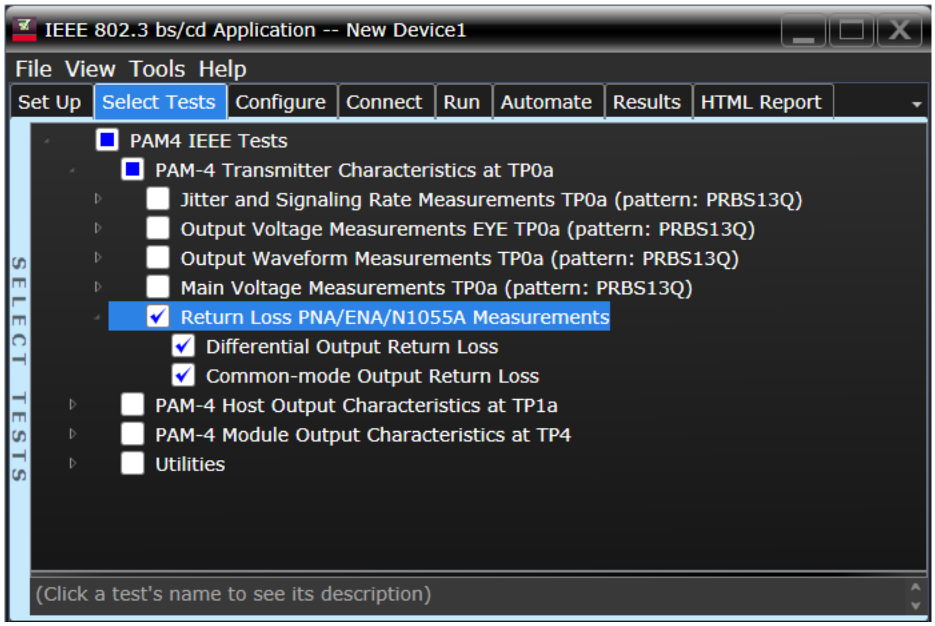


Figure 17 Selecting Return Loss PNA/ENA Measurements Tests

Refer to the section C2C transmitter characteristics for information on the pass limits for each test that is displayed for the selected standard option.

To know about the measurement algorithm for each Return Loss PNA/ENA/N1055A Measurements tests, see:

- “Differential Output Return Loss” on page 82
- “Common-mode Output Return Loss” on page 83

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.

4 PAM4 Transmitter Characteristics at TP2

This section provides the Methods of Implementation (MOIs) for the IEEE PAM4 Transmitter Characteristics at TP2. Measurements are made at test point TP2.

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.

C2C transmitter characteristics

For CR tests

See Table 7 for pass limits pertaining to 50GBASE-CR, 100GBASE-CR2, and 200GBASE-CR4 PAM4 tests, which are specified in IEEE P802.3cd™ / D3.0 (Draft Standard for Ethernet Amendment 10: Media Access Control Parameters, Physical Layers and Management Parameters for 50Gb/s, 100Gb/s, and 200Gb/s Operation) section 136.9.3, Table 136-11.

Table 7 **50GBASE-CR, 100GBASE-CR2, and 200GBASE-CR4 C2C transmitter characteristics at TP2**

Parameter	Reference	Value	Units
Differential pk-to-pk output voltage (max) with TX disabled[a]	See Sec. 93.8.1.3 of the IEEE specification	30	mV
DC common-mode voltage (min) DC common-mode voltage (max)[a]	See Sec. 93.8.1.3 of the IEEE specification	0 1.9	V
AC common-mode RMS output voltage, v_{cmi} (max)[a]	See Sec. 93.8.1.3 of the IEEE specification	30	mV
Differential pk-to-pk, v_{di} (max)[a]	See Sec. 93.8.1.3 of the IEEE specification	1200	mV
Effective return loss (ERL) (min)	See Sec. 136.9.3.4 of the IEEE specification	See Equation (136-6) of the IEEE specification	dB
Differential output return loss (min)	See Sec. 92.8.3.2 of the IEEE specification	See Equation (92-1) of the IEEE specification	dB
Common-mode to differential mode output return loss (min)	See Sec. 92.8.3.3 of the IEEE specification	See Equation (92-2) of the IEEE specification	dB
Common-mode to common-mode output return loss (min)	See Sec. 92.8.3.4 of the IEEE specification	See Equation (92-3) of the IEEE specification	dB
Transmitter steady-state voltage, vf (min) Transmitter steady-state voltage, vf (max)	See Sec. 136.9.3.1.2 of the IEEE specification	0.34 0.6	V V
Linear fit pulse peak (min)	See Sec. 136.9.3.1.2 of the IEEE specification	0.49 × vf	V
Level separation mismatch ratio R_{LM} (min)	See Sec.120D.3.1.2 of the IEEE specification	0.95	-
Transmitter output waveform abs step size for c(-1), c(0), and c(1) (min.) abs step size for c(-1), c(0), and c(1) (max.) abs step size for c(-2) (min.) abs step size for c(-2) (max.) value at maximum state for c(-1) and c(1) (max.) value at maximum state for c(-2) (min.)	See Sections 136.9.3.1.4 136.9.3.1.4 136.9.3.1.4 136.9.3.1.4 136.9.3.1.5 136.9.3.1.5	 0.005 0.05 0.005 0.025 -0.25 0.1	 - - - - - -
Signal-to-noise-and-distortion ratio SNDR (min)	See Sec.120D.3.1.6 of the IEEE specification	33.3	dB

Parameter	Reference	Value	Units
SNR_{ISI} (min)[b]	See Sec. 120D.3.1.7 of the IEEE specification	36.8	dB
Output jitter (max.)	See Sections		
JRMS	120D.3.1.8	0.023	UI
J3u	120D.3.1.8	0.115	UI
Even-odd jitter, pk-pk	120D.3.1.8	0.019	UI
Signaling rate per lane (range)		26.5625 ± 100 ppm	GBd

a. Measurement uses the method described in section 93.8.1.3 of IEEE specification with the exception that the PRBS13Q test pattern is used.

b. Measured only in unequalized setting.

Jitter and Signaling Rate Measurements TP2

The Jitter and Signaling Rate Measurement procedures described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

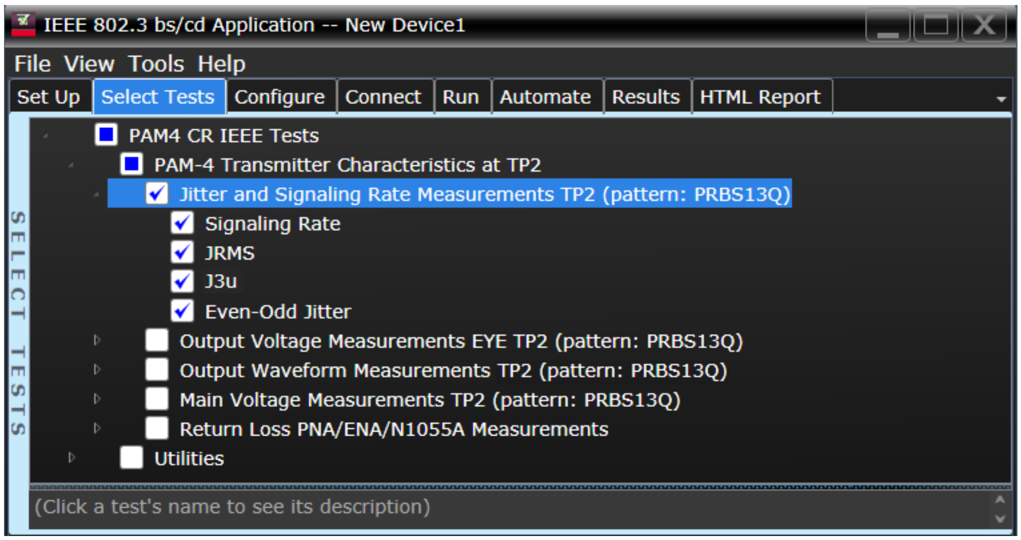


Figure 18 Selecting Jitter and Signaling Rate Measurement Tests

Refer to the section C2C transmitter characteristics for information on the pass limits for each test that is displayed for the selected standard option.

To know about the measurement algorithm for each Jitter and Signaling Rate Measurements TP2 (pattern: PRBS13Q) tests, see:

- “Signaling Rate” on page 89
- “JRMS” on page 90
- “J3u” on page 91
- “Even-Odd Jitter” on page 92

Signaling Rate

Test Overview The purpose of this test is to verify that the signaling rate meets the specified standards.

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1. Obtain sample or acquire signal data.
2. Check that the signal is connected, has a bit-rate of 53.125 GHz and that data pattern exists (PRBS13Q must be used for this test).
3. In the **Configure** tab, set **Signaling Rate** to 26.5625 Gb/s.
4. Measure minimum and maximum data rate.
5. Report minimum and maximum values.
6. Compare the mean data rate value with the specified standards. Report the resulting value.

JRMS

Test Overview The purpose of this test is to verify that differential signal's JRMS meets the specified standards. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Conditions Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1 Obtain sample or acquire signal data.

NOTE **Signal must be of PRBS13Q 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 (26.5625 Gbps) and Loop Bandwidth to 4 MHz.

   b Using PAM4 jitter measurements, at least 10,000 PRBS13Q patterns are captured to collect the measurement data of 12 edges.

   c Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

4 Compare and report the JRMS value to the specified standards.

J3u

Test Overview The purpose of this test is to verify that differential signal's J3u meets the specified standards. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Conditions Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1 Obtain sample or acquire signal data.

NOTE **Signal must be of PRBS13Q 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 (26.5625 Gbps) and Loop Bandwidth to 4 MHz.

   b Using PAM4 jitter measurements, at least 10,000 PRBS13Q patterns are captured to collect the measurement data of 12 edges.

   c Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

4 Compare and report the J3u value meets the specified standards.

Even-Odd Jitter

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

Pass Conditions Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1 Obtain sample or acquire signal data.

NOTE

Signal must be of PRBS13Q 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 (26.5625 Gbps) and Loop Bandwidth to 4 MHz.

   b Using PAM4 jitter measurements, at least 10,000 PRBS13Q patterns are captured to collect the measurement data of 12 edges.

   c Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

4 Compare and report the Even-Odd Jitter value to the specified standards.

Output Voltage Measurements EYE TP2

The Output Voltage Measurement EYE procedures for a signal with PRBS13Q pattern that are described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

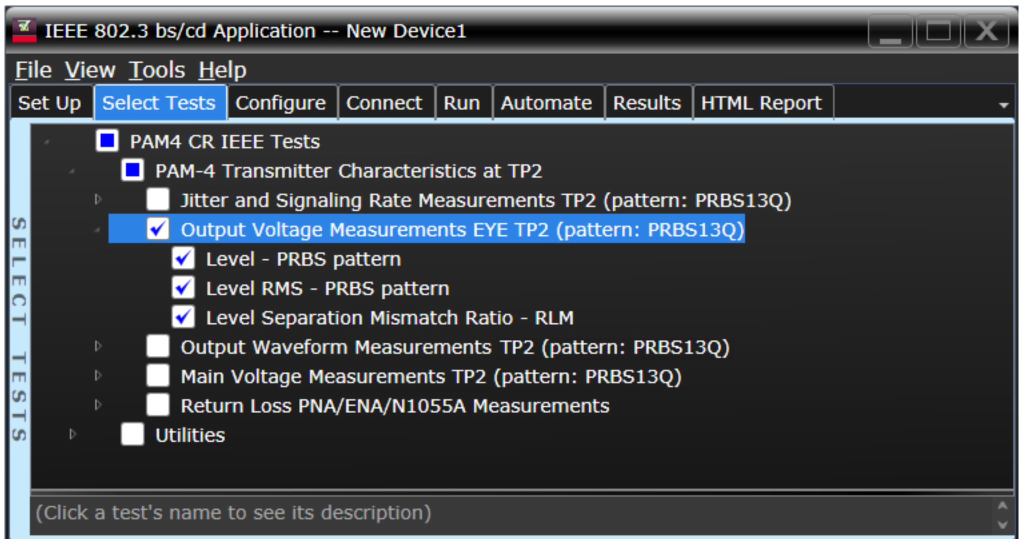


Figure 19 Selecting Output Voltage Measurements EYE Tests

Refer to the section C2C transmitter characteristics for information on the pass limits for each test that is displayed for the selected standard option.

To know about the measurement algorithm for each Output Voltage Measurements EYE TP2 (pattern: PRBS13Q) tests, see:

- “Level - PRBS Pattern” on page 94
- “Level RMS - PRBS Pattern” on page 95
- “Level Separation Mismatch Ratio - RLM” on page 96

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 PRBS13Q 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 (PRBS13Q pattern must be used for this test).
2. V_0, V_1, V_2 and V_3 are the mean signal levels of the symbols corresponding to the PAM4 symbol levels 0, 1, 2 and 3 respectively, as defined in IEEE P802.3bs™ /D3.5 (Draft Standard for Ethernet Amendment 10: Media Access Control Parameters, Physical Layers and Management Parameters for 200Gb/s and 400Gb/s Operation), Annex 120D.3.1.2. The calculation of mean signal levels is also defined in section 120D.3.1.2.1.
3. The mean level V_{mid} is defined by equation (120D-3), which is,

$$V_{mid} = (V_0 + V_3) / 2$$

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 PRBS13Q 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 IEEE P802.3bs™ /D3.5 (Draft Standard for Ethernet Amendment 10: Media Access Control Parameters, Physical Layers and Management Parameters for 200Gb/s and 400Gb/s Operation), Annex 120D.3.1.2.
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 PRBS13Q pattern.

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

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_0 corresponds to -1, V_1 to -ES1, V_2 to ES2 and V_3 to 1.

3 ES1 and ES2 are calculated using equations (120D-4) and (120D-5), respectively of the IEEE P802.3bs^{TM} /D3.5 (Draft Standard for Ethernet Amendment 10: Media Access Control Parameters, Physical Layers and Management Parameters for 200Gb/s and 400Gb/s Operation), Annex 120D.3.1.2.

$$ES1 = (V_1 - V_{mid}) / (V_0 - V_{mid})$$

$$ES2 = (V_2 - V_{mid}) / (V_3 - V_{mid})$$

4 The level separation mismatch ratio R_{LM} is defined by equation (120D-5).

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

5 Report this value for information-only purpose.

Output Waveform Measurements TP2

The Output Waveform Measurement procedures that are described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

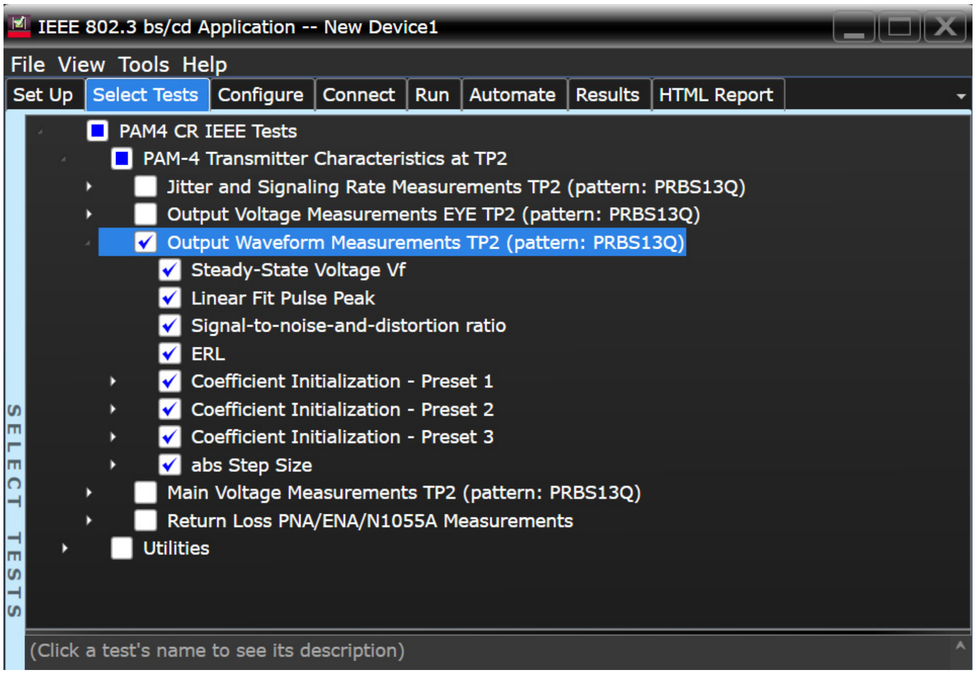


Figure 20 Selecting Transmitter Output Waveform Measurement Tests

Refer to the section C2C transmitter characteristics for information on the pass limits for each test that is displayed for the selected standard option.

To know about the measurement algorithm for each Output Waveform Measurements TP2 (pattern: PRBS13Q) tests, see:

- "Steady State Voltage Vf" on page 98
- "Linear Fit Pulse Peak" on page 99
- "Signal-to-noise-and-distortion ratio" on page 100
- "ERL" on page 101
- "Coefficient Initialization - Preset n" on page 102
- "abs Step Size" on page 103

Steady State Voltage V_f

Test Overview The purpose of this test is to verify that the Steady State Voltage is between 0.4V and 0.6V.

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1 Check that signal is connected and proper data pattern exists (PRBS13Q must be used for this test).

2 Set memory depth and sample rate to capture the 8191 bits of the PRBS13Q pattern.

3 Calculate V_f 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 Compare and report the resulting value in the range between 0.4V and 0.6V.

Linear Fit Pulse Peak

Test Overview The purpose of this test is to verify that the Linear Fit Pulse meets the specified standards.

NOTE **Run the Steady-State Voltage Vf test as a prerequisite to running the Linear Fit Pulse Peak test.**

Pass Conditions Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1 Check that signal is connected and proper data pattern exists (PRBS13Q must be used for this test).
2 Set memory depth and sample rate to capture the 8191 bits of the PRBS13Q pattern.
3 Calculate Linear Fit Pulse 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 Compare the specified standards to the resulting value.

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) meets the specified standards.

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

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

2 Compare the resulting value of SNDR to the specified standards.

ERL

Test Overview The purpose of this test is to verify that the Effective Return Loss (ERL) meets the specified standards.

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1. In the **Set Up** tab of the Compliance Test Application, click **ERL File Setup** button to set up the s-parameter file (refer to Annex 93A.5.1 of the IEEE P802.3cd™ specification for more information about the standards defined to create the s-parameters).
2. Click the **Select Tests** tab and check the ERL test to measure the effective return loss.
3. Click **Run** under the **Run** tab. The Compliance Test Application automatically calculates the effective return loss.
4. Calculate ERL using equation (136-6).

Coefficient Initialization - Preset n

Test Overview The purpose of this test is to verify that the Coefficients meets the specified standards. These test groups consist of the following tests:

- Coefficient Initialization - Preset 1
  - Coefficient Initialization - Preset 1 for c(-1)
  - Coefficient Initialization - Preset 1 for c(0)
  - Coefficient Initialization - Preset 1 for c(1)
  - Coefficient Initialization - Preset 1 for c(-2)
- Coefficient Initialization - Preset 2
  - Coefficient Initialization - Preset 2 for c(-1)
  - Coefficient Initialization - Preset 2 for c(0)
  - Coefficient Initialization - Preset 2 for c(1)
  - Coefficient Initialization - Preset 2 for c(-2)
- Coefficient Initialization - Preset 3
  - Coefficient Initialization - Preset 3 for c(-1)
  - Coefficient Initialization - Preset 3 for c(0)
  - Coefficient Initialization - Preset 3 for c(1)
  - Coefficient Initialization - Preset 3 for c(-2)

Pass Condition

Preset\Coefficient	c(-1)	c(0)	c(1)	c(-2)
Preset 1	[-0.05, 0.05]	[0.95, 1.050]	[-0.05, 0.05]	[-0.025, 0.025]
Preset 2	[-0.2, -0.1]	[0.7, 0.8]	[-0.15, -0.05]	[-0.025, 0.025]
Preset 3	[-0.3, -0.2]	[0.7, 0.8]	[-0.05, 0.05]	[-0.025, 0.025]

Measurement Algorithm

1 Request Transmitter to be set to “PRESET n” condition.
2 Capture full pattern of PRBS13Q at 32 points per UI.
3 Calculate linear fit pulse response at “PRESET” condition as per section 85.8.3.3.5.
4 Define r(m) from “PRESET” as per equation 136-1.
5 Request preset # (for each test).
6 Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 2.
7 Calculate coefficients c(i) using equation 136-2.
8 Report c(#) value from step 7.

abs Step Size

Test Overview The purpose of this test is to verify the abs Step Size.

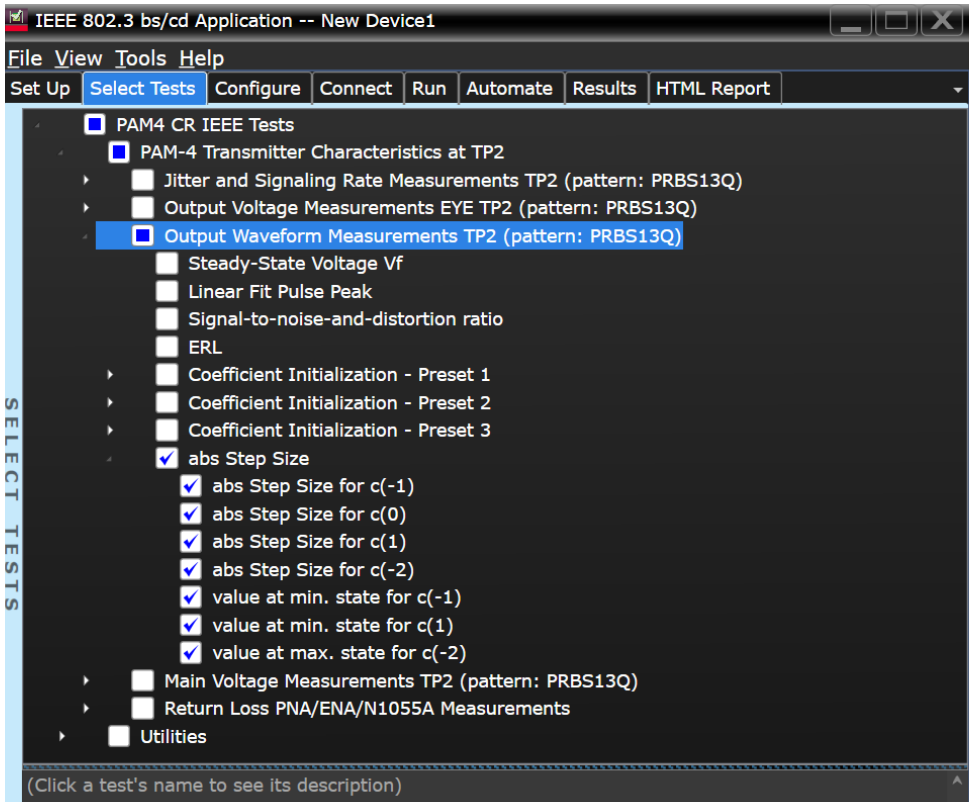


Figure 21 Selecting abs Step Size Tests

To know about the measurement algorithm for each abs Step Size test, see:

- "abs Step Size for c(-1)" on page 104
- "abs Step Size for c(0)" on page 105
- "abs Step Size for c(1)" on page 106
- "abs Step Size for c(-2)" on page 107
- "value at min. state for c(-1)" on page 108
- "value at min. state for c(1)" on page 109
- "value at max. state for c(-2)" on page 110

abs Step Size for c(-1)

Test Overview The purpose of this test is to verify that the abs Step Size for c(-1) is within limits.

Pass Condition When abs Coefficient Step Size - c(-1) is greater than or equal to 5mV and less than or equal to 50 mV.

Measurement Algorithm

1. Request Transmitter to be set to “PRESET” condition.
2. Capture full pattern of PRBS13Q at 32 points per UI.
3. Calculate linear fit pulse response at “PRESET” condition as per section 85.8.3.3.5.
4. Define r(m) from “PRESET” as per equation 136-1.
5. Request to change c(-1) to the first step.
6. Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 3.
7. Calculate coefficients c(i) using equation 136-2.
8. Save coefficient c(-1) as base step value.
9. Request next c(-1) step.
10. Calculate linear fit pulse response as per section 85.8.3.3.5 with N_p = 200, D_p = 3.
11. Calculate coefficients c(i) using equation 136-2.
12. Calculate the step size as coefficient value from step 11 – coefficient value from step 7.
13. 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.

abs Step Size for c(0)

Test Overview The purpose of this test is to verify that the abs Step Size for c(0) is within limits.

Pass Condition When abs Coefficient Step Size - c(0) is greater than or equal to 5mV and less than or equal to 50 mV.

Measurement Algorithm

1 Request Transmitter to be set to “PRESET” condition.
2 Capture full pattern of PRBS13Q at 32 points per UI.
3 Calculate linear fit pulse response at “PRESET” condition as per section 85.8.3.3.5.
4 Define r(m) from “PRESET” as per equation 136-1.
5 Request to change c(0) to the first step.
6 Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 3.
7 Calculate coefficients c(i) using equation 136-2.
8 Save coefficient c(0) as base step value.
9 Request next c(0) step.
10 Calculate linear fit pulse response as per section 85.8.3.3.5 with N_p = 200, D_p = 3.
11 Calculate coefficients c(i) using equation 136-2.
12 Calculate the step size as coefficient value from step 11 – coefficient value from step 7.
13 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.

abs Step Size for c(1)

Test Overview The purpose of this test is to verify that the abs Step Size for c(1) is within limits.

Pass Condition When abs Coefficient Step Size - c(1) is greater than or equal to 5mV and less than or equal to 50 mV.

Measurement Algorithm

1. Request Transmitter to be set to “PRESET” condition.
2. Capture full pattern of PRBS13Q at 32 points per UI.
3. Calculate linear fit pulse response at “PRESET” condition as per section 85.8.3.3.5.
4. Define r(m) from “PRESET” as per equation 136-1.
5. Request to change c(1) to the first step.
6. Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 3.
7. Calculate coefficients c(i) using equation 136-2.
8. Save coefficient c(1) as base step value.
9. Request next c(1) step.
10. Calculate linear fit pulse response as per section 85.8.3.3.5 with N_p = 200, D_p = 3.
11. Calculate coefficients c(i) using equation 136-2.
12. Calculate the step size as coefficient value from step 11 – coefficient value from step 7.
13. 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.

abs Step Size for c(-2)

Test Overview The purpose of this test is to verify that the abs Step Size for c(-2) is within limits.

Pass Condition When abs Coefficient Step Size - c(-2) is greater than or equal to 5mV and less than or equal to 25 mV.

Measurement Algorithm

1. Request Transmitter to be set to “PRESET” condition.
2. Capture full pattern of PRBS13Q at 32 points per UI.
3. Calculate linear fit pulse response at “PRESET” condition as per section 85.8.3.3.5.
4. Define r(m) from “PRESET” as per equation 136-1.
5. Request to change c(-2) to the first step.
6. Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 3.
7. Calculate coefficients c(i) using equation 136-2.
8. Save coefficient c(-2) as base step value.
9. Request next c(-2) step.
10. Calculate linear fit pulse response as per section 85.8.3.3.5 with N_p = 200, D_p = 3.
11. Calculate coefficients c(i) using equation 136-2.
12. Calculate the step size as coefficient value from step 11 – coefficient value from step 7.
13. 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.

value at min. state for c(-1)

Test Overview The purpose of this test is to verify that the value at min. state for c(-1) is within limits.

Pass Condition When value at min. state for c(-1) is less than or equal to -250 m.

Measurement Algorithm

1 Request Transmitter to be set to “PRESET” condition. If preset has already been calculated during trial, steps 1-4 are skipped.
2 Capture full pattern of PRBS13Q at 32 points per UI.
3 Calculate linear fit pulse response at “PRESET” condition as per section 85.8.3.3.5.
4 Define r(m) from “PRESET” as per equation 136-1.
5 Request user to set c(-3), c(-2), and c(1) to zero. Decrement both c(0) and c(-1) to their minimum value.
6 Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 2.
7 Calculate coefficients c(i) using equation 136-2.
8 Report c(-1) value from step 7.

value at min. state for c(1)

Test Overview The purpose of this test is to verify that the value at min. state for c(1) is within limits.

Pass Condition When value at min. state for c(1) is less than or equal to -250 m.

Measurement Algorithm

1 Request Transmitter to be set to “PRESET” condition. If preset has already been calculated during trial, steps 1-4 are skipped.
2 Capture full pattern of PRBS13Q at 32 points per UI.
3 Calculate linear fit pulse response at “PRESET” condition as per section 85.8.3.3.5.
4 Define r(m) from “PRESET” as per equation 136-1.
5 Request user to set c(-2), c(-1), and c(1) to zero. Decrement both c(0) and c(1) to their minimum value.
6 Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 2.
7 Calculate coefficients c(i) using equation 136-2.
8 Report c(-3) value from step 7.

value at max. state for c(-2)

Test Overview The purpose of this test is to verify that the value at max. state for c(-2) is within limits.

Pass Condition When value at max. state for c(-2) is greater than or equal to 100 m.

Measurement Algorithm

1 Request Transmitter to be set to “PRESET” condition. If preset has already been calculated during trial, steps 1-4 are skipped.
2 Capture full pattern of PRBS13Q at 32 points per UI.
3 Calculate linear fit pulse response at “PRESET” condition as per section 85.8.3.3.5.
4 Define r(m) from “PRESET” as per equation 136-1.
5 Request user to set c(-3), c(-1), and c(1) to zero. Increment both c(0) and c(-2) to their maximum value.
6 Calculate linear fit pulse response as per 85.8.3.3.5 with N_p = 200, D_p = 2.
7 Calculate coefficients c(i) using equation 136-2.
8 Report c(-2) value from step 7.

Main Voltage Measurements TP2

The Main Voltage measurement procedures described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

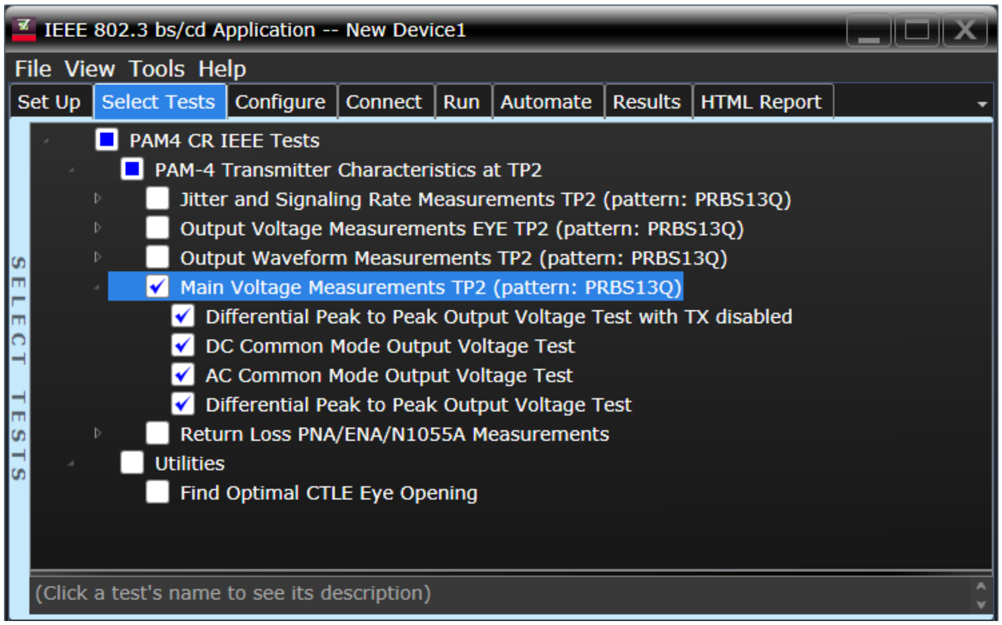


Figure 22 Selecting Main Voltage Measurement Tests

Refer to the section C2C transmitter characteristics for information on the pass limits for each test that is displayed for the selected standard option.

To know about the measurement algorithm for each Main Voltage Measurements TP0a (pattern: PRBS13Q) tests, see:

- "Differential Peak to Peak Output Voltage Test with TX Disabled" on page 112
- "DC Common Mode Output Voltage Test" on page 113
- "AC Common Mode Output Voltage Test" on page 114
- "Differential Peak-to-Peak Output Voltage Test" on page 115

Differential Peak to Peak Output Voltage Test with TX Disabled

Test Overview The purpose of this test is to verify that when TX is disabled, the peak-to-peak voltage meets the specified standards.

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1. Obtain a sample or acquire the signal data.
2. Ensure that TX is disabled on the acquired signal (no valid data transitions).
3. Measure peak-to-peak voltage of the signal.
4. Compare the maximum peak-to-peak voltage to the specified standards.

DC Common Mode Output Voltage Test

Test Overview The purpose of this test is to verify that the common mode signal meets the specified standards.

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

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

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 specified standards.

AC Common Mode Output Voltage Test

Test Overview The purpose of this test is to verify that the common mode signal meets the specified standards.

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

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

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 the specified standards.

Differential Peak-to-Peak Output Voltage Test

Test Overview The purpose of this test is to verify that the peak-to-peak voltage of the differential signal on a PRBS13Q pattern meets the specified standards.

Pass Condition Refer to the section C2C transmitter characteristics for the pass limits pertaining to each standard option.

Measurement Algorithm

1. Obtain sample or acquire signal data.
2. Verify that the signal is connected, has TX enabled and has a PRBS13Q pattern.
3. Measure the peak-to-peak voltage of the differential signal on DUT+ and DUT-.
4. Compare the maximum peak-to-peak voltage to the specified standards.

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 DCA oscilloscope along with either a PNA, ENA or an N1055A and the N1091BSCB 400G IEEE FlexDCA Compliance 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 device is calibrated.

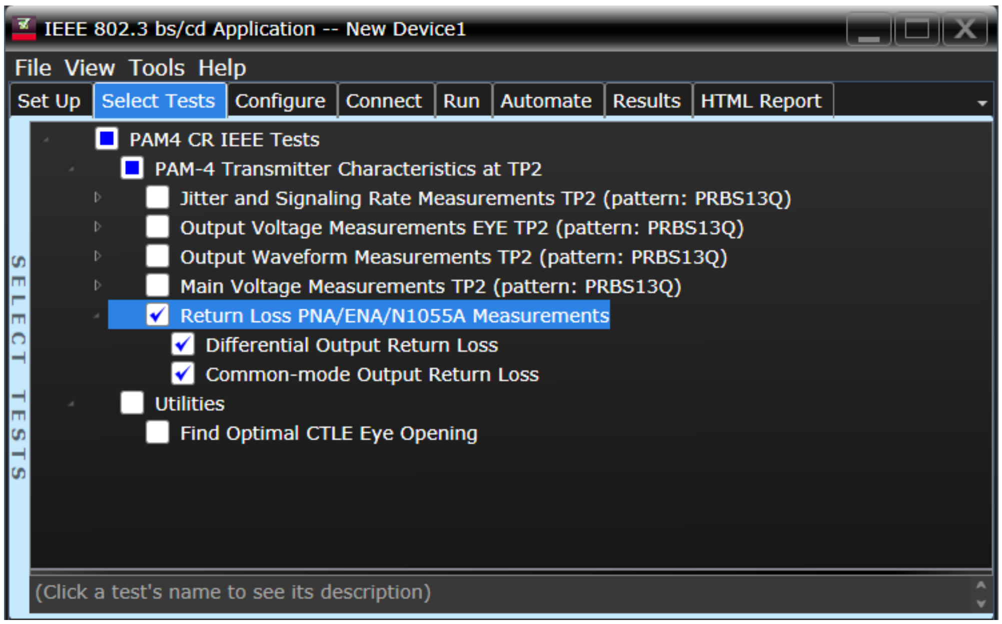


Figure 23 Selecting Return Loss PNA/ENA Measurements Tests

Refer to the section C2C transmitter characteristics for information on the pass limits for each test that is displayed for the selected standard option.

To know about the measurement algorithm for each Return Loss PNA/ENA/N1055A Measurements tests, see:

- “Differential Output Return Loss” on page 117
- “Common-mode Output Return Loss” on page 118

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.

5 PAM4 Host Output Characteristics at TP1a

This section provides the Methods of Implementation (MOIs) for the PAM4 200GAUI and 400GAUI IEEE PAM4 Host Output Characteristics at TP1a as specified in IEEE P802.3bs™ /D3.5 (Draft Standard for Ethernet Amendment 10: Media Access Control Parameters, Physical Layers and Management Parameters for 200Gb/s and 400Gb/s Operation), Annex 120E.3.1, Table 120E-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.

200GAUI-4 and 400GAUI-8 C2M host output electrical characteristics

Table 8 200GAUI-4 and 400GAUI-8 C2M host output characteristics at TP1a

Parameter	Reference	Value	Units
Signaling rate per lane (range)	See Sec. 120E.3.1.1 of the IEEE specification	26.5625 ± 100 ppm	GBd
DC common-mode output voltage (max)	See Sec. 120E.3.1.2 of the IEEE specification	2.8	V
DC common-mode output voltage (min)	See Sec. 120E.3.1.2 of the IEEE specification	-0.3	V
Single-ended output voltage (max)	See Sec. 120E.3.1.2 of the IEEE specification	3.3	V
Single-ended output voltage (min)	See Sec. 120E.3.1.2 of the IEEE specification	-0.4	V
AC common-mode output voltage (max, RMS)	See Sec. 120E.3.1.2 of the IEEE specification	17.5	mV
Differential peak-to-peak output voltage (max) Transmitter disabled Transmitter enabled	See Sec. 120E.3.1.2 of the IEEE specification	 35 880	mV
ESMW (Eye symmetry mask width)	See Sec. 120E.4.2 of the IEEE specification	0.22	UI
Eye height, differential (min)	See Sec. 120E.4.2 of the IEEE specification	32	mV
Differential output return loss (min)	See Sec. 83E.3.1.3 of the IEEE specification	See Equation (83E-2) of the IEEE specification	dB
Common to differential mode conversion return loss (min)	See Sec. 83E.3.1.3 of the IEEE specification	See Equation (83E-3) of the IEEE specification	dB
Transition time (min, 20% to 80%)	See Sec. 120E.3.1.5 of the IEEE specification	10	ps

Main Voltage Measurements TP1a

The Main Voltage measurement procedures described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

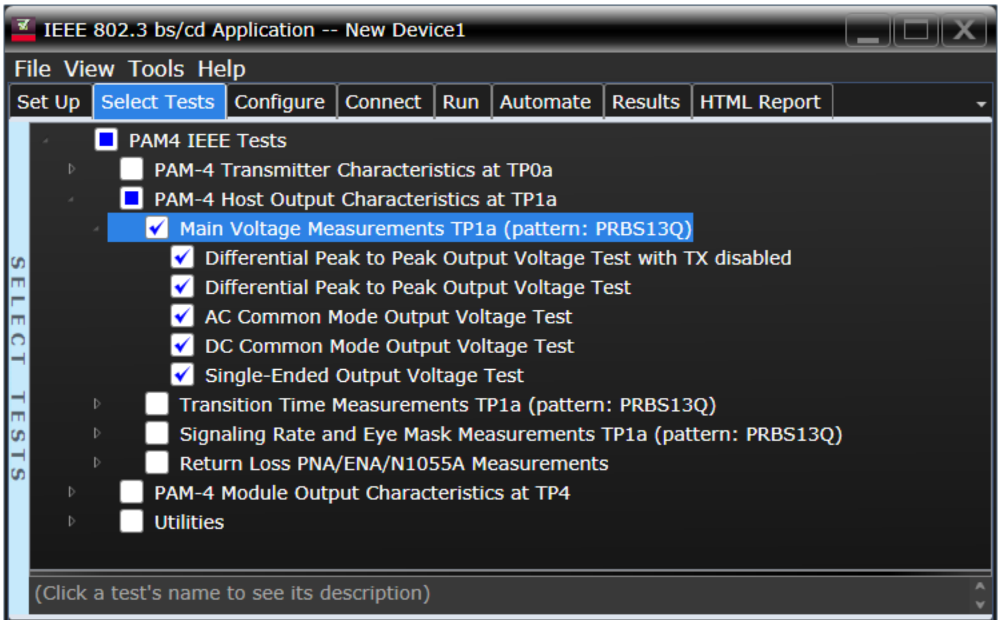


Figure 15 Selecting Main Voltage Measurement Tests

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

To know about the measurement algorithm for each Main Voltage Measurements TP1a (pattern: PRBS13Q) tests, see:

- "Differential Peak-to-Peak Output Voltage Test with TX Disabled" on page 122
- "Differential Peak-to-Peak Output Voltage Test" on page 123
- "AC Common Mode Output Voltage Test" on page 124
- "DC Common Mode Output Voltage Test" on page 125

Differential Peak-to-Peak Output Voltage Test with TX Disabled

Test Overview The purpose of this test is to verify that when TX is disabled, the peak-to-peak voltage must be less than 35mV.

Pass Condition Refer to Table 8.

Measurement Algorithm

1 Obtain a sample or acquire the signal data.
2 Ensure that TX is disabled on the acquired signal (no valid data transitions).
3 Measure peak-to-peak voltage of the signal.
4 Compare the maximum peak-to-peak voltage to 35mV.

Differential Peak-to-Peak Output Voltage Test

Test Overview The purpose of this test is to verify that the peak-to-peak voltage of the differential signal on a PRBS13Q pattern is less than 880mV.

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 PRBS13Q pattern.
3. Measure the peak-to-peak voltage of the differential signal on DUT+ and DUT-.
4. Compare the maximum peak-to-peak voltage with 880mV.

AC Common Mode Output Voltage Test

Test Overview The purpose of this test is to verify that the common mode signal 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 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 with 17.5mV.

DC Common Mode Output Voltage Test

Test Overview The purpose of this test is to verify that the common mode signal is between -300mV and 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 Set common mode signal using the common mode function.
3 Measure minimum and maximum voltage of the common mode signal.
4 Compare the voltage measurement to the range between -300mV and 2.8V.

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 -400mV and that the maximum voltage is less than 3.3V.

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

Pass Condition Refer to Table 8.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that there is a signal and that the connection is dual single-ended.
3 Measure the minimum and maximum voltage on each single-ended signal.
4 Compare the voltage measurements with the range between -400mV and 3.3V.

Transition Time Measurements TP1a

The Transition Time Measurement procedures described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

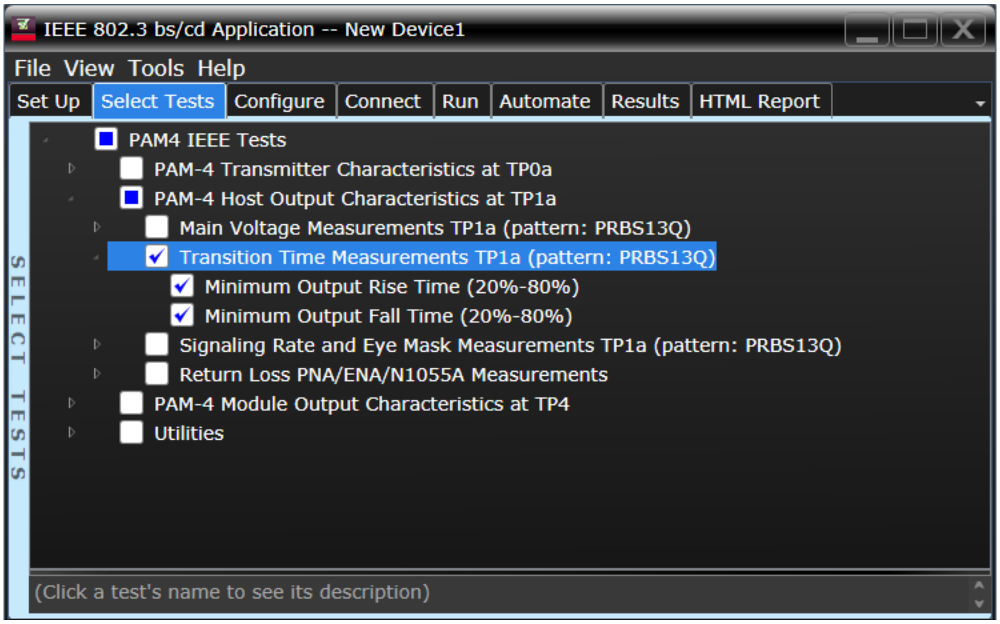


Figure 16 Selecting Transition Time Measurement Tests

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

To know about the measurement algorithm for each Transition Time Measurements TP1a (pattern: PRBS13Q) tests, see:

- "Minimum Output Rise Time (20%-80%)" on page 128
- "Minimum Output Fall Time (20%-80%)" on page 129

Minimum Output Rise Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum rise fall time is 10ps.

Pass Condition Refer to Table 8.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is PRBS13Q.
3 Find pattern 000333 for the rising edge.
4 Measure rise time from 20% to 80% of the signal amplitude.
5 Compare the minimum rise time with 10ps.

Minimum Output Fall Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum rise and fall times are 10ps.

Pass Condition Refer to Table 8.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is PRBS13Q.
3 Find pattern 333000 for the falling edge.
4 Measure fall time from 20% to 80% of the signal amplitude.
5 Compare the minimum rise time with 10ps.

Signaling Rate and Eye Mask Measurements TP1a

The Signaling Rate and Eye Mask Measurement procedures that are described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

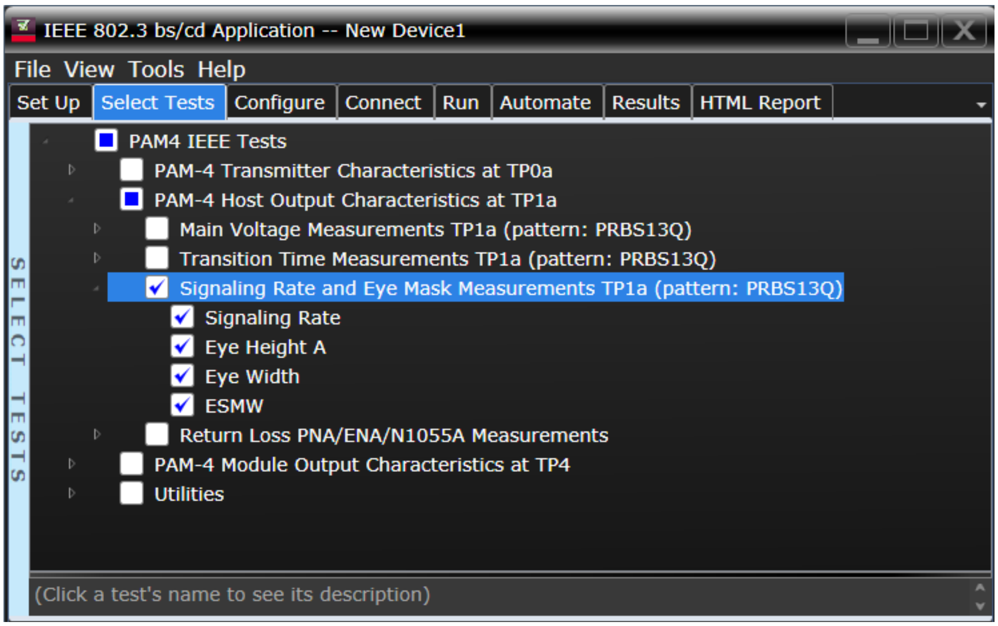


Figure 17 Selecting Signaling Rate and Eye Mask Measurement Tests

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

To know about the measurement algorithm for each Signaling Rate and Eye Mask Measurements TP1a (pattern: PRBS13Q) tests, see:

- “Signaling Rate” on page 131
- “Eye Height A” on page 132
- “Eye Width” on page 133
- “ESMW” on page 134

Signaling Rate

Test Overview The purpose of this test is to verify that the signaling rate mean is between 26.5625 ±100ppm GBd.

Pass Condition Refer to Table 8.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Check that the signal is connected, has a bit-rate of 53.125 GHz and that data pattern exists (PRBS13Q must be used for this test).
3 In the **Configure** tab, set **Signaling Rate** to 26.5625 Gb/s.
4 Measure minimum, maximum and mean data rate.
5 Report minimum and maximum values.
6 Compare the mean data rate value with 26.5625 ±100ppm GBd.
7 Report the resulting value.

Eye Height A

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Eye Height A is greater than 32mV.

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'. See IEEE 802.3bs D3.0, Section 120E, Table 120E-2 (Reference CTLE Coefficients).

2 Obtain sample or acquire signal data.

3 Measure the Eye Height A at an **Eye Height/Width Probability** setting of 1E-5.

4 On the Oscilloscope,
   a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4MHz.
   b Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

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

Eye Width

Test Overview The purpose of this test is to measure the Eye Width for a defined range of CTLE settings.

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

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’. See IEEE 802.3bs D3.0, Section 120E, Table 120E-2 (Reference CTLE Coefficients).

2 Obtain sample or acquire signal data.

3 Measure the Eye Width at an **Eye Height/Width Probability** setting of 1E-5.

4 On the Oscilloscope,
   a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4MHz.
   b Set 4th Order Bessel Thompson filter to 33 GHz with 3 dB gain.

5 Report the resulting value of Eye Width.

NOTE **The Eye Width measurement is considered as an “Information-Only” test and cannot be used for compliance validation.**

ESMW

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the ESMW is greater than 220mUI (that is, 110mUI each for the left and right eye).

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’. See IEEE 802.3bs D3.0, Section 120E, Table 120E-2 (Reference CTLE Coefficients).

2 Obtain sample or acquire signal data.

3 Measure the ESMW at an **Eye Height/Width Probability** setting of 1E-5.

4 On the Oscilloscope,
   a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4MHz.
   b Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

5 Calculate ESMW for each given eye (left and right) using the equations:

Left = (Eye Width / 2) - Eye Skew

Right = (Eye Width / 2) + Eye Skew

6 Compare the ESMW with 220mUI (that is, 110mUI each for the left and right eye). 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 DCA oscilloscope along with either a PNA, ENA or an N1055A and the N1091BSCB 400G IEEE FlexDCA Compliance 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 device is calibrated.

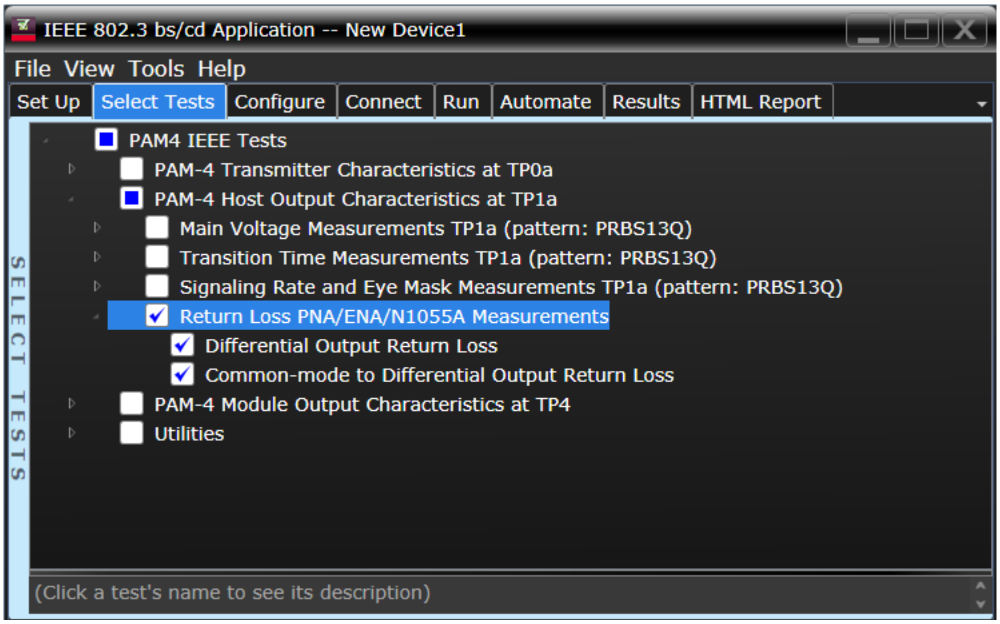


Figure 18 Selecting Return Loss Measurement Tests

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

To know about the measurement algorithm for each Return Loss PNA/ENA/N1055A Measurements tests, see:

- "Differential Output Return Loss" on page 136
- "Common-mode to Differential Output Return Loss" on page 137

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 to 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.

6 PAM4 Module Output Characteristics at TP4

This section provides the Methods of Implementation (MOIs) for the PAM4 200GAUI and 400GAUI IEEE PAM4 Module Output Characteristics at TP4 as specified in IEEE P802.3bs™ /D3.5 (Draft Standard for Ethernet Amendment 10: Media Access Control Parameters, Physical Layers and Management Parameters for 200Gb/s and 400Gb/s Operation), Annex 120E.3.2, Table 120E-3. 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.

200GAUI-4 and 400GAUI-8 C2M module output electrical characteristics

Table 9 200GAUI-4 and 400GAUI-8 C2M module output characteristics at TP4

Parameter	Reference	Value	Units
Signaling rate per lane (range)	See Sec. 120E.3.1.1 of the IEEE specification	26.5625 ± 100 ppm	GBd
AC common-mode output voltage (max, RMS)	See Sec. 120E.3.1.2 of the IEEE specification	17.5	mV
Differential peak-to-peak output voltage (max)	See Sec. 120E.3.1.2 of the IEEE specification	900	mV
Near-end ESMW (Eye symmetry mask width)	See Sec. 120E.4.2 of the IEEE specification	0.265	UI
Near-end Eye height, differential (min)	See Sec. 120E.4.2 of the IEEE specification	70	mV
Far-end ESMW (Eye symmetry mask width)	See Sec. 120E.4.2 of the IEEE specification	0.2	UI
Far-end Eye height, differential (min)	See Sec. 120E.4.2 of the IEEE specification	30	mV
Differential output return loss (min)	See Sec. 83E.3.1.3 of the IEEE specification	See Equation (83E-2) of the IEEE specification	dB
Common to differential mode conversion return loss (min)	See Sec. 83E.3.1.3 of the IEEE specification	See Equation (83E-3) of the IEEE specification	dB
Transition time (min, 20% to 80%)	See Sec. 120E.3.1.5 of the IEEE specification	9.5	ps
DC common mode voltage (min)[a]	See Sec. 120E.3.1.2 of the IEEE specification	-350	mV
DC common mode voltage (max)[a]	See Sec. 120E.3.1.2 of the IEEE specification	2850	mV

a. DC common mode voltage is generated by the host. Specification includes effects of ground offset voltage.

Main Voltage Measurements TP4

The Main Voltage measurement procedures described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

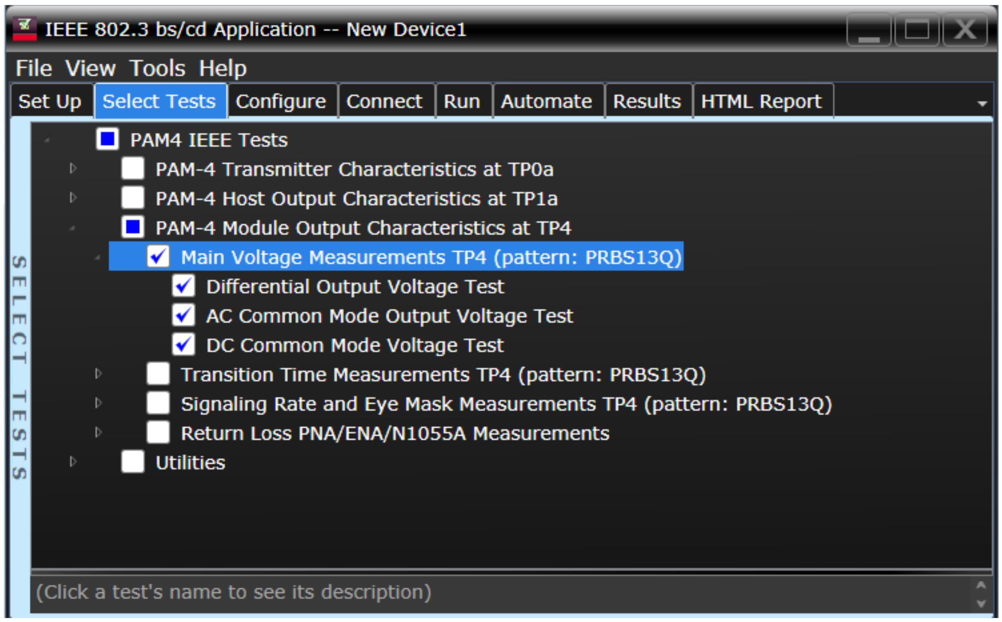


Figure 19 Selecting Main Voltage Measurement Tests

Refer to Table 9 for information on the pass limits for each test.

To know about the measurement algorithm for each Main Voltage Measurements TP4 (pattern: PRBS13Q) tests, see:

- "Differential Output Voltage Test" on page 142
- "AC Common Mode Output Voltage Test" on page 143
- "DC Common Mode Voltage Test" on page 144

Differential Output Voltage Test

Test Overview The purpose of this test is to verify that the peak-to-peak voltage of the differential signal on a PRBS13Q 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 PRBS13Q 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.

AC Common Mode Output Voltage Test

Test Overview The purpose of this test is to verify that the common-mode voltage of the signal 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 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 with 17.5mV.

DC Common Mode Voltage Test

Test Overview The purpose of this test is to verify that the common-mode voltage of the signal is between -350mV and 2.85V.

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 between -350mV and 2.85V.

Transition Time Measurements TP4

The Transition Time Measurement procedures described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

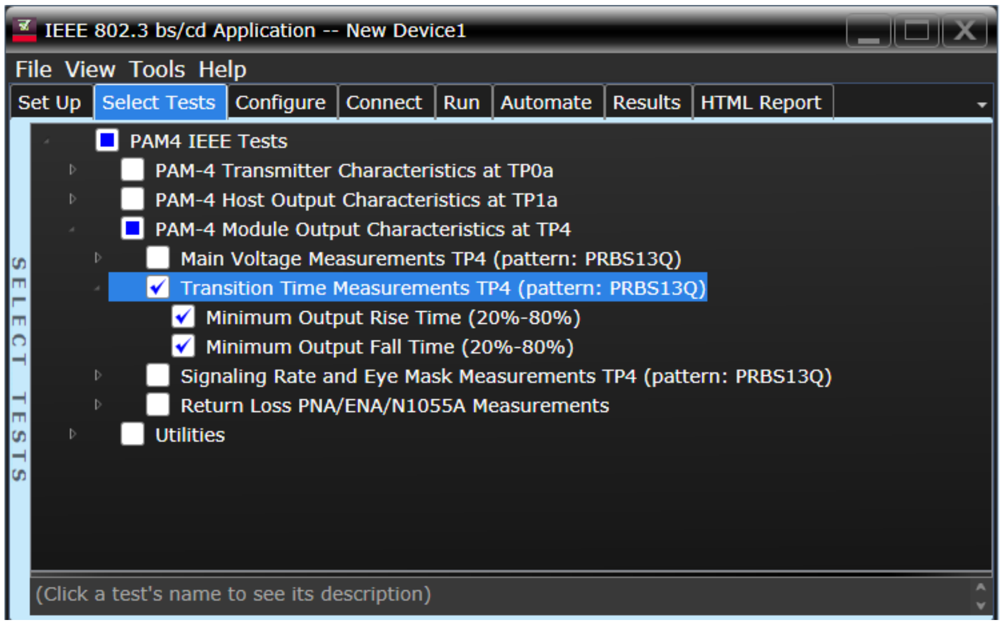


Figure 20 Selecting Transition Time Measurement Tests

Refer to Table 9 for information on the pass limits for each test.

To know about the measurement algorithm for each Transition Time Measurements TP4 (pattern: PRBS13Q) tests, see:

- “Minimum Output Rise Time (20%-80%)” on page 146
- “Minimum Output Fall Time (20%-80%)” on page 147

Minimum Output 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 9.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is PRBS13Q.
3 Find pattern 000333 for rising edge.
4 Measure rise time from 20% to 80% of the signal amplitude.
5 Compare the minimum rise time with 9.5ps.

Minimum Output 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 9.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is PRBS13Q.
3 Find pattern 333000 for the falling edge.
4 Measure fall time from 20% to 80% of the signal amplitude.
5 Compare the minimum fall time with 9.5ps.

Signaling Rate and Eye Mask Measurements TP4

The Signaling Rate and Eye Mask Measurement procedures that are described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

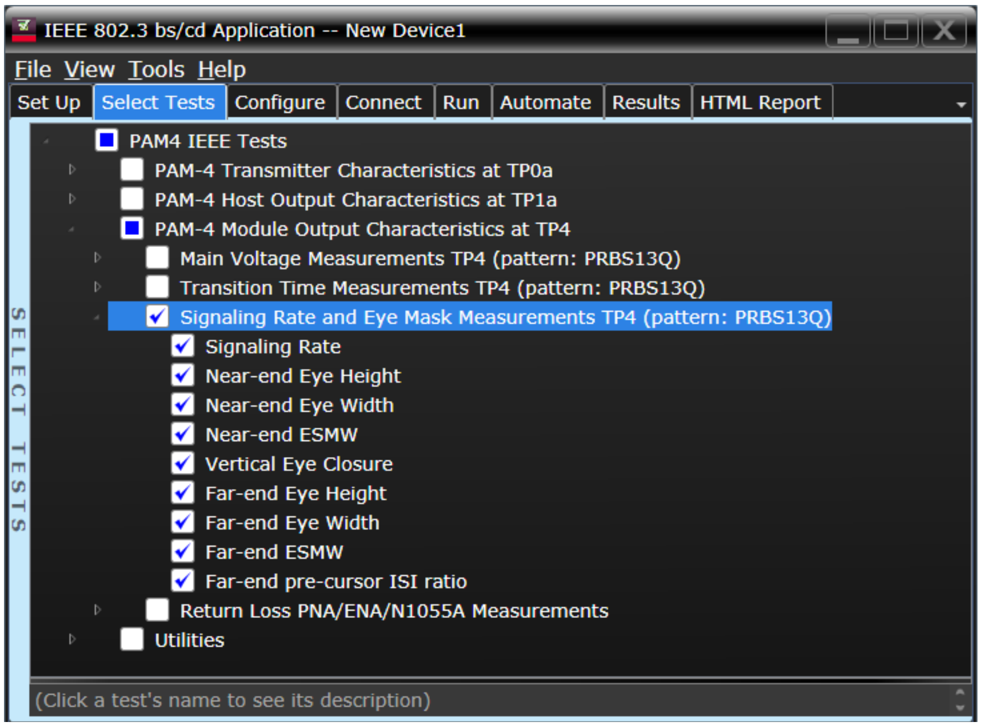


Figure 21 Selecting Signaling Rate and Eye Mask Measurement Tests

Refer to Table 9 for information on the pass limits for each test.

To know about the measurement algorithm for each Signaling Rate and Eye Mask Measurements TP4 (pattern: PRBS13Q) tests, see:

- "Signaling Rate" on page 149
- "Near-end Eye Height" on page 150
- "Near-end Eye Width" on page 151
- "Near-end ESMW" on page 152
- "Vertical Eye Closure" on page 153
- "Far-end Eye Height" on page 154
- "Far-end Eye Width" on page 155
- "Far-end ESMW" on page 156
- "Far-end pre-cursor ISI ratio" on page 157

Signaling Rate

Test Overview The purpose of this test is to verify that the signaling rate mean is between 26.5625 ±100ppm GBd.

Pass Condition Refer to Table 9.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Check that the signal is connected, has a bit-rate of 53.125 GHz and that data pattern exists (PRBS13Q must be used for this test).
3 In the **Configure** tab, set **Signaling Rate** to 26.5625 Gb/s.
4 Measure minimum, maximum and mean data rate.
5 Report minimum and maximum values.
6 Compare the mean data rate value with 26.5625 ±100ppm GBd.
7 Report the resulting value.

Near-end Eye Height

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 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 Measure the Near-end Eye Height at an **Eye Height/Width Probability** setting of 1E-5.

4 On the Oscilloscope,

   a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4MHz.

   b Set 4th Order Bessel Thompson filter to 33 GHz with 3 dB gain.

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

Near-end Eye Width

Test Overview The purpose of this test is to measure the Near-end Eye Width for a defined range of CTLE settings.

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

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 Measure the Near-end Eye Width at an **Eye Height/Width Probability** setting of 1E-5.

4 On the Oscilloscope,

   a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4 MHz.

   b Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

5 Report the resulting value of Near-end Eye Width.

NOTE **The Near-end Eye Width measurement is considered as an "Information-Only" test and cannot be used for compliance validation.**

Near-end ESMW

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Near-end ESMW is greater than 265mUI (that is, 132.5mUI each for the left and right eye).

Pass Conditions Refer to Table 9.

> **NOTE** The Near-end ESMW test checks for margins to the left and right of TC_{min}. Therefore, the limit used for measurements in this test is 0.1325UI.

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. Measure the Near-end ESMW ESMW at an **Eye Height/Width Probability** setting of 1E-5.
4. On the Oscilloscope,
   a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4 MHz.
   b Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.
5. Calculate Near-end ESMW for each given eye (left and right) using the equations:

$$\text{Left} = (\text{Eye Width} / 2) - \text{Eye Skew}$$

$$\text{Right} = (\text{Eye Width} / 2) + \text{Eye Skew}$$

6. Compare the Near-end ESMW with 265mUI (that is, 132.5mUI each for the left and right eye). Report the resulting value.

Vertical Eye Closure

Test Overview The purpose of this test is to measure the Vertical Eye Closure at EH5 (1E-5).

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

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 Measure the Vertical Eye Closure at an **Eye Height/Width Probability** setting of 1E-5 (EH5).

4 On the Oscilloscope,

   a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4 MHz.

   b Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

5 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.

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

$$VEC = 20\log(AV/EH5)$$

7 Report the resulting value of Vertical Eye Closure.

NOTE The Vertical Eye Closure measurement is considered as an “Information-Only” test and cannot be used for compliance validation.

Far-end Eye Height

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 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 Measure the Far-end Eye Height at an **Eye Height/Width Probability** setting of 1E-5.
4 On the Oscilloscope,
   a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4 MHz.
   b Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.
5 Compare the Far-end Eye Height with 30mV. Report the resulting value.

Far-end Eye Width

Test Overview The purpose of this test is to measure the Far-end Eye Width for a defined range of CTLE settings.

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

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 Measure the Far-end Eye Width at an **Eye Height/Width Probability** setting of 1E-5.

4 On the Oscilloscope,
   a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4 MHz.
   b Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

5 Report the resulting value of Far-end Eye Width.

NOTE **The Far-end Eye Width measurement is considered as an "Information-Only" test and cannot be used for compliance validation.**

Far-end ESMW

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Far-end ESMW is greater than 200mUI (that is, 100mUI each for the left and right eye).

Pass Conditions Refer to Table 9.

> **NOTE** The Far-end ESMW test checks for margins to the left and right of TC_{min}. Therefore, the limit used for measurements in this test is 0.1UI.

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. Measure the Far-end ESMW ESMW at an **Eye Height/Width Probability** setting of 1E-5.
4. On the Oscilloscope,
   - *a* set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4 MHz.
   - *b* Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.
5. Calculate Far-end ESMW for each given eye (left and right) using the equations:

   Left = (Eye Width / 2) - Eye Skew

   Right = (Eye Width / 2) + Eye Skew
6. Compare the Far-end ESMW with 200mUI (that is, 100mUI each for the left and right eye). Report the resulting value.

Far-end pre-cursor ISI ratio

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Far-end pre-cursor ISI ratio is greater than the limits defined in the specification. The CTLE values range from 1dB lower than the user-defined optimal CTLE to 1dB higher than the user-defined optimal CTLE.

Pass Conditions Refer to Table 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 Enable (set to ON) pattern averaging to capture PRBS13Q pattern at 32 points per UI for 16 averages.

3 Calculate linear fit p(k) of signal captured in step 2.

- P_{max} is the max value of p(k). P_{pre} is the value of p(k) 1UI prior to the max.

4 Calculate Far-end ISI using the equation:

$$\text{Far-end ISI} = Ppre / Pmax * 100$$

5 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 DCA oscilloscope along with either a PNA, ENA or an N1055A and the N1091BSCB 400G IEEE FlexDCA Compliance 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 device is calibrated.

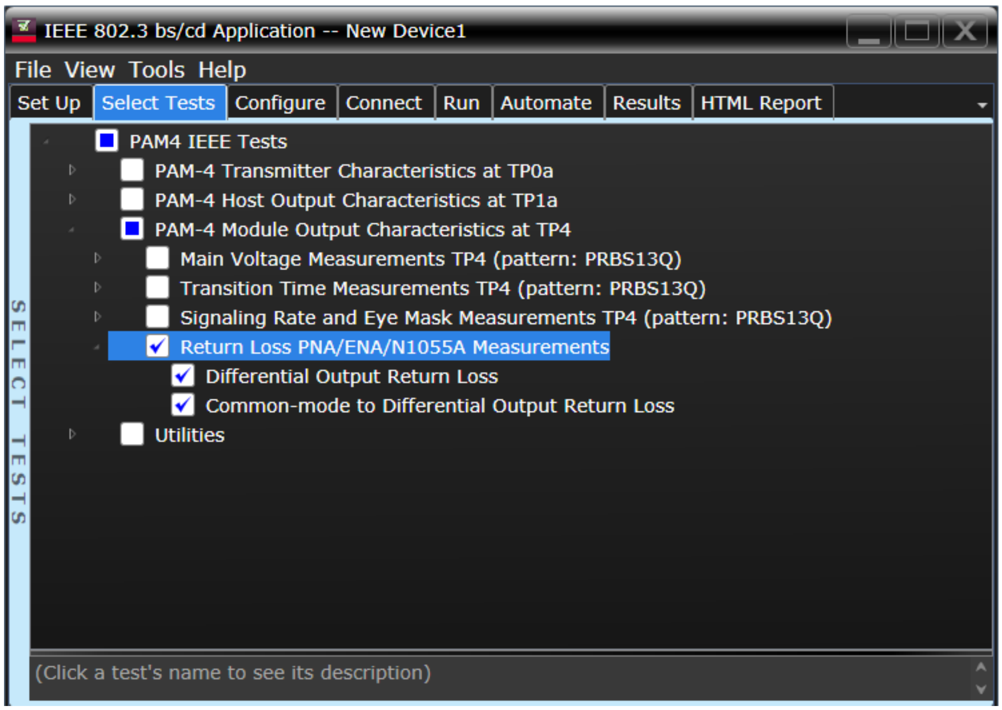


Figure 22 Selecting Return Loss Measurement Tests

Refer to Table 9 for information on the pass limits for each test.

To know about the measurement algorithm for each Return Loss PNA/ENA/N1055A Measurements tests, see:

- "Differential Output Return Loss" on page 159
- "Common-mode to Differential Output Return Loss" on page 160

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 to 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.

7 NRZ Transmitter Characteristics at TP0a

This section provides the Methods of Implementation (MOIs) for the 200GAUI and 400GAUI IEEE NRZ Transmitter Characteristics at TP0a as specified in IEEE Std. 802.3-2015 (IEEE standard for Ethernet), Annex 83D.3.1, Table 83D-1 with 120B.3.1. 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.

CAUI-4 C2C transmitter electrical characteristics

Table 10 CAUI-4 C2C transmitter characteristics at TP0a

Parameter	Reference	Value	Units
Signaling rate per lane (range)	See Sec. 93.8.1.2 of the IEEE specification	25.78125 ± 100 ppm	GBd
Differential peak-to-peak output voltage (max) Transmitter disabled Transmitter enabled	See Sec. 93.8.1.3 of the IEEE specification	 30 1200	 mV mV
Common-mode voltage (max)	See Sec. 93.8.1.3 of the IEEE specification	1.9	V
Common-mode voltage (min)	See Sec. 93.8.1.3 of the IEEE specification	0	V
AC common-mode output voltage (max, RMS)	See Sec. 93.8.1.3 of the IEEE specification	12	mV
Differential output return loss (min)	See Sec. 93.8.1.4 of the IEEE specification	See Equation (93-3) of the IEEE specification	dB
Common-mode output return loss (min)	See Sec. 93.8.1.4 of the IEEE specification	See Equation (93-4) of the IEEE specification	dB
Output waveform[a] Steady state voltage vf (max) Steady state voltage vf (min) Linear fit pulse peak (min) Pre-cursor equalization Post-cursor equalization	See Sections 93.8.1.5.2[b] 93.8.1.5.2[b] 93.8.1.5.2[b] 83D.3.1.1 83D.3.1.1	 0.6 0.4 0.71 × vf Table 83D–2 Table 83D–3	 V V V - -
Signal-to-noise-and-distortion ratio (min)	See Sec. 93.8.1.6[b] of the IEEE specification	27	dB
Output jitter (max) Even-odd jitter Effective bounded uncorrelated jitter, peak-to-peak[c] Effective total uncorrelated jitter, peak-to-peak[c,d]	See Sec. 92.8.3.8 of the IEEE specification	 0.035 0.1 0.26	 UI UI UI

a. The state of the transmit equalizer is controlled by management interface.

b. The values of the parameters are measured as defined in the referenced sub-clause except that the values of Np and Nw are 5.

c. Effective bounded uncorrelated jitter and effective total uncorrelated jitter are measured as defined in section 92.8.3.8.2 of the IEEE specification except that the range for fitting CDFLi and CDFRi, (as defined in section 92.8.3.8.2 c), shall be from 10^{-6} to 10^{-4}.

d. Effective total uncorrelated jitter, peak-to-peak is specified to a probability of 10^{-15}.

200GAUI-8 and 400GAUI-16 C2C transmitter characteristics

A 200GAUI-8 or a 400GAUI-16 chip-to-chip transmitter shall meet all specifications in section 83D.3.1 of the IEEE specification (refer to Table 10 for limits corresponding to Table 83D-1) with the following exceptions:

- The signaling rate per lane is 26.5625 Gbd ± 100 ppm.
- The value for the “Linear fit pulse peak (min)” in Table 83D-1 is 0.75 × vf.
- The value for the “Effective total uncorrelated jitter, peak-to-peak” in Table 10 is 0.19 UI.
- The value of the probability in footnote ‘d’ of Table 10 is 10^{-6}.
- The high-pass filter used for the jitter measurements in section 92.8.3.8 of the IEEE specification has a 3 dB frequency of 4 MHz.

If a Clause 45 MDIO is implemented, *Local_eq_cm1* and *Local_eq_c1* for each lane (0 through 7 for 200GAUI-8 and 0 through 15 for 400GAUI-16) and direction (transmit and receive) are accessible through registers 1.500 through 1.531 (see sections 45.2.1.116d through 45.2.1.116g of the IEEE specification).

Jitter and Signaling Rate Measurements TP0a

The Jitter and Signaling Rate Measurement procedures described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

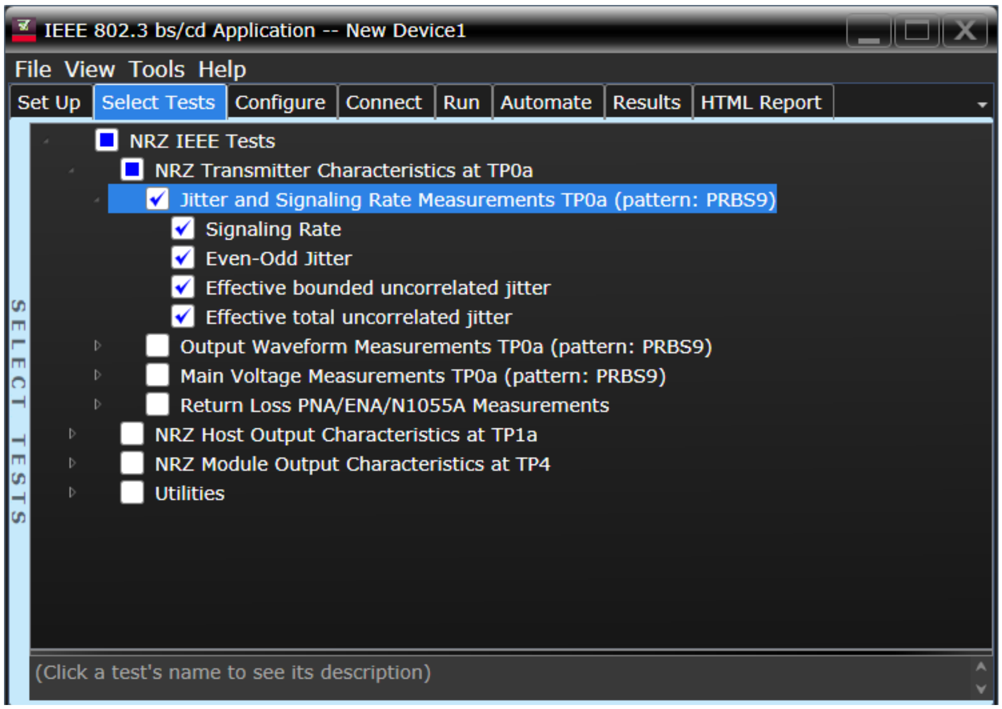


Figure 23 Selecting Main Voltage Measurement Tests

Refer to Table 10 for information on the pass limits for each test.

To know about the measurement algorithm for each Jitter and Signaling Rate Measurements TP0a (pattern: PRBS9) tests, see:

- "Signaling Rate" on page 165
- "Even-Odd Jitter" on page 166
- "Effective bounded uncorrelated jitter" on page 167
- "Effective total uncorrelated jitter" on page 168

Signaling Rate

Test Overview The purpose of this test is to verify that the signaling rate is between 26.5625 ±100ppm GBd.

Pass Condition Refer to the exceptions described in "200GAUI-8 and 400GAUI-16 C2C transmitter characteristics" on page 163.

Measurement Algorithm

1. Obtain sample or acquire signal data.
2. Check that the signal is connected, has a bit-rate of 53.125 GHz and that data pattern exists (PRBS9 must be used for this test).
3. In the **Configure** tab, set **Signaling Rate** to 26.5625 Gb/s.
4. Measure minimum and maximum data rate.
5. Report minimum and maximum values.
6. Compare the mean data rate value with 26.5625 ±100ppm GBd. Report the resulting value.

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 Conditions Refer to Table 10.

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 (26.5625 Gbps) and Loop Bandwidth to 4 MHz.

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

c Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

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

Effective bounded uncorrelated jitter

Test Overview The purpose of this test is to verify that differential signal's peak-to-peak effective bounded uncorrelated jitter is less than 0.1 UI. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Conditions Refer to Table 10.

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 (26.5625 Gbps) and Loop Bandwidth to 4 MHz.

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

c Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

4 Compare and report the effective bounded uncorrelated jitter value to the respective maximum specification.

Effective total uncorrelated jitter

Test Overview The purpose of this test is to verify that differential signal's peak-to-peak effective total uncorrelated jitter is less than 0.19 UI. All jitter tests are run in a single measurement. However, each test can be run individually.

Pass Conditions Refer to Table 10 and the exceptions described in "200GAUI-8 and 400GAUI-16 C2C transmitter characteristics" on page 163.

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 (26.5625 Gbps) and Loop Bandwidth to 4 MHz.

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

   c Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

4 Compare and report the effective total uncorrelated jitter value to the respective maximum specification.

Output Waveform Measurements TP0a

The Output Waveform Measurement procedures that are described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

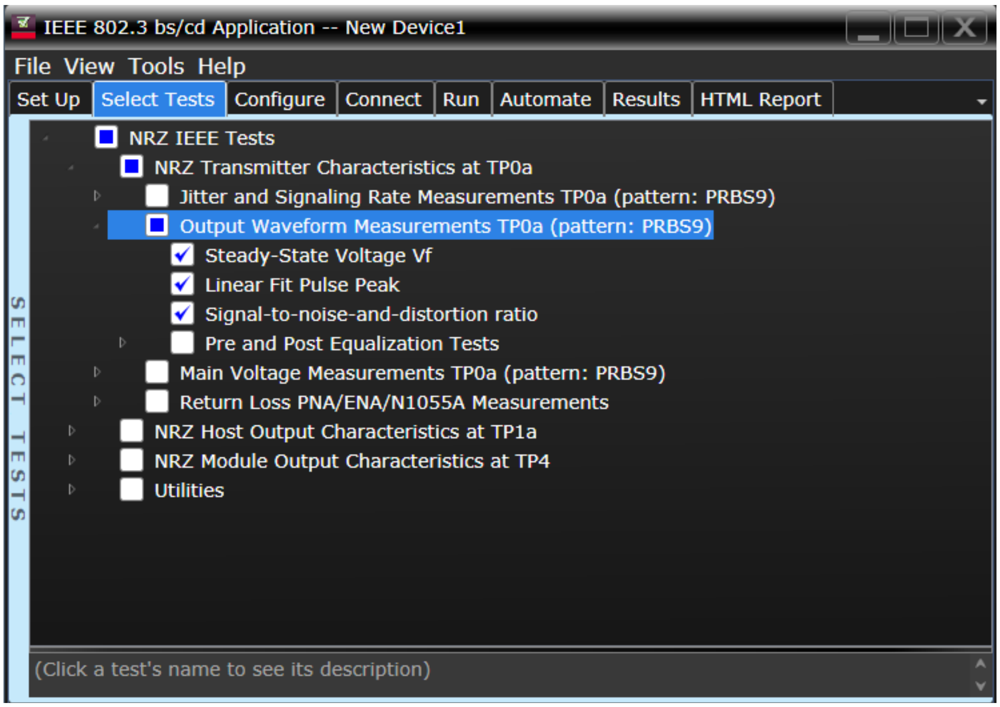


Figure 24 Selecting Jitter and Signaling Rate Measurement Tests

Refer to Table 10 for information on the pass limits for each test.

To know about the measurement algorithm for each Output Waveform Measurements TP0a (pattern: PRBS9) tests, see:

- "Steady State Voltage Vf" on page 170
- "Linear Fit Pulse Peak" on page 171
- "Signal-to-noise-and-distortion ratio" on page 172
- "Pre and Post Equalization Tests" on page 173

Steady State Voltage V_f

Test Overview The purpose of this test is to verify that the Steady State Voltage is between 0.4V and 0.6V.

Pass Condition Refer to Table 10.

Measurement Algorithm

1 Check that signal is connected and proper data pattern exists (PRBS9 must be used for this test).
2 Set memory depth and sample rate to capture the 511 bits of the PRBS9 pattern.
3 Calculate V_f 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 Compare and report the resulting value in the range between 0.4V and 0.6V.

Linear Fit Pulse Peak

Test Overview The purpose of this test is to verify that the Linear Fit Pulse is greater than (V_f x 0.75).

NOTE **Run the Steady-State Voltage Vf test as a prerequisite to running the Linear Fit Pulse Peak test.**

Pass Conditions Refer to Table 10 and the exceptions described in "200GAUI-8 and 400GAUI-16 C2C transmitter characteristics" on page 163.

Measurement Algorithm

1. Check that signal is connected and proper data pattern exists (PRBS9 must be used for this test).
2. Set memory depth and sample rate to capture the 511 bits of the PRBS9 pattern.
3. Calculate Linear Fit Pulse 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. Compare and report the resulting value with (V_f x 0.75).

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 27 dB.

Pass Condition Refer to Table 10.

Measurement Algorithm

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

2 Compare and report the value of SNDR with 27 dB.

Pre and Post Equalization Tests

Test Overview The purpose of this test is to verify the Pre-cursor and Post-cursor equalization ratios.

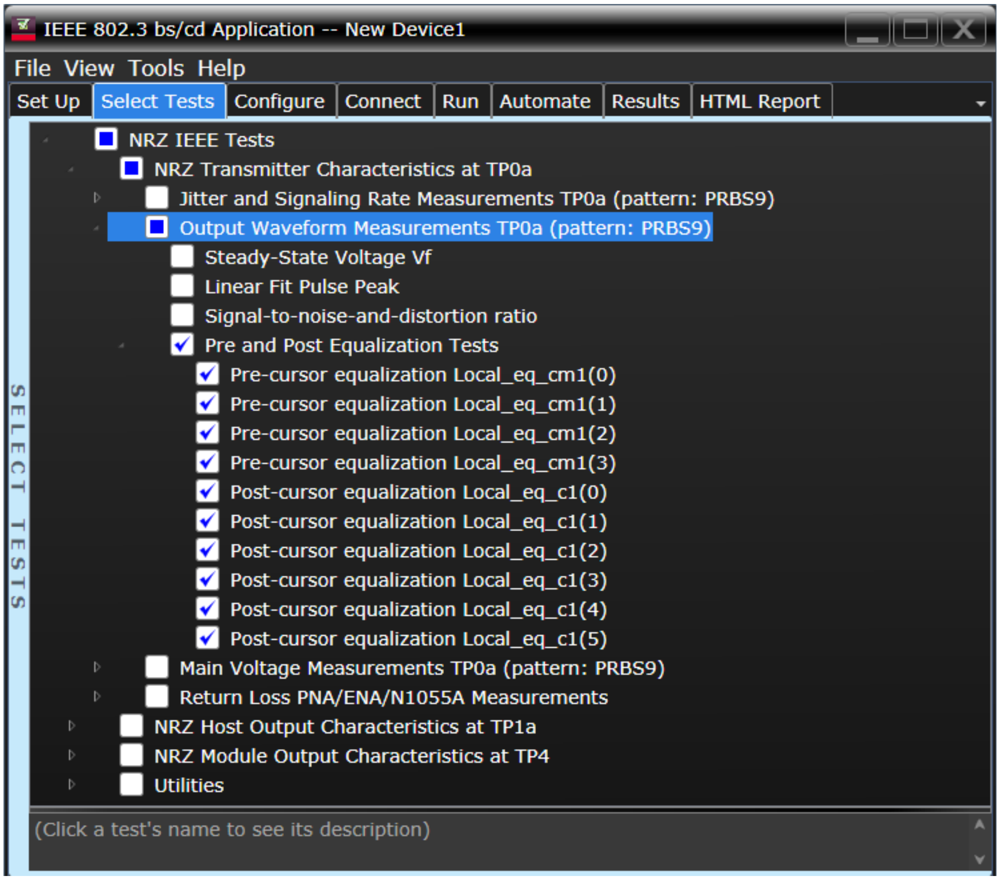


Figure 25 Selecting Transmitter Output Waveform Tests

To know about the measurement algorithm for each Pre and Post Equalization Tests, see:

- "Pre-cursor equalization Local_eq_cm1(0)" on page 174
- "Pre-cursor equalization Local_eq_cm1(1)" on page 175
- "Pre-cursor equalization Local_eq_cm1(2)" on page 176
- "Pre-cursor equalization Local_eq_cm1(3)" on page 177
- "Pre-cursor equalization Local_eq_c1(0)" on page 178
- "Post-cursor equalization Local_eq_c1(1)" on page 179
- "Post-cursor equalization Local_eq_c1(2)" on page 180
- "Post-cursor equalization Local_eq_c1(3)" on page 181
- "Post-cursor equalization Local_eq_c1(4)" on page 182
- "Post-cursor equalization Local_eq_c1(5)" on page 183

Pre-cursor equalization Local_eq_cm1(0)

Test Overview The purpose of this test is to verify that the Pre-cursor equalization ratio is 0 ± 0.04.

Pass Condition When the Pre-cursor equalization with weight Local_eq_cm1 = 0, the ratio defined by C(-1) / [|C(-1)| + |C(0)| + |C(1)|} must be within 0 ± 0.04.

Measurement Algorithm

1. Request Transmitter to be set to “PRESET” condition.
2. Set memory depth to capture one full PRBS9 pattern and scale.
3. Calculate linear fit pulse response at “PRESET” condition.
4. Define matrix Rm using equation (92-4) from IEEE 802.3.
5. Request to change the eq setting to Pre-cursor equalization with weight local_eq_cm1 = 0.
6. Calculate linear fit pulse response as per section 93.8.1.5.2 of the IEEE Std. 802.3-2015 specification document, with N_p = 200, D_p = 2.
7. Calculate coefficients using equation (92-5) from IEEE 802.3.
8. Calculate pre-cursor ratio using the equation C(-1) / [|C(-1)| + |C(0)| + |C(1)|}.
9. Compare and report the value of pre-cursor ratio with 0 ± 0.04.

Pre-cursor equalization Local_eq_cm1(1)

Test Overview The purpose of this test is to verify that the Pre-cursor equalization ratio is -0.05 ± 0.04.

Pass Condition When the Pre-cursor equalization with weight Local_eq_cm1 = 1, the ratio defined by C(-1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.05 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS9 pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Pre-cursor equalization with weight local_eq_cm1 = 1.
6 Calculate linear fit pulse response as per section 93.8.1.5.2 of the IEEE Std. 802.3-2015 specification document, with N_p = 200, D_p = 2.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate pre-cursor ratio using the equation C(-1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of pre-cursor ratio with -0.05 ± 0.04.

Pre-cursor equalization Local_eq_cm1(2)

Test Overview The purpose of this test is to verify that the Pre-cursor equalization ratio is -0.1 ± 0.04.

Pass Condition When the Pre-cursor equalization with weight Local_eq_cm1 = 2, the ratio defined by C(-1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.1 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS9 pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Pre-cursor equalization with weight local_eq_cm1 = 2.
6 Calculate linear fit pulse response as per section 93.8.1.5.2 of the IEEE Std. 802.3-2015 specification document, with N_p = 200, D_p = 2.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate pre-cursor ratio using the equation C(-1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of pre-cursor ratio with -0.1 ± 0.04.

Pre-cursor equalization Local_eq_cm1(3)

Test Overview The purpose of this test is to verify that the Pre-cursor equalization ratio is -0.15 ± 0.04.

Pass Condition When the Pre-cursor equalization with weight Local_eq_cm1 = 3, the ratio defined by C(-1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.15 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS9 pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Pre-cursor equalization with weight local_eq_cm1 = 3.
6 Calculate linear fit pulse response as per section 93.8.1.5.2 of the IEEE Std. 802.3-2015 specification document, with N_p = 200, D_p = 2.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate pre-cursor ratio using the equation C(-1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of pre-cursor ratio with -0.15 ± 0.04.

Pre-cursor equalization Local_eq_c1(0)

Test Overview The purpose of this test is to verify that the Post-cursor equalization ratio is 0 ± 0.04.

Pass Condition When the Post-cursor equalization with weight Local_eq_c1 = 0, the ratio defined by C(1) / [|C(-1)| + |C(0)| + |C(1)|} must be within 0 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS9 pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Post-cursor equalization with weight local_eq_c1 = 0.
6 Calculate linear fit pulse response as per section 93.8.1.5.2 of the IEEE Std. 802.3-2015 specification document, with N_p = 200, D_p = 2.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate post-cursor ratio using the equation C(1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of post-cursor ratio with 0 ± 0.04.

Post-cursor equalization Local_eq_c1(1)

Test Overview The purpose of this test is to verify that the Post-cursor equalization ratio is -0.05 ± 0.04.

Pass Condition When the Post-cursor equalization with weight Local_eq_c1 = 1, the ratio defined by C(1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.05 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS9 pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Post-cursor equalization with weight local_eq_c1 = 1.
6 Calculate linear fit pulse response as per section 93.8.1.5.2 of the IEEE Std. 802.3-2015 specification document, with N_p = 200, D_p = 2.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate post-cursor ratio using the equation C(1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of post-cursor ratio with -0.05 ± 0.04.

Post-cursor equalization Local_eq_c1(2)

Test Overview The purpose of this test is to verify that the Post-cursor equalization ratio is -0.1 ± 0.04.

Pass Condition When the Post-cursor equalization with weight Local_eq_c1 = 2, the ratio defined by C(1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.1 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS9 pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Post-cursor equalization with weight local_eq_c1 = 2.
6 Calculate linear fit pulse response as per section 93.8.1.5.2 of the IEEE Std. 802.3-2015 specification document, with N_p = 200, D_p = 2.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate post-cursor ratio using the equation C(1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of post-cursor ratio with -0.1 ± 0.04.

Post-cursor equalization Local_eq_c1(3)

Test Overview The purpose of this test is to verify that the Post-cursor equalization ratio is -0.15 ± 0.04.

Pass Condition When the Post-cursor equalization with weight Local_eq_c1 = 3, the ratio defined by C(1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.15 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS9 pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Post-cursor equalization with weight local_eq_c1 = 3.
6 Calculate linear fit pulse response as per section 93.8.1.5.2 of the IEEE Std. 802.3-2015 specification document, with N_p = 200, D_p = 2.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate post-cursor ratio using the equation C(1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of post-cursor ratio with -0.15 ± 0.04.

Post-cursor equalization Local_eq_c1(4)

Test Overview The purpose of this test is to verify that the Post-cursor equalization ratio is -0.2 ± 0.04.

Pass Condition When the Post-cursor equalization with weight Local_eq_c1 = 4, the ratio defined by C(1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.2 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS9 pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Post-cursor equalization with weight local_eq_c1 = 4.
6 Calculate linear fit pulse response as per section 93.8.1.5.2 of the IEEE Std. 802.3-2015 specification document, with N_p = 200, D_p = 2.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate post-cursor ratio using the equation C(1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of post-cursor ratio with -0.2 ± 0.04.

Post-cursor equalization Local_eq_c1(5)

Test Overview The purpose of this test is to verify that the Post-cursor equalization ratio is -0.25 ± 0.04.

Pass Condition When the Post-cursor equalization with weight Local_eq_c1 = 5, the ratio defined by C(1) / [|C(-1)| + |C(0)| + |C(1)|} must be within -0.25 ± 0.04.

Measurement Algorithm Skip to step 5 if the first four steps have already been measured/calculated in a previous equalization test of the same trial.

1 Request Transmitter to be set to “PRESET” condition.
2 Set memory depth to capture one full PRBS9 pattern and scale.
3 Calculate linear fit pulse response at “PRESET” condition.
4 Define matrix Rm using equation (92-4) from IEEE 802.3.
5 Request to change the eq setting to Post-cursor equalization with weight local_eq_c1 = 5.
6 Calculate linear fit pulse response as per section 93.8.1.5.2 of the IEEE Std. 802.3-2015 specification document, with N_p = 200, D_p = 2.
7 Calculate coefficients using equation (92-5) from IEEE 802.3.
8 Calculate post-cursor ratio using the equation C(1) / [|C(-1)| + |C(0)| + |C(1)|}.
9 Compare and report the value of post-cursor ratio with -0.25 ± 0.04.

Main Voltage Measurements TP0a

The Main Voltage measurement procedures described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

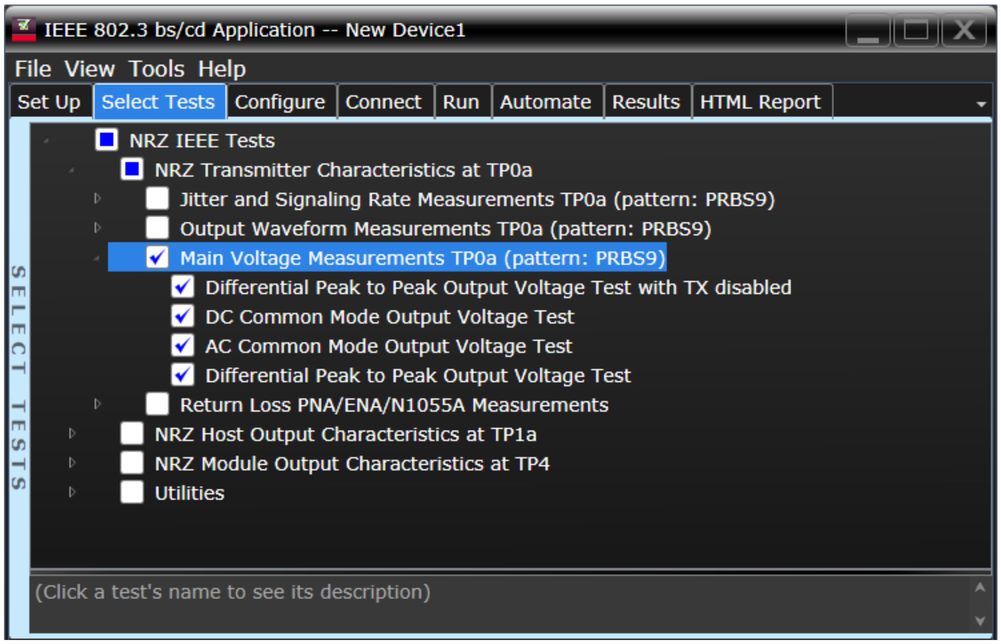


Figure 26 Selecting Transmitter Output Voltage Measurement EYE Tests

Refer to Table 10 for information on the pass limits for each test.

To know about the measurement algorithm for each Main Voltage Measurements TP0a (pattern: PRBS9) tests, see:

- "Differential Peak-to-Peak Output Voltage Test with TX Disabled" on page 185
- "DC Common Mode Output Voltage Test" on page 186
- "AC Common Mode Output Voltage Test" on page 187
- "Differential Peak-to-Peak Output Voltage Test" on page 188

Differential Peak-to-Peak Output Voltage Test with TX Disabled

Test Overview The purpose of this test is to verify that when TX is disabled, the peak-to-peak voltage must be less than 30mV.

Pass Condition Refer to Table 10.

Measurement Algorithm

1. Obtain a sample or acquire the signal data.
2. Ensure that TX is disabled on the acquired signal (no valid data transitions).
3. Measure peak-to-peak voltage of the signal.
4. Compare the maximum peak-to-peak voltage with 30mV.

DC Common Mode Output Voltage Test

Test Overview The purpose of this test is to verify that the common mode signal 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 10.

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 1.9 V.

AC Common Mode Output Voltage Test

Test Overview The purpose of this test is to verify that the common mode signal 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 10.

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 with 12mV.

Differential Peak-to-Peak Output Voltage Test

Test Overview The purpose of this test is to verify that the peak-to-peak voltage of the differential signal on a PRBS9 pattern is less than 1200mV.

Pass Condition Refer to Table 10.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is connected, has TX enabled and has a PRBS9 pattern.
3 Measure the peak-to-peak voltage of the differential signal on DUT+ and DUT-.
4 Compare the maximum peak-to-peak voltage with 1200mV.

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 DCA oscilloscope along with either a PNA, ENA or an N1055A and the N1091BSCB 400G IEEE FlexDCA Compliance 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 device is calibrated.

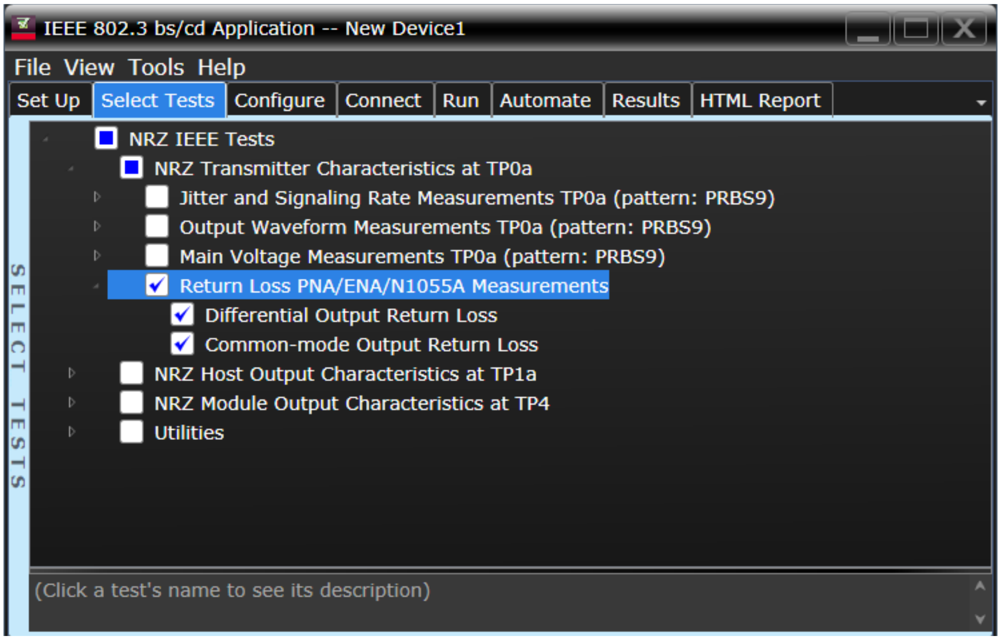


Figure 27 Selecting Return Loss Measurement Tests

Refer to Table 10 for information on the pass limits for each test.

To know about the measurement algorithm for each Return Loss PNA/ENA/N1055A Measurements tests, see:

- "Differential Output Return Loss" on page 190
- "Common-mode Output Return Loss" on page 191

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 Output Characteristics at TP1a

This section provides the Methods of Implementation (MOIs) for the 200GAUI and 400GAUI IEEE NRZ Host Output Characteristics at TP1a as specified in IEEE Std. 802.3-2015 (IEEE standard for Ethernet), Annex 83E.3.1, Table 83E-1 with 120C.3.1. Measurements are made at TP1a.

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

KEYSIGHT TECHNOLOGIES

CAUI-4 C2M host output electrical characteristics

Table 11 CAUI-4 C2C host output characteristics at TP1a

Parameter	Reference	Value	Units
Signaling rate per lane (range)	See Sec. 83E.3.1.1 of the IEEE specification	25.78125 ± 100 ppm	GBd
DC Common-mode voltage (max)	See Sec. 83E.3.1.2 of the IEEE specification	2.8	V
DC Common-mode voltage (min)	See Sec. 83E.3.1.2 of the IEEE specification	-0.3	V
Single-ended output voltage (max)	See Sec. 83E.3.1.2 of the IEEE specification	3.3	V
Single-ended output voltage (min)	See Sec. 83E.3.1.2 of the IEEE specification	-0.4	V
AC common-mode output voltage (max, RMS)	See Sec. 83E.3.1.2 of the IEEE specification	17.5	mV
Differential peak-to-peak output voltage (max) Transmitter disabled Transmitter enabled	See Sec. 83E.3.1.2 of the IEEE specification	 35 900	 mV mV
Eye width (min)	See Sec. 83E.3.1.6 of the IEEE specification	0.46	UI
Eye height A, differential (min)	See Sec. 83E.3.1.6 of the IEEE specification	95	mV
Differential output return loss (min)	See Sec. 83E.3.1.3 of the IEEE specification	See Equation (83E-2) of the IEEE specification	dB
Common to differential mode conversion return loss (min)	See Sec. 83E.3.1.3 of the IEEE specification	See Equation (83E-3) of the IEEE specification	dB
Transition time (min, 20% to 80%)	See Sec. 83E.3.1.5 of the IEEE specification	10	dB

200GAUI-8 and 400GAUI-16 C2M host output characteristics

A 200GAUI-8 or a 400GAUI-16 chip-to-module host output shall meet all specifications in section 83E.3.1 of the IEEE specification (refer to Table 11 for limits corresponding to Table 83E-1) with the following exceptions:

- The signaling rate per lane is 26.5625 Gbd ± 100 ppm.
- The clock recovery unit corner frequency is 4 MHz.

If a Clause 45 MDIO is implemented, the variable *Recommended_CTLE_value* is accessible in the module for lanes 0 through 7 for 200GAUI-8 and 0 through 15 for 400GAUI-16 through registers 1.400 to 1.415 (see sections 45.2.1.116a and 45.2.1.116b of the IEEE specification).

Main Voltage Measurements TP1a

The Main Voltage measurement procedures described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

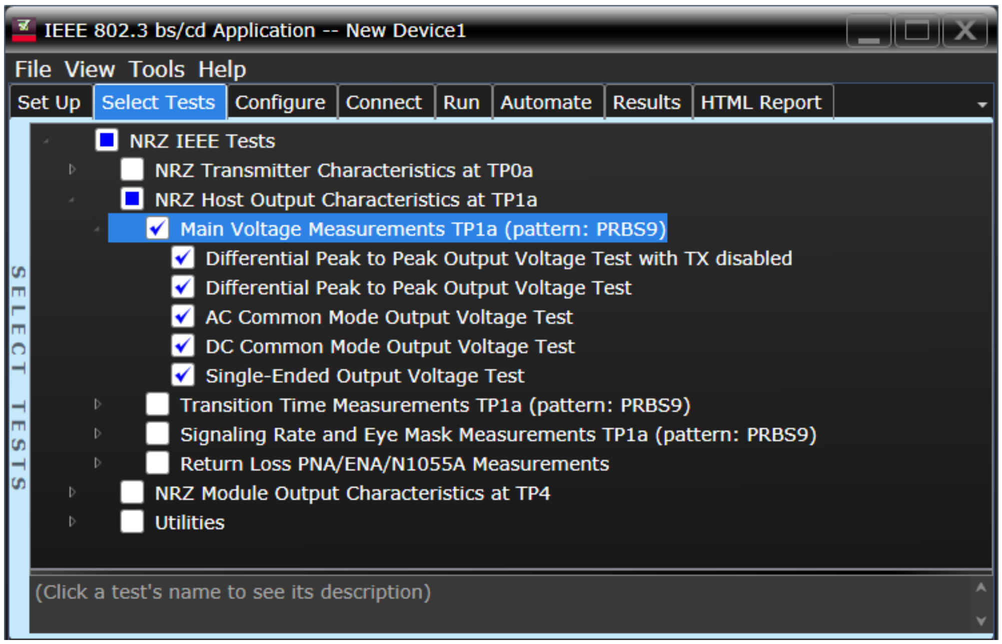


Figure 28 Selecting Main Voltage Measurement Tests

Refer to Table 11 for information on the pass limits for each test.

To know about the measurement algorithm for each Main Voltage Measurements TP1a (pattern: PRBS9) tests, see:

- "Differential Peak-to-Peak Output Voltage Test with TX Disabled" on page 197
- "Differential Peak-to-Peak Output Voltage Test" on page 198
- "AC Common Mode Output Voltage Test" on page 199
- "DC Common Mode Output Voltage Test" on page 200
- "Single-ended Output Voltage Test" on page 201

Differential Peak-to-Peak Output Voltage Test with TX Disabled

Test Overview The purpose of this test is to verify that when TX is disabled, the peak-to-peak voltage must be less than 35mV.

Pass Condition Refer to Table 11.

Measurement Algorithm

1 Obtain a sample or acquire the signal data.
2 Ensure that TX is disabled on the acquired signal (no valid data transitions).
3 Measure peak-to-peak voltage of the signal.
4 Compare the maximum peak-to-peak voltage to 35mV.

Differential Peak-to-Peak Output Voltage Test

Test Overview The purpose of this test is to verify that the peak-to-peak voltage of the differential signal on a PRBS9 pattern is less than 900mV.

Pass Condition Refer to Table 11.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is connected, has TX enabled and has a PRBS9 pattern.
3 Measure the peak-to-peak voltage of the differential signal on DUT+ and DUT-.
4 Compare the maximum peak-to-peak voltage with 900mV.

AC Common Mode Output Voltage Test

Test Overview The purpose of this test is to verify that the common mode signal 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 11.

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 with 17.5mV.

DC Common Mode Output Voltage Test

Test Overview The purpose of this test is to verify that the common mode signal is between -300mV and 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 11.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Set common mode signal using the common mode function.
3 Measure minimum and maximum voltage of the common mode signal.
4 Compare the voltage measurement to the range between -300mV and 2.8V.

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 -400mV and that the maximum voltage is less than 3.3V.

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

Pass Condition Refer to Table 11.

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 -400mV and 3.3V.

Transition Time Measurements TP1a

The Transition Time Measurement procedures described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

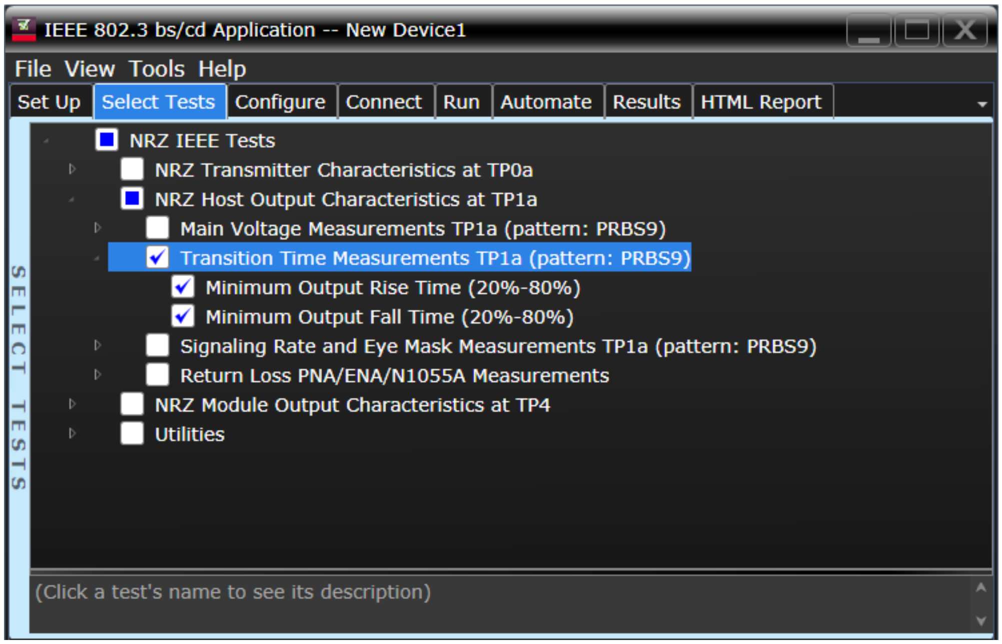


Figure 29 Selecting Transition Time Measurement Tests

Refer to Table 11 for information on the pass limits for each test.

To know about the measurement algorithm for each Transition Time Measurements TP1a (pattern: PRBS9) tests, see:

- "Minimum Output Rise Time (20%-80%)" on page 203
- "Minimum Output Fall Time (20%-80%)" on page 204

Minimum Output Rise Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum rise fall time is 10ps.

Pass Condition Refer to Table 11.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is PRBS9.
3 Find pattern 000333 for the rising edge.
4 Measure rise time from 20% to 80% of the signal amplitude.
5 Compare the minimum rise time with 10ps.

Minimum Output Fall Time (20%-80%)

Test Overview The purpose of this test is to verify that the minimum rise and fall times are 10ps.

Pass Condition Refer to Table 11.

Measurement Algorithm

1. Obtain sample or acquire signal data.
2. Verify that the signal is PRBS9.
3. Find pattern 333000 for the falling edge.
4. Measure fall time from 20% to 80% of the signal amplitude.
5. Compare the minimum rise time with 10ps.

Signaling Rate and Eye Mask Measurements TP1a

The Signaling Rate and Eye Mask Measurement procedures that are described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

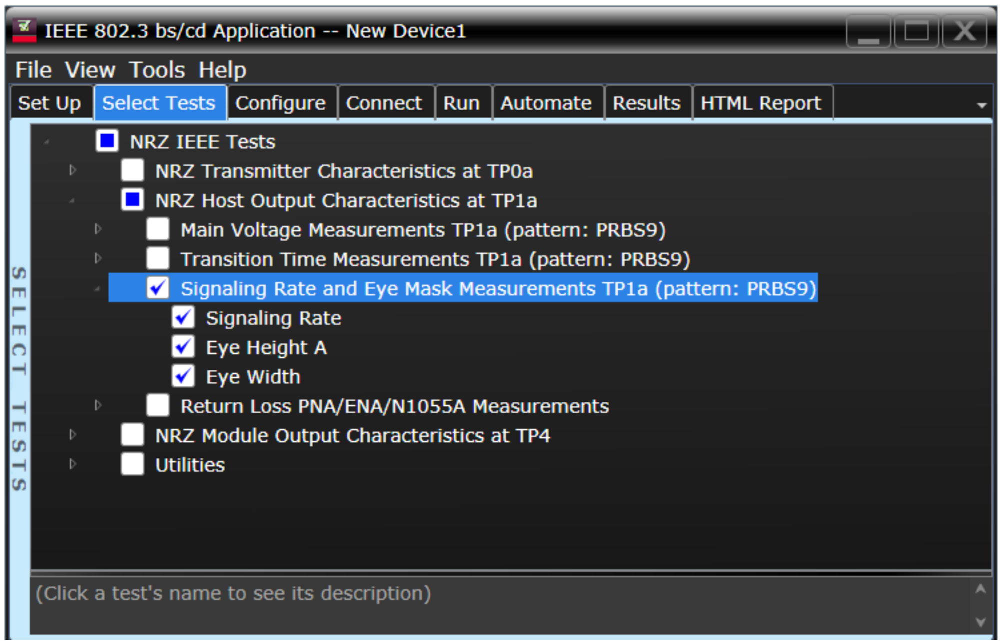


Figure 30 Selecting Eye Mask Measurement Tests

Refer to Table 11 for information on the pass limits for each test.

To know about the measurement algorithm for each Signaling Rate and Eye Mask Measurements TP1a (pattern: PRBS9) tests, see:

- “Signaling Rate” on page 206
- “Eye Height A” on page 207
- “Eye Width” on page 208

Signaling Rate

Test Overview The purpose of this test is to verify that the signaling rate mean is between 26.5625 ±100ppm GBd.

Pass Condition Refer to the exceptions described in "200GAUI-8 and 400GAUI-16 C2M host output characteristics" on page 195.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Check that the signal is connected, has a bit-rate of 53.125 GHz and that data pattern exists (PRBS9 must be used for this test).
3 In the **Configure** tab, set **Signaling Rate** to 26.5625 Gb/s.
4 Measure minimum, maximum and mean data rate.
5 Report minimum and maximum values.
6 Compare the mean data rate value with 26.5625 ±100ppm GBd.
7 Report the resulting value.

Eye Height A

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Eye Height A is greater than 95mV.

Pass Conditions Refer to Table 11.

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 Measure the Eye Height A at an **Eye Height/Width Probability** setting of 1E-5.

4 On the Oscilloscope,
  a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4 MHz.
  b Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

5 Compare the Eye Height A with 95mV. Report the resulting value.

Eye Width

Test Overview The purpose of this test is to verify that for a defined range of CTLE settings, the Eye Width is greater than 460mUI.

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

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 Measure the Eye Width at an **Eye Height/Width Probability** setting of 1E-5.

4 On the Oscilloscope,

a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4 MHz.

b Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

5 Compare the Eye Width with 460mUI. 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 DCA oscilloscope along with either a PNA, ENA or an N1055A and the N1091BSCB 400G IEEE FlexDCA Compliance 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 device is calibrated.

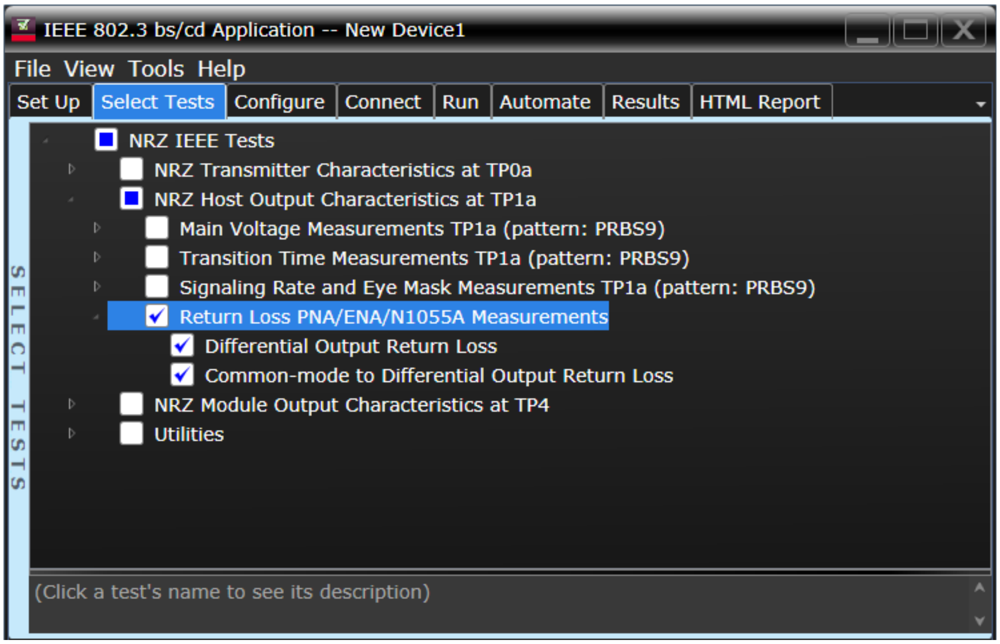


Figure 31 Selecting Return Loss Measurement Tests

Refer to Table 11 for information on the pass limits for each test.

To know about the measurement algorithm for each Return Loss PNA/ENA/N1055A Measurements tests, see:

- “Differential Output Return Loss” on page 210
- “Common-mode to Differential Output Return Loss” on page 211

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 to 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.

9 NRZ Module Output Characteristics at TP4

This section provides the Methods of Implementation (MOIs) for the 200GAUI and 400GAUI IEEE NRZ Transmitter Characteristics at TP4 as specified in IEEE Std. 802.3-2015 (IEEE standard for Ethernet), Annex 83E.3.2, Table 83E-3 with 120C.3.2. 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.

CAUI-4 module output characteristics

Table 12 CAUI-4 module output characteristics at TP4

Parameter	Reference	Value	Units
Signaling rate per lane (range)	See Sec. 83E.3.1.1 of the IEEE specification	25.78125 ± 100 ppm	GBd
AC common-mode output voltage (max, RMS)	See Sec. 83E.3.1.2 of the IEEE specification	17.5	mV
Differential output voltage (max)	See Sec. 83E.3.1.2 of the IEEE specification	900	mV
Eye-width (min)	See Sec. 83E.3.2.1 of the IEEE specification	0.57	UI
Eye height, differential (min)	See Sec. 83E.3.2.1 of the IEEE specification	228	mV
Vertical Eye Closure (max)	See Sec. 83E.4.2.1 of the IEEE specification	5.5	dB
Differential output return loss (min)	See Sec. 83E.3.1.3 of the IEEE specification	See Equation (83E-2) of the IEEE specification	dB
Common to differential mode conversion return loss (min)	See Sec. 83E.3.1.3 of the IEEE specification	See Equation (83E-3) of the IEEE specification	dB
Transition time (min, 20% to 80%)	See Sec. 83E.3.1.5 of the IEEE specification	12	ps
DC common mode voltage (min)[a]	See Sec. 83E.3.1.2 of the IEEE specification	-350	mV
DC common mode voltage (max)[a]	See Sec. 83E.3.1.2 of the IEEE specification	2850	mV

a. DC common mode voltage is generated by the host. Specification includes effects of ground offset voltage.

200GAUI-8 and 400GAUI-16 C2M module output characteristics

A module output of 200GAUI-8 or a 400GAUI-16 chip-to-module shall meet all specifications in section 83E.3.2 of the IEEE specification (refer to Table 12 for limits corresponding to Table 83E-3) with the following exceptions:

- The signaling rate per lane is 26.5625 Gbd ± 100 ppm.
- The eye height, eye width, and vertical eye closure are as specified in section 109B.3.2.1 of the IEEE specification, for a PHY that includes an RS-FEC sublayer.
- The clock recovery unit corner frequency is 4 MHz.

Main Voltage Measurements TP4

The Main Voltage measurement procedures described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

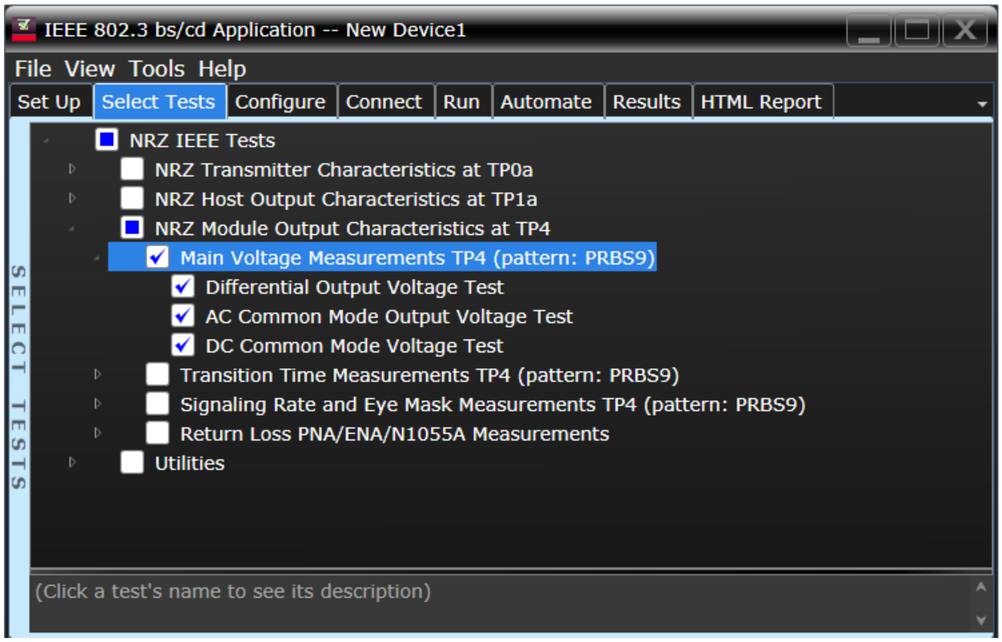


Figure 32 Selecting Main Voltage Measurement Tests

Refer to Table 12 for information on the pass limits for each test.

To know about the measurement algorithm for each Main Voltage Measurements TP4 (pattern: PRBS9) tests, see:

- "Differential Output Voltage Test" on page 217
- "AC Common Mode Output Voltage Test" on page 218
- "DC Common Mode Voltage Test" on page 219

Differential Output Voltage Test

Test Overview The purpose of this test is to verify that the peak-to-peak voltage of the differential signal on a PRBS9 pattern is less than 900mV.

Pass Condition Refer to Table 12.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is connected, has TX enabled and has a PRBS9 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.

AC Common Mode Output Voltage Test

Test Overview The purpose of this test is to verify that the common-mode voltage of the signal 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 12.

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 with 17.5mV.

DC Common Mode Voltage Test

Test Overview The purpose of this test is to verify that the common-mode voltage of the signal is between -350mV and 2.85V.

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

Pass Condition Refer to Table 12.

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 between -350mV and 2.85V.

Transition Time Measurements TP4

The Transition Time Measurement procedures described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

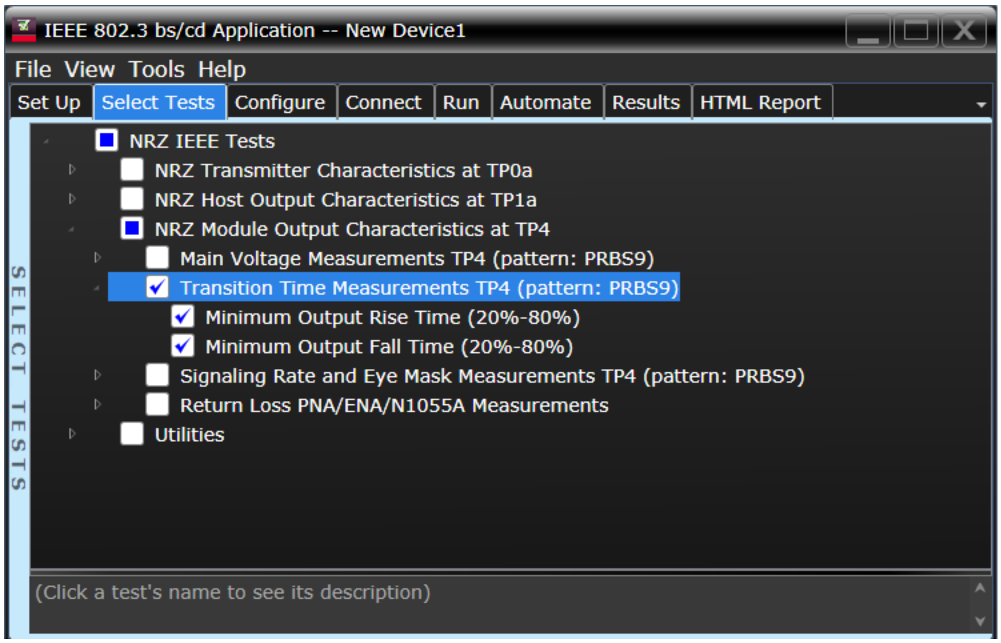


Figure 33 Selecting Transition Time Measurement Tests

Refer to Table 12 for information on the pass limits for each test.

To know about the measurement algorithm for each Transition Time Measurements TP4 (pattern: PRBS9) tests, see:

- "Minimum Output Rise Time (20%-80%)" on page 221
- "Minimum Output Fall Time (20%-80%)" on page 222

Minimum Output 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 12.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is PRBS9.
3 Find pattern 000333 for rising edge.
4 Measure rise time from 20% to 80% of the signal amplitude.
5 Compare the minimum rise time with 12ps.

Minimum Output 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 12.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Verify that the signal is PRBS9.
3 Find pattern 333000 for the falling edge.
4 Measure fall time from 20% to 80% of the signal amplitude.
5 Compare the minimum fall time with 12ps.

Signaling Rate and Eye Mask Measurements TP4

The Signaling Rate and Eye Mask Measurement procedures that are described in this section are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

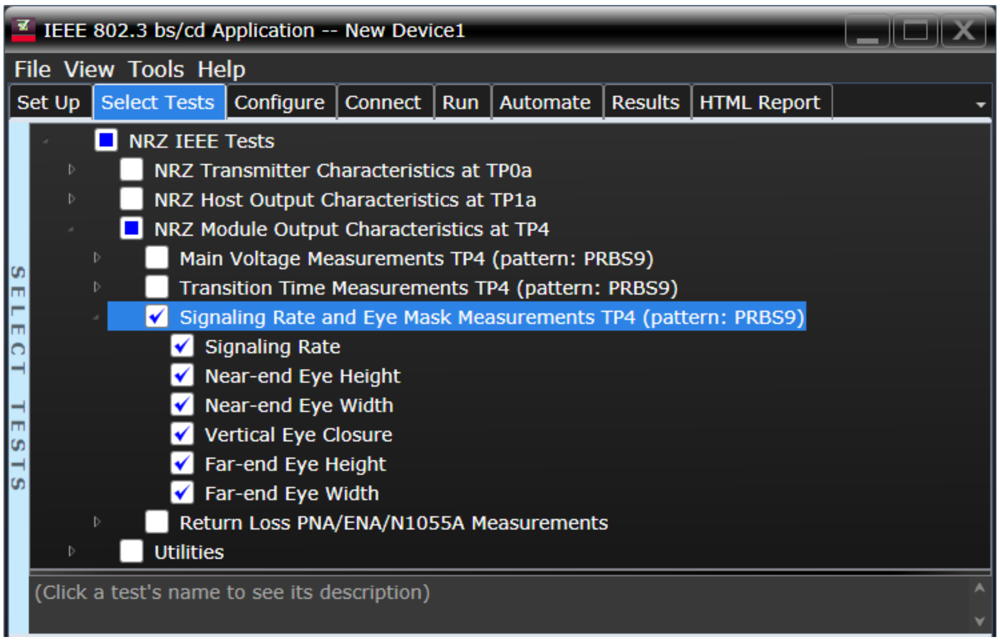


Figure 34 Selecting Eye Mask Measurement Tests

Refer to Table 12 for information on the pass limits for each test.

To know about the measurement algorithm for each Signaling Rate and Eye Mask Measurements TP4 (pattern: PRBS9) tests, see:

- “Signaling Rate” on page 224
- “Near-end Eye Height” on page 225
- “Near-end Eye Width” on page 226
- “Vertical Eye Closure” on page 227
- “Far-end Eye Height” on page 228
- “Far-end Eye Width” on page 229

Signaling Rate

Test Overview The purpose of this test is to verify that the signaling rate mean is between 26.5625 ±100ppm GBd.

Pass Condition Refer to Table 12.

Measurement Algorithm

1 Obtain sample or acquire signal data.
2 Check that the signal is connected, has a bit-rate of 53.125 GHz and that data pattern exists (PRBS9 must be used for this test).
3 In the **Configure** tab, set **Signaling Rate** to 26.5625 Gb/s.
4 Measure minimum, maximum and mean data rate.
5 Report minimum and maximum values.
6 Compare the mean data rate value with 26.5625 ±100ppm GBd.
7 Report the resulting value.

Near-end Eye Height

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 228mV.

Pass Conditions Refer to Table 12.

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 Measure the Near-end Eye Height at an **Eye Height/Width Probability** setting of 1E-5.

4 On the Oscilloscope,
   a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4 MHz.
   b Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

5 Compare the Near-end Eye Height with 228mV. Report the resulting value.

Near-end Eye Width

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 570mUI.

Pass Conditions Refer to Table 12.

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. Measure the Near-end Eye Width at an **Eye Height/Width Probability** setting of 1E-5.
4. On the Oscilloscope,
   a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4 MHz.
   b Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.
5. Compare the Near-end Eye Width with 570mUI. Report the resulting value.

Vertical Eye Closure

Test Overview The purpose of this test is to verify that the Vertical Eye Closure at EH5 (1E-5) is less than 5.5 dB.

Pass Conditions Refer to Table 12.

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. Measure the Vertical Eye Closure at an **Eye Height/Width Probability** setting of 1E-5 (EH5).
4. On the Oscilloscope,
   a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4 MHz.
   b Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.
5. 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.
6. Calculate Vertical Eye Closure (VEC) using the equation:

$$VEC = 20\log(AV/EH5)$$

7. Compare the Vertical Eye Closure with 5.5 dB. Report the resulting value.

Far-end Eye Height

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 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 Measure the Far-end Eye Height at an **Eye Height/Width Probability** setting of 1E-5.
4 On the Oscilloscope,
   a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4 MHz.
   b Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.
5 Compare the Far-end Eye Height with 30mV. Report the resulting value.

Far-end Eye Width

Test Overview The purpose of this test is to measure the Far-end Eye Width for a defined range of CTLE settings.

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

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 Measure the Far-end Eye Width at an **Eye Height/Width Probability** setting of 1E-5.

4 On the Oscilloscope,
   a set the Clock Recovery to OJTF First Order PLL with Nominal Data Rate (26.5625 Gbps) and Loop Bandwidth to 4 MHz.
   b Set 4^{th} Order Bessel Thompson filter to 33 GHz with 3 dB gain.

5 Report the resulting value of Far-end Eye Width.

NOTE The Far-end Eye Width measurement is considered as an “Information-Only” test and cannot be used for compliance validation.

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 DCA oscilloscope along with either a PNA, ENA or an N1055A and the N1091BSCB 400G IEEE FlexDCA Compliance 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 device is calibrated.

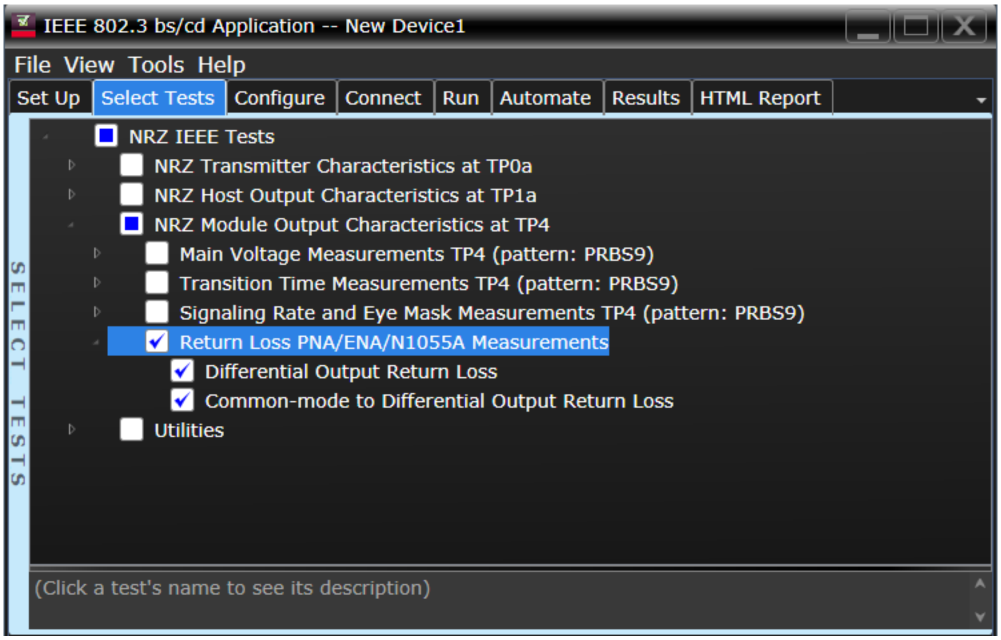


Figure 35 Selecting Return Loss Measurement Tests

Refer to Table 12 for information on the pass limits for each test.

To know about the measurement algorithm for each Return Loss PNA/ENA/N1055A Measurements tests, see:

- "Differential Output Return Loss" on page 231
- "Common-mode to Differential Output Return Loss" on page 232

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 to 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.

10 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” or “Find Optimal Far-end CTLE Eye Opening” (for Far-end tests) to determine the correct CTLE value to use in subsequent eye height and eye width tests.
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.

KEYSIGHT TECHNOLOGIES

Utilities in IEEE Tests

The procedure described in this section to find Optimal CTLE Eye Opening are performed using a Keysight DCA oscilloscope and the N1091BSCB 400G IEEE FlexDCA Compliance Application.

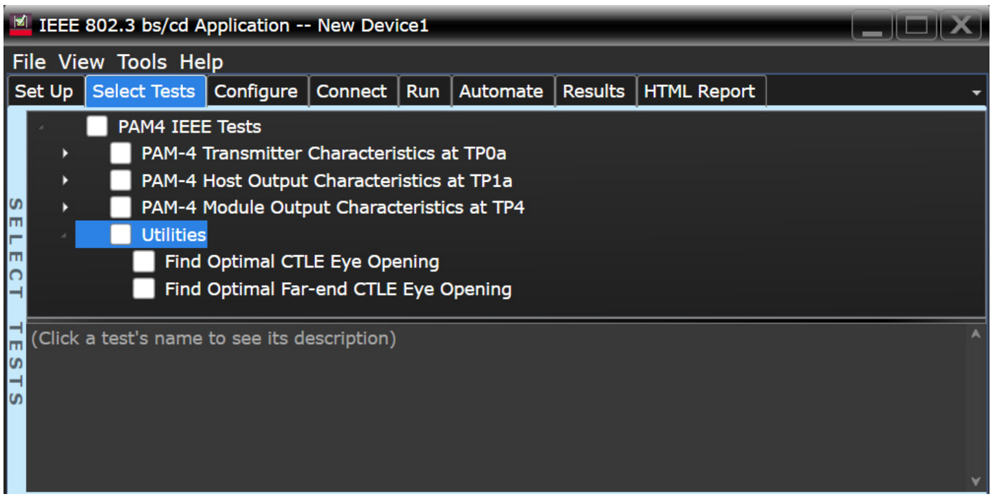


Figure 36 Selecting Utilities under the Select Tests tab

NOTE

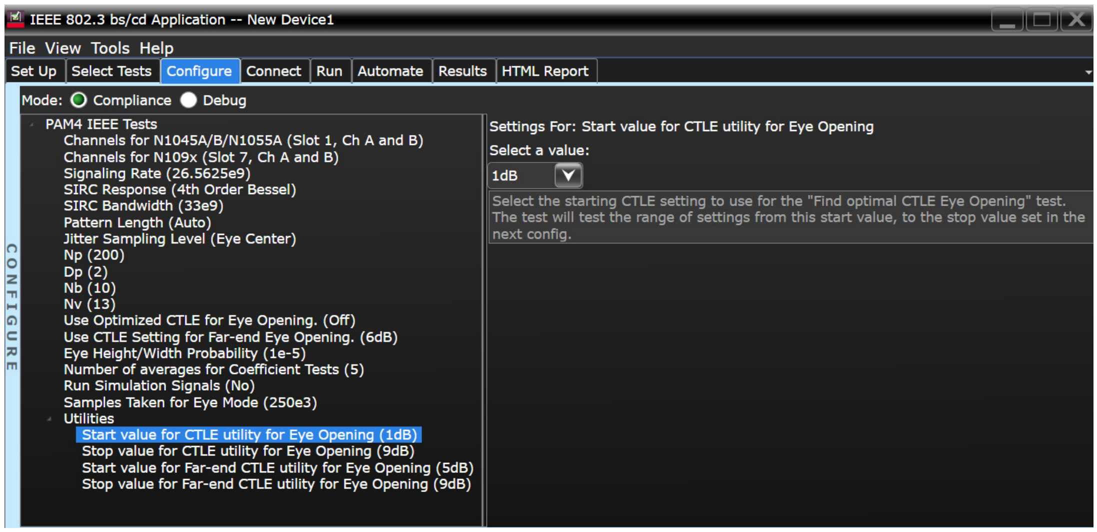
The test group **Utilities**, which contains the **Find Optimal CTLE Eye Opening** test, is available for each combination of **Standard Option** and **Signal Type** under the **Set Up** tab. This chapter describes the procedure for the option **200GAUI-x and 400GAUI-x**, **NRZ** signals only. However, you can apply the same procedure for the rest of the combinations as well.

Find Optimal CTLE Eye Opening

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.

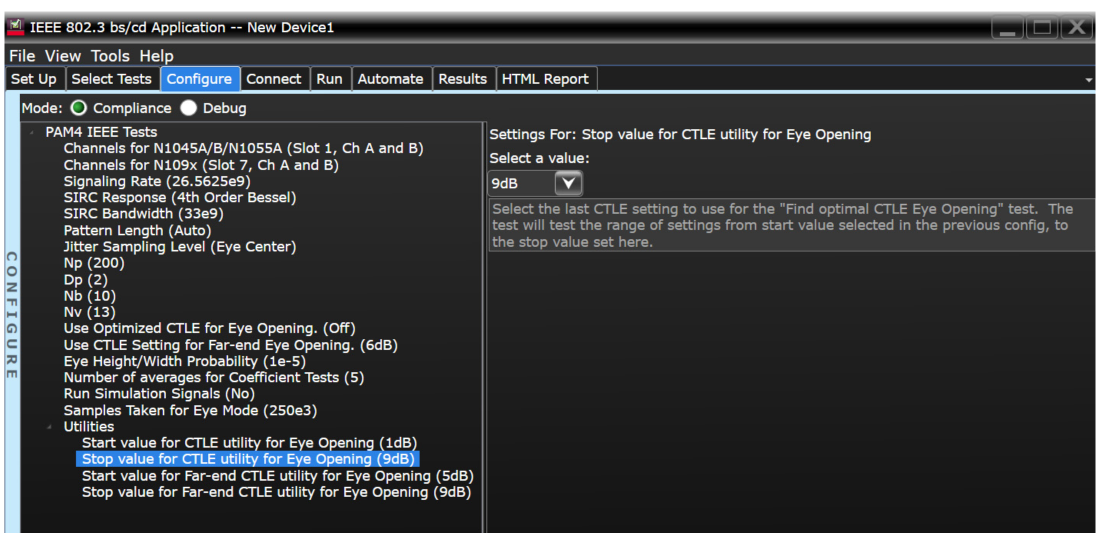
3 Set memory depth to capture 1 million UI.

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 33 GHz with 3 dB gain.

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.



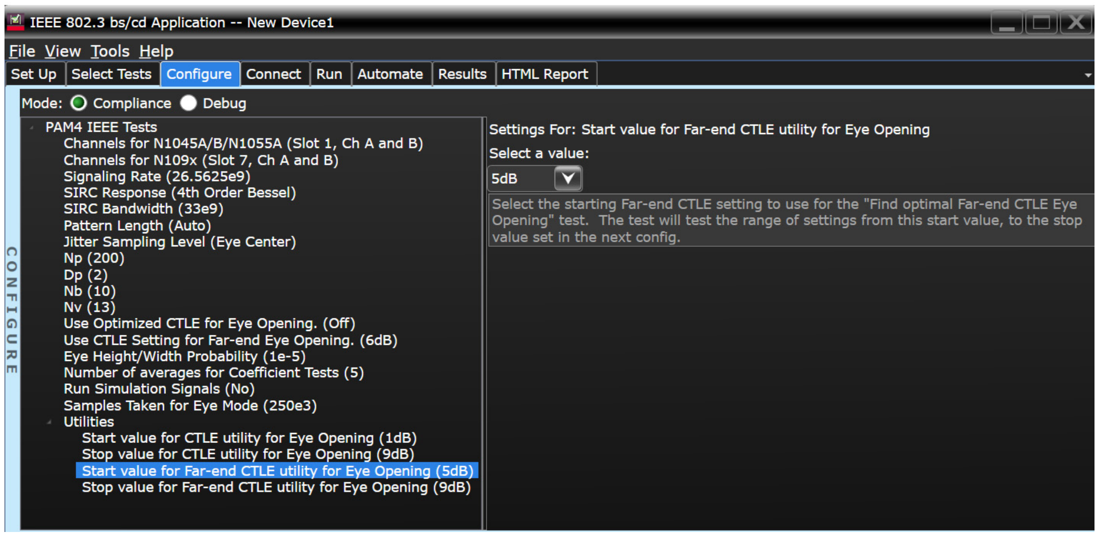
8 Report the CTLE setting with the largest eye area. The Application automatically changes the configured CTLE setting to the optimal value.

Find Optimal Far-end CTLE Eye Opening

Test Overview The purpose of this test is to loop through Far-end CTLE settings to find the optimal Far-end 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 Far-end CTLE utility for Eye Opening** in the **Configure** tab.



2 Add Far-end channel tf4.

3 Obtain or acquire signal data.

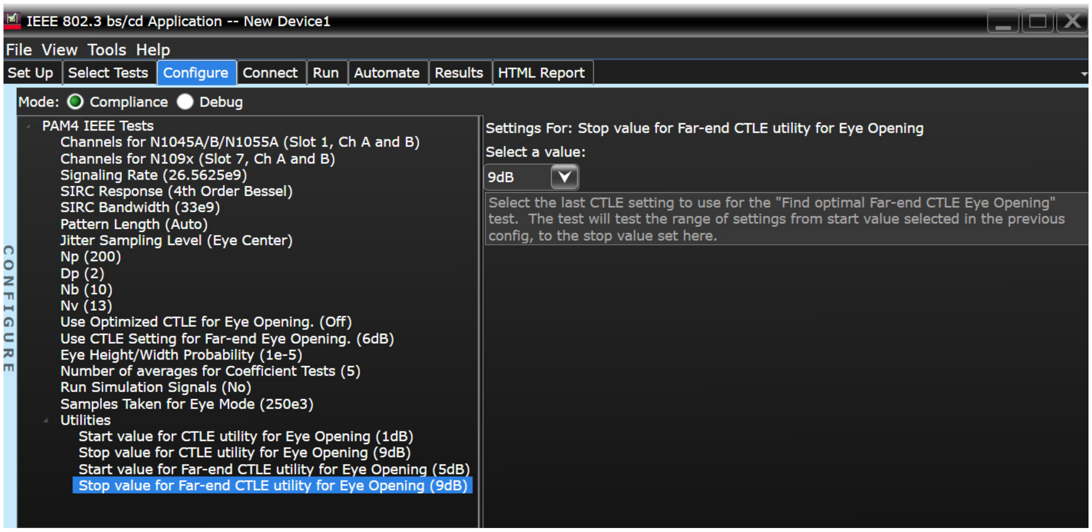
4 Set memory depth to capture 1 million UI.

5 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 33 GHz with 3 dB gain.

6 Measure Eye Height and Eye Width.

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

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



9 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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