



TekExpress® FRL Solution
Printable Application Help





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- In North America, call 1-800-833-9200.
- Worldwide, visit www.tek.com to find contacts in your area.

Table of Contents

Welcome	v
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Getting help and support

Related documentation	1
Conventions	2
Technical support	2

Getting started

Required Oscilloscopes	5
Recommended accessories	5
Recommended probes	6
Windows 10 user accounts	6
Installing the software	7
Activate the license	8
View version and license information	9

Application basics

Run the application	11
Application panels overview	12
Global application controls	14
Application controls	14
Options menu	15
Instrument control settings	17
Configure email settings	20
Setup panel	21
Setup panel overview	21
Set DUT parameters	22
Select tests	28
Set acquisition parameters	29
Set configuration tab parameters	32
Set test notification preferences	38
Status panel overview	39
Results panel	41
Results panel overview	41
View test results	42

View test- related files	43
Reports panel	44
Reports panel overview	44
Select report options	44
View a report	46
Report contents	47
Exit the application	49

Running tests

Equipment connection setup for Source	51
Equipment connection setup for Sink	53
Prerequisite	56
Compensate the signal path	56
Deskew	56
Running tests	57

Saving and recalling test setup

Test setup files overview	59
Save a test setup	59
Open (load) a saved test setup	60
Create a test setup from default settings	60
Create a test setup using an existing one	60

FRL Source tests

HFR1-1: DC Common Mode Voltage	61
HFR1-2: Vse_max,Vse_min	62
HFR1-3: Rise/Fall Slew Rate	63
HFR1-4: Inter-Pair Skew	64
HFR1-5: FRL Rates	64
HFR1-6: Data Jitter (RJ)	65
HFR1-7: Data Eye Diagram	66
HFR1-8: AC Common Mode Voltage	68
HFR1-9: FFE Monotonicity-Method 1	68
HFR1-9: FFE Monotonicity-Method 2	70

FRL Sink Tests

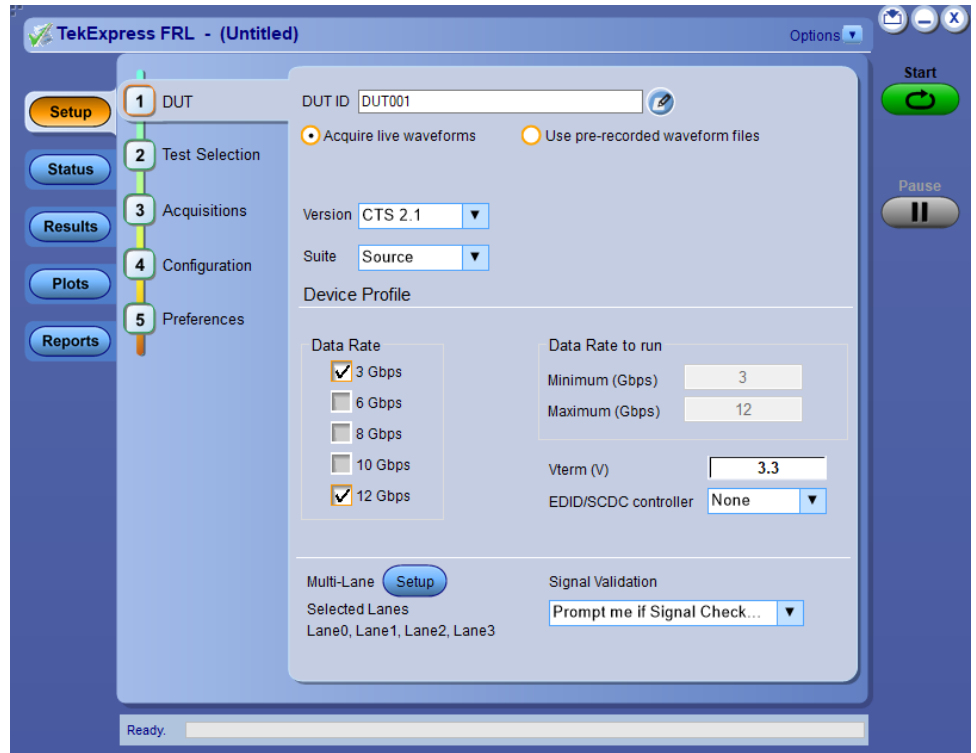
HRF2-1:Max Differential Swing Tolerance	71
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HRF2-2:Intra-Pair Skew	72
HRF2-3:Inter-Pair Skew	73
HRF2-4:Minimum Link Rate Tolerance	74
HFR2-5:Jitter Tolerance	75
BER estimation procedure	76

SCPI commands

About SCPI command	77
Socket configuration for SCPI commands	77
TEKEXP:*IDN?	85
TEKEXP:*OPC?	85
TEKEXP:ACQUIRE_MODE	86
TEKEXP:ACQUIRE_MODE?	86
TEKEXP:EXPORT	87
TEKEXP:INFO?	87
TEKEXP:INSTRUMENT	88
TEKEXP:INSTRUMENT?	88
TEKEXP:LASTERROR?	89
TEKEXP:LIST?	89
TEKEXP:MODE	90
TEKEXP:MODE?	90
TEKEXP:POPUP	91
TEKEXP:POPUP?	91
TEKEXP:REPORT	92
TEKEXP:REPORT?	92
TEKEXP:RESULT?	93
TEKEXP:SELECT	94
TEKEXP:SELECT?	94
TEKEXP:SETUP	95
TEKEXP:STATE	95
TEKEXP:STATE?	96
TEKEXP:VALUE	96
TEKEXP:VALUE?	97
Command parameters	98
Examples	104

Welcome



The FRL (Fixed Rate Link) is a video signaling technology supported in the HDMI 2.1 Specification. FRL supports up to 4 K at 120 Hz and 8 K at 60 Hz - for compressed and uncompressed video content. FRL supports only predefined discrete data rates (3 Gbps, 6 Gbps, 8 Gbps, 10 Gbps, and 12 Gbps) on each of its 4 lanes which means that the FRL supports post encoded link bandwidth of up to 48 Gbps.

The TekExpress FRL compliance application gives you the tools to easily run the High Definition Multimedia Interface (HDMI) tests under the HDMI compliance test specification 2.1. It displays a complete and reliable solution for quick testing.

The TekExpress FRL supports the following **Source** and **Sink** measurements:

Source measurements

1. HFR1-1: DC Common Mode Voltage
2. HFR1-2: Vse_max, Vse_min
3. HFR1-3: Rise/Fall Slew Rate
4. HFR1-4: Inter-Pair Skew
5. HFR1-5: FRL Rates
6. HFR1-6: Data Jitter (Rj)
7. HFR1-7: Data Eye Diagram
8. HFR1-8: AC Common Mode Voltage
9. HFR1-9: FFE Monotonicity-Method 1
10. HFR1-9: FFE Monotonicity-Method 2

Sink measurements

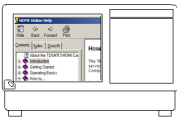
1. HFR2-1: Max Differential Swing Tolerance
2. HFR2-2: Intra-Pair Skew
3. HFR2-3: Inter-Pair Skew
4. HFR2-4: Minimum Link Rate Tolerance
5. HFR2-5: Jitter Tolerance

Getting help and support

Related documentation

The following documentation is available as part of the TekExpress® FRL application.

Table 1: Product documentation

Item	Purpose	Location
Help	Application operation and User Interface help	
PDF of the help	Printable version of the compiled help	 PDF file that ships with FRL application distribution (<i>TekExpress FRL-Automated-Test-application-Software-Printable-Help-EN-US.pdf</i>).

See also [Technical support](#) on page 2

Conventions

Help uses the following conventions:

- The term "Application," and "Software" refers to the TekExpress FRL application.
- The term “DUT” is an abbreviation for Device Under Test.
- The term “select” is a generic term that applies to the two methods of choosing a screen item (button, control, list item): using a mouse or using the touch screen.

Table 2: Icon descriptions

Icon	Meaning
	This icon identifies important information.
	This icon identifies conditions or practices that could result in loss of data.
	This icon identifies additional information that will help you use the application more efficiently.

Technical support

Tektronix values your feedback on our products. To help us serve you better, please send us your suggestions, ideas, or comments on your application or oscilloscope. Contact Tektronix through mail, telephone, or the Web site, www.tek.com.

When you contact Tektronix Technical Support, please include the following information (be as specific as possible):

General Information

- All instrument model numbers
- Hardware options, if any
- Probes used
- Your name, company, mailing address, phone number, FAX number
- Please indicate if you would like to be contacted by Tektronix about your suggestion or comments.

**Application Specific
Information**

- Software version number
- Description of the problem such that technical support can duplicate the problem
- If possible, save the setup files for all the instruments used and the application.
- If possible, save the TekExpress setup files, log.xml, *.TekX (session files and folders), and status messages text file.
- If possible, save the waveform on which you are performing the measurement as a .wfm file.

Getting started

Required Oscilloscopes

DPO70000SX/DX Series Real Time Oscilloscopes with Bandwidth ≥ 20 GHz

Recommended accessories

Table 3: Recommended accessories

Instruments/Accessories	Description	Quantity
Arbitrary Waveform Generator	AWG70001A/B	4
Sync Hub	Synchronizes the signal outputs of up to four AWG70001A/B series instruments (AWGs). One instrument becomes the master and three instruments become slaves.	1
AWG-HD	Performs amplification, sets the skew on positive and negative legs and sets the bias voltage.	1
HDMIA2-TPA-P	Wilder Fixture, HDMI Type A(v2.1) Test Point Adapter	1
HDMIA2-TPA-R	Wilder Fixture, HDMI Type A(v2.1) Test Point Receptacle	1
EDID/SCDC controller	HDMI_EDID2.1-EMSS (Wilder) or AJSC-1 (Allion)	1
Synchronisation cable (for stack configuration)		1
SMA torque		1
AWG Synchronization Hub		1
External box		1
Ethernet Hub		1

Recommended probes

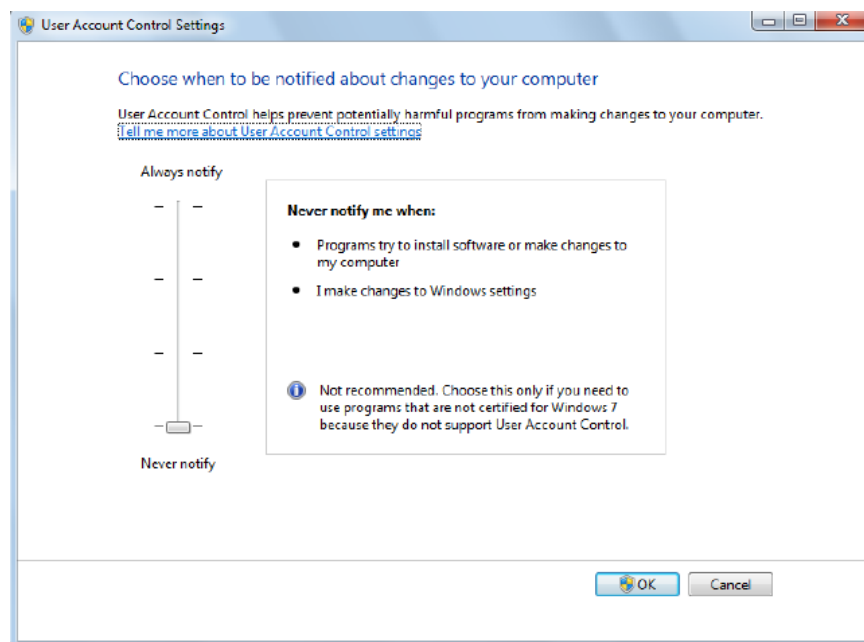
Table 4: Recommended probes

Probes	Quantity
SMA Cables	10
P7625/P7633 Tri-mode probe with P76CA-292C	4
P7720 Tri-mode probe with P77C292MM	

Windows 10 user accounts

Windows 10 instruments need to have the User Account Control Settings set to **Never Notify**. To set the User Account Control Settings:

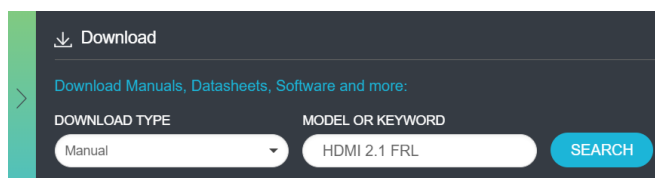
1. Go to **Control Panel > User Accounts > Change User Account Control settings**.
2. Set it to **Never Notify** as shown in the image.



Installing the software

Complete the following steps to download and install the latest FRL application. See [Recommended accessories](#) on page 5 for compatibility.

1. Go to www.tek.com.
2. Click **Downloads**. In the Downloads menu, select DOWNLOAD TYPE as Software and enter *HDMI 2.1 FRL* in the MODEL OR KEYWORD field and click **SEARCH**.



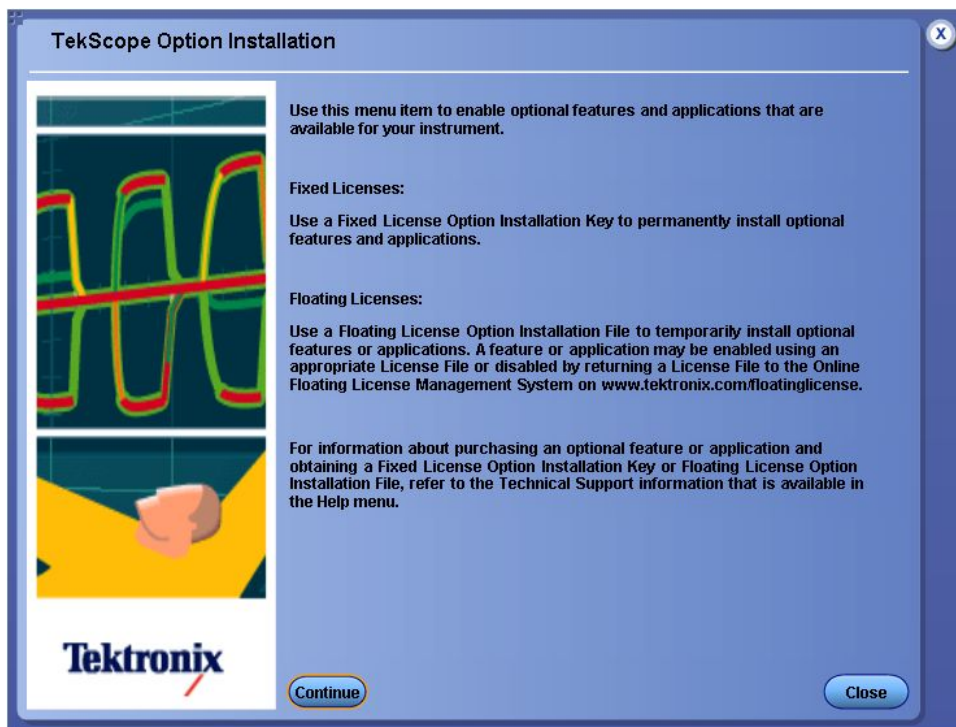
3. Select the latest version of software and follow the instructions to download. Copy the executable file to the oscilloscope.
4. Double-click the executable and follow the on-screen instructions. The software is installed at *C:\Program Files\Tektronix\TekExpress\TekExpress FRL*.
5. Select **Analyze > Tekexpress FRL** from the TekScope menu to [Run the application](#) on page 11.

Activate the license

Activate the license using the option installation wizard on the oscilloscope. Complete the following steps to activate the TekExpress FRL license:

1. From the oscilloscope menu bar, click **Utilities > Option Installation**.

The TekScope Option Installation wizard opens.



2. Instructions for using the Options Installation window to activate licenses for installed applications is provided in the oscilloscope online help. Press the **F1** key on the oscilloscope keyboard to open the Option Installation help topic. Follow the directions in the topic to activate the license.

See Also

[View version and license information](#) on page 9

View version and license information

Use the following instructions to view application version information and version information for the application modules such as the Programmatic interface and the Programmatic interface client.

To view version information:

From the Options menu, select **About TekExpress**.



To view license information:

1. From the oscilloscope Help menu, select **About TekScope**.

The Options section in the dialog box displays a list of installed options, including TekExpress FRL.

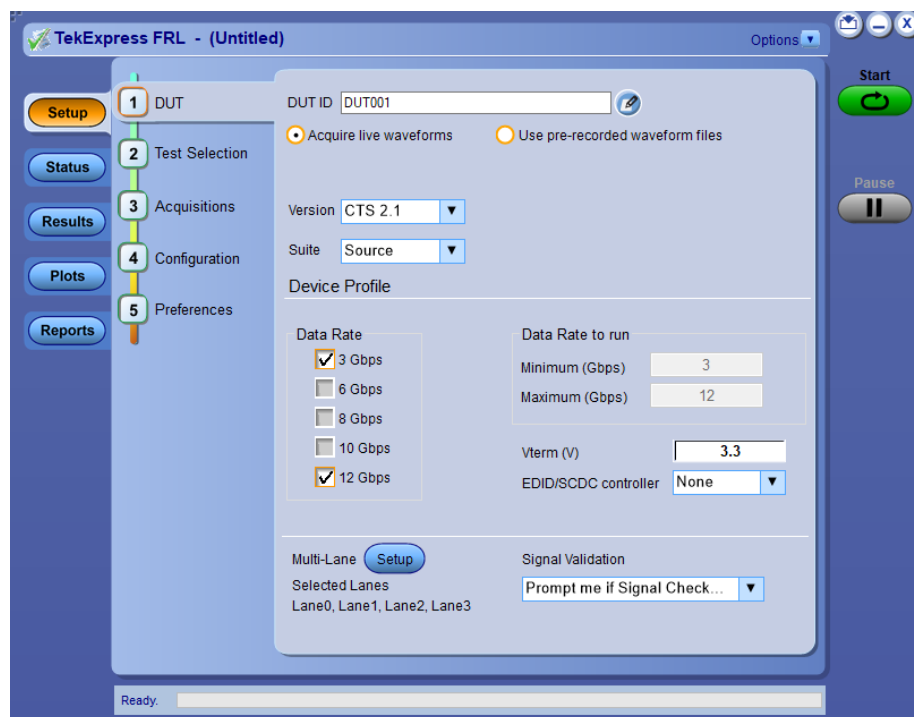
2. To view the Option key, look in the Option Installation Key section. When finished, click **OK** to close the dialog box.

See Also [Activate the license](#) on page 8
[Options menu](#) on page 15

Application basics

Run the application

To launch the TekExpress HDMI 2.1 FRL application, select **Analyze > TekExpress FRL** from the TekScope menu.



When you launch the application for the first time, the file C:\Users\<username>\My Documents\My TekExpress\FRL\Resource.xml is mapped to drive X:. This file contains information about the available network-connected instruments. The session files are stored in X:\FRL\. If this file is not found, then the application runs Instrument Discovery Program to detect the network-connected instruments before launching FRL application.

If the application is behind the oscilloscope application, click **Analyze > TekExpress FRL** to bring it to the front. To keep the TekExpress FRL application window on top, select **Keep On Top** from the TekExpress FRL [Options menu](#) on page 15.

See also [Application controls](#) on page 14
[Application panels overview](#) on page 12

Application panels overview

The FRL application uses panels to group Configuration, Results, and Reports settings. Click any button to open the associated panel. A panel may have one or more tabs that list the selections available in that panel. The configurations in a tab changes depending on the settings made in the same tab or another tab.

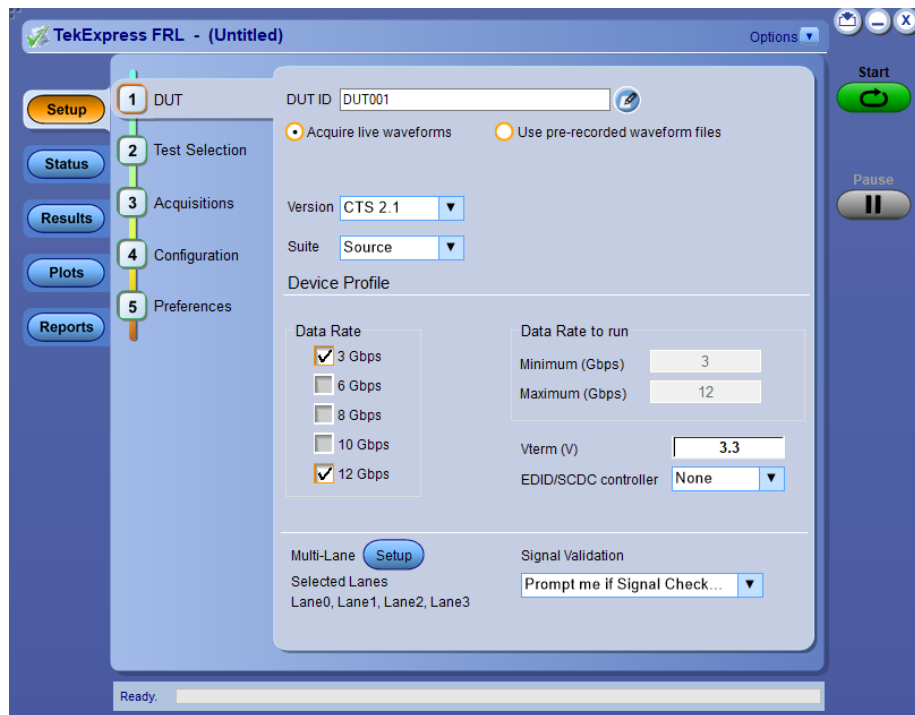


Table 5: Application panels overview

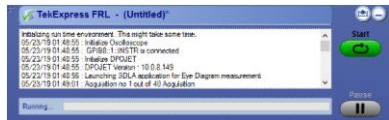
Panel Name	Purpose
Setup panel overview on page 21	The Setup panel shows the test setup controls. Click the Setup button to open this panel. Use this panel to: ■ Set DUT parameters on page 22 ■ Select tests on page 28 ■ Set acquisition parameters on page 29 (Only available when Suite=Source) ■ Set configuration tab parameters on page 32 ■ Set test notification preferences on page 38
Status panel overview on page 39	View the progress, analysis status of the selected tests, and view test logs.
Results panel overview on page 41	View the summary of test results and select result viewing preferences.
Reports panel overview on page 44	Browse for reports, save reports as specific file types, specify report naming conventions, select report content to include (summary information, detailed information, user comments, setup configuration, application configuration), and select report viewing options.

See also [Application controls](#) on page 14

Global application controls

Application controls **Table 6: Application control descriptions**

Item	Description
Options menu on page 15	Opens the Options menu for access to global controls.
Panels	Visual frames with sets of related options.
Command buttons	Buttons that initiate an immediate action such as the Start, Stop, Pause, Continue, and Clear command buttons.
Start button 	Starts continuous measurement acquisition and analysis. If prior acquired measurements have not been cleared, the new measurements are added to the existing set.
Stop button 	Stops (aborts) the current execution.
Pause \ Continue button 	Use the Pause button to temporarily interrupt the current acquisition. When a test is paused, the button name changes to Continue.
Clear button 	Clears all existing measurement results. This button is available only on the Results panel overview on page 41.
Clear Log 	This button is available only on the Status panel overview on page 39 and it is used to clear all the status log.
Save 	This button is available only on the Status panel overview on page 39 and it is used to save the status log locally for the future use.

Item	Description
Application window move icon 	Place the cursor over the three-dot pattern in the upper left corner of the application window. When the cursor changes to a hand, drag the window to the desired location.
Mini view / Normal view 	Toggles the application between mini view and normal view.  Mini view displays the run messages with the time stamp, progress bar, Start / Stop button, and Pause / Continue button. The application moves to mini view when you click the Start button.

Options menu The Options menu is located in the upper right corner of the application.

The Options menu has the following selections:

Default Test Setup
Open Test Setup
Save Test Setup
Save Test Setup As
Open Recent ▶
Instrument Control Settings
Keep On Top
Email Settings
Suite ▶
Identify A/WG-HD
Help
About TekExpress

Menu	Function
Default Test Setup	Opens an untitled test setup with defaults selected.
Open Test Setup	Opens a saved test setup.
Save Test Setup	Saves the current test setup selections.
Save Test Setup As	Creates a new test setup based on an existing one.
Open Recent	Displays a menu of recently opened test setups from which to select.

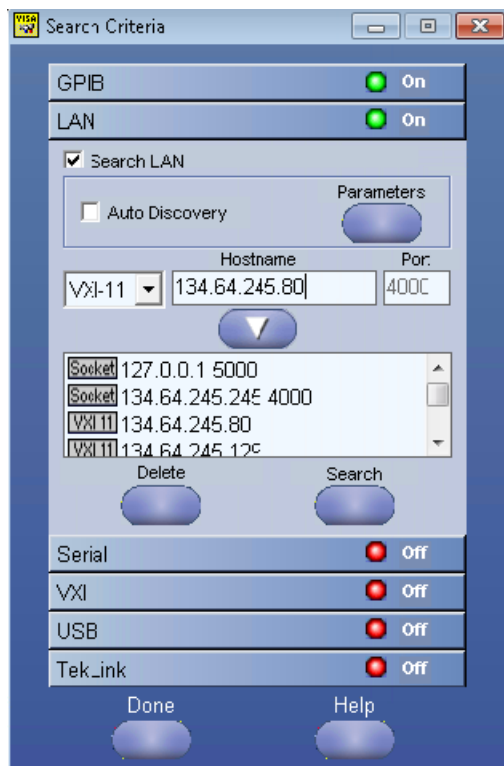
Menu	Function
Instrument control settings on page 17	Shows the list of instruments connected to the test setup and allows you to locate and refresh connections to connected instruments.
Keep On Top	Keeps the TekExpress FRL utility on top of other open windows on the desktop.
Email Settings	Displays configure email options for test run and results notifications.
Suite	Displays the suite selected as 'Source' or 'Sink'.
Identify AWG-HD	(Only available when Suite = Sink) Identifies the AWG-HD through MAC address 
Help	Displays TekExpress FRL application Help document (This document).
About TekExpress	■ Displays application details such as software name, version number, and copyright. ■ Provides access to View version and license information on page 9 for your TekExpress FRL application installation. ■ Provides a link to the Tektronix site.

See also.

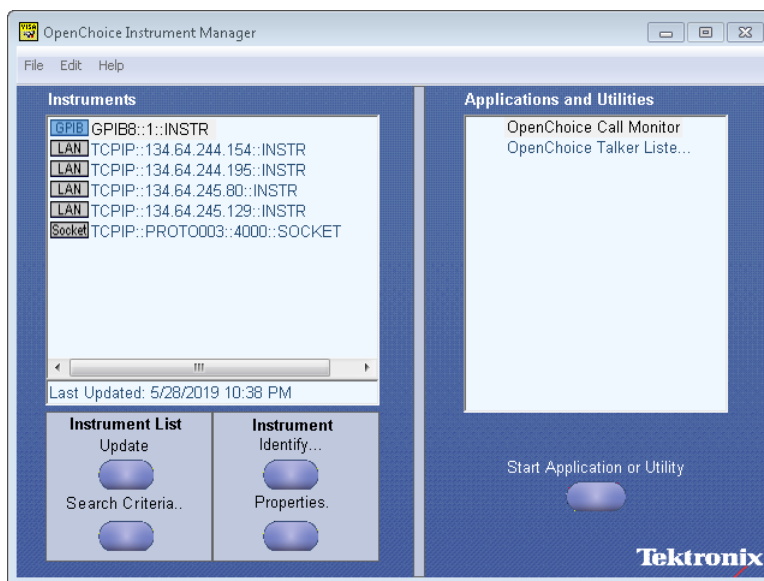
[Application controls](#) on page 14

Instrument control settings

Use the TekExpress Instrument Control Settings dialog box to search and list the connected resources (instruments) found on specified connections (LAN, GPIB, USB, and so on) and each instruments connection information.



Identify all the instruments through VISA resource manager, before discovering the instruments in "Instrument control settings" and can access this dialog box from the Options menu.



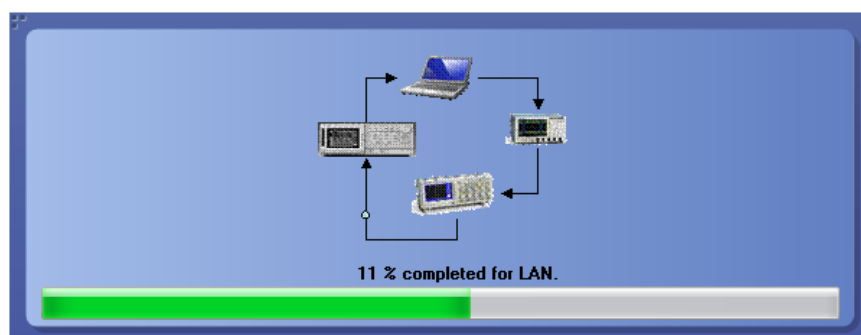
Use the Instrument Control Settings feature to view instrument connection details. Connected instruments displayed here and are selected for use in the Global Settings tab in the configuration section. See [Set configuration tab parameters](#) on page 32 for details.

To refresh the list of connected instruments:

1. From the Options menu, select **Instrument Control Settings**
2. In the **Search Criteria** section of the Instrument Control Settings dialog box, select the connection types of the instruments for which to search.

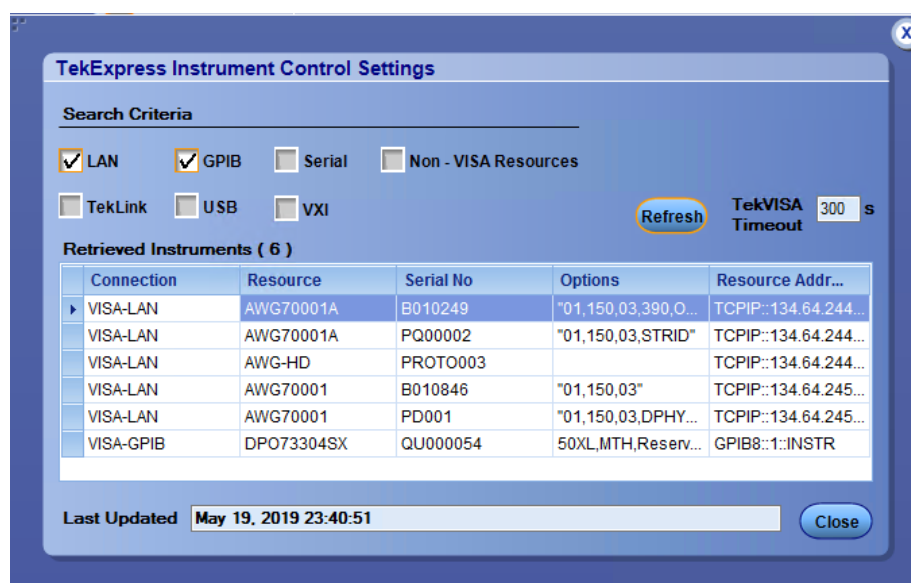
Instrument search is based on the VISA layer, but different connections determine the resource type, such as LAN, GPIB, and USB. For example, if you choose LAN, the search will include all the instruments supported by TekExpress that are communicating over the LAN.

3. Click **Refresh**. TekExpress searches for connected instruments.



4. After searching, the dialog box lists the instrument-related details based on the search criteria you selected. For example, if you selected LAN and GPIB as the search criteria, the application checks for the availability of instruments over LAN, then GPIB, and then lists detected instruments on those connection types.

The Retrieved Instruments table lists instrument details. The time and date of the last time this table was updated is displayed in the Last Updated field.



See also.

[Options menu](#) on page 15

Configure email settings

To be notified by email when a test completes, fails, or produces an error, configure the email settings.

1. Select **Options > Email Settings** to open the Email settings dialog box.

2. (Required) For Recipient email Address(es), enter one or more email addresses to which to send the test notification. To include multiple addresses, separate the addresses with commas.
3. (Required) For Sender's Address, enter the email address used by the instrument. This address consists of the instrument name, followed by an underscore, followed by the instrument serial number, the @ symbol and then the email server used. For example:
DPO72004C_B130099@yourcompany.com.
4. (Required) In the Server Configuration section, type the SMTP Server address of the Mail server configured at the client location, and the SMTP Port number, in the corresponding fields.

If this server requires password authentication, enter a valid login name, password, and host name in the corresponding fields.

NOTE. If any of the above required fields are left blank, the settings will not be saved and email notifications will not be sent.

5. In the Email Attachments section, select from the following options:
 - **Reports:** Attach the test report to the notification email.
 - **Status Log:** Attach the test status log to the notification email. If you select this option, then also select whether you want to receive the full log or just the last 20 lines.

6. In the Email Configuration section:
 - Select the message file format to send: HTML (default) or plain text.
 - Enter a maximum file size for the email message (message plus attachment files). Messages with attachments larger than this limit will be truncated. The default is 5 MB.
 - Enter the number in the Number of Attempts to Send field, to limit the number of attempts that the system makes to send a notification. The default is 1. You can also specify a timeout period.
7. Select the **Email Test Results When complete or on error** check box. Use this check box to quickly enable or disable email notifications.
8. To test your email settings, click **Test Email**.
9. To save your settings, click **Apply**.
10. Click **Close** when finished.

Setup panel

Setup panel overview

The Setup panel contains sequentially ordered tabs that you guides through the test setup and execution process. The configurations in the Setup panel changes depending on the **Suite** selection as **Source** or **Sink**.

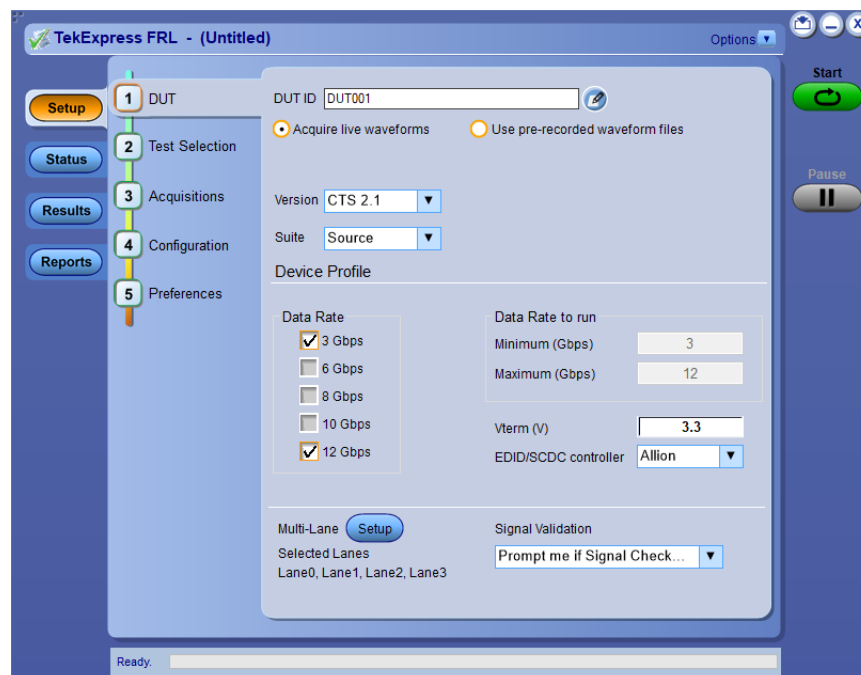


Figure 1: Setup panel for Source

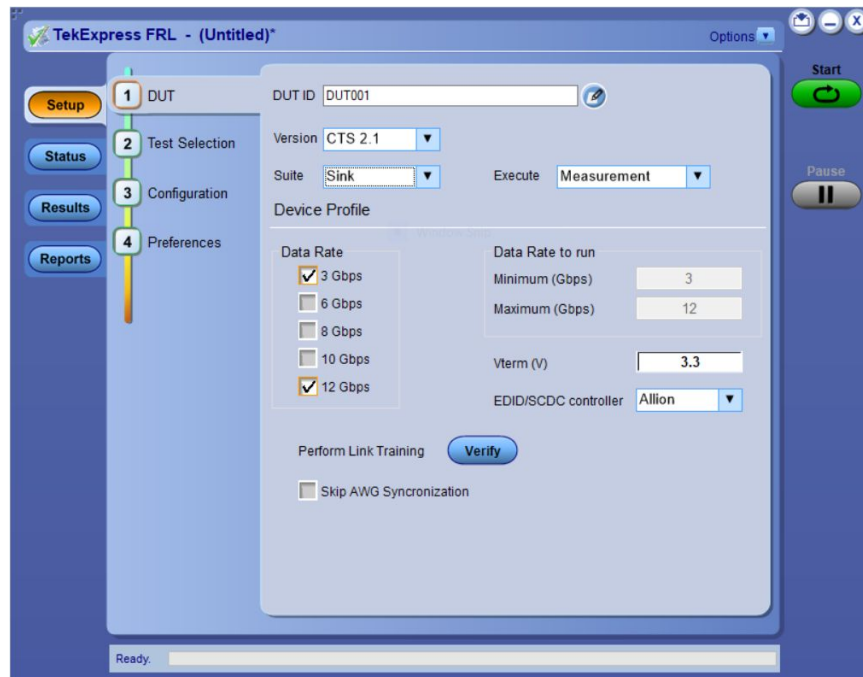


Figure 2: Setup panel for Sink

Set DUT parameters

Use the DUT tab to select the parameters for the device under test. The settings are global and apply to all tests for the current session. The configurations available in other tabs may depend on the settings in the DUT tab.

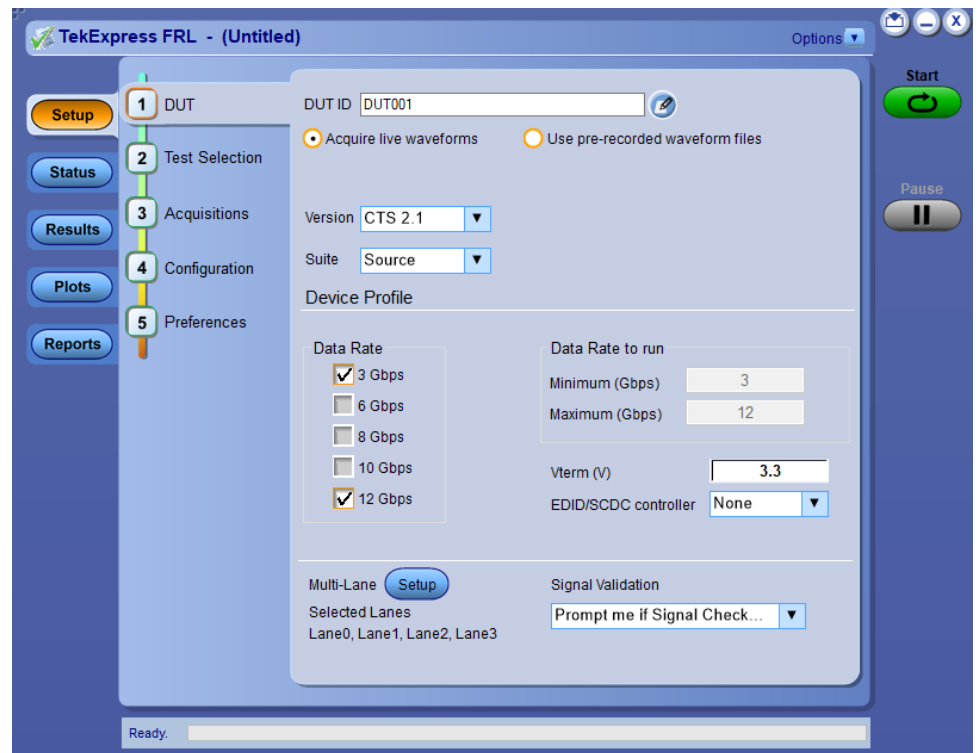


Figure 3: DUT tab for Source

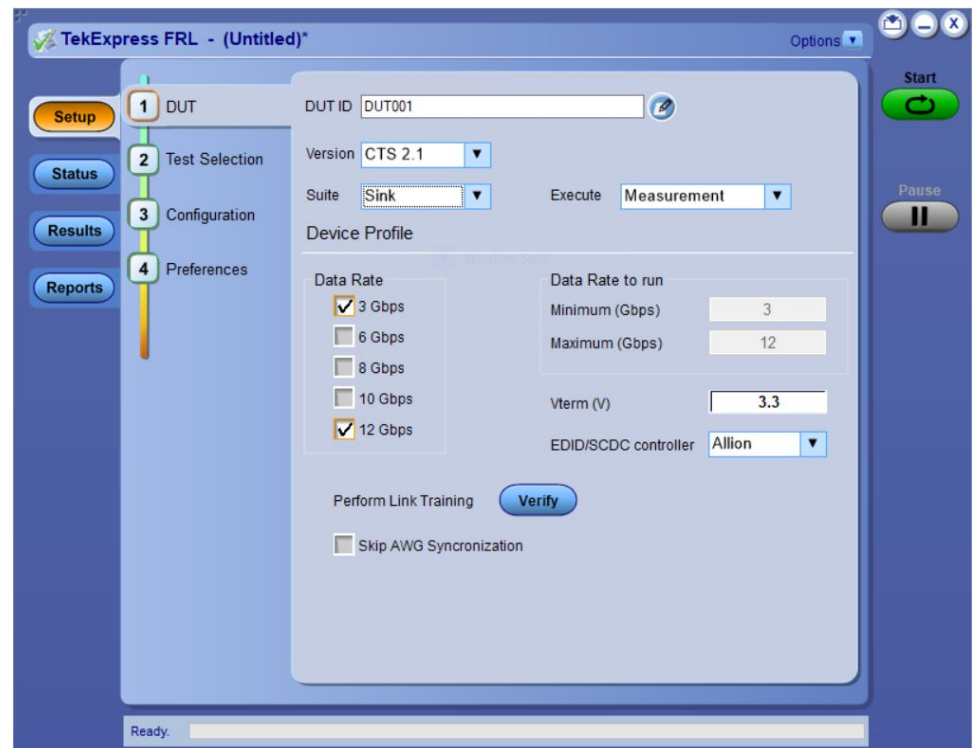
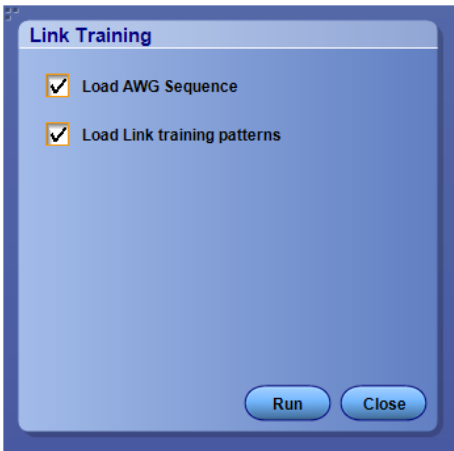
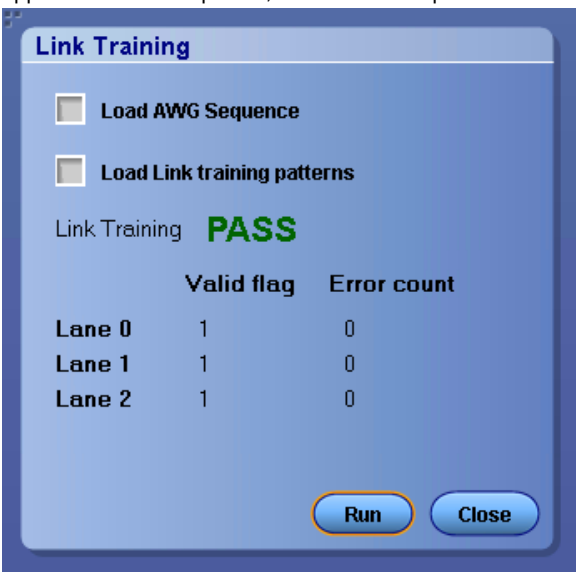


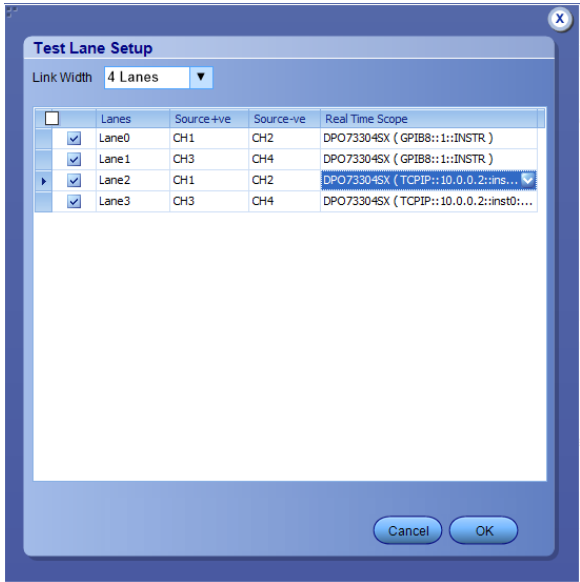
Figure 4: DUT tab for Sink

Table 7: DUT tab settings

Setting	Description
DUT ID	Adds an optional text label for the DUT to reports. The default value is DUT001. The maximum number of characters is 32. You cannot use the alphanumeric characters in an ID name (.,,.,.,.,\,/:?"<> *)
Comments icon  (to the right of the DUT ID field)	Opens Comments dialog box to enter text to add to the report. Maximum size is 256 characters. To enable or disable comments appearing on the test report, see <i>Select report options</i> .
Acquire live waveforms	Acquire active signals from the DUT for testing.
Use pre-recorded waveform files	The tests on a saved run session file. Select a run session file from the list.
Version	Select the required CTS Version from the drop-down list. The available option is 2.1
Suite	Select the suite from the drop-down list. The available options are Source and Sink . The configurations in the setup panel varies depending on the Suite selection made as Source or Sink in the DUT tab.
Execute	(Only available when Suite = Sink) The available options are the following: ■ Select Measurements to performs the FRL Sink electrical measurements as per the CTS. ■ Select Verify Calibration to verify the patterns used for FRL Sink electrical measurements
Device Profile	
Data Rate	Select all the data rate supported by the DUT.
Data Rate to run	All selected measurements will run on minimum and/or maximum data rate as per CTS.
Vterm(V)	Applies termination voltage. Vterm value is selected to 3.3 V
EDID/SSDC controller	Select the controller option from the drop-down list. The available options are Allion, Wilder, and None. By default, Wilder is selected. NOTE. Ensure that the Allion driver software is installed on the oscilloscope while using Allion for testing FRL Source and FRL Sink.
Perform Link Training	(Only available when Suite = Sink and Execute = Measurement) Performs the Link Training and verifies that the link training is working as expected, before performing the sink measurements.

Setting	Description
Verify 	Select Load AWG sequence to load the sequences on all AWGs. Select Load link training patterns to load the appropriate patterns in AWGs.  Click Run. Depending upon the selections made in the Link Training window, the application loads sequence, waveforms and performs link training on the patterns.  NOTE. If you want to perform link training on selected patterns, you can load sequence and nominal waveforms manually in AWG and you can run by unselecting load sequence and waveforms.
Skip AWG Synchronization	(Only available when Suite = Sink) Select to skip the synchronization of AWG(s).

Setting	Description																									
Multi-Lane Setup	(Only available when Suite=Source) Click Setup to configure the multi-lane setup for the test. Choose an approach from the below options to continue with ☒ P76XX / P77XX ☐ Dual Stack Cancel OK Select P76XX/P77XX configuration. 1. Select P76XX/P77XX and click OK. 2. In the Test Lane Setup menu, select the number of lanes selected, the Source, and the Probe connection for each lane and click OK. Test Lane Setup Link Width4 Lanes <table><thead><tr><th>☐</th><th>Lanes</th><th>Source+ve</th><th>Source-ve</th><th>Probe Connection</th></tr></thead><tbody><tr><td>☒</td><td>Lane0</td><td>CH1</td><td>CH3</td><td>+ve</td></tr><tr><td>☒</td><td>Lane1</td><td>CH1</td><td>CH3</td><td>+ve</td></tr><tr><td>☒</td><td>Lane2</td><td>CH2</td><td>CH4</td><td>-ve</td></tr><tr><td>☒</td><td>Lane3</td><td>CH2</td><td>CH4</td><td>-ve</td></tr></tbody></table> Cancel OK Select Dual Stack configuration. ■ Select Dual Stack and click OK. ■ In the Test Lane Setup menu, select the number of lanes selected, the Source, and the IP address of the oscilloscope for each lane and click OK.	☐	Lanes	Source+ve	Source-ve	Probe Connection	☒	Lane0	CH1	CH3	+ve	☒	Lane1	CH1	CH3	+ve	☒	Lane2	CH2	CH4	-ve	☒	Lane3	CH2	CH4	-ve
☐	Lanes	Source+ve	Source-ve	Probe Connection																						
☒	Lane0	CH1	CH3	+ve																						
☒	Lane1	CH1	CH3	+ve																						
☒	Lane2	CH2	CH4	-ve																						
☒	Lane3	CH2	CH4	-ve																						

Setting	Description
	The default IP address for oscilloscope and the extension oscilloscope is GPIB8::1::INSTR & 10.0.0.2 respectively. 
Signal Validation	(Only available when Suite = Source) Validation of the Signal can be done by three options and they can be selected from the drop-down list provided: Prompt me if Signal Check Fails When selected, user is prompted if Signal validation fails. The user will be given the option to Reacquire, Use Anyway, Skip and Abort the execution. Skip Test if Signal Check Fails When selected, signal validation fails for the selected test is skipped. Turn Off Signal Check When selected, FRL application does not perform any signal validation.

Select tests Use the Test Selection tab to select the tests to run on the connected DUT.

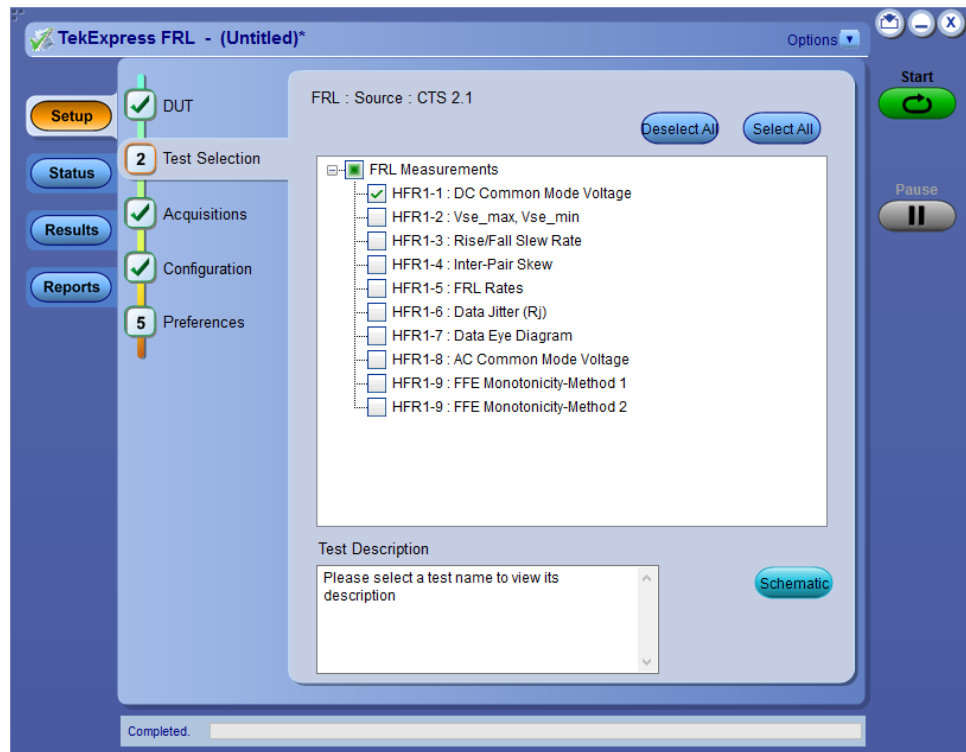


Figure 5: Test selections tab for Source

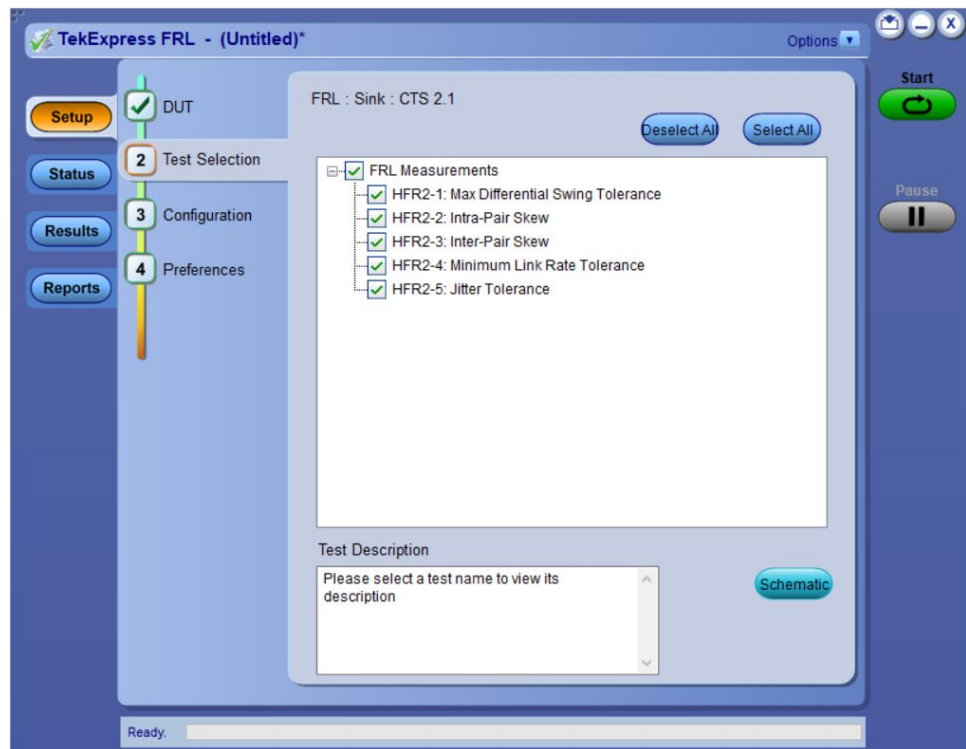


Figure 6: Test selection tab for Sink

See also. [FRL Source tests](#) on page 61

[FRL Sink Tests](#) on page 71

Set acquisition parameters

Use the Acquisitions tab to view the test acquisition parameters. The contents displayed in this tab depends on the DUT type and the tests selected. This tab is available when the Suite in the DUT tab is selected as **Source**.

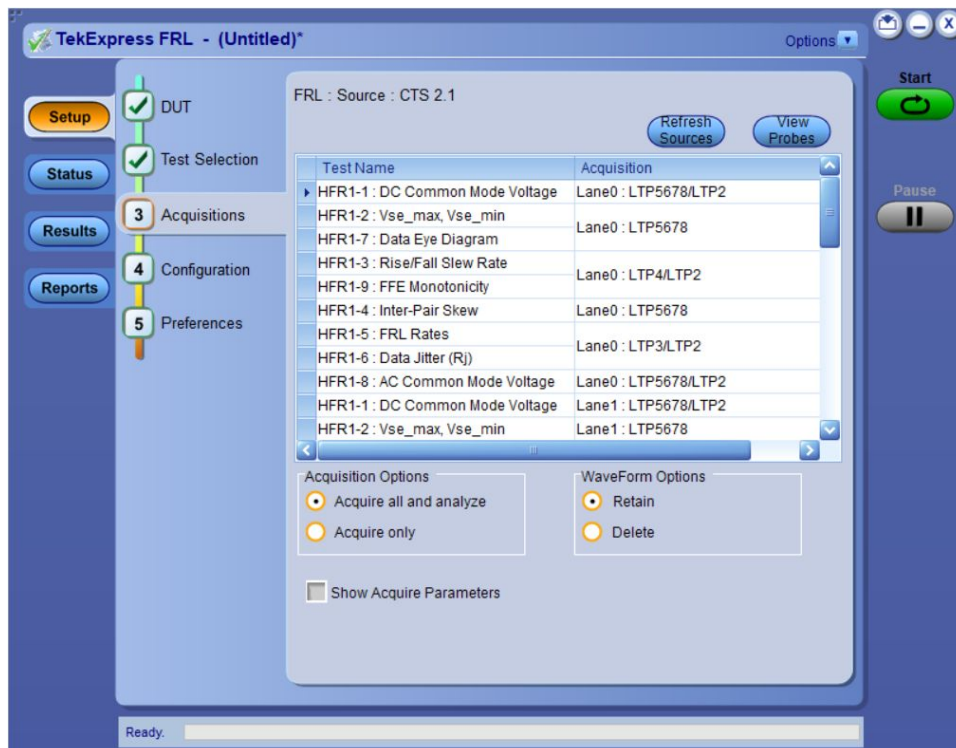
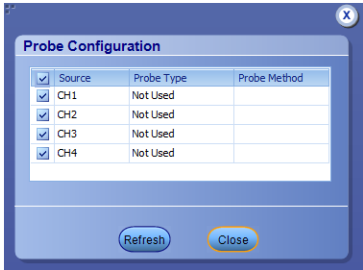
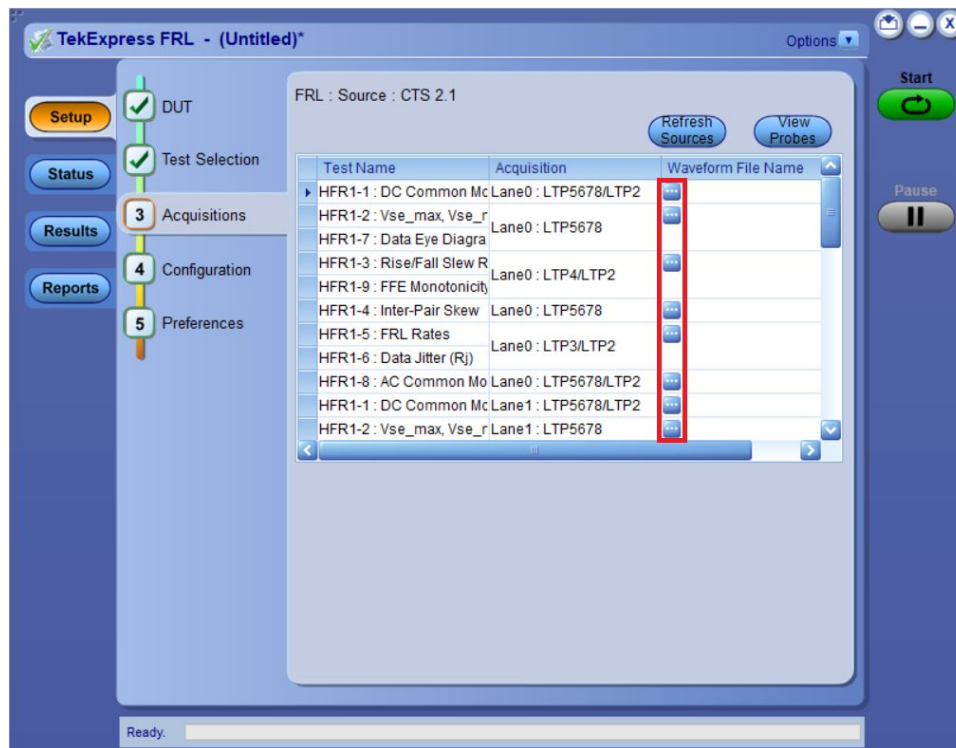


Table 8: Acquisition tab settings

Settings	Description
Refresh Sources	Displays the sources connected to the different channels of the oscilloscope. Updates the list of available channel sources as used by the Source fields in the Device list. Click this button when you change the channel connections in the test setup.
View Probes	Displays the probes connected to the different channels of the oscilloscope. Click to view the detected probes and enable or disable the probe signal source access in the application. 
Acquisition Options	■ Acquire all and analyze Acquire waveforms for all the valid acquisitions and analyzes using the saved waveforms. ■ Acquire only Acquires waveforms for all the valid acquisitions.
Waveform Options	■ Retain The Retain is enabled only when acquire all and analyze is selected and it retains the saved waveforms for offline analysis. ■ Delete Deletes the saved waveforms at the end of analysis.
Show Acquire Parameters	Select to review the acquire parameters.

Running tests on prerecorded (saved) waveforms. To load a saved waveform file:

1. Click **DUT**.
2. Click **Use pre-recorded waveform files**.
3. Click **Acquisitions**. The Waveform Filename column now shows browse buttons.



4. Click the browse button (⋮) for each test acquisition type (Lane 0, Lane 1, Lane 2, Lane 3)
5. Navigate to and select the appropriate waveform file(s). You must select all waveforms required for the acquisition type.
6. To change, remove, or add a file to the list, click the browse button next to the file name to change, and use the menu items to replace, remove (delete) or add a file in the list.
7. Click **Start**.

NOTE.

Waveform naming based on the Acquire Parameters.

Data Rate: 12 Gbps

Target Lane: Lane0

Victim Lane Pattern : LTP5678

Quite Lane Pattern : LTP5678(When Quite lane not present, Quite Lane Pattern = Victim Lane Pattern)

FFE Level: 0

Run no: 1

Example 1:

FRL_Lane0_12Gbps_LTP5678_LTP5678_FFE0_SE_Pos_R1.wfm

Example 2: Specific to HFR 1-4 Measurement

Allowed lane combination in compliance Mode:

Stack: L0L1,L0L2,L0L3

Probe: L0L2,L1L3,L0L3,L1L2

FRL_Lane0_12Gbps_LTP5678_LTP5678_FFE0_SE_Neg_L0L2_R1.wfm

Set configuration tab parameters

Use Configuration tab to configure the Global Settings and the test measurement configurations. The Global Settings and the measurements with configurations are available in this tab depend on the Standards selected in the DUT tab.

Source configuration settings. Use the configuration tab to configure the Global Settings and Measurement settings for the measurements. The settings described in this tab is available when Suite in the DUT tab is selected as Source.

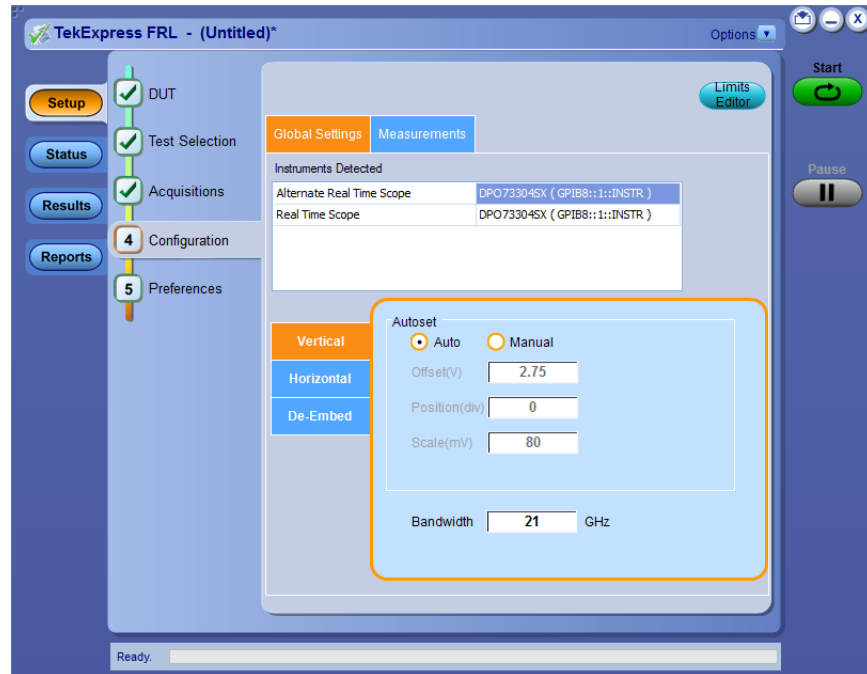


Figure 7: Source configuration: Global settings

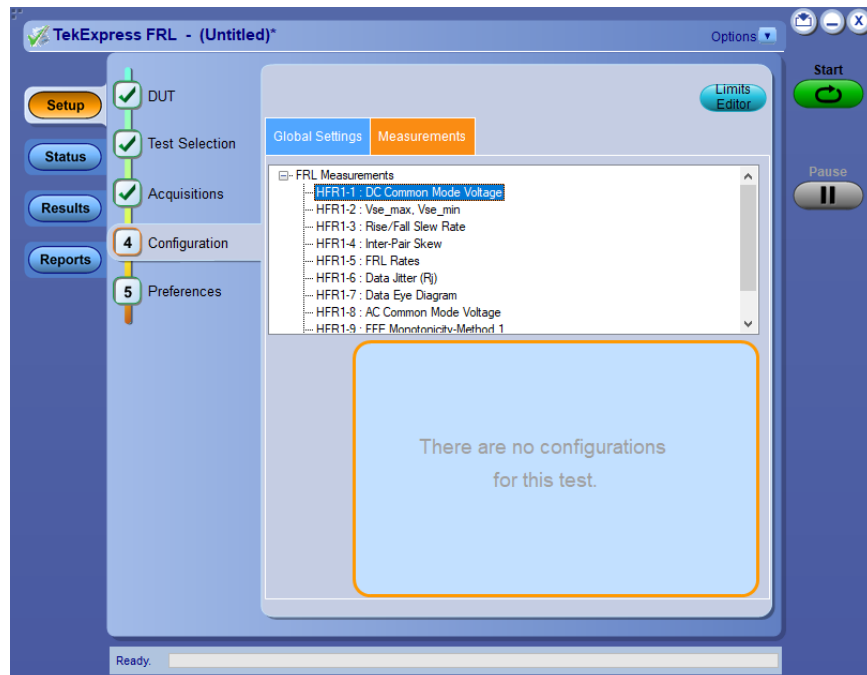


Figure 8: Source configuration: Measurement settings

Table 9: Source Configuration tab settings

Settings	Description	
Compliance mode settings		
Global settings		
Instruments Detected	Displays the instruments connected to this application. Click on the instrument name to open a list of available (detected) instruments. Select Options > Instrument Control Settings and click Refresh to update the instrument list. NOTE. Verify that the GPIB search criteria (default setting) in the Instrument Control Settings is selected when using the TekExpress FRL application.	
Vertical		
Autoset	Auto (Default value)	Manual
Offset (V)	2.75 V	-5 V to 5 V
Position (div)	0	-4 to 4
Scale(mV)	80 mV	3.48 mV to 5350 mV
Bandwidth	Values changes from 2.5 GHz to 21 GHz.	
De-Embed Filter	Apply De-Embed	Select to apply the de-embed filter file. Click Browse and select the de-embedding filter files (.flt). NOTE. Browse option is enabled only when you select Apply De-Embed checkbox.

Table 10: Measurement configurations for Source

Measurement Name	Configuration			Default value
HFR1-6: Data Jitter (RJ)	Clock Recovery	PLL Custom BW	PLL Model: Type I Loop BW (MHz)	-
			3 Gbps	4
			6 Gbps	4
			8 Gbps	5.333
			10 Gbps	6.666
			12 Gbps	8
	Cable Settings	Cable Model		Both

Measurement Name	Configuration			Default value
HFR1-7: Data Eye Diagram	Clock Recovery	PLL Custom BW	PLL Model: Type I Loop BW (MHz)	-
			3 Gbps	4
			6 Gbps	4
			8 Gbps	5.333
			10 Gbps	6.666
			12 Gbps	8
	Cable Settings	Cable Model		Both
		Crosstalk		With
		Equalizer Options		CTLE+DFE
		Apply Custom Mask File		Select to apply the custom mask file. Click Browse and select the custom mask files.
HFR1-8: AC Common Mode Voltage	Acquire	Bandwidth (GHz)	3 Gbps	2
			6 Gbps	3
			8 Gbps	4
			10 Gbps	5
			12 Gbps	6

Sink configuration settings. Use the configuration tab to configure the Global Settings and Measurement settings for the measurements. The settings described in this tab is available when Suite in the DUT tab is selected as Sink.

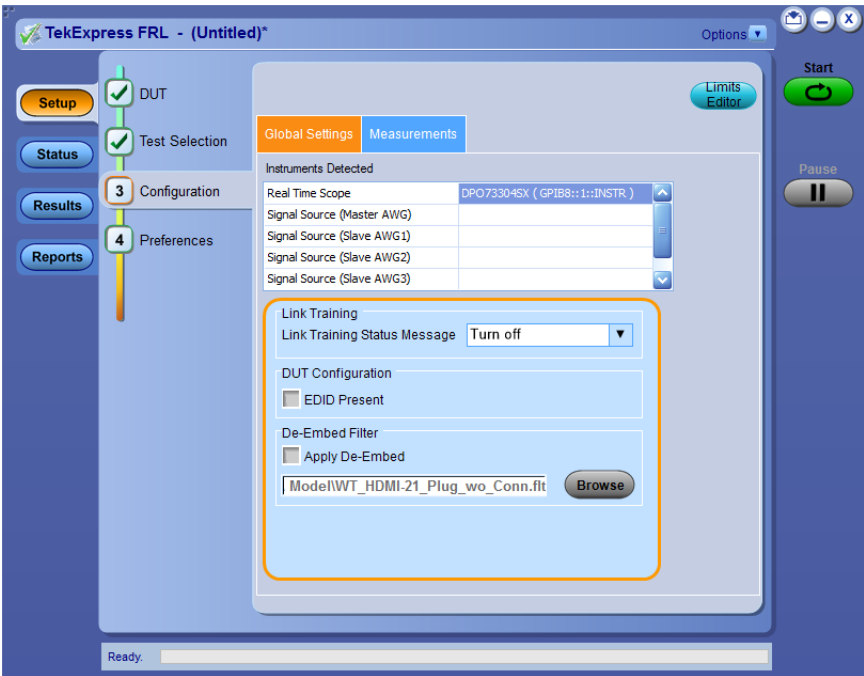


Figure 9: Global settings tab for Sink configuration

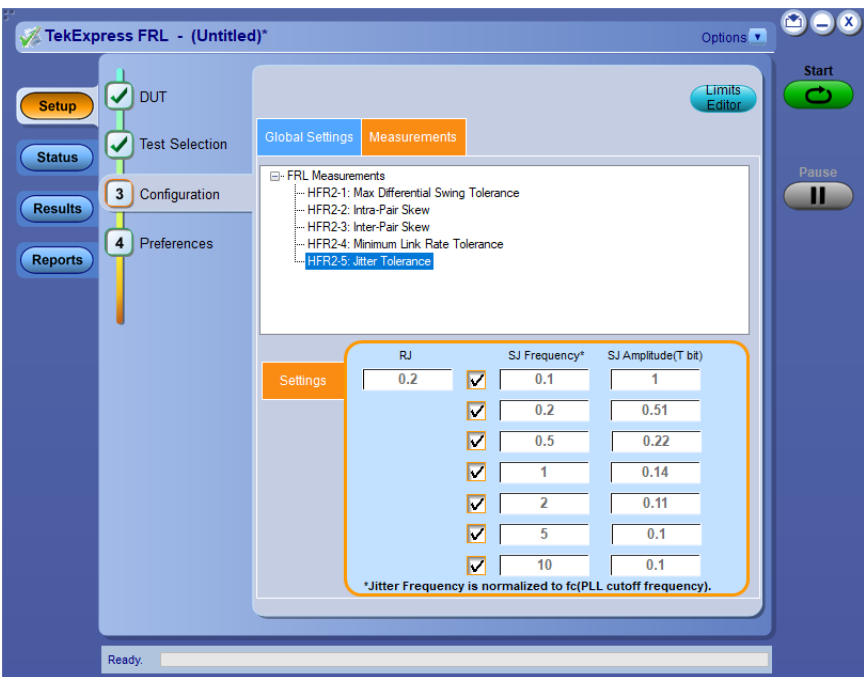


Figure 10: Measurement tab for Sink configuration

Table 11: Sink configuration tab settings

Setting	Description		
Compliance mode settings			
Global Settings			
Instruments Detected	Displays the instruments connected. Click on the instrument IP to open a list of available (detected) instruments and assign the appropriate IP address of corresponding instruments connected . Select Options > Instrument Control Settings and click Refresh to update the instrument list. NOTE. Verify that the GPIB search criteria (default setting) in the Instrument Control Settings is selected when using the TekExpress FRL application.		
Link Training			
Link Training Status Message	■ Turn off When selected, link training status messages are not displayed. ■ Prompt always When selected, displays the status (either pass or fail) of link training status messages. ■ Prompt on failure When selected, only failure link training status messages are displayed.		
DUT Configuration			
EDID Present	The selection of EDID Present is dependent on the presence of EDID on the Sink DUT.		
De-embed filter			
Apply De-embed	Select to apply the de-embed filter file. Click Browse and select the de-embedding filter files (.flt). NOTE. <i>Browse option is enabled only when you select Use filter file for de-embedding.</i>		
Measurements			
HFR2-5: Jitter Tolerance	Settings	RJ T _{bit}	Default value (0.2)
		SJ Frequency (Default value)	SJ Amplitude (T_{bit}) (Default value)
		0.1	1
		0.2	0.51
		0.5	0.22
		1	0.14
		2	0.11
		5	0.1
		10	0.1

Set test notification preferences

Use the Preferences tab to set the application to send an notification when a test measurement completes:

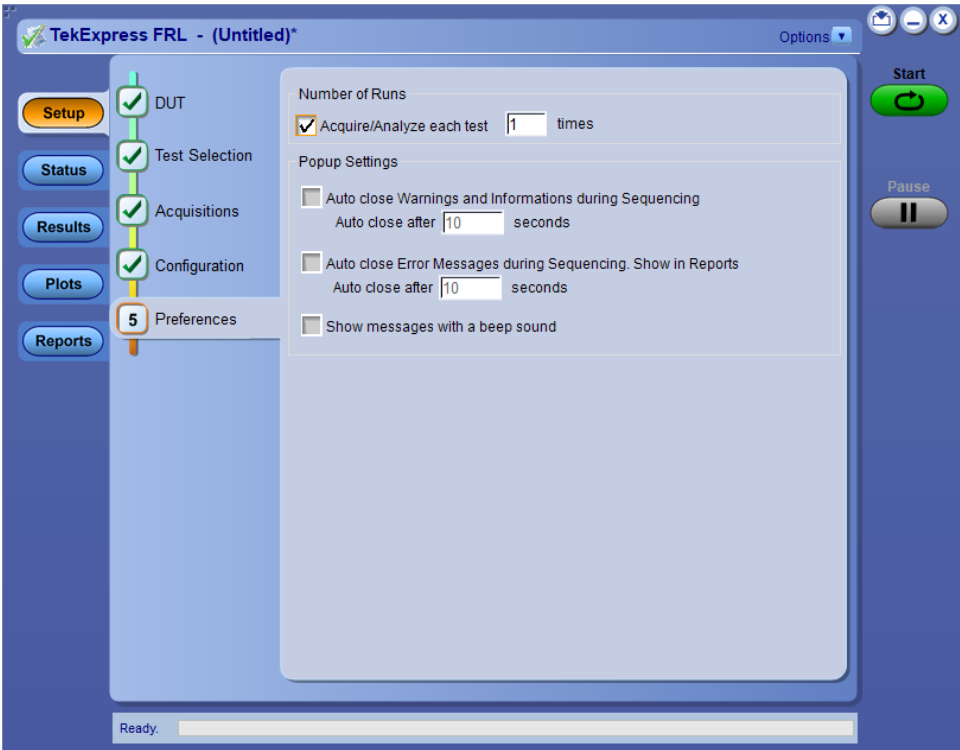


Table 12: Preferences tab settings

Setting	Description
Number of Runs	
Acquire/Analyze each test <number> times	Select to repeat the test run by setting the number of times. By default, it is selected with 1 run. The number of run feature is available only during the live mode.
Popup Settings	
Auto Close Warnings and information during Sequencing Auto close after <number> Seconds	Select to auto close warnings/information during sequencing. Set the Auto close time. By default it is unselected.
Auto Close Error Messages during Sequencing. Show in Reports Auto close after <number> Seconds	Select to auto close Error Messages during Sequencing. Set the Auto close time. By default it is unselected.
Show messages with a beep sound	Select to display the messages with a beep sound. By default it is unselected.
Read Error Counter	Only available when Suite = Sink Enter the number of times the Error count needs to be read.

See also.

[Select report options](#) on page 44

Status panel overview

The Status panel provides status on test acquisition and analysis (Test Status tab) and a listing of test tasks performed (Log View tab). The application opens the Test Status tab when you start a test run. You can select the Test Status or the Log View tab to view these items while tests are running.

The Test Status tab lists a high level status for each test.

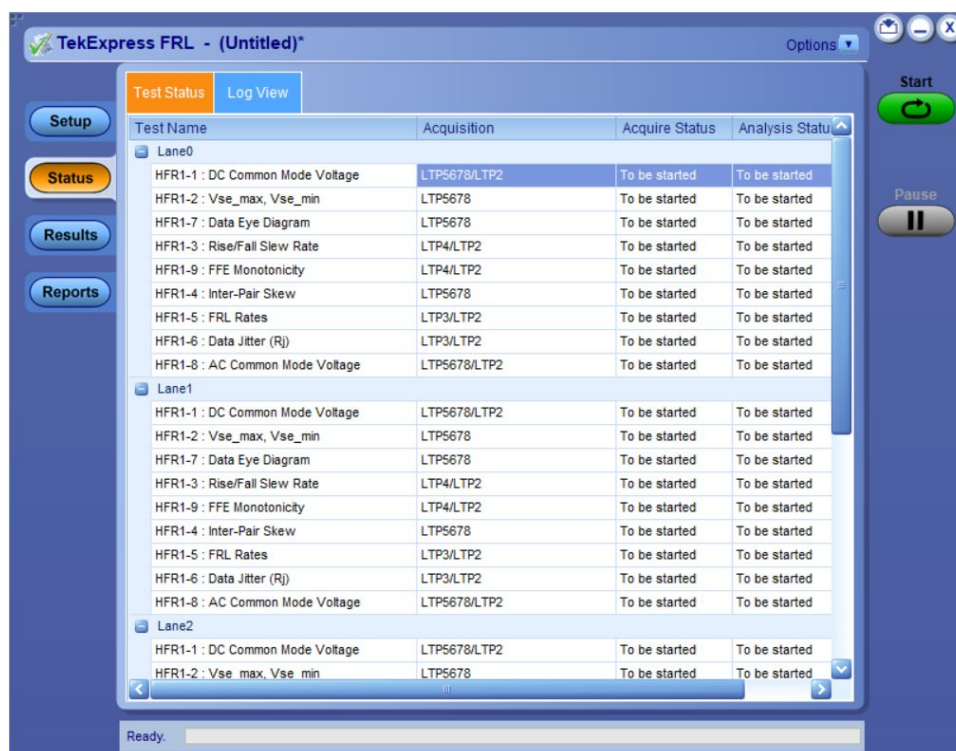


Table 13: Test Status tab

Column	Description
Test Name	Name of the test
Acquisition, Analysis Status	Status of the signal acquisition or test analysis ■ To be started ■ In progress ■ Completed

The Log View tab provides a list of the actions executed during the test. Use this information to review or troubleshoot tests.

Log View tab

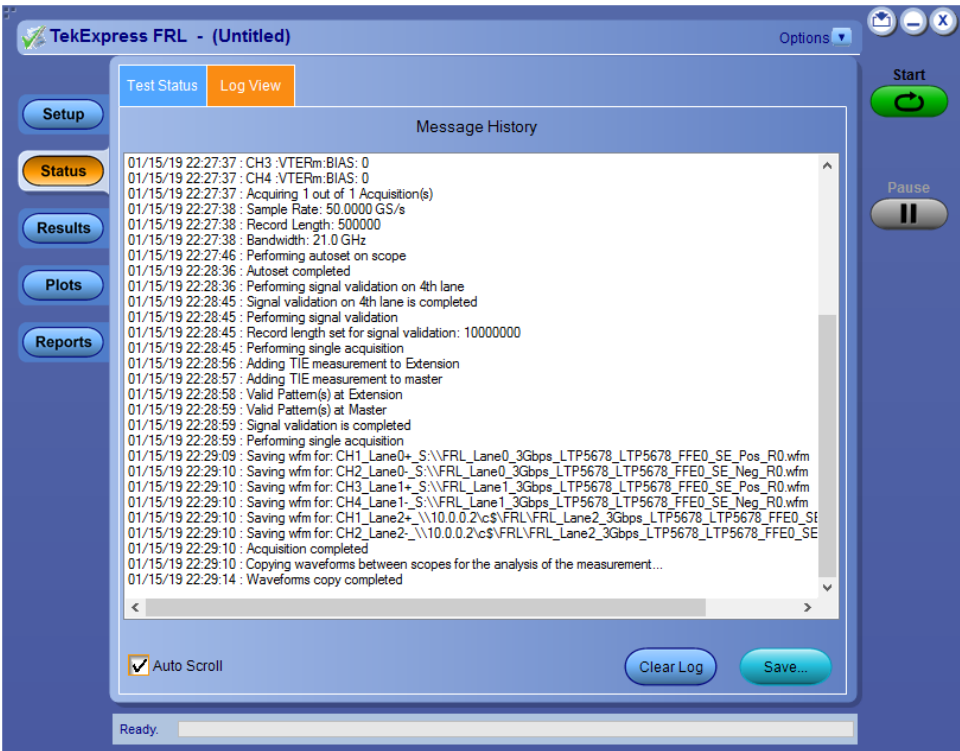


Table 14: Log View fields

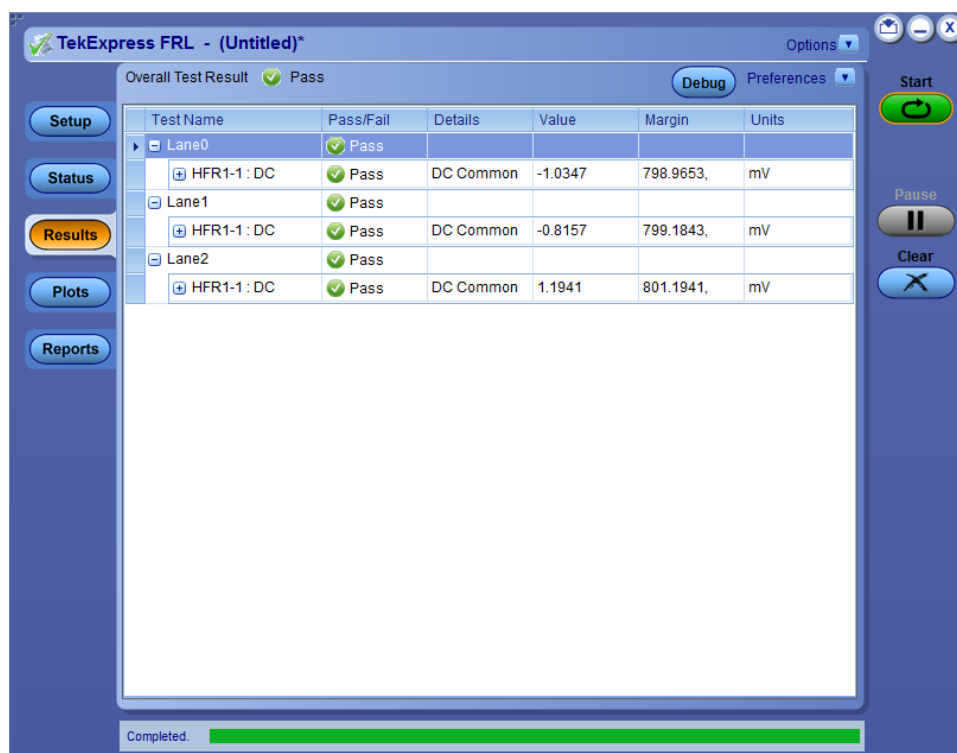
Item	Description
Message History	Displays all run messages with timestamp information
Auto Scroll	Sets the program to automatically scroll down the Message History window as information is added to the log during the test.
Clear Log	Clears all messages in the Message History window.
Save	Saves the log file as a text file for examination. Displays a standard Save As File window and saves the status messages in the file that you specify.

See also [View test results](#) on page 42

Results panel

Results panel overview

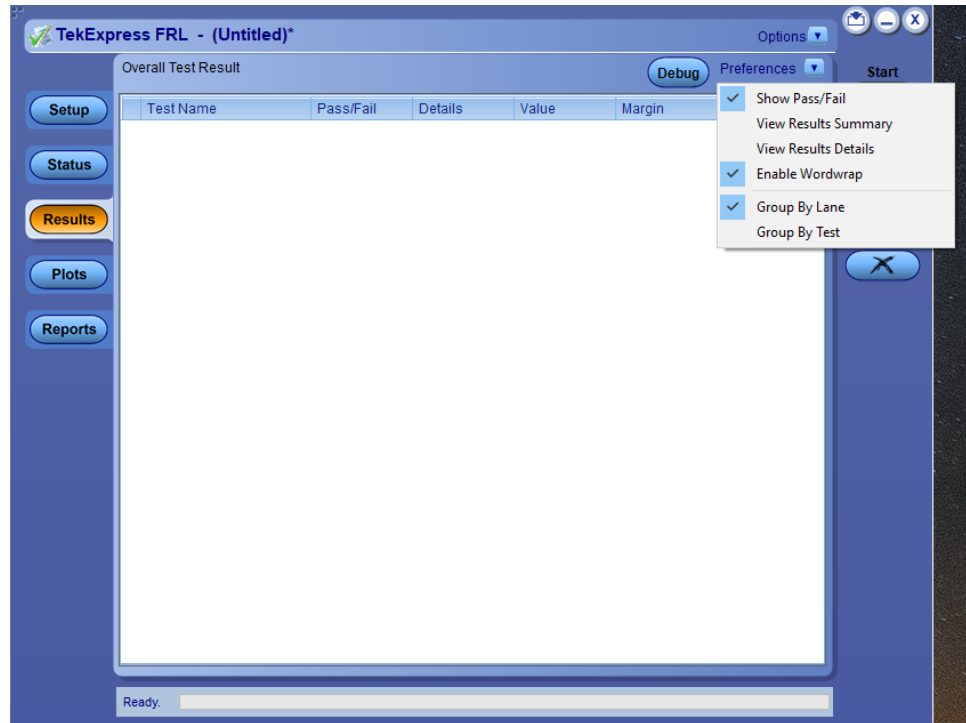
When a test finishes, the application switches to the Results panel to display a summary of test results. Set viewing preferences for this panel from the Preferences menu in the upper right corner. Viewing preferences include showing whether a test passed or failed, summary results or detailed results, and enabling wordwrap. For information on using this panel, see [View test results](#) on page 42.



View test results

When a test finishes, the application switches to the [Results panel](#) on page 41, which displays a summary of test results. The overall test result is displayed at the top left of the Results table. If all of the tests for the session pass, the overall test result will be Pass. If one or more tests fail, the overall test result will show Fail.

Each test result occupies a row in the Results table. By default, results are displayed in summary format with the measurement details collapsed and with the Pass/Fail column visible. Change the view in the following ways:



- To expand all tests listed, select **View Results Details** from the Preferences menu in the upper right corner.
- To expand and collapse tests, click the plus and minus buttons.
- To collapse all expanded tests, select **Preferences > View Results Summary**.
- To remove or restore the Pass/Fail column, select **Preferences > Show Pass/Fail**.
- To enable or disable the wordwrap feature, select **Preferences > Enable Wordwrap**.
- To expand the width of a column, place the cursor over the vertical line that separates the column from the column to the right. When the cursor changes to a double-ended arrow, hold down the mouse button and drag the column to the desired width.
- To sort the test information by column, click the column head. When sorted in ascending order, a small up arrow is displayed. When sorted in descending order, a small down arrow is displayed.
- To clear all test results displayed, click **Clear**.

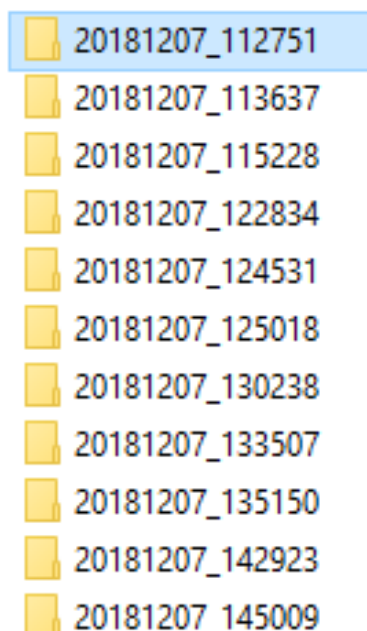
See also.

[View a report](#) on page 46

View test- related files

Files related to tests are stored in the Documents\My TekExpress\FRL folder. In the FRL folder, each test setup has a test setup file and a test setup folder, both with the test setup name. The test setup file is preceded by the FRL icon and usually has no visible file extension.

Inside the test setup folder is another folder named for the DUT ID used in the test sessions. The default is DUT001.



Inside the DUT001 folder are the session folders and files. Each session has a folder and file pair, both named for the test session using the naming convention (date)_(time). Each session file is stored outside its matching session folder.

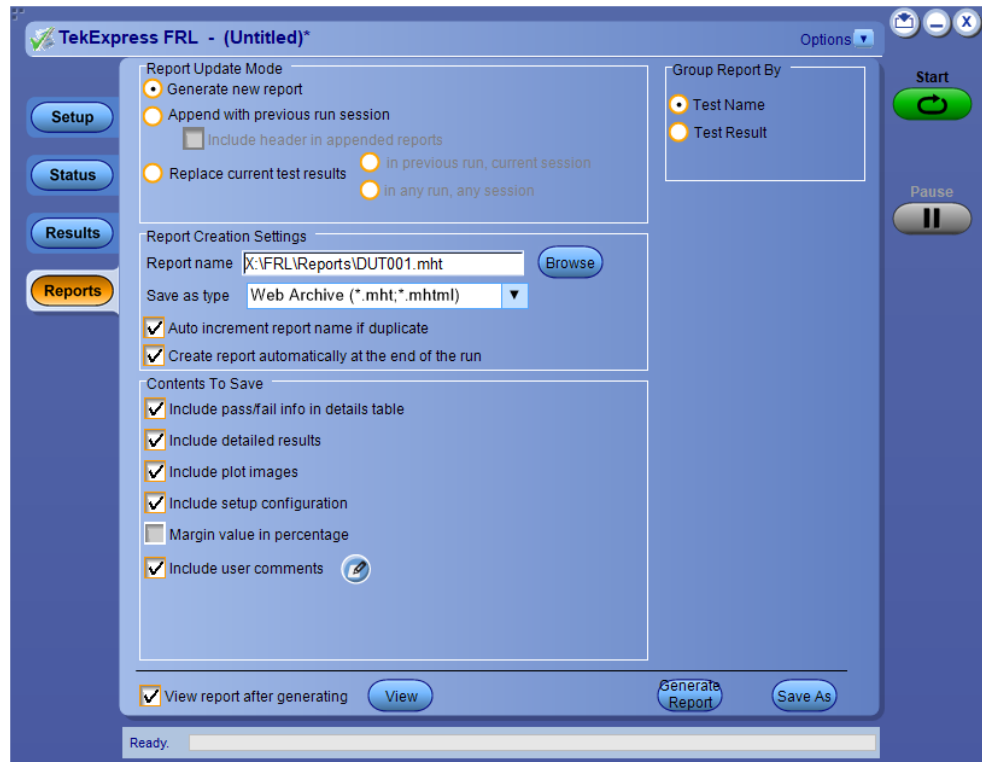
The first time you run a new, unsaved session, the session files are stored in the Untitled Session folder located at ..\My TekExpress\FRL. When you name and save the session, the files are placed in a folder with the name that you specify.

Reports panel

Reports panel overview

Use the Reports panel to save reports, select report content to include, and select report viewing options.

For information on setting up reports, see [Select report options](#) on page 44. For information on viewing reports, see [View a report](#) on page 46.



Select report options

Use the [Reports panel](#) on page 44 to select which test information to include in the report, and the naming conventions to use for the report. For example, always give the report a unique name or select to have the same name increment each time you run a particular test. Generally, you would select report options before running a test or when creating and saving test setups. Report settings are included in saved test setups.

In the Reports panel, select from the following options:

Table 15: Report options

Setting	Description
Report Update Mode	
Generate new report	Creates a new report. The report can be in either .mht or html or .pdf file formats
Append with previous run session	Appends the latest test results to the end of the current test results report.
Include header in appended reports	Includes header in appended reports.
Replace current test in previous run session	Replaces the previous test results with the latest test results.
Report Creation Settings	
Report name	Displays the name and location from which to open a FRL report. The default location is at \My TekExpress\ FRL \Untitled Session. The report file in this folder gets overwritten each time you run a test unless you specify a unique name or select to auto increment the report name. Change the report name or location. Do one of the following: ■ In the Report Path field, type over the current folder path and name. ■ Double-click in the Report Path field and then make selections from the popup keyboard and click the Enter button. Be sure to include the entire folder path, the file name, and the file extension. For example: C: \Documents and Settings\your user name \My Documents\My TekExpress\ FRL\<Username> \DUT001.mht. This folder (C: \Documents and Settings\<user name> \MyDocuments\My TekExpress) is mapped as X drive in the scope. Open an existing report. Click Browse, locate and select the report file and then click View at the bottom of the panel.
Save as type	Saves a report in the specified file type, selected from the dropdown list. NOTE. If you select a file type different from the default, be sure to change the report file name extension in the Report Name field to match.
Auto increment report name if duplicate	Sets the application to automatically increment the name of the report file if the application finds a file with the same name as the one being generated. For example: DUT001, DUT002, DUT003. This option is enabled by default.
Create report automatically at the end of the run	Creates report at the end of the run.
Contents To Save	

Setting	Description
Include pass/fail info in details Table	Includes pass/fail info in the details table of the report.
Include detailed results	Includes detailed results in the report.
Include plot images	Includes plot images in the report.
Include setup configuration	Sets the application to include hardware and software information in the summary box at the top of the report. Information includes: the oscilloscope model and serial number, the oscilloscope firmware version, and software versions for applications used in the measurements.
Margin value in percentage	Enable to Display the margin value in percentage
Include user comments	Select to include any comments about the test that you or another user added in the DUT tab of the Setup panel. Comments appear in the Comments Section, under the summary box at the beginning of each report.
View report after generating	Automatically opens the report in a Web browser when the test completes. This option is selected by default.
View	Click to view the most current report.
Generate Report	Generates a new report based on the current analysis results
Save As	Specify a name for the report.
Include complete application configuration	Displays the general and measurement specific parameters in the report

See also.

[View a report](#) on page 46

View a report

The application automatically generates a report when test analysis is completed and displays the report in your default Web browser (unless you cleared the **View Report After Generating** check box in the Reports panel before running the test). If you cleared this check box, or if you want to view a different test report, do the following:

1. Click the **Reports > Browse** button and locate and select the report file to view.

NOTE. *If you did not save the test setup after running the test and you either closed the application or you ran another test, the report file was not saved.*

2. At the bottom of the Reports panel, click **View**.

For information on changing the file type, file name, and other report options, see [Select report options](#) on page 44.

Report contents A report shows specified test details, as defined in the Reports panel.

Setup configuration information

Setup configuration information is listed in the summary box at the top of the report. This information includes the oscilloscope model and serial number, probe model and serial number, and software versions. To exclude this information from the report, clear the **Include setup configuration** check box in the Reports panel before running the test.

 TekExpress Automated Test Solution TekExpress FRL			
Setup Information			
DUT ID	DUT001	Master Scope Information	DPO73304SX, QU000056
Date/Time	2019-01-21 21:25:15	SPC, Factory Calibration Master	PASS;PASS
Device Type	FRL Source	Scope F/W Version Master	10.9.1 Build 16
App Version	FRL:10.0.0.199	DPOJET Version Master	10.0.8.177
TekExpress Version	Framework:4.9.0.5	Extension Scope Information	DPO73304SX, QU000054
Execution Mode	Live	SPC, Factory Calibration Extension	PASS;PASS
Mode	Compliance	Scope F/W Version Extension	10.9.1 Build 16
Overall Result	Pass	DPOJET Version Extension	10.0.7.9
Connector	Standard	Master CH1 Probe Information	TCA-SMA, N/A
CTS Version	FRL Source v1.0	Master CH2 Probe Information	TCA-SMA, N/A
Overall Execution Time	0:06:15	Master CH3 Probe Information	TCA-SMA, N/A
		Master CH4 Probe Information	TCA-SMA, N/A
		Extension CH1 Probe Information	TCA-SMA, N/A
		Extension CH2 Probe Information	TCA-SMA, N/A
		Extension CH3 Probe Information	TCA-SMA, N/A
		Extension CH4 Probe Information	TCA292D, N/A
DUT COMMENT:	General Comment – FRL		

Figure 11: Report for Source

HFR1-1 : DC Common Mode Voltage								
Lane	Iteration	Measurement Details	Measured Value	Units	Test Result	Margin	Low Limit	High Limit
Lane0	Run1	DC Common Mode at 3Gbps	2660.1790	mV	Pass	160.1790, 669.8210	2500.0	3330.0
Lane1	Run1	DC Common Mode at 3Gbps	2689.9866	mV	Pass	189.9866, 640.0134	2500.0	3330.0
Lane2	Run1	DC Common Mode at 3Gbps	2664.8135	mV	Pass	164.8135, 665.1865	2500.0	3330.0
Lane0	Run1	DC Common Mode at 12Gbps	2662.0594	mV	Pass	162.0594, 667.9406	2500.0	3330.0
Lane1	Run1	DC Common Mode at 12Gbps	2690.0634	mV	Pass	190.0634, 639.9366	2500.0	3330.0
Lane2	Run1	DC Common Mode at 12Gbps	2665.3040	mV	Pass	165.3040, 664.6960	2500.0	3330.0
Lane3	Run1	DC Common Mode at 12Gbps	2669.3794	mV	Pass	169.3794, 660.6206	2500.0	3330.0
COMMENTS								

Tektronix®

TekExpress Automated Test Solution

TekExpress FRL Sink – Calibration Report

Setup Information

DUT ID	DUT001	Master AWG Model	AWG70001
Date/Time	2019-05-24 01:08:05	Master AWG F/W Version	6.1.0056.0
Device Type	FRL	Slave AWG Model	AWG70001
App Version	10.1.0.90	Slave AWG F/W Version	7.1.0162.0
TekExpress Framework Version	4.10.0.35	Scope Model	DPO73304DX
Overall Execution Time	0:04:58	Scope F/W Version	10.8.3 Build 3
		DPOJET Version	10.0.8.149
		EDID/SCDC controller	Wilder
DUT COMMENT:	General Comment – FRL Sink		

Test Name Summary Table

HFR2-1: Max Differential Swing Tolerance	Informative
--	-------------

HFR2-1: Max Differential Swing Tolerance

Data Rate	Measurement Details	Lane	Measured Value	Expected Value
3Gbps	Max	Lane0	1211.400 mV	1200 mV
3Gbps	Nominal	Lane0	1005.033 mV	1000 mV
COMMENTS				

Figure 12: Calibration report for Sink

TekExpress Automated Test Solution

TekExpress FRL Sink – Measurement Report

Setup Information

DUT ID	DUT001	Master AWG Model	AWG70001
Date/Time	2019-04-26 00:24:52	Master AWG F/W Version	6.1.0056.0
Device Type	FRL	Slave AWG Model	AWG70001
App Version	10.1.0.48	Slave AWG F/W Version	7.1.0162.0
TekExpress Framework Version	4.10.0.35	Scope Model	DPO73304DX
Overall Test Result	Pass	Scope F/W Version	10.8.3 Build 3
Overall Execution Time	0:05:27	DPOJET Version	10.0.8.149
DUT COMMENT:	General Comment – FRL Sink		

Test Name Summary Table

HFR2-1: Max Differential Swing Tolerance	Pass
--	------

HFR2-1: Max Differential Swing Tolerance

Data Rate	Details	Lane	Error Count	Max Allowed Error	Max Limit (BER)	Pass/Fail	Run Number
6Gbps	Max	Lane0	0	0			1
6Gbps	Max	Lane1	0	0			1
6Gbps	Max	Lane2	0	0			1
6Gbps	Max	Lane3	0	0			1
6Gbps	Max	All Lanes	0	0	1e-10	Pass	1
COMMENTS							

Figure 13: Measurement report for Sink

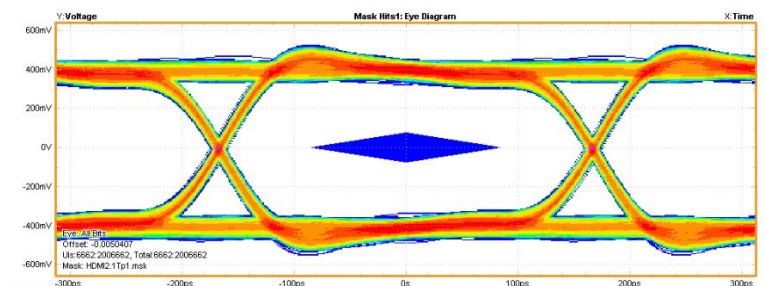
User comments

If you selected to include comments in the test report, any comments you added in the DUT tab of the Setup panel appear in the Comments section directly below the summary box.

Test results

This table lists the tests results. The contents of this table depend on the selections made in the Reports panel before running the test (Include pass/fail results summary, Include user comments, Include detailed results, Include setup configuration, and Include user comments).

If Include plots images is selected, then measurement waveform plots are shown below the test results table.



See also.

[View test results](#) on page 42

[View test- related files](#) on page 43

Exit the application

Use the following method to exit the application:

1. Click  on the application title bar.
2. Do one of the following:
 - If you have an unsaved session or test setup open, you are asked to save it before exiting. To save it, click **Yes**. Otherwise click **No**. The application closes.
 - A message box appears asking if you really want to exit TekExpress. To exit, click **Yes**.

NOTE. Using other methods to exit the application results in abnormal termination of the application.

Running tests

Equipment connection setup for Source

All the tests can be performed by connecting the equipments in probe configuration or stack configuration.

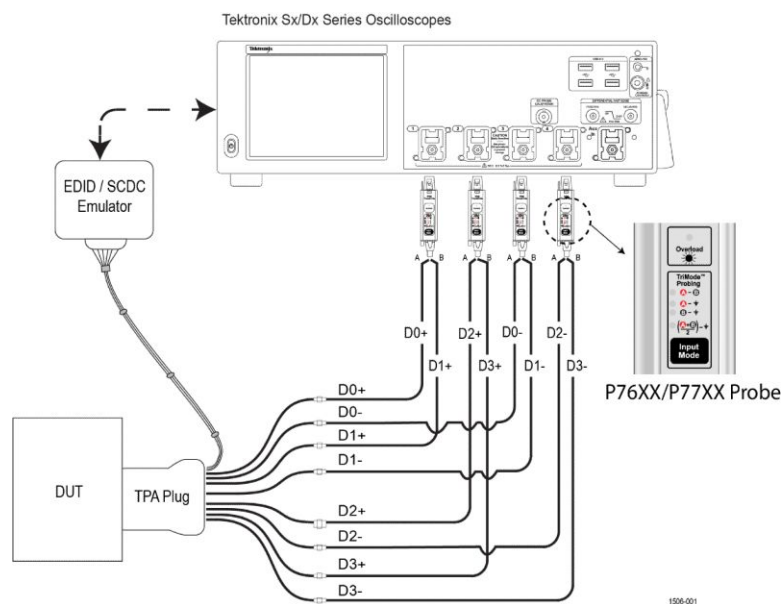


Figure 14: Probe configuration for Source

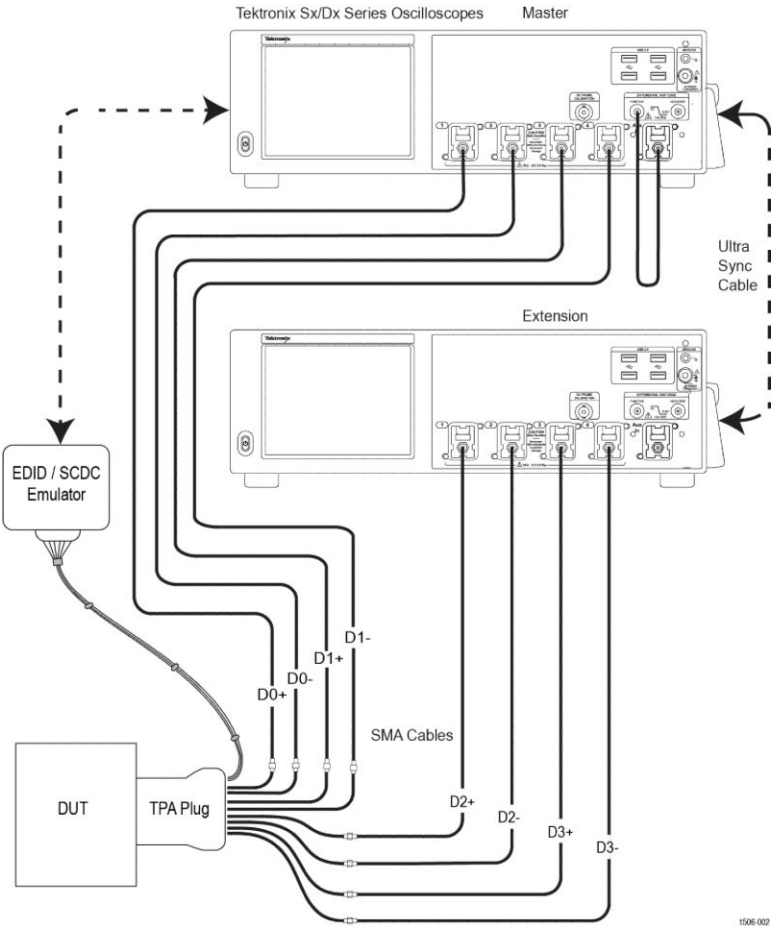


Figure 15: Stack configuration for Source

See also [Recommended accessories](#) on page 5

Equipment connection setup for Sink

All the tests can be performed by connecting the equipments in probe configuration or stack configuration.

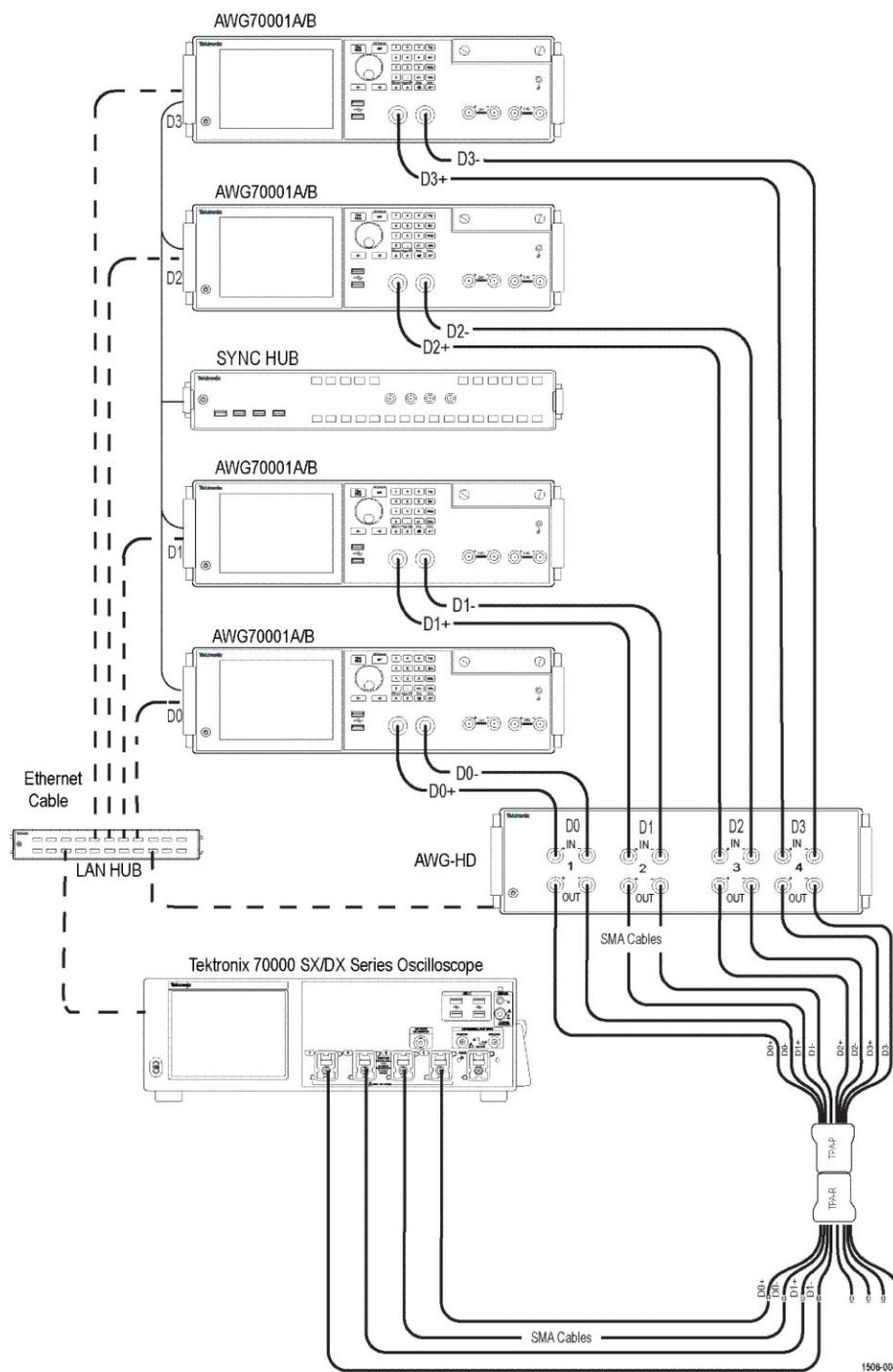


Figure 16: Calibration configuration for Sink

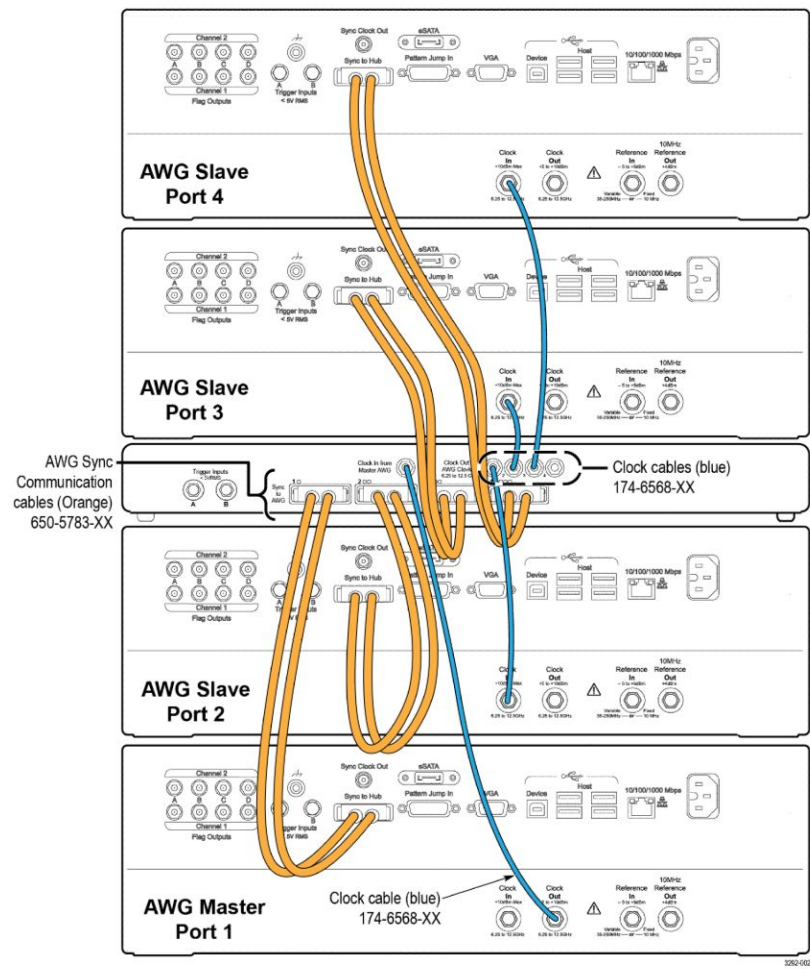


Figure 17: Sink Hub configuration setup

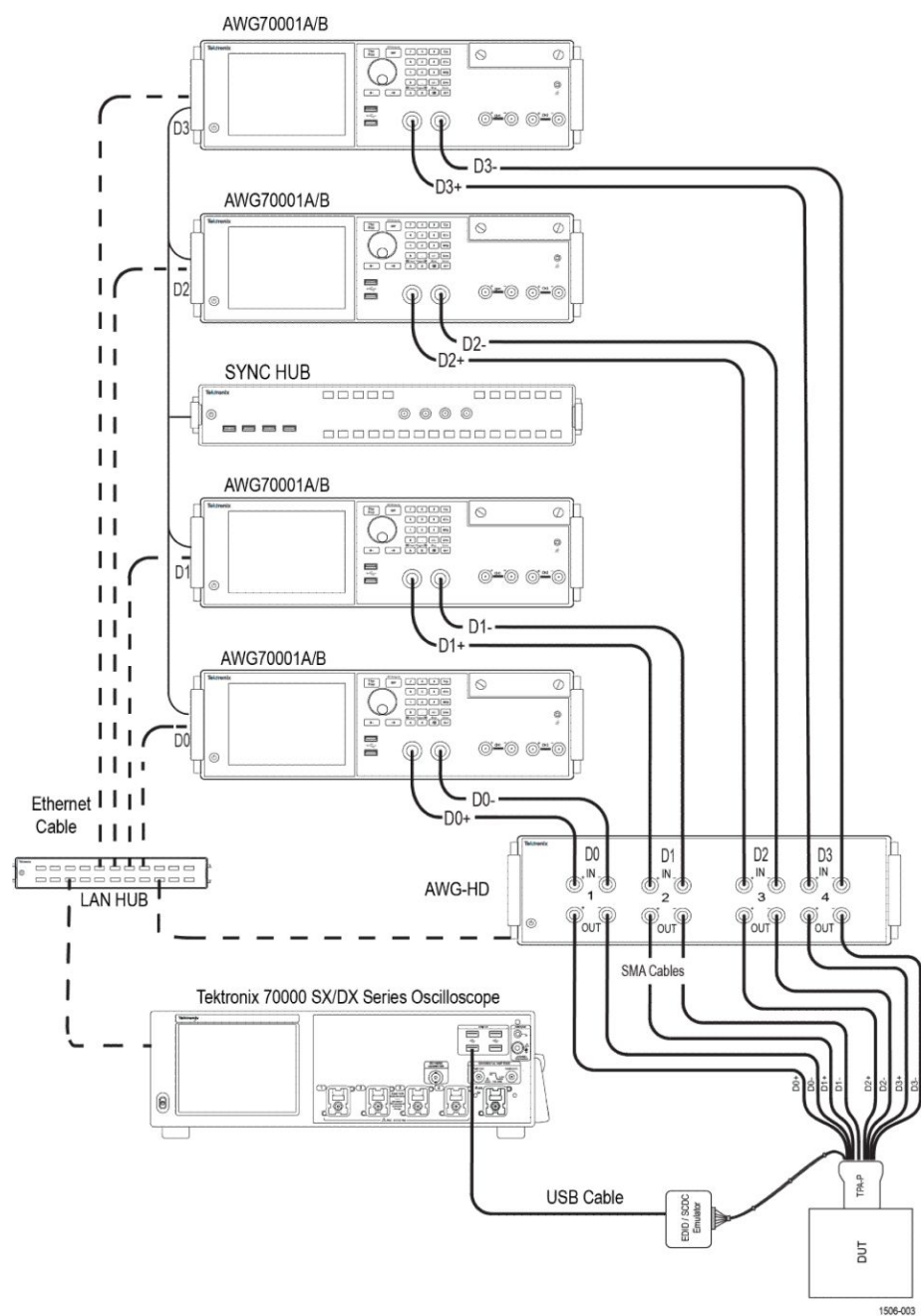


Figure 18: Measurement configuration for Sink

See also [Recommended accessories](#) on page 5

Prerequisite

Compensate the signal path

Use the following procedure to compensate the internal signal acquisition path. Perform this procedure if the ambient temperature has changed more than 5 °C (9 °F) since you performed the last signal path compensation. Perform the signal path compensation once a week. Failure to do so may result in the instrument not meeting warranted performance levels.

1. Power on and wait for the instrument to complete its warm up period before continuing with this procedure.
2. Disconnect any probes you have connected to the input channels.
3. Set the instrument to Menu mode.
4. Select Instrument Calibration from the Utilities menu.
5. Note any instructions that appear in the resulting control window.
6. Click Run SPC to begin the procedure. The procedure may take several minutes to complete.
7. Verify that the Status changes to Compensated after the procedure is complete. If the Calibration Status field indicates anything other than Compensated, see Signal Path Compensation Status for information on the readout and recommended action.

NOTE. When making measurements at vertical scale settings less than or equal to 5 mV, you should perform the signal path compensation at least once a week. Failure to do so may result in the instrument not meeting warranted performance levels at those volts/div settings.

Deskew

If skew is present between positive and negative channels, then the channels need to be deskewed before being used for waveform measurements. TekExpress FRL provides support for channel deskew and attenuation using the following method:

There are no different types of deskew methods. These are the pre-requisites that need to be performed before running the measurements.

- For Source:
 1. Stack deskew :
 - a. Perform scope SPC
 - b. Perform scope channel deskew
 2. Probe deskew :
 - a. Perform scope SPC
 - b. Probe DC Compensation
- For Sink:
 - Perform Scope spc
 - Perform scope channel deskew
 - Perform WEBAC deskew
 - Perform all AWG Calibration
 - Perform Sync hub deskew

Running tests

[Select tests](#) on page 28, [Set acquisition parameters](#) on page 29, [Set configuration tab parameters](#) on page 32, [Set test notification preferences](#) on page 38, and click **Start** to run the tests. While tests are running, you cannot access the Setup or Reports panels. To monitor the test progress, switch between the Status panel and the Results panel.

While the tests are running, other applications may display windows in the background. The TekScope application takes precedence over other applications, but you can switch to other applications by using **Alt + Tab** key combination. To keep the TekExpress FRL application on top, select **Keep On Top** from the TekExpress Options menu.

Once the test execution is completed, the application displays the report.

Prerun checklist

1. Make sure that the instruments are warmed up (approximately 20 minutes) and stabilized.
2. Perform compensation: In the oscilloscope main menu, select **Utilities > Instrument Compensation**. Click **Help** in the compensation window for steps to perform instrument compensation.

Saving and recalling test setup

Test setup files overview

Saved test setup information (such as the selected oscilloscope, general parameters, acquisition parameters, measurement limits, waveforms (if applicable), and other configuration settings) are saved under the setup name at **X:\FRL**.

Use test setups to:

- Run a new session, acquiring live waveforms, using a saved test configuration.
- Create a new test setup using an existing one.
- View all the information associated with a saved test, including the log file, the history of the test status as it executed, and the results summary.
- Run a saved test using saved waveforms.

See also [Save a test setup](#) on page 59
 [Open \(load\) a saved test setup](#) on page 60

Save a test setup

You can save a test setup before or after running a test. You can create a test setup from [Create a test setup using an existing one](#) on page 60, or using [Create a test setup from default settings](#) on page 60. When you select the default test setup, the parameters are set to the application's default value.

Select **Options > Save Test Setup** to save the opened setup.

Select **Options > Save Test Setup As** to save the setup with different name.

Open (load) a saved test setup

To Open (load) a saved test setup, do the following:

1. Select **Options > Open Test Setup**.
2. Select the setup from the list and click **Open**. Setup files are located at **X:\FRL**.

See also [Test setup files overview](#) on page 59
[Create a test setup using an existing one](#) on page 60
[Create a test setup from default settings](#) on page 60

Create a test setup from default settings

To create a test setup using default settings, follow the steps:

1. Select **Options > Default Test Setup**. For default test setup, the parameters are set to the application's default value.
2. Click application [Setup panel](#) on page 21 and set the parameters
3. Click application [Reports panel](#) on page 44 and set the report options
4. Optional: Click **Start** to run the test and verify that it runs correctly and captures the specified test information and reports. If it does not, then edit the parameters and repeat this step until the test runs to your satisfaction
5. Select **Options > Save Test Setup**. Enter the file name and click Save. The application saves the file to X:\FRL*<session_name>*

Create a test setup using an existing one

To create a test setup using an existing one, follow the steps:

1. Select **Options > Open Test Setup**
2. Select a setup from the list and then click **Open**
3. Click application [Setup panel](#) on page 21 and modify the parameters
4. Click application [Reports panel](#) on page 44 and modify the report options
5. Select **Options > Save Test Setup As**
6. Enter test setup name, and click **Save**

FRL Source tests

HFR1-1: DC Common Mode Voltage

This test measurement verify that the DC bias of each side of each Data lane.

Required test equipment *Equipment connection setup for Source* on page 51
Recommended accessories on page 5

- Measurement procedure**
1. Configure the DUT to transmit the lowest supported FRL data rate with TxFFE Level set to 0.
 2. Set the DUT to output LTP5, LTP6, LTP7, LTP8 pattern Lane0, Lane1, Lane2, and Lane3 respectively.
 3. Connect the L_X_p (+ve) and L_X_m (-ve) (waveforms) to Digital oscilloscope using either Tektronix recommended probe or TCA-SMA cable.
 4. Capture L_X_p (+ve) and L_X_m (-ve) single-ended signals.
 5. Set the cursor gating to 221184 unit intervals (3*4096 FRL characters).
 6. Optionally de-embed Plug TPA using the TPA vendor's de-embed file.
 7. Calculate L_X_DC Common Mode Voltage as,
$$L_X_DC \text{ Common Mode voltage} = \text{Average} ((L_X_p + L_X_m)/2)$$
 8. If $L_X_DC \text{ Common Mode Voltage} < AV_{cc} - 800 \text{ mV}$, then FAIL.
Similarly if $L_X_DC \text{ Common Mode Voltage} > AV_{cc} + 30 \text{ mV}$, then FAIL.
 9. Repeat step 6 and step 7 for all FRL lanes.

HFR1-2: Vse_max,Vse_min

This test measurement measures the single ended max and min voltages for each side of each data lane.

Required test equipment *Equipment connection setup for Source* on page 51
Recommended accessories on page 5

- Measurement procedure**
1. Configure the DUT to transmit lowest supported FRL data rate with TxFFE Level set to 0.
 2. Set the DUT to output LTP5, LTP6, LTP7, LTP8 pattern Lane0, Lane1, Lane2, and Lane3 respectively.
 3. Connect L_X_p (+ve) and L_X_m (-ve) (waveforms) to Digital oscilloscope using either Tektronix recommended probe or TCA-SMA cables.
 4. Capture L_X_p (+ve) and L_X_m (-ve) single-ended signals.
 5. Set the cursor gating to 221184 unit intervals (2*4096 FRL characters).
 6. Optionally de-embed the Plug TPA using vendor's de-embed file.
 7. Perform the L_X_DC Common Mode measurement as per Test ID HFR1-1.
 8. Find the Maximum L_X_p voltage as
$$\text{Max } V_{L_X_p} = \text{MAX}(L_X_p)$$
 9. Find the Minimum L_N_p voltage:
$$\text{Min } V_{L_X_p} = \text{MIN}(L_X_p)$$
 10. Find the Maximum L_N_n voltage:
$$\text{Max } V_{L_X_n} = \text{MAX}(L_X_n)$$
 11. Find the Minimum L_N_p voltage:
$$\text{Min } V_{L_X_n} = \text{MIN}(L_X_n)$$
 12. Compare the results with the test limit.
 13. Repeat step 6 to step 12 for all FRL lanes.

HFR1-3: Rise/Fall Slew Rate

The transition time must be more than the specified minimum because of potential for radiated emissions from transmitters with fast edges and skew. This test evaluates the transition time for an FRL Transmitter for rising and falling edges.

Required test equipment *Equipment connection setup for Source* on page 51
Recommended accessories on page 5

- Measurement procedure**
1. Connect the DUT to the digital oscilloscope using TPA-P fixture, in one of the configurations as shown in connection diagram.
 2. Configure the DUT to transmit highest supported FRL data rate with TxFFE Level set to 0.
 3. Set the DUT to output LTP4 pattern for the lane under test and LTP2 for all other non-target lanes.
 4. Adjust the scope vertical settings such that the signal occupies around 8 divisions on the graticule.
 5. Capture L_X_p (+ve) and L_X_m (-ve) single ended signals.
 6. Optionally de-embed Plug TPA using the TPA vendor's de-embed file.
 7. Measure the slew rate of L_X_p (+ve) and L_X_m (-ve) over 60% - 40% reference level. Consider at least 500 rising and 500 falling edges for the measurement.
 8. SlewRise=Average rising edge measurements.
 9. SlewFall=Average falling edge measurements.
 10. If either SlewRise or SlewFall is more than 16 mV/ps then FAIL.
 11. Repeat step 3 to step 10 for all FRL lanes.

HFR1-4: Inter-Pair Skew

This test measures the difference in time between any two FRL Data Lanes.

Required test equipment *Equipment connection setup for Source* on page 51
Recommended accessories on page 5

- Measurement procedure**
1. Configure the DUT to transmit highest supported FRL data rate with TxFFE Level set to 0.
 2. Set the DUT to output LTP5, LTP6, LTP7, LTP8 pattern Lane0, Lane1, Lane2, and Lane3 respectively.
 3. Connect L_X_p (+ve) and L_X_m (-ve) (waveforms) to Digital oscilloscope using either Tektronix recommended probe or TCA-SMA cables.
 4. Capture L_X_p (+ve) and L_X_m (-ve) single-ended signals. Create the differential signal using Math subsystem.
$$L_X = L_X_p - L_X_m$$
 5. For the target lanes A and B, find the SR character in each acquisition.
 6. Evaluate time difference, InterPair Skew_A_B, between the SR characters of the target lanes.
$$T_{\text{INTERPAIR_SKEW_A_B}} = \text{Time Location of SR_A} - \text{Time Location of SR_B}$$
 7. If $T_{\text{INTERPAIR_SKEW_A_B}}$ is greater than $4T_{\text{bit}}$ then FAIL.
 8. Repeat step 4 to step 7 for all combinations of FRL lanes A and B.

HFR1-5: FRL Rates

This test measures the frequency or data rate accuracy to the nominal FRL data rates.

Required test equipment *Equipment connection setup for Source* on page 51
Recommended accessories on page 5

- Measurement procedure**
1. Configure the DUT to transmit lowest supported FRL data rate with TxFFE Level set to 0.
 2. Set the DUT to output LTP3 pattern for the lane under test and LTP2 for all other non-target lanes.
 3. Connect L_X_p (+ve) and L_X_m (-ve) (waveforms) to Digital oscilloscope using either Tektronix recommended probe or TCA-SMA cables.
 4. Set the record length to include 1 million Unit Intervals.
 5. Set the vertical scale such that the signal to noise ratio is minimized.
 6. Capture L_X_p (+ve) and L_X_m (-ve) single-ended signals. Create the differential signal using Math subsystem.

$$L_X = L_X_p - L_X_m$$
 7. Optionally de-embed Plug TPA using the TPA vendor's de-embed file.
 8. Measure data rate for target lane by measuring frequency of signal.

$$L_X_Data\ Rate = Frequency * 2$$
 9. Calculate L_X error from nominal bit rate targeted.
 10.
$$L_X_error = 1E6 * (L_X_Data\ Rate - Nominal\ Data\ Rate\ Setting) / (Nominal\ Data\ Rate\ Setting)$$
 11. If L_X_error > 300 ppm, then FAIL.
 12. Repeat step 6 to step 11 for all FRL lanes.
 13. Repeat step 1 to step 12 for the highest supported FRL data rate.

HFR1-6: Data Jitter (RJ)

This test evaluates Data Jitter (RJ peak-to-peak and RJ RMS) of the FRL link with a clock pattern transmitted on the target channel. Data Jitter can be used in the data eye diagram to compensate a 1E-10 BER mask to a 1E-6 BER mask.

- Required test equipment**
- Equipment connection setup for Source* on page 51
 - Recommended accessories* on page 5

- Measurement procedure**
1. Configure the DUT to transmit lowest supported FRL data rate with Tx FFE Level set to 0.
 2. Set the DUT to output LTP3 pattern for the lane under test and LTP1 for all other non-target lanes.
 3. Connect L_X_p (+ve) and L_X_m (-ve) (waveforms) to Digital oscilloscope using either Tektronix recommended probe or TCA-SMA cables.
 4. Set the record length to 1 million User Intervals.
 5. Set the vertical scale such that the signal to noise ratio is minimized.
 6. Capture L_X_p (+ve) and L_X_m (-ve) single-ended signals. Create the differential signal using Math subsystem.
$$L_X = L_X_p - L_X_m$$
 7. Optionally de-embed Plug TPA using the TPA vendor's de-embed file.
 8. Measure the RJ (RMS) and RJ (Pk-Pk) after applying the 8 dB CTLE and WCM3 cable model.
 9. If RJ (Pk-Pk) > 0.2 T_{bit}, then FAIL.
 10. Repeat step 8 and step 9 with 1dB CTLE and SCM3 cable model.
 11. Repeat step 2 and step 10 for all FRL lanes.
 12. Repeat step 1 to step 11 for the highest supported FRL data rate.

HFR1-7: Data Eye Diagram

This test evaluates that the waveform parameters over a significant interval of time to verify that with proper clock recovery there is no signal incursion into regions defined by a mask to result in correct demodulation of data.

- Required test equipment**
- Equipment connection setup for Source* on page 51
 - Recommended accessories* on page 5

Measurement procedure

1. Configure the DUT to transmit lowest supported FRL data rate with TxFFE Level set to 0.
2. Set the DUT to output LTP5, LTP6, LTP7, LTP8 pattern Lane0, Lane1, Lane2, and Lane3 respectively.
3. Connect L_X_p (+ve) and L_X_m (-ve) (waveforms) to Digital oscilloscope using either Tektronix recommended probe or TCA-SMA cables.
4. Set the scope sampling rate to 100 G Sa/s.
5. Set the vertical scale such that the signal to noise ratio is minimized.
6. Set the record length to 2 million User Intervals.
7. Acquire single-ended L_X_p (+ve) and L_X_m (-ve) signals for all lanes. Create the differential signal using Math subsystem.

$$L_X = L_X_p - L_X_m$$

8. Optionally de-embed Plug TPA using the TPA vendor's de-embed file.
9. For the target lane, a channel model is applied to the acquisition waveform for that lane to comprehend the differential insertion loss for that lane.
10. Crosstalk from the non-target lanes is applied using acquisitions for each lane and applying the crosstalk transfer function derived from the channel model.
11. Apply the equalization (CTLE and DFE, if 12 Gbps; Only CTLE, for any other data rate) on the resulting summed waveform.

FRL rate	Cable Model	CTLE	DFE
12 Gbps	WCM3S	8 db	25 mV
12 Gbps	SCM3S	1 db	n/a
3/6/8/10 Gbps	WCM3S	8 db	n/a
3/6/8/10 Gbps	SCM3S	1 db	n/a

12. Apply the PLL clock recovery with the below Loop Bandwidth.
 Loop BW = $(R_{bit} / 1500)$, where R_{bit} 12 Gbps, 10 Gbps, 8 Gbps and 6 Gbps
 = 4MHz when R_{bit} 3Gbps
13. Render eye diagram and verify no point incursions in mask area.
14. Repeat step 8 to step 13 for both channel models (WCM and SCM).
15. Repeat step 8 to step 14 for each data lane.
16. Repeat step 1 to step 15 for the highest supported FRL data rate.

HFR1-8: AC Common Mode Voltage

This test verifies that the AC common mode noise of a transmitter is limited to a percentage of the nominal DC differential swing to ensure that radiated emissions due to the common mode noise are limited.

Required test equipment [Equipment connection setup for Source](#) on page 51
[Recommended accessories](#) on page 5

- Measurement procedure**
1. Configure the DUT to transmit highest supported FRL data rate with TxFFE Level set to 0.
 2. Set the DUT to output LTP5, LTP6, LTP7, LTP8 pattern Lane0, Lane1, Lane2, and Lane3 respectively.
 3. Connect L_X_p (+ve) and L_X_m (-ve) (waveforms) to Digital oscilloscope using either the recommended probe or TCA-SMA cables.
 4. Set the oscilloscope bandwidth to one half the data rate.
 5. Capture L_X_p (+ve) and L_X_m (-ve) single-ended signals.
 6. Optionally de-embed Plug TPA using the TPA vendor's de-embed file.
 7. Create Common Mode Waveform of the target lane:
$$L_XCM = (L_X_plus + L_X_minus)/2$$
 8. Measure VCM_L_X_pp = peak to peak voltage of L_XCM.
 9. If VCM_L_X_pp > 150 mV, then FAIL.
 10. Repeat step 6 to step 9 for all FRL lanes.

HFR1-9: FFE Monotonicity-Method 1

This test verifies that the parameters of FFE, pre-shoot amplitude and de-emphasis, are monotonic from one FFE state to the next FFE state.

Required test equipment [Equipment connection setup for Source](#) on page 51
[Recommended accessories](#) on page 5

Measurement procedure

1. Configure the DUT to transmit highest supported FRL data rate with TxFFE Level set to 0.
2. Set the DUT to output LTP4 pattern for the lane under test and LTP2 for all other non-target lanes.
3. Connect L_X_p (+ve) and L_X_m (-ve) (waveforms) to Digital oscilloscope using either Tektronix recommended probe or TCA-SMA cables.
4. Set the vertical scale such that the signal to noise ratio is minimized.
5. Setup time scale to demonstrate ~192 UI with the positive going pulse in the middle of the screen.
6. Optionally de-embed Plug TPA using the TPA vendor's de-embed file.
7. Configure the DUT in de-emphasis only mode by setting xFFE_De_Emphasis Only bit.
8. Capture L_X_p (+ve) and L_X_m (-ve) single-ended signals
9. Measure Vd,
10. Configure the DUT in pre-emphasis only mode by setting TxFFE_Pre_Shoot Only bit.
11. Capture L_X_p (+ve) and L_X_m (-ve) single-ended signals.
12. Measure Vp.
13. Configure the DUT in Vn when FFE is in state 0.
14. Capture L_X_p (+ve) and L_X_m (-ve) single-ended signals.
15. Measure Vn.
16. $\text{dBDe-emphasis_FFE0} = 20 * \text{Log}(Vn/Vp)$
17. $\text{dBPre-Shoot_FFE0} = 20 * \text{Log}(Vd/Vn)$
18. Repeat step 7 to step 15 for all FFE states, X and calculate dBDeemphasis_FFEX and dBPre-Shoot_FFEX.
19. If the difference of pre-shoot between any two successive FFE levels is greater than 0dB then Pass. Similarly If the difference of de-emphasis between any two successive FFE levels is less than 0dB then Pass.
20. Repeat step 7 to step 19 for all FRL lanes.

HFR1-9: FFE Monotonicity-Method 2

This test verifies that the parameters of FFE, pre-shoot amplitude and de-emphasis, are monotonic from one FFE state to the next FFE state.

Required test equipment *Equipment connection setup for Source* on page 51
Recommended accessories on page 5

- Measurement procedure**
1. Configure the DUT to transmit highest supported FRL data rate with TxFFE Level set to 0.
 2. Set the DUT to output LTP4 pattern for the lane under test and LTP2 for all other non-target lanes.
 3. Connect L_X_p (+ve) and L_X_m (-ve) (waveforms) to Digital oscilloscope using either Tektronix recommended probe or TCA-SMA cables.
 4. Set the vertical scale such that the signal to noise ratio is minimized.
 5. Setup time scale to demonstrate ~192 UI with the positive going pulse in the middle of the screen.
 6. Optionally de-embed Plug TPA using the TPA vendor's de-embed file.
 7. Configure the DUT in de-emphasis only mode by setting xFFE_De_Emphasis Only bit.
 8. Capture L_X_p (+ve) and L_X_m (-ve) single-ended signals.
 9. Measure $V_d = V_0 - |V_{+1}|$.
 10. Configure the DUT in pre-emphasis only mode by setting TxFFE_Pre_Shoot Only bit.
 11. Capture L_X_p (+ve) and L_X_m (-ve) single-ended signals.
 12. Measure $V_p = V_0 - |V_{-1}|$.
 13. Configure the DUT in No FFE mode by setting the TxFFE_NO_FFE bit.
 14. Capture L_X_p (+ve) and L_X_m (-ve) single-ended signals.
 15. Measure V_0 .
 16.
$$\text{dBDe-emphasis_FFE0} = 20 \cdot \log \left(\frac{V_0 - |V_{-1}| - |V_{+1}|}{V_0 - |V_{-1}| + |V_{+1}|} \right)$$
 17.
$$\text{dBPre-Shoot_FFE0} = 20 \cdot \log \left(\frac{V_0 + |V_{-1}| - |V_{+1}|}{V_0 - |V_{-1}| - |V_{+1}|} \right)$$
 18. Repeat step 7 to step 15 for all FFE states, X and calculate dBDeemphasis_FFEX and dBPre-Shoot_FFEX.
 19. If the difference of pre-shoot between any two successive FFE levels is greater than 0dB then Pass. Similarly If the difference of de-emphasis between any two successive FFE levels is less than 0dB then Pass.
 20. Repeat step 7 to step 19 for all FRL lanes.

FRL Sink Tests

HRF2-1:Max Differential Swing Tolerance

This test confirms that the Sink supports FRL differential voltages at maximum level.

Required test equipment *Equipment connection setup for Sink* on page 53
Recommended accessories on page 5

- Measurement procedure**
1. Connect the AWGs (AWG70001A/AWG70001B) to the oscilloscope through AWG-HD box, Sync hub and TPA-PR fixture, as shown in the *Figure 18: Measurement configuration for Sink* on page 55.
 2. Configure the AWGs to lowest FRL rate supported by the DUT.
 3. Adjust the common mode voltage (VICM) to a level defined in HDMI version 2.1 Table 6-25
 4. Calibrate differential mode swing voltage of the AWG at PTP2_cal with no cable model applied to Maximum Differential Swing 1200 mV using RXSB33PAT pattern.
 5. Connect the AWGs to the Sink DUT using TPA-P as shown in *Figure 18: Measurement configuration for Sink* on page 55.
 6. Complete the Link Training between Sink DUT and FRL Signal Generator for the selected FRL Rate. If Link Training is not successful, then FAIL
 7. Configure the AWGs to transmit RXSB33PAT pattern.
 8. Read the Error Counter from Sink DUT using I2C controller.
 9. Conduct error counter test as described in section *BER estimation procedure* on page 76. If error counter check fails, then FAIL.
 10. Configure the AWG to highest FRL rate supported by the DUT and connect the AWGs to the oscilloscope using AWG-HD box, Sync hub, TPA-P and TPA-R.
 11. Repeat Steps 4 to step 9 for successful link training.

HRF2-2:Intra-Pair Skew

This test confirm that the maximum allowed timing skew within each FRL pair is supported by the Sink DUT

Required test equipment *Equipment connection setup for Sink* on page 53
 Recommended accessories on page 5

- Measurement procedure**
1. Connect the AWGs (AWG70001A/AWG70001B) to the oscilloscope through AWG-HD box, Sync hub and TPA-PR fixture, as shown in the *Figure 18: Measurement configuration for Sink* on page 55.
 2. Configure the AWGs to lowest FRL rate supported by the DUT.
 3. Adjust the common mode voltage (VICM) to a level defined in HDMI version 2.1 Table 6-25.
 4. For all FRL Signals, set the single ended swing to 500 mV.
 5. Calibrate for a skew of $0.15 \cdot T_{\text{bit}}$ on a line of the FRL target lane against its complement, at TP2 using WCM3 cable model.
 6. Connect the AWGs to the Sink DUT using TPA-P as shown in *Figure 18: Measurement configuration for Sink* on page 55.
 7. Complete the Link Training between Sink DUT and FRL Signal Generator for the selected FRL Rate. If Link Training is not successful, then FAIL.
 8. Configure the AWGs to transmit RXSB33PAT pattern.
 9. Read the Error Counter from Sink DUT using I2C controller.
 10. Conduct error counter test as described in section *BER estimation procedure* on page 76. If error counter check fails, then FAIL.
 11. Switch the setting of the signal delay on the complement line for the target FRL Lane pair. Repeat step 7 to Step 10.
 12. Configure the AWG to highest FRL rate supported by the DUT and connect the AWGs to the oscilloscope using AWG-HD box, Sync hub, TPA-P and TPA-R.
 13. Repeat Steps 5 to step 11 for all the FRL lines.

HRF2-3:Inter-Pair Skew

This test confirm that the maximum allowed skew between FRL Lanes is supported by the Sink DUT.

Required test equipment *Equipment connection setup for Sink* on page 53

Recommended accessories on page 5

- Measurement procedure**
1. Connect the AWGs (AWG70001A/AWG70001B) to the oscilloscope through AWG-HD box, Sync hub and TPA-PR fixture, as shown in the *Figure 18: Measurement configuration for Sink* on page 55.
 2. Configure the AWGs to lowest FRL rate supported by the DUT.
 3. Adjust the common mode voltage (VICM) to a level defined in HDMI version 2.1 Table 6-25
 4. For all FRL Signals, set the single ended swing to 500 mV.
 5. Calibrate for the inter pair skew of $[4T_{\text{bit}} + 500 \text{ ps}]$ on FRL Lane0 against all other lanes, in positive direction. Perform the calibration at TP2 using WCM3 cable model.
 6. Connect the AWGs to the Sink DUT using TPA-P as shown in *Figure 18: Measurement configuration for Sink* on page 55.
 7. Complete the Link Training between Sink DUT and FRL Signal Generator for the selected FRL Rate. If Link Training is not successful, then FAIL.
 8. Configure the AWGs to transmit RXSB33PAT pattern.
 9. Read the Error Counter from Sink DUT using I2C controller.
 10. Conduct error counter test as described in section “*BER estimation procedure* on page 76”. If error counter check fails, then FAIL.
 11. Calibrate for the inter pair skew of $[4T_{\text{bit}} + 500 \text{ ps}]$ on FRL Lane0 against all other lanes, in negative direction. Perform the calibration at TP2 using WCM3 cable model. Repeat step 6 to Step 10.
 12. Repeat the test for the remaining untested FRL lane.
 13. Configure the AWG to highest FRL rate supported by the DUT and connect the AWGs to the oscilloscope using AWG-HD box, Sync hub, TPA-P and TPA-R.
 14. Repeat Steps 5 to Step 12 for all FRL lanes.

HRF2-4:Minimum Link Rate Tolerance

This test confirm that the Sink DUT meets FRL Link Rate Tolerance requirements.

Required test equipment *Equipment connection setup for Sink* on page 53
Recommended accessories on page 5

- Measurement procedure**
1. Connect the AWGs (AWG70001A/AWG70001B) to the oscilloscope through AWG-HD box, Sync hub and TPA-PR fixture, as shown in the *Figure 18: Measurement configuration for Sink* on page 55.
 2. Configure the AWGs to lowest FRL rate supported by the DUT.
 3. Adjust the common mode voltage (VICM) to a level defined in HDMI version 2.1 Table 6-25.
 4. For all FRL Signals, set the single ended swing to 500 mV.
 5. Calibrate the data rate for +300 ppm for all FRL lanes, at TP2 using WCM3 cable model.
 6. Connect the AWGs to the Sink DUT using TPA-P as shown in *Figure 18: Measurement configuration for Sink* on page 55.
 7. Complete the Link Training between Sink DUT and FRL Signal Generator for the selected FRL Rate. If Link Training is not successful, then FAIL.
 8. Configure the AWGs to transmit RXSB33PAT pattern.
 9. Read the Error Counter from Sink DUT using I2C controller.
 10. Conduct error counter test as described in section *BER estimation procedure* on page 76. If error counter check fails, then FAIL.
 11. Calibrate the data rate for -300 ppm for all FRL lanes, at TP2 using WCM3 cable model. Repeat step 6 to step 10.
 12. Configure the AWG to highest FRL rate supported by the DUT and connect the AWGs to the oscilloscope using AWG-HD box, Sync hub, TPA-P and TPA-R.
 13. Repeat Steps 5 to Step 11 for all FRL Lanes.

HFR2-5:Jitter Tolerance

This test confirm that the maximum allowed jitter is supported by the Sink DUT.

Required test equipment *Equipment connection setup for Sink* on page 53
Recommended accessories on page 5

- Measurement procedure**
1. Connect the AWGs (AWG70001A/AWG70001B) to the oscilloscope through AWG-HD box, Sync hub and TPA-PR fixture, as shown in the *Figure 18: Measurement configuration for Sink* on page 55.
 2. Configure the AWGs to lowest FRL rate supported by the DUT.
 3. Adjust the common mode voltage (VICM) to a level defined in HDMI version 2.1 Table 6-25.
 4. For all FRL Signals, set the single ended swing to 500 mV.
 5. Calibrate Random Jitter (RJ) = $0.2 T_{\text{bit}}$ @ BER 10 - 10 using LTP3 pattern.
 6. Add accurate amount of SJ = $0.10 UI$ @ $10 *fc$.
 7. Configure the AWGs to output RXSB33PAT with WCM3_CTS applied, by keeping RJ and SJ as per step 5 and step 6.
 8. Calibrate the resulting signal, marginal to the TP2_EQ eye diagram mask for the following conditions:
 - a. Condition 1: V_{min} (mV) = 150 mV and $H(T_{\text{bit}})$ @ BER 10 - 10 = 0.5 if FRL rate is 3 Gbps.
 - b. Condition 2: V_{min} (mV) = 150 mV and $H(T_{\text{bit}})$ @ BER 10 - 10 = 0.4 if FRL rate is 6 Gbps.
 - c. Condition 3: V_{min} (mV) = 135 mV and $H(T_{\text{bit}})$ @ BER 10 - 10 = 0.385 if FRL rate is 8 Gbps.
 - d. Condition 4: V_{min} (mV) = 120 mV and $H(T_{\text{bit}})$ @ BER 10 - 10 = 0.37 if FRL rate is 10 Gbps.
 - e. Condition 1: V_{min} (mV) = 100 mV and $H(T_{\text{bit}})$ @ BER 10 - 10 = 0.35 if FRL rate is 12 Gbps.
 - a. Adjust DJ (ISI) until the measured total jitter becomes $1 - H(T_{\text{bit}})$ @ BER 10 - 10 from step 8 when measured with CRU as defined in Equation 6-4 of HDMI version 2.1 specification.
 - b. Adjust the Differential swing until the vertical opening is V_{min} (mV) @ BER 10 - 10 in step 8 measured with CRU as defined in Equation 6 - 4 of HDMI version 2.1 specification.
 9. Connect the AWGs to the Sink DUT using TPA-P as shown in *Figure 18: Measurement configuration for Sink* on page 55.
 10. Complete the Link Training between Sink DUT and FRL Signal Generator for the selected FRL Rate. If Link Training is not successful, then FAIL.
 11. Configure the AWGs to transmit RXSB33PAT pattern.
 12. Read the Error Counter from Sink DUT using I2C controller.

13. Conduct error counter test as described in section [BER estimation procedure](#) on page 76. If error counter check fails, then FAIL.
14. Repeat Steps 6 to step 13 with following SJ:
 - a. SJ = 1.0 UI @ 0.1*fc
 - b. SJ = 0.51 UI @ 0.2*fc
 - c. SJ = 0.22 UI @ 0.5*fc
 - d. SJ = 0.14 UI @ 1*fc
 - e. SJ = 0.11 UI @ 2*fc
 - f. SJ = 0.10 UI @ 5*fc
15. Configure the AWG to highest FRL rate supported by the DUT and connect the AWGs to the oscilloscope using AWG-HD box, Sync hub, TPA-P and TPA-R
16. Repeat Steps 5 to Step 14 for error control link.

BER estimation procedure

BER estimation check on all active lanes should be the PASS/FAIL criteria for FRL Sink Electrical Tests.

1. Read the CED counter to clear it, make sure the Valid flag is set.
2. Count the errors until at least 10^{11} bits were received.
3. Read error counter, calculate BER based on accumulated errors and total elapsed time.
 - a. calculate the BER as (total number of errors reported by DUT since the test started) / (bitrate * total time elapsed since the test started).
 - b. If BER is greater than 10^{-10} , then FAIL.
 - c. If BER is greater than 5×10^{-11} (i.e. half of the allowed maximum), repeat test period to acquire more data.
 - d. If this is already the 10th repetition, and BER is greater than 10^{-10} , then FAIL, otherwise, continue to next step.
 - e. Check if tested lanes are all locked; if any lane is not locked, then FAIL.

SCPI commands

About SCPI command

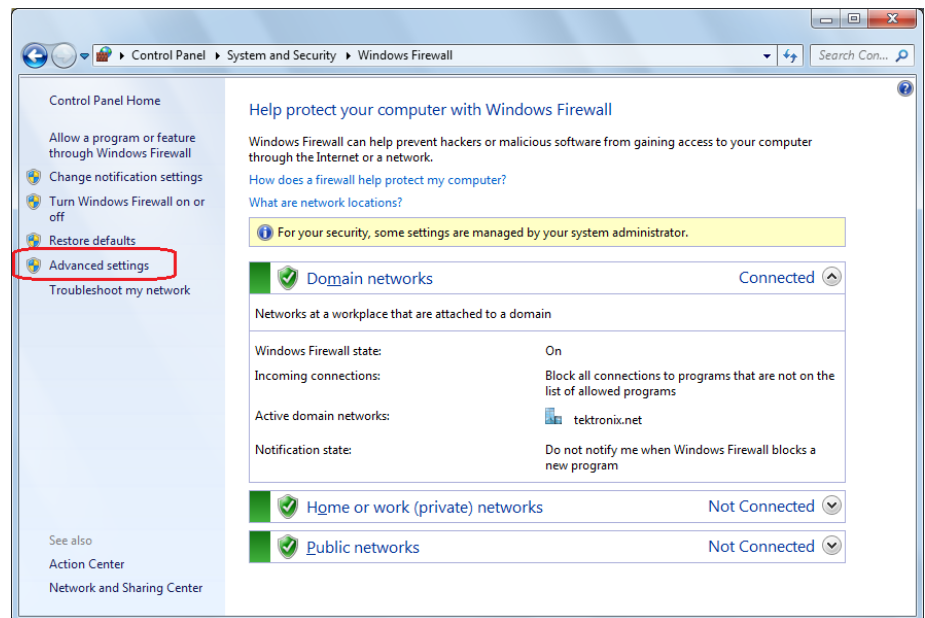
You can use Standard Commands for Programmable Instruments (SCPI) to communicate with the TekExpress application.

Socket configuration for SCPI commands

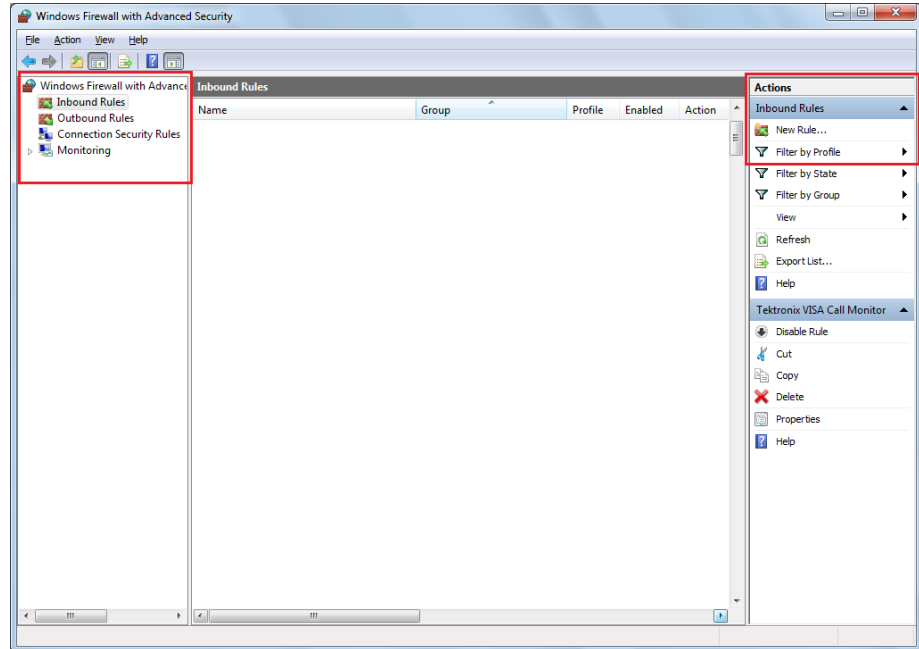
This section describes the steps for TCP/IP socket configuration and TekVISA configuration to execute the SCPI commands.

TCP/IP socket configuration

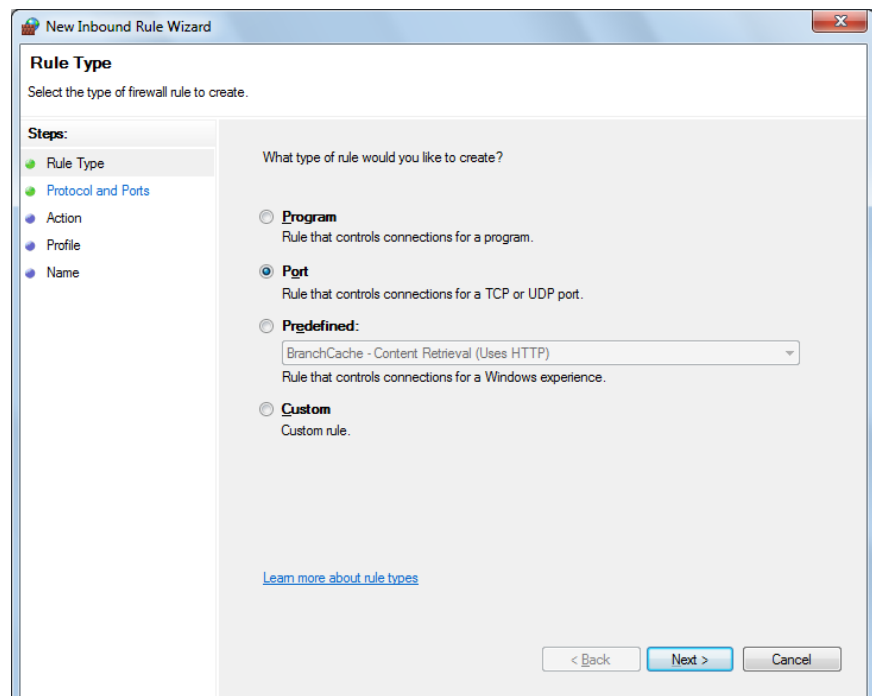
1. Click **Start > Control Panel > System and Security > Windows Firewall > Advanced settings**.



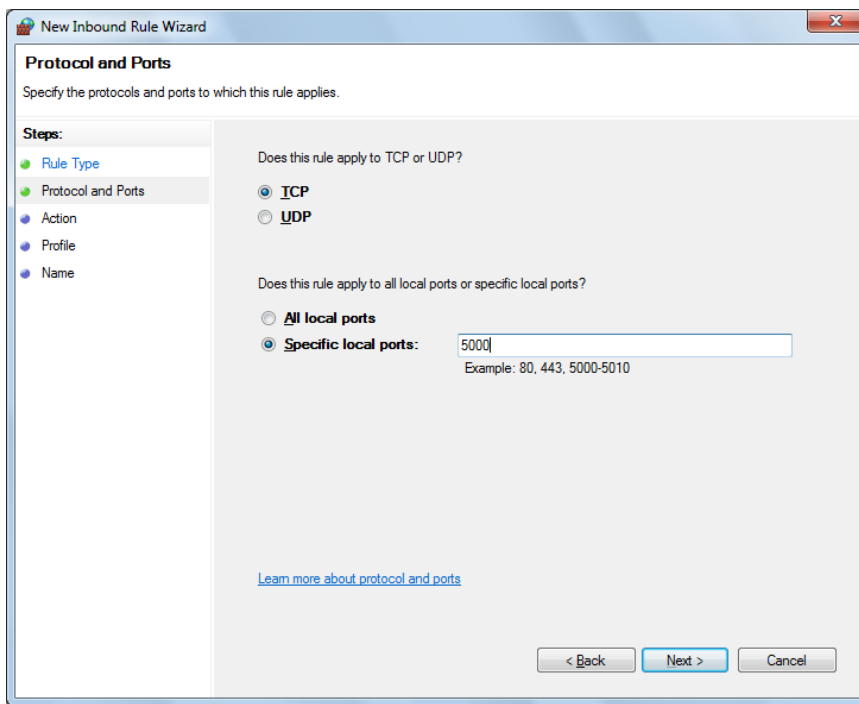
2. In Windows Firewall with Advanced Security menu, select **Windows Firewall with Advanced Security on Local Computer > Inbound Rules** and click New Rule...



3. In New Inbound Rule Wizard menu
 - a. Select **Port** and click **Next**.

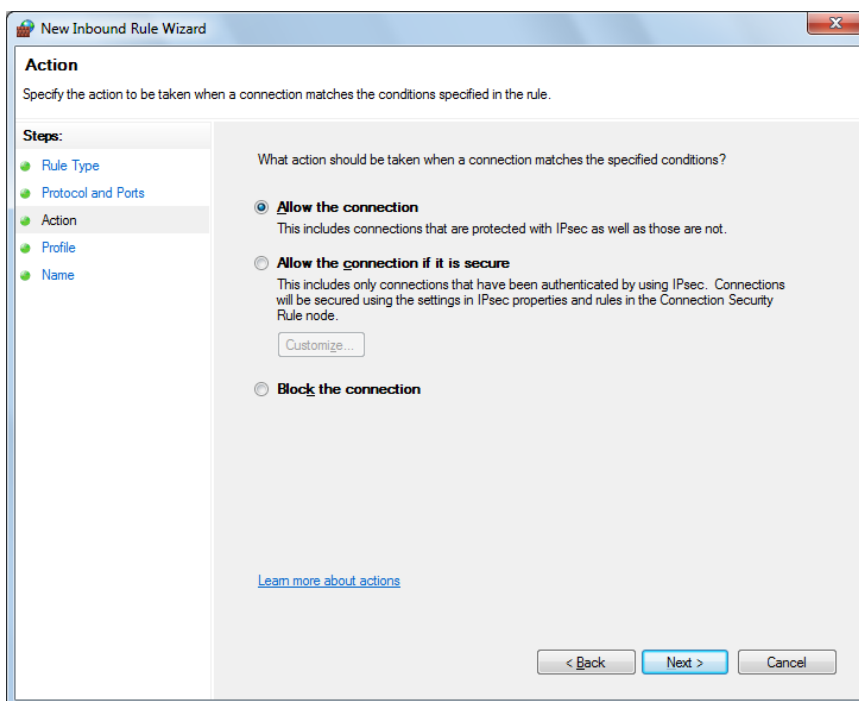


- b. Select **TCP** as rule apply and enter 5000 for **Specific local ports** and click **Next**.



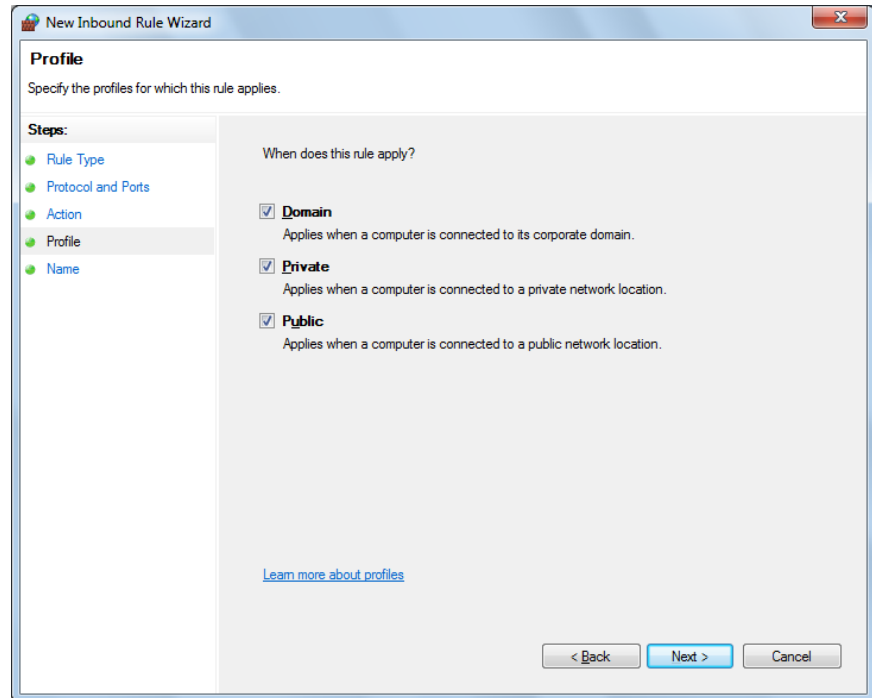
The screenshot shows the 'New Inbound Rule Wizard' window, specifically the 'Protocol and Ports' step. The window title is 'New Inbound Rule Wizard'. The main heading is 'Protocol and Ports' with the instruction 'Specify the protocols and ports to which this rule applies.' On the left, a 'Steps:' pane lists 'Rule Type', 'Protocol and Ports' (selected), 'Action', 'Profile', and 'Name'. The main area contains two questions: 'Does this rule apply to TCP or UDP?' with radio buttons for 'TCP' (selected) and 'UDP'; and 'Does this rule apply to all local ports or specific local ports?' with radio buttons for 'All local ports' and 'Specific local ports:' (selected). The 'Specific local ports:' section has a text box containing '5000' and an example 'Example: 80, 443, 5000-5010'. At the bottom right are buttons for '< Back', 'Next >', and 'Cancel'. A link 'Learn more about protocol and ports' is at the bottom left.

- c. Select **Allow the connection** and click **Next**.



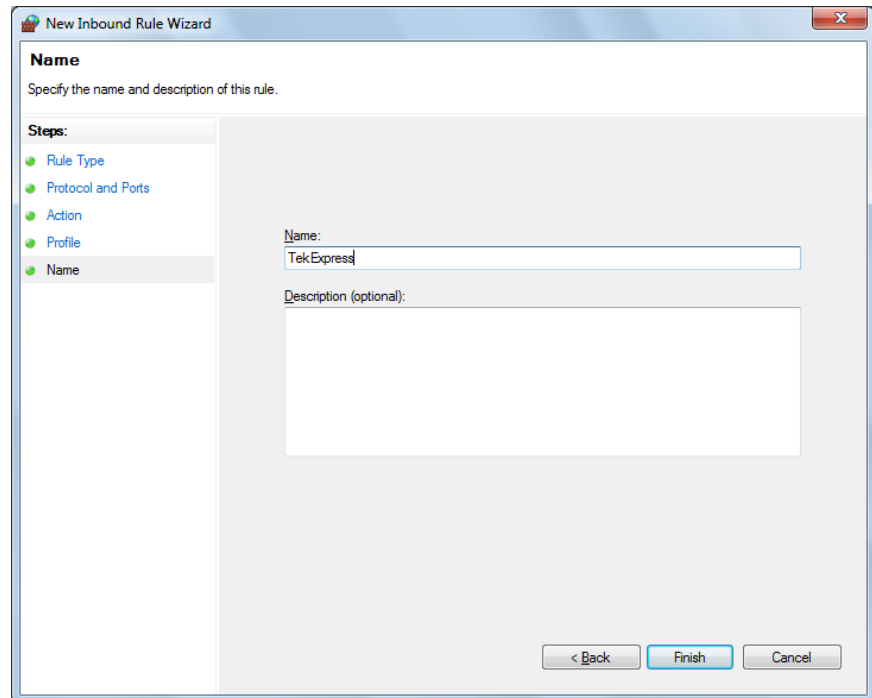
The screenshot shows the 'New Inbound Rule Wizard' window, specifically the 'Action' step. The window title is 'New Inbound Rule Wizard'. The main heading is 'Action' with the instruction 'Specify the action to be taken when a connection matches the conditions specified in the rule.' On the left, a 'Steps:' pane lists 'Rule Type', 'Protocol and Ports', 'Action' (selected), 'Profile', and 'Name'. The main area contains the question 'What action should be taken when a connection matches the specified conditions?' with three radio button options: 'Allow the connection' (selected), 'Allow the connection if it is secure', and 'Block the connection'. The 'Allow the connection' option has a description: 'This includes connections that are protected with IPsec as well as those are not.' The 'Allow the connection if it is secure' option has a description: 'This includes only connections that have been authenticated by using IPsec. Connections will be secured using the settings in IPsec properties and rules in the Connection Security Rule node.' and a 'Customize...' button. At the bottom right are buttons for '< Back', 'Next >', and 'Cancel'. A link 'Learn more about actions' is at the bottom left.

- d. Select **Domain**, **Private**, **Public** and click **Next**.



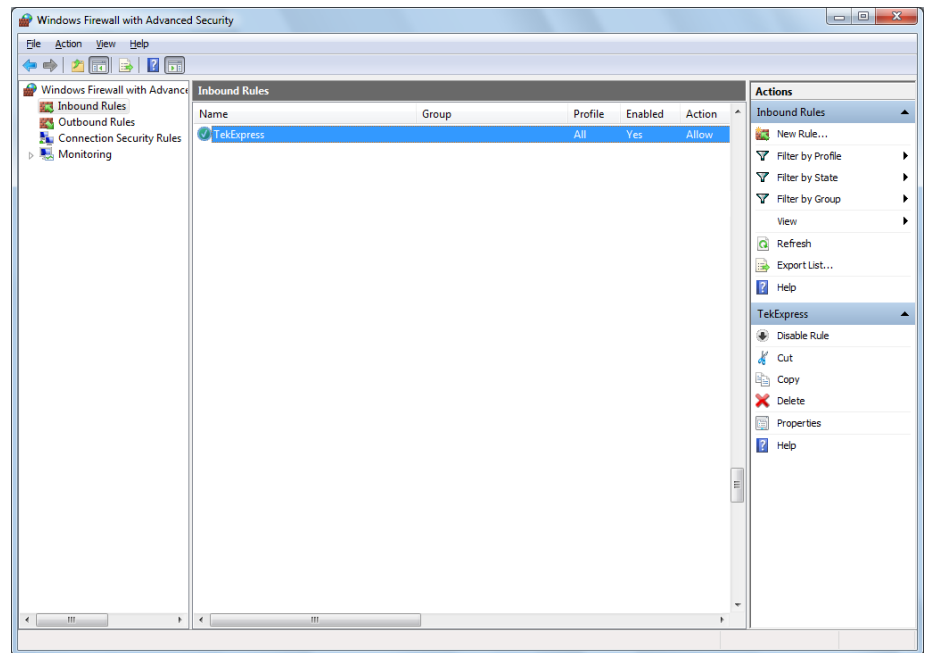
The screenshot shows the 'New Inbound Rule Wizard' window at the 'Profile' step. The title bar reads 'New Inbound Rule Wizard'. The main heading is 'Profile' with the instruction 'Specify the profiles for which this rule applies.' On the left, a 'Steps:' list includes 'Rule Type', 'Protocol and Ports', 'Action', 'Profile' (highlighted), and 'Name'. The main area is titled 'When does this rule apply?' and contains three checked options: 'Domain' (Applies when a computer is connected to its corporate domain.), 'Private' (Applies when a computer is connected to a private network location.), and 'Public' (Applies when a computer is connected to a public network location.). A link 'Learn more about profiles' is at the bottom left. Navigation buttons '< Back', 'Next >', and 'Cancel' are at the bottom right.

- e. Enter **Name**, Description (optional), and click **Finish**.

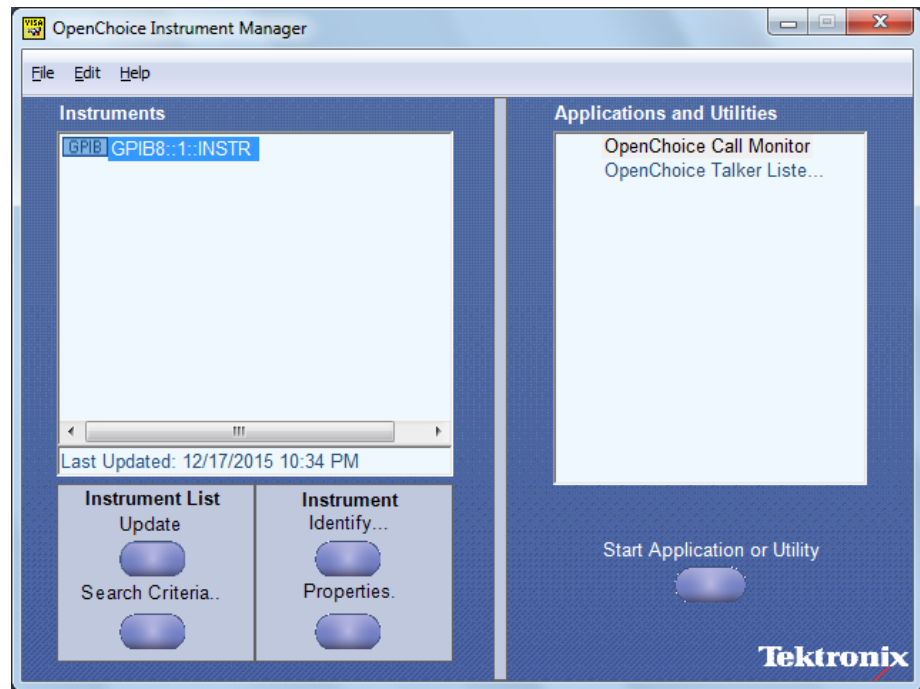


The screenshot shows the 'New Inbound Rule Wizard' window at the 'Name' step. The title bar reads 'New Inbound Rule Wizard'. The main heading is 'Name' with the instruction 'Specify the name and description of this rule.' On the left, a 'Steps:' list includes 'Rule Type', 'Protocol and Ports', 'Action', 'Profile', and 'Name' (highlighted). The main area has a 'Name:' label followed by a text box containing 'TekExpress'. Below it is a 'Description (optional):' label followed by a larger text box. Navigation buttons '< Back', 'Finish', and 'Cancel' are at the bottom right.

4. Check whether the Rule name is displayed in **Windows Firewall with Advanced Security** menu > **Inbound Rules**.



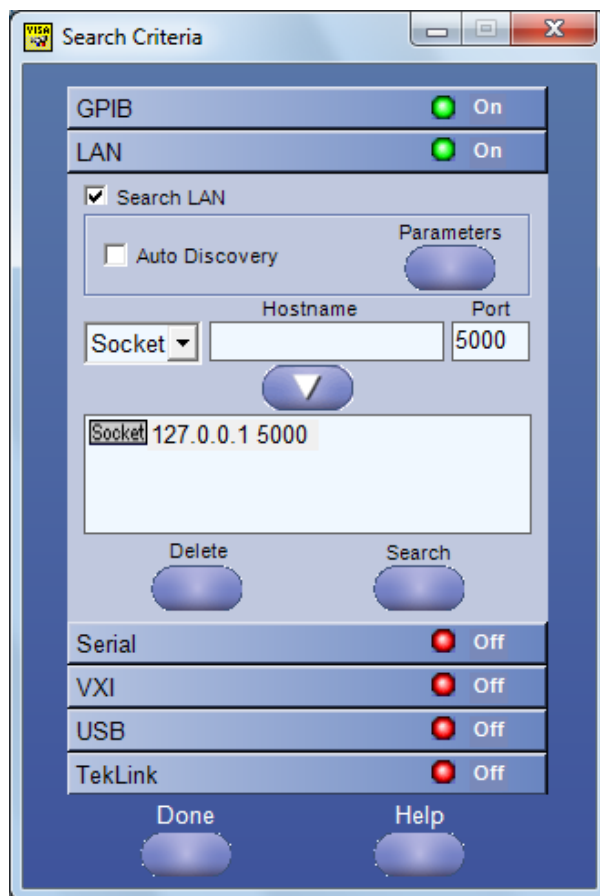
- TekVISA configuration**
1. Click **Start > All Programs > TekVISA > OpenChoice Instrument Manager**.



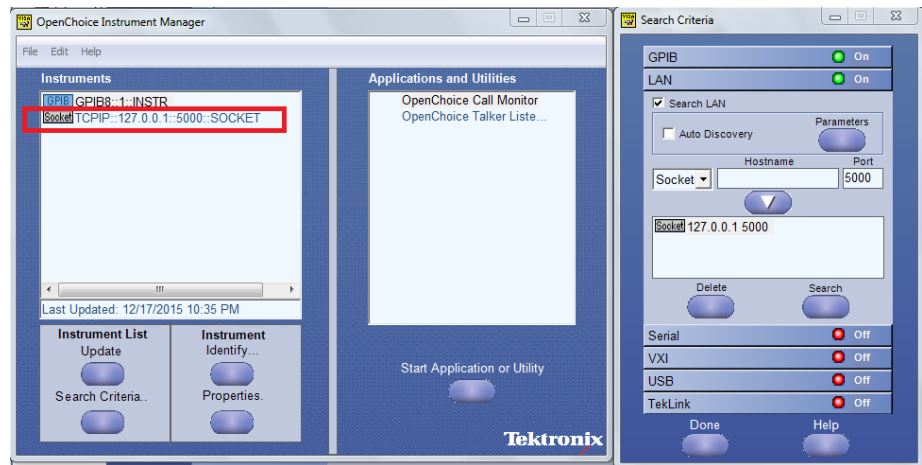
2. Click **Search Criteria**. In Search Criteria menu, click **LAN** to Turn-on. Select **Socket** from the drop-down list, enter the IP address of the

TekExpress device in **Hostname** and type **Port** as 5000. Click  to configure the IP address with Port.

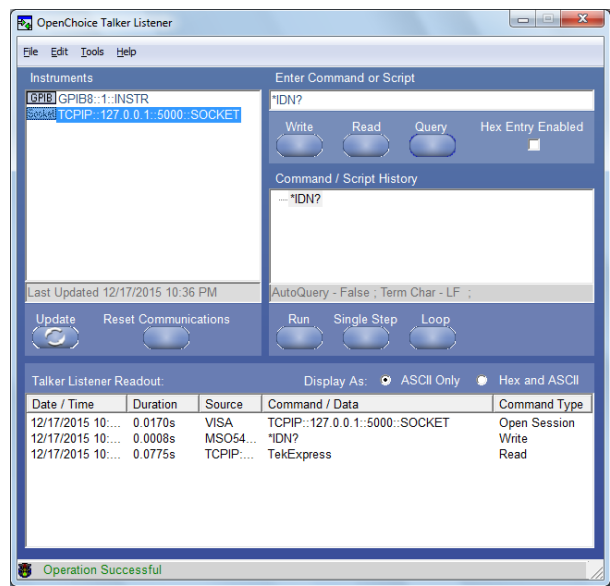
Enter the Hostname as 127.0.0.1 if the TekVISA and TekExpress application are in the same system, else enter the IP address of the TekExpress application system.



3. Click **Search** to setup the TCP/IP connection with the host. Check whether the TCP/IP host name is displayed in **OpenChoice Instrument Manager > Instruments**.



4. Double-click **OpenChoice Talker Listener** and enter the Command ***IDN?** in command entry field and click **Query**. Check that the Operation is successful and Talker Listener Readout displays the Command / Data.



TEKEXP:*IDN?

This command queries the active TekExpress application name running on the oscilloscope.

Syntax TEKEXP:*IDN?\n

Inputs NA

Outputs Returns active TekExpress application name running on the oscilloscope.

TEKEXP:*OPC?

This command queries the execution status of the last executed command.

Syntax TEKEXP:*OPC?\n

Inputs NA

Outputs 0 - last command execution is not complete
 1 - last command execution is complete

TEKEXP:ACQUIRE_MODE

This command sets the acquire mode as live or pre-recorded.

Syntax TEKEXP:ACQUIRE_MODE {LIVE | PRE-RECORDED}\n

Inputs {LIVE | PRE-RECORDED}

Outputs NA

TEKEXP:ACQUIRE_MODE?

This command queries the acquire mode type.

Syntax TEKEXP:ACQUIRE_MODE?\n

Inputs NA

Outputs {LIVE | PRE-RECORDED}

TEKEXP:EXPORT

This command returns all the bytes of data to the specified file.

Syntax	Outputs
TEKEXP:EXPORT REPORT\n	Returns the report file in bytes
TEKEXP:EXPORT WFM,"<FileName>"\n	Returns the specified waveform file in bytes
TEKEXP:EXPORT IMAGE,"<FileName>"\n	Returns the specified image file in bytes

Inputs FileName - Specifies the file name

TEKEXP:INFO?

This command queries the information about the file(s).

Syntax	Outputs
TEKEXP:INFO? REPORT\n	<ReportFileSize>,"<ReportFileName.mht>"
TEKEXP:INFO? WFM\n	<WfmFile1Size>,"<WfmFileName1.wfm>";<WfmFile2Size>,"<WfmFileName2.wfm>";...
TEKEXP:INFO? IMAGE\n	<Image1FileSize>,"<Image1FileName>";<Image2FileSize>,"<Image2FileName>";...

TEKEXP:INSTRUMENT

This command sets the value for the selected instrument type.

Syntax TEKEXP:INSTRUMENT "<InstrumentType>",<Value>"\n

Inputs InstrumentType
 Value



TIP. Check Command parameters list section for *InstrumentType* and *Value* parameters.

Outputs NA

TEKEXP:INSTRUMENT?

This command queries the instrument selected for the specified instrument type.

Syntax TEKEXP:INSTRUMENT? "<InstrumentType>"\n

Inputs InstrumentType



TIP. Check Command parameters list section for *InstrumentType* parameters.

Outputs Returns the instrument selected for the specified instrument type

TEKEXP:LASTERROR?

This command queries the last error string occurred for the current TCP session. If there are no errors since startup, or since the last call to TEKEXP:LASTERROR?\n, this command returns an empty string.

Syntax TEKEXP:LASTERROR?\n

Inputs NA

Outputs <string>

TEKEXP:LIST?

This command queries the list of available device, suite, test, version or instrument.

Syntax	Outputs
TEKEXP:LIST? DEVICE\n	Returns the list of available device(s) as comma separated values.
TEKEXP:LIST? SUITE\n	Returns the list of available suite(s) as comma separated values.
TEKEXP:LIST? TEST\n	Returns the list of available test(s) as comma separated values.
TEKEXP:LIST? VERSION\n	Returns the list of available version(s) as comma separated values.
TEKEXP:LIST? INSTRUMENT,"<InstrumentType>\n	Returns the list of available instruments' for the given Instrument type as comma separated values.

NOTE. This command returns the list of items within double quotes (""). Iterate the receive procedure until the list ends with double quotes otherwise the next query commands won't work as expected.

Inputs InstrumentType



TIP. Check Command parameters list section for InstrumentType parameters.

TEKEXP:MODE

This command sets the execution mode as compliance or user defined.

Syntax TEKEXP:MODE {COMPLIANCE | USER-DEFINED}\n

Inputs {COMPLIANCE | USER-DEFINED}

Outputs NA

TEKEXP:MODE?

This command queries the execution mode type.

Syntax TEKEXP:MODE?\n

Inputs NA

Outputs {COMPLIANCE | USER-DEFINED}

TEKEXP:POPUP

This command sets the response to the active popup shown in the application.

Syntax TEKEXP:POPUP "<PopupResponse>"\n

Inputs PopupResponse

Outputs NA

TEKEXP:POPUP?

This command queries the active popup information shown in the application.

Syntax TEKEXP:POPUP?\n

Inputs NA

Outputs Returns the active popup information in the application.

TEKEXP:REPORT

This command generates the report for the current session.

Syntax TEKEXP:REPORT GENERATE\n

Inputs GENERATE

Outputs NA

TEKEXP:REPORT?

This command queries the queried header field value in the report.

Syntax TEKEXP:REPORT? "<HeaderField>"\n

Inputs HeaderField - Specifies to return the measured value for the indicated test.



TIP. Check **Report** for HeaderField parameters.

Outputs Returns the queried header field value in the report

TEKEXP:RESULT?

This command queries the result available in report summary/details table.

Syntax	Outputs
TEKEXP:RESULT? "<TestName>"\n	Return Pass/Fail status of the test.
TEKEXP:RESULT? "<TestName>","<ColumnName>"\n	Returns all the row values of the specified column for the test.
TEKEXP:RESULT? "<TestName>","<ColumnName>",<RowNumber>\n	Returns the column value for the specified row number ¹

- Inputs**
- TestName - Specifies the name of the test for which to obtain the test result value.
 - ColumnName - Specifies the column name for the measurement
 - RowNumber - Specifies the row number of the measurement



TIP. Check **Results** panel for TestName, ColumnName, and RowNumber parameters.

¹ Row number starts from zero.

TEKEXP:SELECT

This command selects the device, suite, version, or test.

Syntax `TEKEXP:SELECT <string1>,<string2>,<string4>\n`
`TEKEXP:SELECT TEST,<string3>,<string4>\n`

Inputs `<string1> = {DEVICE | SUITE | VERSION}`
`<string2> = {DeviceName | SuiteName | VersionName}`
`<string3> = {"<TestName>" | ALL | REQUIRED }`
`<string4> = {TRUE | FALSE}`



TIP. Check Command parameters list section for DeviceName, SuiteName, VersionName, and TestName parameters.

Outputs NA

TEKEXP:SELECT?

This command queries the name of the selected device, suite, version, or test.

Syntax `TEKEXP:SELECT? {DEVICE | SUITE | TEST | VERSION}\n`

Inputs `{DEVICE | SUITE | TEST | VERSION}`

Outputs Returns the name of the selected device, suite, version, or test.

TEKEXP:SETUP

This command sets the value of the current setup.

Syntax	Outputs
TEKEXP:SETUP DEFAULT\n	Restore to default Setup
TEKEXP:SETUP OPEN,"<SessionName>"\n	Open the session
TEKEXP:SETUP SAVE\n	Saves the already existing modified session
TEKEXP:SETUP SAVE,"<SessionName>"\n	Save the session

Inputs SessionName - The name of the session

TEKEXP:STATE

This command sets the execution state of the application.

Syntax TEKEXP:STATE {RUN | STOP | PAUSE | RESUME}\n

Inputs {RUN | STOP | PAUSE | RESUME}

Outputs NA

TEKEXP:STATE?

This command queries the current setup state.

Syntax	Outputs
TEKEXP:STATE?	RUNNING PAUSED WAIT ERROR READY
TEKEXP:STATE? SETUP	SAVED NOT_SAVED

TEKEXP:VALUE

This command sets the value of parameters of type General, Acquire, Analyze, or DUTID.

Syntax TEKEXP:VALUE GENERAL,"<ParameterName>","<Value>"\n
 TEKEXP:VALUE ACQUIRE,"<TestName>","<AcquireType>","<ParameterName>","<Value>"\n
 TEKEXP:VALUE ANALYZE,"<TestName>","<ParameterName>". "<Value>"\n
 TEKEXP:VALUE DUTID,"<Value>"\n
 TEKEXP:VALUE VERBOSE,{TRUE | FALSE}\n
 TEKEXP:VALUE
 WFMFILE,<Test_Name>,<Acquire_Type>,<FileName1\$FileName2>\n

Inputs ParameterName - Specifies the parameter name
 TestName - Specifies the test name
 AcquireType - Specifies the acquire type
 Value - Specifies the value to set
 FileName1\$FileName2 - Specifies the waveform file name
 TRUE - Pop-ups are enabled
 FALSE - Pop-ups are disabled



TIP. Check Command parameters list section for ParameterName, AcquireType, and Value parameters.

Outputs NA

TEKEXP:VALUE?

This command queries the value of the parameter for type General, Acquire, Analyze, or DUTID.

Syntax	Outputs
TEKEXP:VALUE? GENERAL,"<ParameterName>"\n	Returns the value of Parameter for type GENERAL
TEKEXP:VALUE? ACQUIRE,"<TestName>", "<AcquireType>","<ParameterName>"\n	Returns the value of Parameter for type ACQUIRE
TEKEXP:VALUE? ANALYZE, "<TestName>","<ParameterName>"\n	Returns the value of Parameter for type ANALYZE
TEKEXP:VALUE? DUTID\n	Returns the DUTID value
TEKEXP:VALUE? WFMFILE,<Test_Name>,<Acquire_Type>\n	Returns the waveform file name
TEKEXP:VALUE? VERBOSE	Returns the verbose mode type

Inputs ParameterName - Specifies the parameter name

TestName - Specifies the test name

AcquireType - Specifies the acquire type

TRUE - Pop-ups are enabled

FALSE - Pop-ups are disabled



TIP. Check Command parameters list section for ParameterName and AcquireType parameters.

Outputs Returns the value of Parameter for type GENERAL | ACQUIRE | ANALYZE | DUTID.

Command parameters

This section provides the parameters list for the SCPI commands.

Specifies the Parameter Name and Value for DUT, Test selection, Acquisition, Configuration and Preferences tabs.

Parameters	Description
DUT ID	Specifies the value parameters For DUTID, valid value is: Comment
Acquiremode	Specifies the acquire mode parameters ■ Acquire live waveforms ■ Use pre-recorded waveform files
Mode	■ Compliance ■ User Defined
Version	CTS 2.1
Suite	■ Source ■ Sink
Device Profile	
Data Rate	For 3,6,8,10,12 ■ TRUE ■ FALSE
Data Rate to run Minimum (Gbps)	3
Data Rate to run Maximum (Gbps)	12
Vterm(V)	0 to 3.4
EDID/SCDC Controller	■ None
Signal Validation	■ Prompt me if Signal Check Fails ■ Skip Test if Signal Check Fails ■ Turn Off Signal Check
Multi-Lane (Setup)	■ P76XX/P77XX ■ Dual Stack ■ Lane 0 ■ Lane 1 ■ Lane 2 ■ Lane 3

Table 16: Parameter Name and Value for Test Selection tab

Parameters	Description
Source	Specifies the test measurement name ■ HFR1-1: DC Common Mode Voltage ■ HFR1-2: Vse_max ,Vse_min ■ HFR1-3: Rise/Fall Slew Rate ■ HFR1-4: Inter-Pair Skew ■ HFR1-5: FRL Rates ■ HFR1-6: Data Jitter(RJ) ■ HFR1-7: Data Eye Diagram ■ HFR1-8: AC Common Mode Voltage ■ HFR1-9: FFE Monotonicity-Method 1 ■ HFR1-9: FFE Monotonicity-Method 2
Sink	Specifies the test measurement name ■ HFR2-1: Max Differential Swing Tolerance ■ HFR2-2: Intra-Pair Skew ■ HFR2-3: Inter-Pair Skew ■ HFR2-4: Minimum Link Rate Tolerance ■ HFR2-5: Jitter Tolerance

Table 17: Parameter Name and Value for Acquisitions tab

Parameters	Description
Acquisition Options	■ Acquire all and analyze ■ Acquire only
Waveform Options	■ Retain ■ Delete
Show Acquire Parameters	■ TRUE ■ FALSE

Table 18: Parameter Name and Value for Preferences tab

Parameters	Description
Number of Runs	
Acquire/Analyze each test	■ TRUE ■ FALSE 1 to 1000 times
Popup Settings	
Auto close Warnings and informations during Sequencing	■ TRUE ■ FALSE Value to be given in seconds
Auto close Error Messages during Sequencing. Show in Reports	■ TRUE ■ FALSE Value to be given in seconds
Show messages with a beep sound	■ TRUE ■ FALSE

Table 19: Parameter Name and Value for General

Parameters	Description
Generate new report	■ TRUE ■ FALSE
Append with previous run session	■ TRUE ■ FALSE
Replace current test results	■ TRUE ■ FALSE ■ in previous run, current session ■ in any run, any session
Include Header in appended reports	■ TRUE ■ FALSE
Save As Type	■ Web Archive (*.mht;*.mhtml) ■ PDF (*.pdf) ■ CSV (*.csv)

Parameters	Description
Auto increment report name if duplicate	■ TRUE ■ FALSE
Create report automatically at the end of the run	■ TRUE ■ FALSE
Include pass/fail results Summary	■ TRUE ■ FALSE
Include detailed results	■ TRUE ■ FALSE
Include plot images	■ TRUE ■ FALSE
Include setup configuration	■ TRUE ■ FALSE
Include user comments	■ TRUE ■ FALSE
Margin value in percentage	■ TRUE ■ FALSE
View report after generating	■ TRUE ■ FALSE
Vertical Autoset	■ Auto ■ Manual
Vertical Offset(V)	0 to 4
Vertical Position(div)	-1 to 1
Vertical Scale(mV)	30 to 100
Vertical Bandwidth	0.5 to 21
Horizontal Sampling Rate(GS/s)	50 to 200
Record Length	8000000 to 16000000
Apply DE-Embed	■ TRUE ■ FALSE

Table 20: Parameter Name and Value for Acquire

Test Name	Acquire Type	Parameter Name	Value
■ HFR1-8: AC Common Mode Noise		Bandwidth (3Gbps)	2 GHz
		Bandwidth (6Gbps)	3 GHz
		Bandwidth (8Gbps)	4 GHz
		Bandwidth (10Gbps)	5 GHz
		Bandwidth (12Gbps)	6 GHz

Table 21: Parameter Name and Value for Clock Recovery

Test Name	Acquire Type	Parameter Name	Value
■ HFR1-6: Data Jitter(RJ) ■ HFR1-7: Data Eye Diagram		PLL Model	■ Type I ■ Type II
		3Gbps : Loop BW(MHz)	0.000001 to 2500
		6Gbps : Loop BW(MHz)	0.000001 to 2500
		8Gbps : Loop BW(MHz)	0.000001 to 2500
		10Gbps : Loop BW(MHz)	0.000001 to 2500
		12Gbps : Loop BW(MHz)	0.000001 to 2500

Table 22: Parameter Name and Value for Cable Settings

Test Name	Acquire Type	Parameter Name	Value
■ HFR1-6: Data Jitter(RJ) ■ HFR1-7: Data Eye Diagram		Cable Model	■ SCM ■ WCM ■ Both
		Crosstalk	■ With ■ Without ■ Both
		Equalizer Options	■ CTLE+DFE ■ CTLE
		CTLE	■ SCM (dB) ■ 1 to 8 , All ■ WCM (dB) ■ 1 to 8 , All
		Apply Custom Mask File	■ TRUE ■ FALSE

Examples

Example	Description
TEKEXP:*IDN?	It returns the active TekExpress application name running on the scope.
TEKEXP:*OPC?	It returns the last command execution status.
TEKEXP:ACQUIRE_MODE PRE-RECORDED	It sets the acquire mode as pre-recorded.
TEKEXP:ACQUIRE_MODE?	It returns LIVE when acquire mode is set to live.
TEKEXP:EXPORT REPORT	It returns the report file in bytes. This can be written into another file for further analysis.
TEKEXP:INFO? REPORT	It returns "100,"ReportFileName.mht", when 100 is the filesize in bytes for the filename ReportFileName.
TEKEXP:INFO? WFM	It returns "100,"WfmFileName1.wfm","200,"WfmFileName2.wfm" when 100 is the filesize in bytes for the filename WfmFileName1.wfm and 200 is the filesize in bytes for the filename WfmFileName2.wfm.
TEKEXP:INSTRUMENT "Real Time Scope",DPO72504D (GPIB8::1::INSTR)	It sets the instrument value as DPO73304SX (GPIB8::1::INSTR) for the selected instrument type Real Time Scope.
TEKEXP:INSTRUMENT? "Real Time Scope"	It returns "DPO73304SX (GPIB8::1::INSTR)", when DPO73304SX (GPIB8::1::INSTR) is the selected instrument for the instrument type Real Time Scope.
TEKEXP:LASTERROR?	It returns ERROR: INSTRUMENT_NOT_FOUND, when no instrument is found.
TEKEXP:LIST? DEVICE	It returns "Source" when Source is the available suite.
TEKEXP:LIST? INSTRUMENT,"Real Time Scope"	It returns "DPO73304SX (GPIB8::1::INSTR),DPO73304SX (TCPIP::134.64.248.91::INSTR)" when DPO73304SX (GPIB8::1::INSTR), DPO73304SX (TCPIP::134.64.248.91::INSTR) are the list of available instruments.
TEKEXP:MODE COMPLIANCE	It sets the execution mode as compliance.
TEKEXP:MODE?	It returns COMPLIANCE when the execution mode is compliance.
TEKEXP:POPOP "OK"	It sets OK as the response to active popup in the application.
TEKEXP:POPOP?	It returns "OK", when OK is the active popup information shown in the application.
TEKEXP:REPORT GENERATE	It generates report for the current session.
TEKEXP:REPORT? "Scope Model"	It returns "DPO73304SX" when DPO73304SX is the scope model.
TEKEXP:REPORT? "DUT ID"	It returns "DUT001" when DNI_DUT001 is the DUT ID.
TEKEXP:RESULT? "HFR1-1: DC Common Mode"	It returns Pass, then the test result is Pass.
TEKEXP:RESULT? "HFR1-1: DC Common Mode", "Margin"	It returns list of values then that is 'Margin' column data.
TEKEXP:RESULT? TEKEXP:RESULT? "HFR1-1: DC Common Mode", "Units",0	It returns the unit of the first row of result.
TEKEXP:SELECT DEVICE,"FRL"	It selects device as "Source".
TEKEXP:SELECT TEST,"HFR1-1: DC Common Mode", TRUE	It selects "HFR1-1: DC Common Mode" measurement.
TEKEXP:SETUP DEFAULT	It restores the application to default setup.
TEKEXP:STATE STOP	It stops the test execution.

Example	Description
TEKEXP:STATE?	It returns as READY when the application is ready to run next measurement.
TEKEXP:STATE? SETUP	It returns as NOT_SAVED when the current setup is not saved.
TEKEXP:VALUE GENERAL, "3 Gbps", " False "	It selects 3 Gbps data rate in the DUT panel by deselecting checkbox.
TEKEXP:SELECT TEST , "HFR2-1: Max Differential Swing Tolerance", True	The test "HFR2-1: Max Differential Swing Tolerance" is selected in test selection panel.
TEKEXP:VALUE GENERAL, "Execute", "Verify Calibration"	It selects verify calibration in the drop-down from DUT panel.

Index

A

- Acquire Status, 41
- Acquisitions tab, 29
- Activating the license, 8
- Analysis Status, 41
- Application panels overview, 12
- Auto Scroll, 40

C

- Clear test log, 40
- Command buttons, 14
- Compensate the signal path, 56
- Create a test setup from default settings, 60
- Create a test setup using an existing one, 60

E

- Email notifications, 20
- Exiting the application, 49

H

- Help conventions, 2

I

- Installing the software
 - switch matrix application, 7
- Instruments
 - viewing connected, 17

K

- Keep on top, 11

L

- Lane source, 29
- License, 9
- License activation, 8
- Loading a test setup, 60
- Log files, 40

- Log View, 41

M

- Menus
 - Options, 15
 - preferences, 42
- Move icon
 - moving the application, 15
- My TekExpress folder, 43

O

- Opening a saved test setup, 60
- Options menu
 - keep on top, 11
- Options Menu
 - Instrument Control Settings, 17
- Oscilloscope compensation, 56

P

- Panels
 - reports, 44
 - results, 41
 - Status, 41
- Pass/Fail summary, 46
- Position the application, 15

R

- Recalling a test setup, 60
- Recommended accessories, 5
- Recommended probes, 6
- Related documentation, 1
- Report contents
 - selecting, 45
- Report file type, 45
- Report names, 45
- Report options, 45
- Reports, 46
- Reports panel, 12, 44
- Resource file, 11
- Results panel, 41, 42
- Running tests, 57

S

Schematic button, 28

SCPI commands

TEKEXP:*IDN?, 85

TEKEXP:*OPC?, 85

TEKEXP:ACQUIRE_MODE, 86

TEKEXP:ACQUIRE_MODE?, 86

TEKEXP:EXPORT, 87

TEKEXP:INFO?, 87

TEKEXP:INSTRUMENT, 88

TEKEXP:INSTRUMENT?, 88

TEKEXP:LASTERROR?, 89

TEKEXP:LIST?, 89

TEKEXP:MODE, 90

TEKEXP:MODE?, 90

TEKEXP:POPUP, 91

TEKEXP:POPUP?, 91

TEKEXP:REPORT, 92

TEKEXP:REPORT?, 92

TEKEXP:RESULT?, 93

TEKEXP:SELECT, 94

TEKEXP:SELECT?, 94

TEKEXP:SETUP, 95

TEKEXP:STATE, 95

TEKEXP:STATE?, 96

TEKEXP:VALUE, 96

TEKEXP:VALUE?, 97

Select lane source, 29

Select Required button, 28

Session files, 43

Session folders, 43

Setup files, 59

Setup panel, 12

Setup tabs

Acquisitions, 29

Test Selection, 28

Signal source validation

overview, 29

setting, 29

Software installation

switch matrix application, 7

Status Panel, 41

Supported oscilloscopes, 5

T

Tab

Acquisitions, 29

Test Selection, 28

Technical support, 2

Test notifications, 38

Test reports, 46

Test results, 42

Test selection controls, 28

Test Selection tab, 28

Test setup files, 43, 59

Test setups

load, 60

open, 60

recalling, 60

Test Status, 41

Tests

running, 57

selecting, 28

U

User account setting (Windows 10), 6

User comments

including in test reports, 45

location in reports, 46

V

Version, 9

W

Windows 10 user account setting, 6