Granite River Labs

Serial Attached SCSI (SAS-4) 22.5 Gb/s Specification Transmitter Test Automation Software

Physical Layer User Guide/Method of Implementation (MOI)

Using

GRL-SAS4-TX Automation Software

with

Teledyne LeCroy High Performance Real-Time Oscilloscope

Published on 14 October 2022

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1 Introduction

This MOI & User Guide provides information on using the GRL-SAS4-TX automation software to set up and test an electrical transmitter (Tx) device for Serial Attached SCSI (SAS-4) standard certification for the 22.5 Gb/s data rate.

The SAS-4 Tx tests in the GRL-SAS4-TX software are implemented based on the SAS-4 Specifications Standard, Revision 9. These tests are used to verify if a Device Under Test (DUT) complies with the transmitter requirements defined in the SAS-4 specification.

The GRL-SAS4-TX software provides automation control for performing SAS-4 based 22.5 Gbit/s signalling tests to evaluate the SAS-4 physical layer functionality for Tx device electrical compliance. The software also supports compatibility for previous SAS physical layer Tx versions. When combined with a satisfactory level of interoperability testing, these tests provide a reasonable level of confidence that the DUT will function properly in most SAS environments.

The GRL-SAS4-TX software performs test automation using the Teledyne LeCroy high performance real-time oscilloscope along with a compliant SAS-4 test fixture in the test setup.

Note: For manual test methodology, refer to Appendix of this MOI & User Guide or approved vendor-specific MOI's as technical reference.

2 Resource Requirements

Note: Equipment requirements may vary according to the lab setup and DUT type. Below are the recommended lists of equipment for the typical test setup.

2.1 Equipment Requirements

TABLE 1. EQUIPMENT REQUIREMENTS – SYSTEMS

System	Qty.	Description/Key Specification Requirement
GRL-SAS4-TX	1	Granite River Labs SAS-4 (22.5 Gb/s) Transmitter Compliance Test Automation Software – www.graniteriverlabs.com *– with Node Locked License to single Oscilloscope/PC OS*
Teledyne LeCroy High Performance Real-Time Oscilloscope [a]	1	≥ 33 GHz bandwidth with Windows 7+ OS (for 22.5 Gb/s) [b]
VISA (Virtual Instrument Software Architecture) API Software	1	VISA Software is required to be installed on the host PC running GRL-SAS4-TX software.
Computer	1	Laptop or desktop PC running Windows 7+ OS for automation control

[a] The Teledyne LeCroy oscilloscope requires scope software such as the SDAIII analysis tool to be used for testing and signal processing which must be pre-installed on the Scope.

[b] Oscilloscope with scope bandwidth as specified in vendor specific MOI's.

TABLE 2. EQUIPMENT REQUIREMENTS – ACCESSORIES

Accessory	Qty.	Description	Key Specification Requirement
SAS-4 Test Fixture	1	*– DUT connector type dependent*	Meets the Zero-Length Test Load requirements of the SAS-4 Specification
SMA Cables		*– DUT connector type and test configuration dependent*	
DC Block	1 pair		
50 Ω Terminator	1 pair		

2.2 Software Requirements

TABLE 3. SOFTWARE REQUIREMENTS

Software	Source
GNU Octave 4.0.0	Download from https://octave.org/download Refer to Appendix of this MOI & User Guide on the Octave 4.0.0 installation procedure.

3 Setting Up GRL-SAS4-TX Automation Software

This section provides the procedures to start up and pre-configure the GRL-SAS4-TX automation software before running tests. It also helps users familiarize themselves with the basic operation of the software.

Note: The GRL software installer will automatically create shortcuts in the Desktop and Start Menu when installing the software.

To start using the GRL software, follow the procedures in the following sections.

3.1 Download GRL-SAS4-TX Software

Download and install the GRL-SAS4-TX software on a PC or an oscilloscope (where GRL-SAS4-TX is referred to as 'Controller PC' or 'Scope' respectively in this User Guide & MOI):

1. Install VISA (Virtual Instrument Software Architecture) on to the PC/Scope where GRL-SAS4-TX is to be used (see Section 2.1).
2. Download the software ZIP file package from the Granite River Labs support site.
3. The ZIP file contains:
   - **SAS4TxTestApplication00000xxxxSetup.exe** – Run this on the Controller PC or Scope to install the GRL-SAS4-TX application.
   - **SAS4_TxTestScopeSetupFilesInstallation00000xxxxSetup.exe** – Run this on the Scope to install the Scope setup files.

3.2 Launch and Set Up GRL-SAS4-TX Software

1. Once the GRL-SAS4-TX software is installed, open the **GRL** folder from the Windows Start menu. Click on **GRL – Automated Test Solutions** within the GRL folder to launch the GRL software framework.

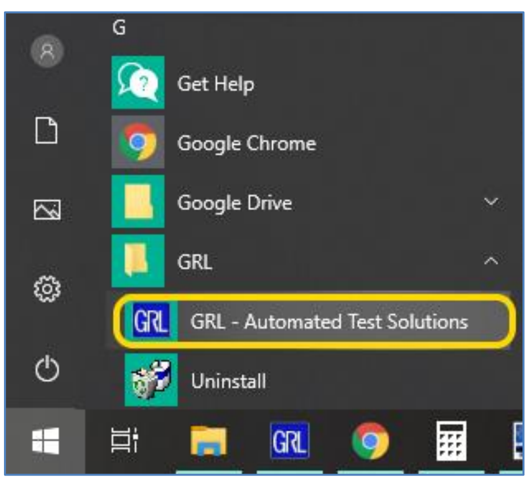


FIGURE 1. SELECT AND LAUNCH GRL FRAMEWORK

2. From the **Application → Framework Test Solution** drop-down menu, select **SAS 4 Tx Test Application** to start the SAS-4 Tx Test Application. If the selection is grayed out, it means that your license has expired.

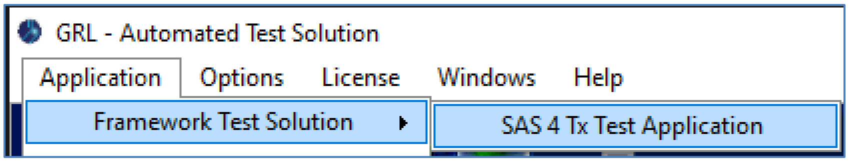


FIGURE 2. START SAS-4 TX TEST APPLICATION

3. To enable license, go to License→License Details.

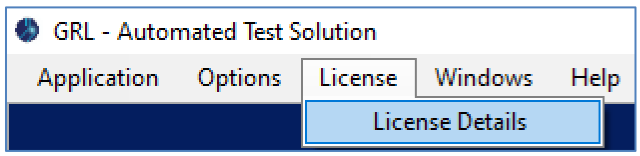


FIGURE 3. SEE LICENSE DETAILS

a) Check the license status for the installed application.

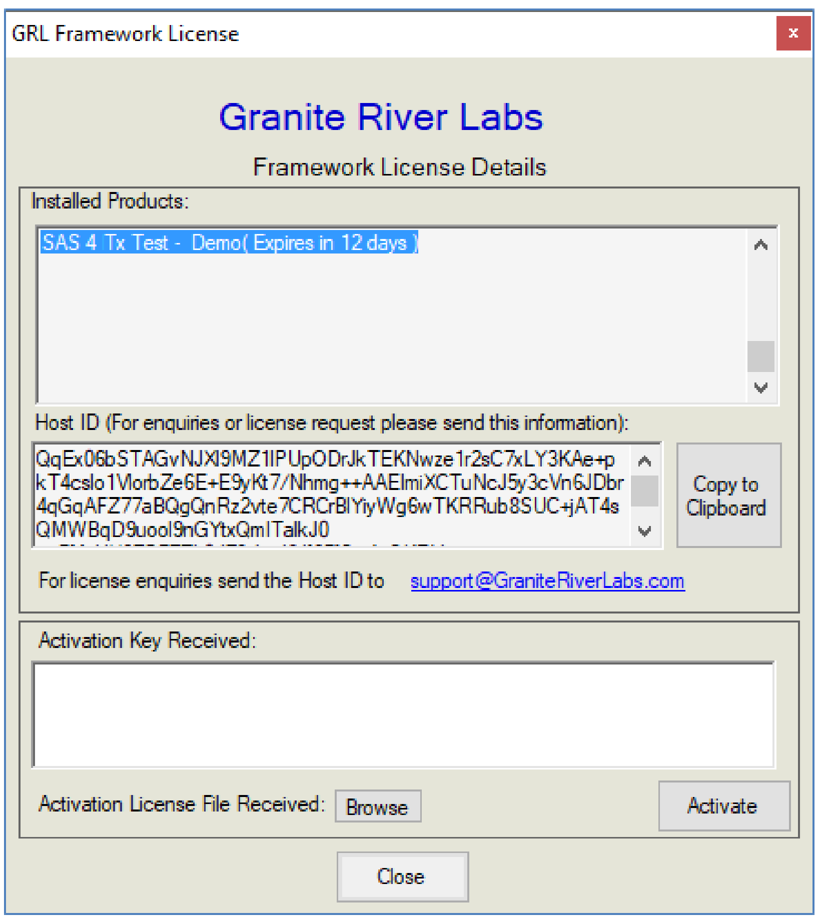


FIGURE 4. CHECK LICENSE FOR INSTALLED APPLICATIONS

b) Activate a License:

- If you have an Activation Key, enter it in the field provided and select “Activate”.
- If you do not have an Activation Key, select “Close” to use a demo version of the software over a free 12-day trial period.

Note: *Once the 12-day trial period ends, you will need to request an Activation Key to continue using the software on the same computer or oscilloscope. For Demo and Beta Customer License Keys, please request an Activation Key by contacting support@graniteriverlabs.com.*

4. Select the Equipment Setup icon on the SAS-4 Tx Test Application menu.
5. If using a controller PC to run the SAS-4 Tx Test Application, connect it to the Scope. On the GRL automation control enabled Scope or controller PC, obtain the network address for the connected instrument from the device settings. Note this address as it will be used to connect the instrument to the GRL automation software.
6. On the Equipment Setup page of the SAS-4 Tx Test Application, type in the address of the connected instrument into the ‘Address’ field. If the GRL software is installed on the PC to control the Scope, type in the Scope IP address, for example “TCPIP0::192.168.0.110::inst0::INSTR”. Note to ***omit*** the Port number from the address.
7. Select the “lightning” button ( ) for each connected instrument.

   The “lightning” button should turn green ( ) once the GRL software has successfully established connection with each instrument.

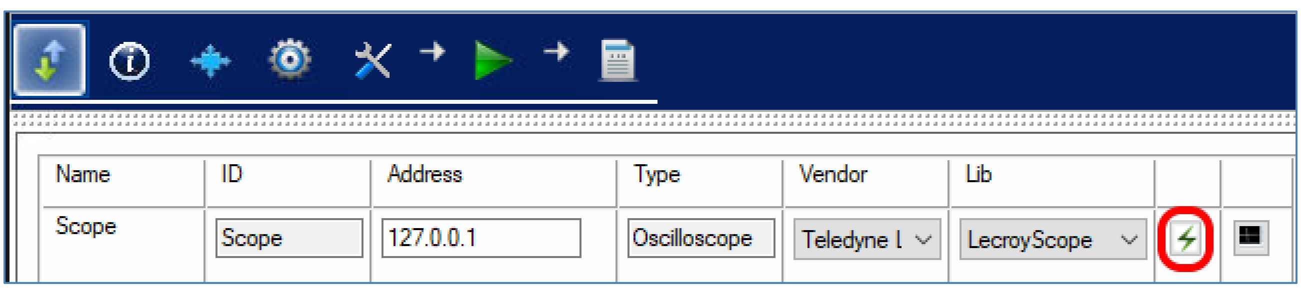


FIGURE 5. CONNECT INSTRUMENTS WITH GRL SOFTWARE

Note: Additional information for connecting the Teledyne LeCroy Scope to the PC is provided in the Appendix of this MOI & User Guide.

3.3 Pre-Configure GRL-SAS4-TX Software Before Calibration/Testing

Once all equipment is successfully connected from the previous section, proceed to set up the preliminary settings before going to the advanced measurement setup.

3.3.1 Enter Test Session Information

Select from the menu to access the **Session Info** page. Enter the information as required for the test session that is currently being run. The information provided will be included in the test report generated by the GRL software once tests are completed.

- The fields under **DUT Info** and **Test Info** are defined by the user.
- The **Software Info** field is automatically populated by the software.

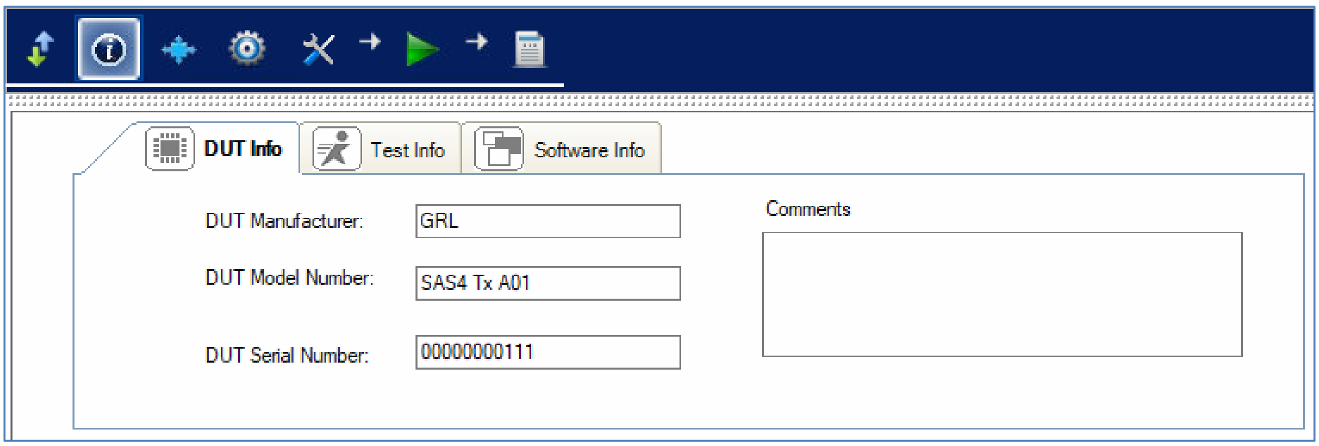


FIGURE 6. SESSION INFO PAGE

4 Compliance Testing Using GRL-SAS4-TX Software

The GRL-SAS4-TX software supports automated Tx compliance testing for the Tx DUT based on the SAS-4 Specification Standards.

The GRL software will also generate a test report detailing all results obtained from the test runs.

4.1 Set Up SAS-4 Tx DUT Test with Automation

The following procedures show how to set up the physical connections to perform automated Tx compliance testing for the DUT.

4.1.1 Connect Equipment for Zero-Length Test Load (Direct Connection)

The connection diagram below shows the recommended equipment setup to test the DUT for Zero-Length test load. The scope will be directly connected to the SAS-4 fixture.

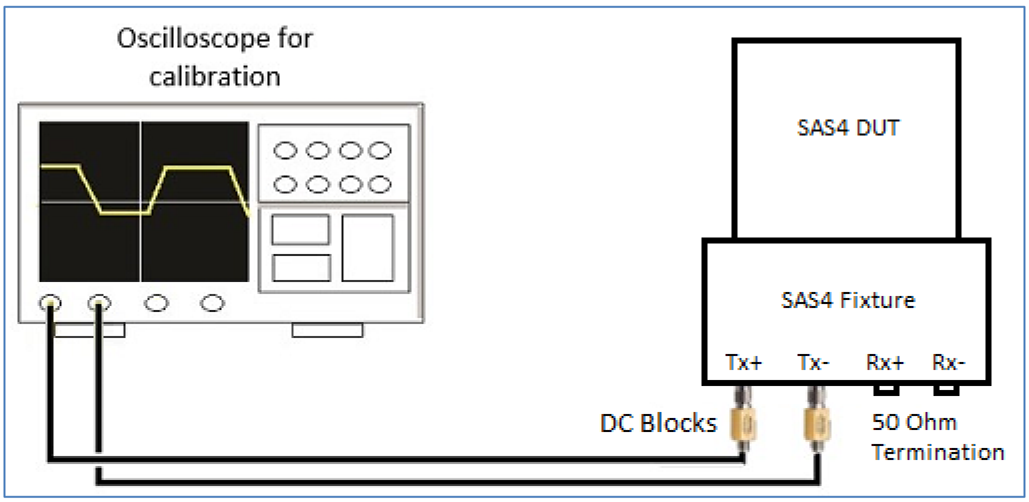


FIGURE 7. COMPLIANCE TEST SETUP FOR TX DUT ZERO-LENGTH TEST LOAD

Connection Steps:

1. Connect channel 1 of the oscilloscope to the Tx+ port of the SAS-4 fixture through a DC block.
2. Connect channel 2 of the oscilloscope to the Tx- port of the SAS-4 fixture through a DC block.
3. Terminate the Rx ports of the SAS-4 fixture that are not under test using 50 Ω terminators.
4. Connect the DUT to the SAS-4 fixture and configure the DUT to transmit the PRBS15 test patterns.

5 Configuring and Selecting Compliance Tests Using GRL-SAS4-TX Software

5.1 Set Up Compliance Test Requirements

After setting up the physical equipment, select  from the GRL SAS-4 Tx Test Application menu to access the Setup Configuration page.

Use this page to configure the necessary measurement-related settings prior to running tests.

5.1.1 SSC Tab

a) Select to enable or disable SSC Capability as supported by the DUT for testing.

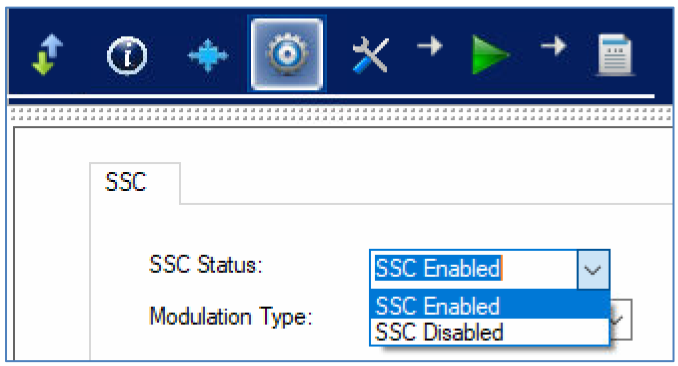


FIGURE 8. ENABLE OR DISABLE SSC

b) Select SSC center-spreading, down-spreading or no-spreading as the SSC modulation option.

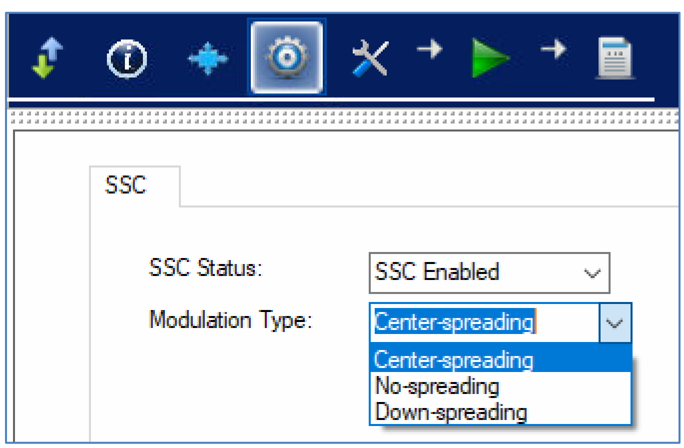


FIGURE 9. SELECT SSC MODULATION

5.2 Select Compliance Tests

After setting up compliance test requirements, go to the test selection page which allows all available Tx DUT compliance tests to be selected. Select the check boxes of the respective tests to be performed.

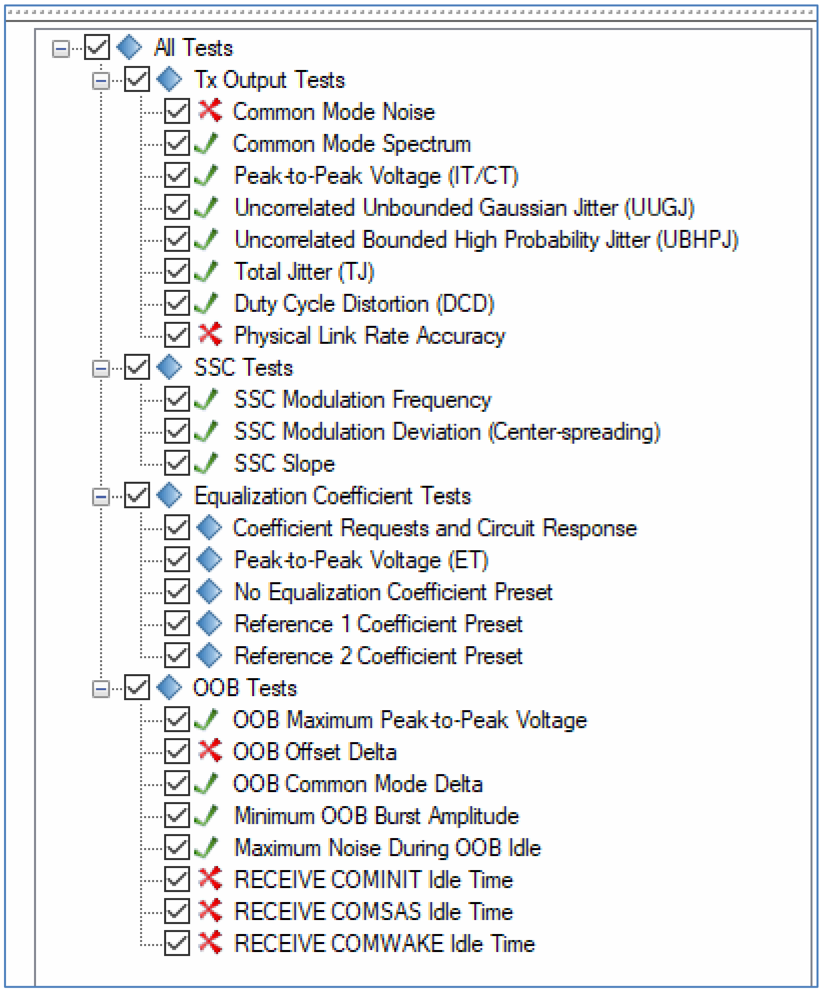


FIGURE 10. TX COMPLIANCE TEST SELECTION

Note: The marking shown on the left of each test parameter indicates the status of the test result of the parameter. In the above example, ◆ indicates that testing has not been run for the specific test parameter. When testing has been run and completed successfully for the specific test parameter with a Pass result, this will be indicated with ✓.

5.3 Compliance Test Parameters Configuration Page

Select  from the menu to access the Configurations page.

Set any of the available parameters required for measurement as described below. To return all parameters to their default values, select the 'Set Default' button.

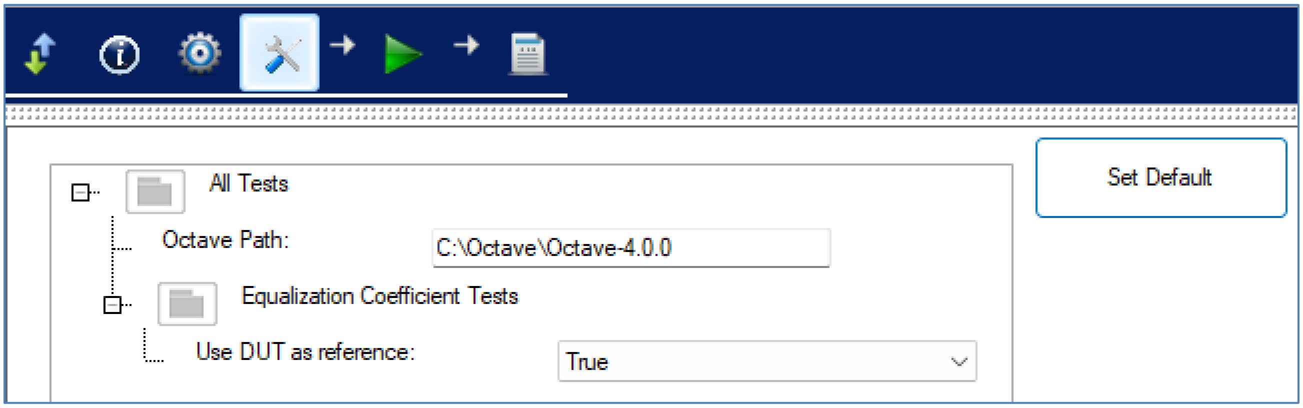


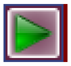
FIGURE 11. CALIBRATION/COMPLIANCE TEST PARAMETERS CONFIGURATION

TABLE 4. CALIBRATION/COMPLIANCE TEST PARAMETERS DESCRIPTION

Parameter	Description
Octave Path	Specify the Octave path to search for test script or function files.
Use DUT as reference	Select 'True' to enable the DUT to be used as reference for testing Tx coefficient requests.

6 Running Automation Tests Using GRL-SAS4-TX Software

Once calibration and tests have been selected and set up from the previous sections, they are now ready to be run.

Select  from the menu to access the Run Tests page. The GRL software automatically runs the selected calibration and tests when initiated.

Before running the tests, select the option to:

- **Skip Test if Result Exists** – If results from previous calibration/tests exist, the software will *skip* those calibration/tests, or
- **Replace if Result Exists** – If results from previous calibration/tests exist, the software will *replace* those calibration/tests with new results.

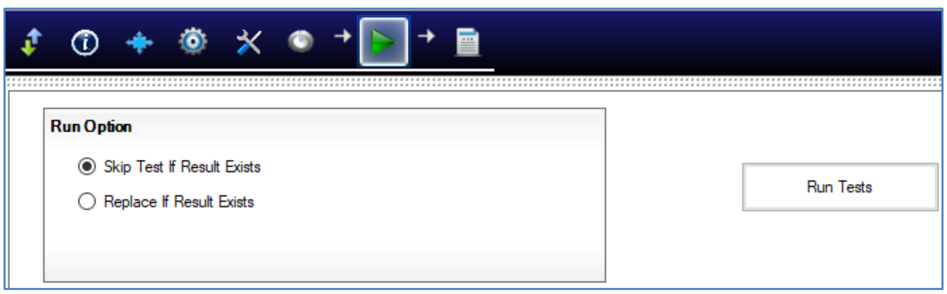


FIGURE 12. RUN TESTS PAGE

Select the **Run Tests** button to automatically start running the selected calibration and tests. At the start of a specific calibration/test, the corresponding connection diagram will initially appear to allow the user to verify with the recommended physical setup before continuing with the next step. Below shows an example of a connection diagram pop-up window.

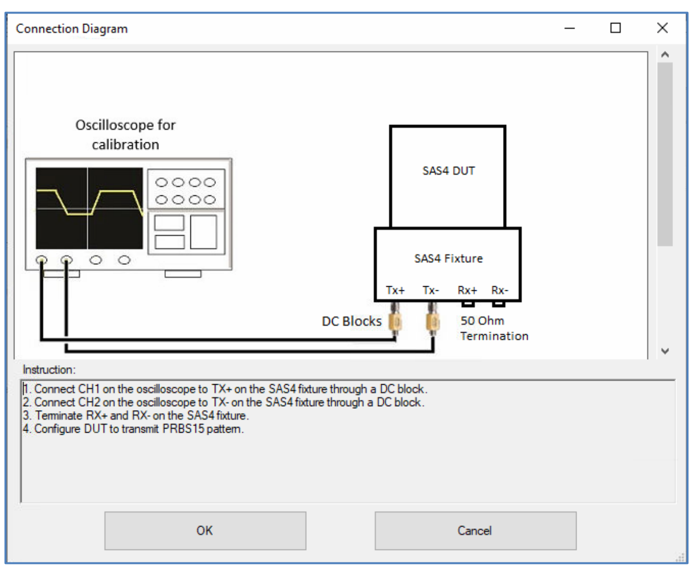


FIGURE 13. CONNECTION DIAGRAM POP-UP WINDOW EXAMPLE

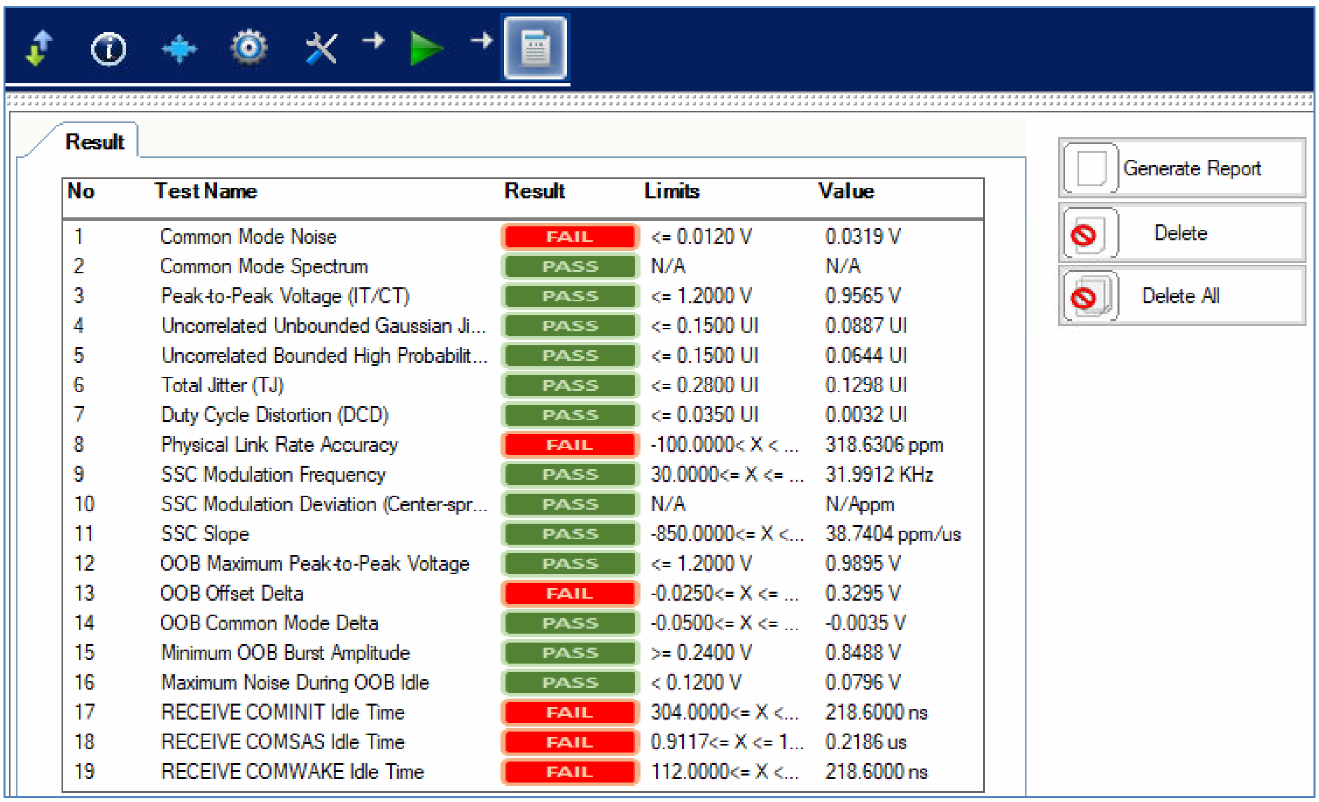
7 Interpreting GRL-SAS4-TX Test Report

When all calibration and test runs have completed from the previous section, the GRL-SAS4-TX software will automatically display the results on the **Report** page.

Select from the menu to access the Report page for a quick view of all results.

If some of the results are not desired, they can be individually deleted by selecting the **Delete** button.

For a detailed test report, select the **Generate report** button to generate a PDF report.



No	Test Name	Result	Limits	Value
1	Common Mode Noise	FAIL	<= 0.0120 V	0.0319 V
2	Common Mode Spectrum	PASS	N/A	N/A
3	Peak-to-Peak Voltage (IT/CT)	PASS	<= 1.2000 V	0.9565 V
4	Uncorrelated Unbounded Gaussian Ji...	PASS	<= 0.1500 UI	0.0887 UI
5	Uncorrelated Bounded High Probabilit...	PASS	<= 0.1500 UI	0.0644 UI
6	Total Jitter (TJ)	PASS	<= 0.2800 UI	0.1298 UI
7	Duty Cycle Distortion (DCD)	PASS	<= 0.0350 UI	0.0032 UI
8	Physical Link Rate Accuracy	FAIL	-100.0000< X < ...	318.6306 ppm
9	SSC Modulation Frequency	PASS	30.0000<= X <= ...	31.9912 KHz
10	SSC Modulation Deviation (Center-spr...	PASS	N/A	N/Appm
11	SSC Slope	PASS	-850.0000<= X <...	38.7404 ppm/us
12	OOB Maximum Peak-to-Peak Voltage	PASS	<= 1.2000 V	0.9895 V
13	OOB Offset Delta	FAIL	-0.0250<= X <= ...	0.3295 V
14	OOB Common Mode Delta	PASS	-0.0500<= X <= ...	-0.0035 V
15	Minimum OOB Burst Amplitude	PASS	>= 0.2400 V	0.8488 V
16	Maximum Noise During OOB Idle	PASS	< 0.1200 V	0.0796 V
17	RECEIVE COMINIT Idle Time	FAIL	304.0000<= X <...	218.6000 ns
18	RECEIVE COMSAS Idle Time	FAIL	0.9117<= X <= 1...	0.2186 us
19	RECEIVE COMWAKE Idle Time	FAIL	112.0000<= X <...	218.6000 ns

FIGURE 14. TEST REPORT PAGE

7.1 Understand Test Report Information

This section gives a general overview of the test report to help users familiarize themselves with the format. Select the **Generate report** button to generate the test report.

7.1.1 Test Session Information

This portion displays the information previously entered on the **Session Info** page.

SAS 4 Tx Test Application Report

DUT Information

DUT Manufacturer	:	GRL
DUT Model Number	:	SAS4 Tx A01
DUT Serial Number	:	00000000111
DUT Comments	:	

Test Information

Test Lab	:	Granite River Labs
Test Operator	:	John
Test Date	:	29 July 2022

Software Version

Software Revision	:	0.0.1

FIGURE 15. TEST SESSION INFORMATION EXAMPLE

7.1.2 Test Summary Table

This table provides an overall view of all the calibration and tests performed along with their conditions and results.

No	TestName	Limits	Value	Results
1	Common Mode Noise	<= 0.0120 V	0.0319 V	Fail
2	Common Mode Spectrum	N/A	N/A	Pass
3	Peak-to-Peak Voltage (IT/CT)	<= 1.2000 V	0.9565 V	Pass
4	Uncorrelated Unbounded Gaussian Jitter (UUGJ)	<= 0.1500 UI	0.0887 UI	Pass
5	Uncorrelated Bounded High Probability Jitter (UBHPJ)	<= 0.1500 UI	0.0644 UI	Pass
6	Total Jitter (TJ)	<= 0.2800 UI	0.1298 UI	Pass
7	Duty Cycle Distortion (DCD)	<= 0.0350 UI	0.0032 UI	Pass
8	Physical Link Rate Accuracy	-100.0000< X < 100.0000 ppm	318.6306 ppm	Fail
9	SSC Modulation Frequency	30.0000<= X <= 33.0000 KHz	31.9912 KHz	Pass
10	SSC Modulation Deviation (Center-spreading)	N/A	N/Appm	Pass
11	SSC Slope	-850.0000<= X <= 850.0000 ppm/us	38.7404 ppm/us	Pass
12	OOB Maximum Peak-to-Peak Voltage	<= 1.2000 V	0.9895 V	Pass
13	OOB Offset Delta	-0.0250<= X <= 0.0250 V	0.3295 V	Fail
14	OOB Common Mode Delta	-0.0500<= X <= 0.0500 V	-0.0035 V	Pass
15	Minimum OOB Burst Amplitude	>= 0.2400 V	0.8488 V	Pass
16	Maximum Noise During OOB Idle	< 0.1200 V	0.0796 V	Pass
17	RECEIVE COMINIT Idle Time	304.0000<= X <= 336.0000 ns	218.6000 ns	Fail
18	RECEIVE COMSAS Idle Time	0.9117<= X <= 1.0080 us	0.2186 us	Fail
19	RECEIVE COMWAKE Idle Time	112.0000<= X <= 101.3000 ns	218.6000 ns	Fail

FIGURE 16. TEST SUMMARY TABLE EXAMPLE

7.1.3 Test Results

This portion displays the results in detail along with supporting data points and screenshots for each calibration/test run.

9. SSC Modulation Frequency

Pass/Fail Stats	:	Pass
Test Limits	:	30.0000<= X <= 33.0000 KHz
Result	:	31.9912 KHz
Test completed time	:	20 July 2022 2:01:31 AM

SSC Modulation Frequency

FIGURE 17. TEST RESULTS EXAMPLE

7.2 Delete Test Results

To individually delete any unwanted calibration/test results, select the corresponding result row and **Delete** button.

To entirely remove all existing calibration/test results, select the **Delete All** button.

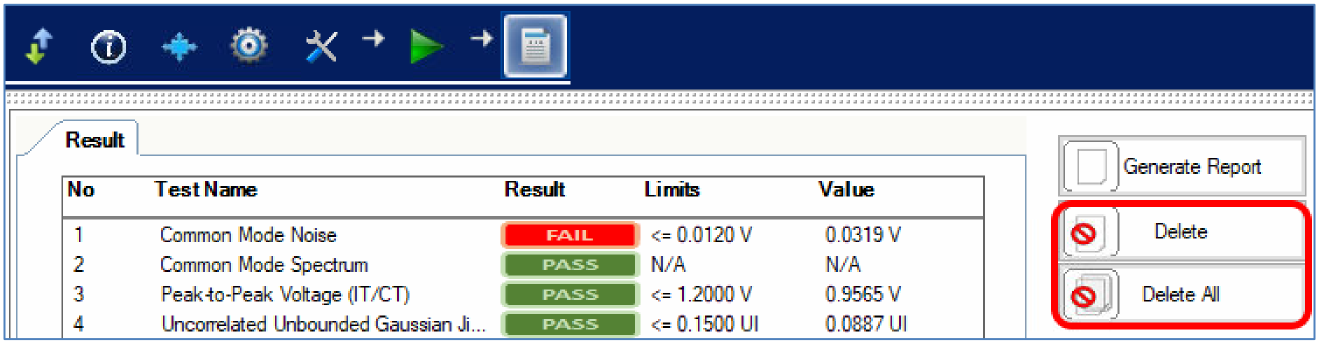


FIGURE 18. TEST REPORT DELETED

8 Saving and Loading GRL-SAS4-TX Test Sessions

The usage model for the GRL-SAS4-TX software is that the test results are created and maintained as a 'Live Session' in the application. This allows the user to quit the application and return later to continue where the user left off.

Save and Load Sessions are used to save a test session that the user may want to recall later. The user can 'switch' between different sessions by saving and loading them when needed.

- To ***save a test session***, with all of the test parameter information, test results, and any waveforms, select the Options drop-down menu and then select 'Save Session'.
- To ***load a test session*** back into the application, including the saved test parameter settings, select Options → 'Load Session'.
- To ***create a new test session*** and return the application back to the default configuration, select Options → 'New Session'.

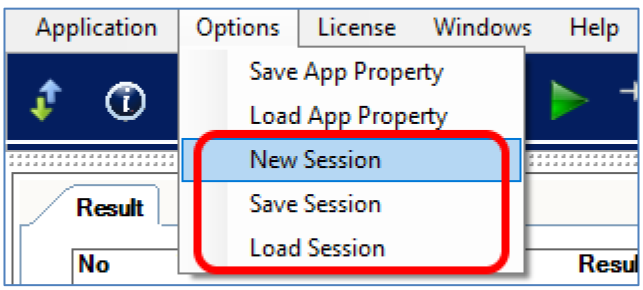


FIGURE 19. SAVE/LOAD/CREATE TEST SESSIONS

The test configuration and session results are saved in a file with the '.ses' extension, which is a compressed zip-style file, containing a variety of information.

9 Appendix A: Method of Implementation (MOI) for Manual SAS-4 Tx Measurements

This section provides the manual SAS-4 22.5G Tx compliance test methodology based on the SAS-4 Specifications Standard, Revision 9.

9.1 SAS-4 Tx Test Connection Setup

Refer to Figure 7 to view the equipment setup for the Zero-Length Test Load test case.

9.2 SAS-4 Tx Compliance Test Procedure

9.2.1 OOB Tests

9.2.1.1 Maximum Peak-to-Peak Voltage

References: SAS-4 Specification, Table 66

Steps:

1. Set up the DUT to source for valid OOB signaling.
2. Capture a single SAS OOB burst waveform.
3. Determine the maximum OOB burst amplitude.

9.2.1.2 OOB Offset Delta

References: SAS-4 Specification, Table 66

Steps:

1. Set up the DUT to source for valid OOB signaling.
2. Capture a single SAS OOB burst waveform.
3. Determine the OOB offset delta as follows:

   Offset Delta = avg(Burst) − avg(Idle)

   where Average(burst) is calculated by extracting a single UI of the OOB waveform and calculating the average of the samples. Average of idle is assumed to be 0 since the setup should be connected using DC blocks.

9.2.1.3 OOB Common Mode Delta

References: SAS-4 Specification, Table 66

Steps:

1. Set up the DUT to source for valid OOB signaling.
2. Capture a single common mode SAS OOB burst waveform.

   Common mode = (pos + neg) / 2

3. Determine the OOB common mode delta as follows:

$$\text{Common Mode Delta} = \text{avg(Common Mode Burst)} - \text{avg(Common Mode Idle)}$$

where Average(burst) is calculated by extracting a single UI of the OOB common mode waveform and calculating the average of the samples. Average of idle is assumed to be 0 since the setup should be connected using DC blocks.

9.2.1.4 Minimum OOB Burst Amplitude

References: SAS-4 Specification, Table 66

Steps:

1. Set the scope bandwidth to 4.5 GHz.
2. Set up the DUT to source for valid OOB signaling.
3. Capture a single SAS OOB burst waveform.
4. Determine the minimum peak amplitude of each of the cycle in the OOB burst.

9.2.1.5 Maximum Noise During OOB Idle

References: SAS-4 Specification, Table 42

Steps:

1. Set the scope bandwidth to at least 33.75 GHz (22.5 x 1.5).
2. Set up the DUT to source for valid OOB signaling.
3. Capture a single SAS OOB Idle waveform.
4. Determine the start and end of the Idle period and calculate the maximum differential noise for the Idle period.

9.2.1.6 RECEIVE COMINIT Idle Time

References: SAS-4 Specification, Table 94

Steps:

1. Set up the DUT to source for valid COMINIT OOB signaling.
2. Capture a single cycle of the COMINIT OOB waveform.
3. Process the waveform to determine the idle time.

9.2.1.7 RECEIVE COMSAS Idle Time

References: SAS-4 Specification, Table 94

Steps:

1. Set up the DUT to source for valid COMSAS OOB signaling.
2. Capture a single cycle of the COMSAS OOB waveform.
3. Process the waveform to determine the idle time.

9.2.1.8 RECEIVE COMWAKE Idle Time

References: SAS-4 Specification, Table 94

Steps:

1. Set up the DUT to source for valid COMWAKE OOB signaling.
2. Capture a single cycle of the COMWAKE OOB waveform.
3. Process the waveform to determine the idle time.

9.2.2 SSC Tests

9.2.2.1 SSC Modulation Frequency

References: SAS-4 Specification, Section 5.6.8.1

Steps:

1. Set up the DUT to transmit a 1010 pattern.
2. Capture the differential signal.
3. Generate the SSC profile as follows:
   a) Set up TIE measurement on a differential signal
   b) Set up a Trend plot on the signal in (a).
   c) Use a 200 kHz 4th Order Butterworth LP filter to produce a smooth straight line to simplify the frequency measurement.
4. Measure the frequency on at least 10 cycles of the SSC profile.

9.2.2.2 SSC Modulation Deviation and Balance

References: SAS-4 Specification, Table 86

Steps:

1. Set up the DUT to transmit a 1010 pattern.
2. Capture the differential signal.
3. Generate the SSC profile as follows:
   a) Set up TIE measurement on a differential signal
   b) Set up a Trend plot on the signal in (a).
   c) Use a 3.7 MHz 2nd Order Butterworth LP filter.
4. Measure deviation of the SSC profile (min/max values of each cycle of the SSC profile over a minimum of 10 cycles). Compute as follows:

   Min Deviation = Center Frequency − Min Frequency

   Max Deviation = Max Frequency − Center Frequency
5. If the DUT supports center-spreading, compute the SSC balance as follows:

   SSC Balance = abs (min deviation − max deviation)

9.2.2.3 SSC DFDT (Informative)

References: SAS-4 Specification, Section 5.8.6.1

Steps:

1. Set up the DUT to transmit a 1010 pattern.
2. Capture the differential signal.
3. Generate the SSC profile as follows:
    a) Set up frequency measurement on a differential signal
    b) Set up a Trend plot on the signal in (a).
    c) Use a 3.7 MHz 2nd Order Butterworth LP filter.
4. Measure DFDT of the SSC profile as defined in Specification:

    slope = (f(t) – f(t – 0.27 μs)) / 0.27 μs

    where f(t) refers to the SSC frequency deviation in ppm
5. To obtain multiple data points, generate a running DFDT window and determine the average and maximum.

9.2.3 Transmitter Signal Output Tests

9.2.3.1 Physical Link Rate Long Term Stability

References: SAS-4 Specification, Table 44

Steps:

1. Set up the DUT to transmit a 1010 pattern.
2. Capture a minimum of 1e6 UI of the differential signal.
3. Generate the frequency trend as follows:
    a) Measure frequency on the captured signal.
    b) Use the Mean value as the compliance value.
4. Determine the Maximum and Minimum of the frequency trend.

9.2.3.2 Common Mode RMS Voltage

References: SAS-4 Specification, Table 61

Steps:

1. Set up the DUT to transmit a PRBS15 pattern.
2. Capture the Common Mode signal.
3. Measure the Common Mode RMS voltage.

9.2.3.3 Common Mode Spectrum

References: SAS-4 Specification, Figure 168

Steps:

1. Set up the DUT to transmit a PRBS15 pattern.
2. Capture the Common Mode signal.
3. Plot the Common Mode Spectrum.

9.2.3.4 Peak-to-Peak Voltage, IT/CT

References: SAS-4 Specification, Table 61

Steps:

1. Set up the DUT to transmit the 7Eh (D30.3) test pattern.
2. Capture the differential signal.
3. Measure the Peak-to-Peak voltage.

9.2.3.5 Total Jitter

References: SAS-4 Specification, Table 61

Steps:

1. Set up the Scope to use the JTF that meets the requirements.
    a) If SSC is not supported, use a 1st order PLL (20 dB/decade)
    b) If SSC is supported, use a 2nd order PLL (40 dB/decade).
2. Set up the DUT to transmit a repeating 1100 pattern.
3. Capture the waveform and measure TJ at 1e-12 and extrapolate to 1e-15.

9.2.3.6 Uncorrelated Unbounded Gaussian Jitter (UUGJ)

References: SAS-4 Specification, Table 61

Steps:

1. Set up the Scope to use the JTF that meets the requirements.
    a) If SSC is not supported, use a 1st order PLL (20 dB/decade)
    b) If SSC is supported, use a 2nd order PLL (40 dB/decade).
2. Set up the DUT to transmit a repeating 1100 pattern.
3. Capture the waveform and compute UUGJ as follows:

    UUGJ = 14 * RJ(rms)

9.2.3.7 Uncorrelated Bounded High Probability Jitter (UBHPJ)

References: SAS-4 Specification, Table 61

Steps:

1. Set up the Scope to use the JTF that meets the requirements.
   a) If SSC is not supported, use a 1st order PLL (20 dB/decade)
   b) If SSC is supported, use a 2nd order PLL (40 dB/decade).
2. Set up the DUT to transmit a repeating 1100 pattern.
3. Capture the waveform and compute UBHPJ as follows:

   UBHPJ = 2*√2 * PJrms + DCD

9.2.3.8 Duty Cycle Distortion

References: SAS-4 Specification, Table 61

Steps:

1. Set up the Scope to use the JTF that meets the requirements.
   a) If SSC is not supported, use a 1st order PLL (20 dB/decade)
   b) If SSC is supported, use a 2nd order PLL (40 dB/decade).
2. Set up the DUT to transmit a repeating 1010 pattern.
3. Capture the waveform and measure Duty Cycle Distortion.

9.2.4 Equalization Coefficient Tests

9.2.4.1 Coefficient Requests and Circuit Response

References: SAS-4 Specification, Table 55

Steps:

1. Set up the DUT to transmit the PRBS15 pattern with no equalization and SSC disabled.
2. Capture the output waveform from the DUT.
3. Set up the DUT to transmit the PRBS15 pattern with default equalization (either no equalization, reference 1 equalization or reference 2 equalization) and SSC disabled.
4. Capture the output waveform from the DUT.
5. Set up the DUT to transmit the PRBS15 pattern with the user selected Tx Coefficient Request and SSC disabled.
6. Capture the output waveform from the DUT.
7. Process the waveform data using the “SAS3_EYEOPENING MATLAB” script.
8. Record the output of the script.
9. Verify the values of VHL Delta, V1 Delta, V2 Delta and V3 Delta.

9.2.4.2 Peak-to-Peak Voltage, ET

References: SAS-4 Specification, Table 61

Steps:

1. Set up the DUT to transmit the PRBS15 pattern with no equalization and SSC disabled.
2. Capture the output waveform from the DUT.
3. Process the waveform data using the “SAS3_EYEOPENING MATLAB” script.
4. Record the output of the script.

9.2.4.3 No Equalization Coefficient Preset

References: SAS-4 Specification, Table 56

Steps:

1. Set up the DUT to transmit the PRBS15 pattern with no equalization and SSC disabled.
2. Capture the output waveform from the DUT.
3. Process the waveform data using the “SAS3_EYEOPENING MATLAB” script.
4. Record the output of the script.
5. Compute R_{pre} and R_{post} with the values obtained from the script as follows:

$$R_{pre} = \frac{v_3}{v_2}$$

$$R_{post} = \frac{v_1}{v_2}$$

9.2.4.4 Reference 1 Coefficient Preset

References: SAS-4 Specification, Table 56

Steps:

1. Set up the DUT to transmit the PRBS15 pattern with Reference 1 equalization and SSC disabled.
2. Capture the output waveform from the DUT.
3. Process the waveform data using the “SAS3_EYEOPENING MATLAB” script.
4. Record the output of the script.
5. Compute R_{pre} and R_{post} with the values obtained from the script as follows:

$$R_{pre} = \frac{v_3}{v_2}$$

$$R_{post} = \frac{v_1}{v_2}$$

9.2.4.5 Reference 2 Coefficient Preset

References: SAS-4 Specification, Table 56

Steps:

1. Set up the DUT to transmit the PRBS15 pattern with Reference 2 equalization and SSC disabled.
2. Capture the output waveform from the DUT.
3. Process the waveform data using the “SAS3_EYEOPENING MATLAB” script.
4. Record the output of the script.
5. Compute R_{pre} and R_{post} with the values obtained from the script as follows:

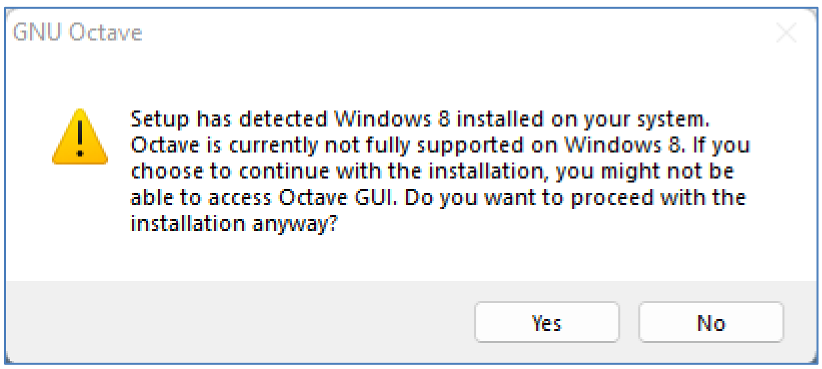
$$R_{pre} = \frac{v_3}{v_2}$$

$$R_{post} = \frac{v_1}{v_2}$$

10 Appendix B: Octave 4.0.0 Installation

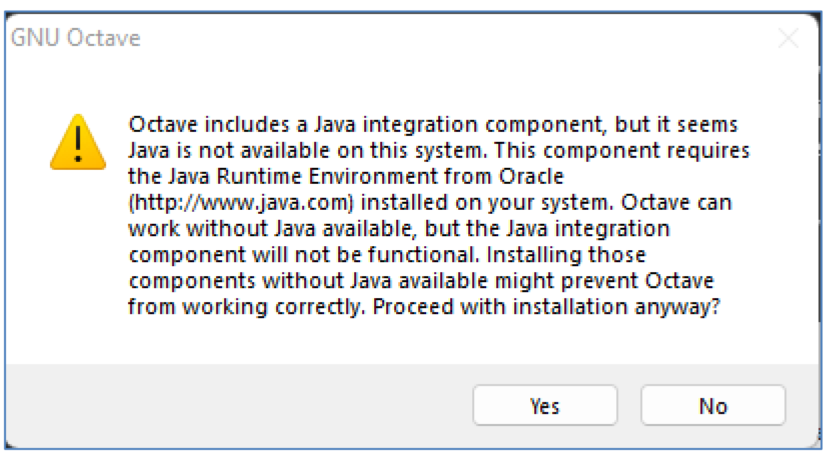
Refer to the following procedure on how to install Octave 4.0.0:

1. Download the Octave 4.0.0 installer:
   - from https://ftpmirror.gnu.org/octave/windows/, or
   - through this direct link— https://mirrors.sarata.com/gnu/octave/windows/octave-4.0.0_0-installer.exe.
2. Double-click to run the installer.
3. The following warning prompt should appear if you are installing on a newer system. Select **Yes** to proceed with the installation.

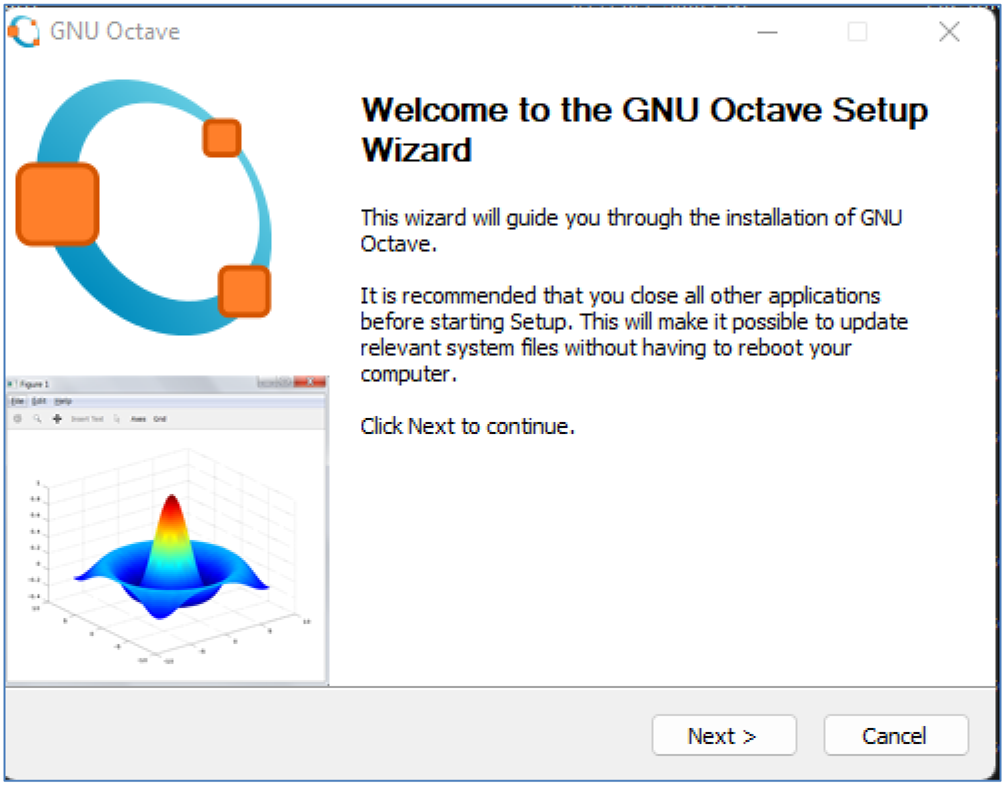


4. The following next warning prompt may appear if you do not have Java installed. Select **Yes** to proceed with the installation.

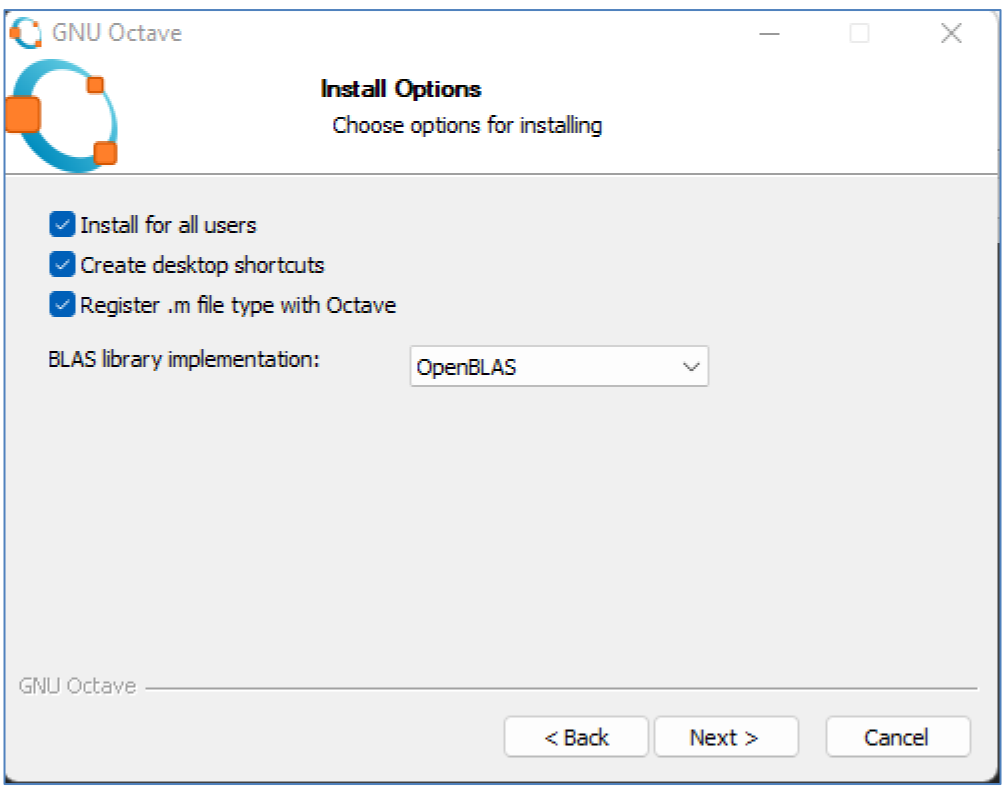
   Note: Java is not required for the GRL-SAS4-TX application.



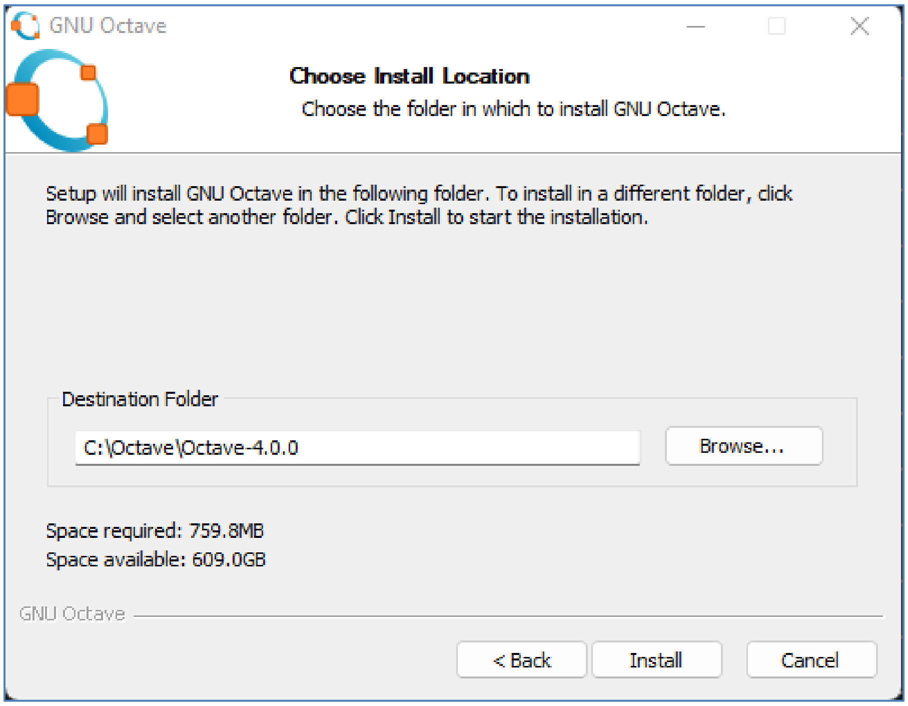
5. Select **Next** to proceed with the next few screens.



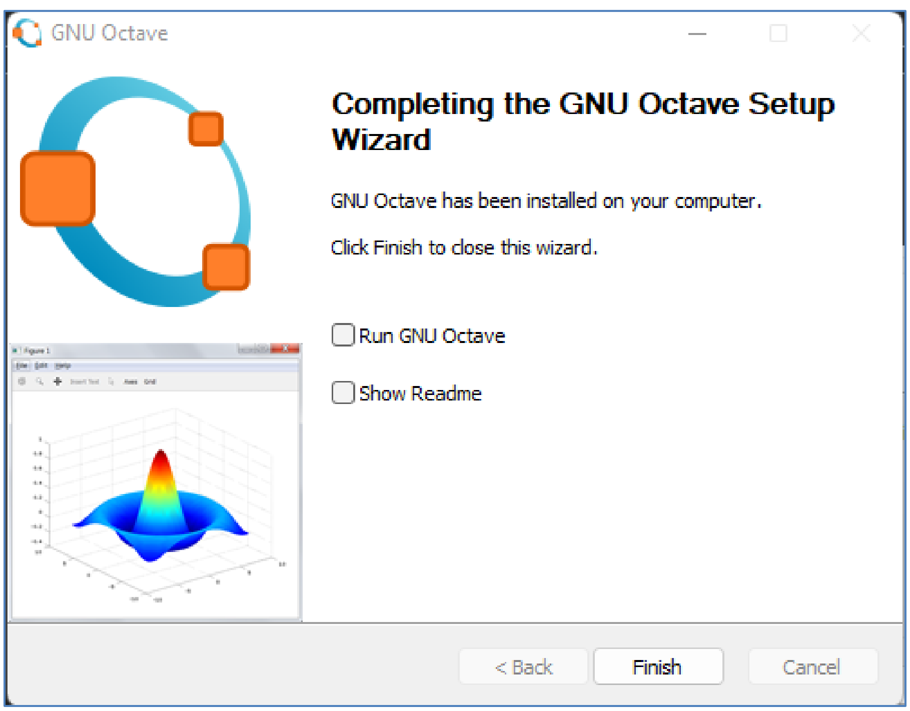
6. In the “Install Options” screen, use the default options and select **Next**.



7. In the “Choose Install Location” screen, ensure the default installation path is set as “C:\Octave\Octave-4.0.0” and select **Install**.



8. Upon completing the installation, uncheck both the “Run GNU Octave” and “Show Readme” check boxes and select **Finish**. The Octave 4.0.0 is now ready to be used with the GRL-SAS4-TX application.



11 Appendix C: Connecting Teledyne LeCroy Oscilloscope to PC

Refer to the following procedure on how to connect the Teledyne LeCroy scope to be used with a PC. The Teledyne LeCroy scope can be connected to the PC through LAN.

1. From the oscilloscope main menu bar, select **Utilities → Utilities Setup…**.

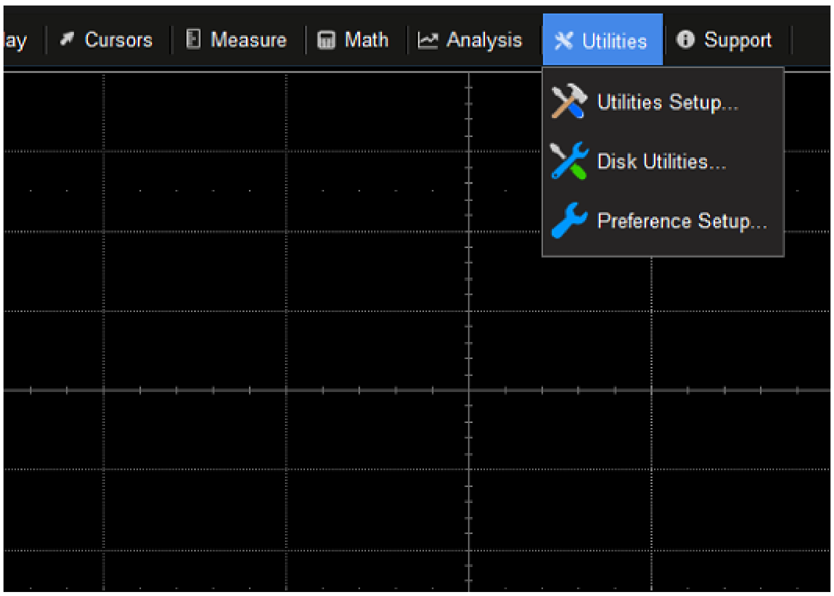


FIGURE 20. UTILITIES SETUP MENU

2. In the **Remote** tab, set the **Control from** settings to **LXI (VXI11)**. Note down the IP address of the scope.

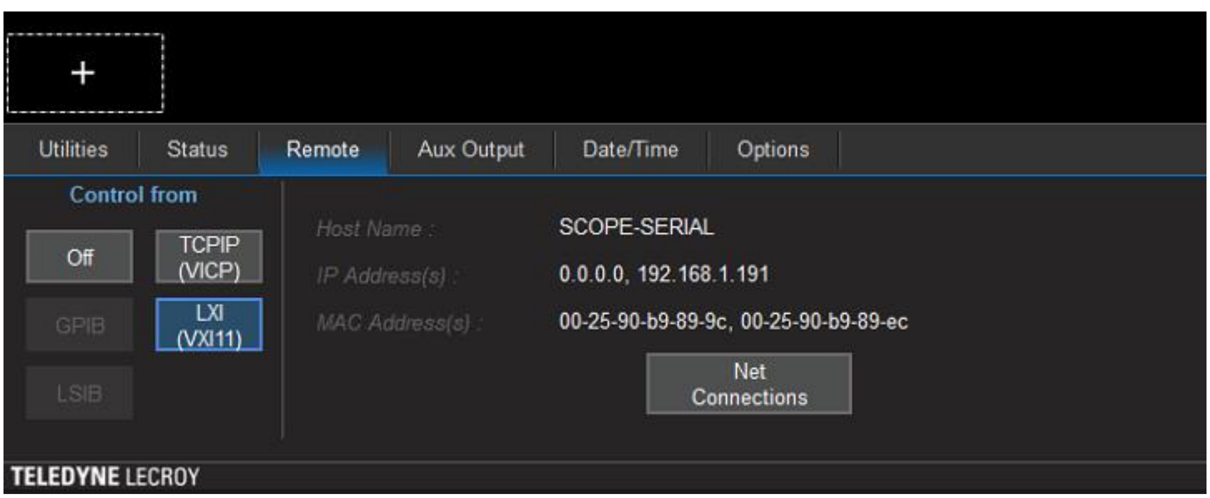


FIGURE 21. OSCILLOSCOPE'S IP ADDRESS

3. On the Equipment Setup page of the GRL SAS-4 Tx Test Application, type in the Scope IP address into the 'Address' field.

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