



QPHY-HDMI2

Operator's Manual

Revision B – November, 2017

Relating to:

XStreamDSO™ Version 8.5.x.x

QualiPHY Version 8.5.x.x



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926386 Rev B
November, 2017

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About This Manual

This manual assumes that you are familiar with using an oscilloscope—in particular the Teledyne LeCroy oscilloscope that will be used with QualiPHY—and that you have purchased the QPHY-HDMI2 software option. Some of the images in this manual may show QualiPHY products other than QPHY-HDMI2, or were captured using different model oscilloscopes, as they are meant to illustrate general concepts only. Rest assured that while the user interface may look different from yours, the functionality is identical.

Introduction

About QualiPHY

QualiPHY is highly automated compliance test software meant to help you develop and validate the PHY (physical-electrical) layer of a device, in accordance with the official documents published by the applicable standards organizations and special interest groups (SIGs). You can additionally set custom variables and limits to test compliance to internal standards.

QualiPHY is composed of a “framework” application that enables the configuration and control of separate tests for each standard through a common user interface. Features include:

- **Multiple Data Source Capability.**
- **User-Defined Test Limits:** Tighten limits to ensure devices are well within the passing region, even if subsequently measured with different equipment.
- **Flexible Test Results Reporting** that includes XML Test Record Generation. Understand a device performance distribution, or obtain process related information from the devices under test.

About QPHY-HDMI2

QPHY-HDMI2 is an automated test package performing all the normative, real-time oscilloscope tests for sources in accordance with version 1.4b and version 2.0 of the High Definition Multimedia Interface Compliance Test Specification (HDMI).

The software can be run on any Teledyne LeCroy oscilloscope with at least 8 GHz bandwidth and 20 GS/s sample rate for HDMI 1.4b testing, or 13 GHz bandwidth and 40 GS/s sample rate for HDMI 2.0 testing.

Note: The HDMI test specification requires 8 GHz bandwidth for testing clock rates above 148.5 MHz.

Required Equipment

- Teledyne LeCroy real-time oscilloscope $\geq$ 8 GHz BW, installed with:
 - o XStreamDSO v.7.9.x.x minimum* with an activated QPHY-HDMI2 option key
 - o QualiPHY v.7.9.x.x minimum with an activated QPHY-HDMI2 component
 - o SDAIII software option (standard on SDA model oscilloscopes)
 - o VirtualProbe software option (for HDMI 2.0 tests HF1-7 and HF1-8)
- 8 SMA Male to SMA Male cables
- 4 TF-HDMI-3.3V test adapters
- HDMI test fixture (see list below)
- 6.5 GB/s serial trigger (for HDMI 2.0 test HF1-3)

For the most complete and up-to-date list, see the HDMI Forum website: <http://www.hdmi.org>

***Note:** The versions of XStreamDSO and QualiPHY software must match, so upgrade your version of QualiPHY if you have upgraded your oscilloscope firmware. The versions listed above are the minimum versions required for this product. The QualiPHY software may be installed on a remote PC, but all other software must be run on the oscilloscope.

Test Fixtures

For HDMI 2.0

Teledyne LeCroy recommends using the Wilder Technologies HDMI2-TPA-12P (plug test adapter) used in conjunction with GRL-HDMI-CONT (EDID Emulator board from Granite River Labs – if required by customer test configuration).

For HDMI 1.4b

Teledyne LeCroy recommends using the Wilder Technologies HDMI-TPA-P (plug test adapter) used in conjunction with HDMI-TPA-E (EDID board with EEPROM). This equipment is available from Wilder Technologies individually or as part of the HDMI-TPA-PRRCE Test Adapter Kit.

Automation

Optionally, customers can automate their tests using two switch boxes from Mini-Circuits (Model No: RC_8SPDT-A18) and one HDMI Terminator HDMI-TPA-T from Wilder Technologies. See [Appendix B: Switch Matrix Configuration](#).

Required Host Computer System

Usually, the oscilloscope is the host computer for the QualiPHY software, and all models that meet the acquisition requirements will also meet the host system requirements. However, if you wish to run the QualiPHY software from a remote computer, these minimum requirements apply:

- Operating System:
 - o Windows 7 Professional
 - o Windows 10 Professional
- 1 GHz or faster processor
- 1 GB (32-bit) or 2 GB (64-bit) of RAM
- Ethernet (LAN) network capability
- Hard Drive:
 - o At least 100 MB free to install the framework application
 - o Up to 2 GB per standard installed to store the log database (each database grows from a few MB to a maximum of 2 GB)

See [Set Up Remote Control](#) for configuration instructions.

Installation and Setup

QualiPHY is a Windows-based application that can be configured with one or more serial data compliance components. Each compliance component is purchased as a software option.

Install Base Application

Download the latest version of the QualiPHY software from:

teledynelecroy.com/support/softwaredownload under Oscilloscope Downloads > Software Utilities.

If the oscilloscope is not connected to the Internet, copy the installer onto a USB memory stick, then transfer it to the oscilloscope desktop or a folder on a D:\ drive to execute it.

Run **QualiPHYInstaller.exe** and follow the installer prompts. Choose all the components you plan to activate. If you omit any components now, you will need to update the installation to activate them later.

By default, the oscilloscope appears as local host when QualiPHY is executed on the oscilloscope. Follow the steps under [Add Connection to QualiPHY](#) to check that the IP address is **127.0.0.1**.

Activate Components

The serial data compliance components are factory installed as part of the main application in your oscilloscope and are individually activated through the use of an alphanumeric code uniquely matched to the oscilloscope's serial number. This option key code is what is delivered when purchasing a software option.

To activate an option on the oscilloscope:

1. From the menu bar, choose **Utilities > Utilities Setup**.
2. On the Options tab, click **Add Key**.
3. Use the Virtual Keyboard to **Enter Option Key**, then click **OK**.

If activation is successful, the key code now appears in the list of Installed Option Keys.

4. Restart the oscilloscope application by choosing **File > Exit**, then double-clicking the **Start DSO** icon on the desktop.

Set Up Dual Monitor Display

Teledyne LeCroy recommends running QualiPHY on an oscilloscope equipped with Dual Monitor Display capability. This allows the waveform and measurements to be shown on the oscilloscope LCD display, while the QualiPHY application and test results are displayed on a second monitor.

See the oscilloscope Operator's Manual or Getting Started Manual for instructions on setting up dual monitor display.

Set Up Remote Control

QualiPHY software can be executed from a remote host computer, controlling the oscilloscope through a LAN Connection. To set up remote control:

- The oscilloscope must be connected to a LAN and assigned an IP address (fixed or dynamic).
- The host computer must be on the same LAN as the oscilloscope.

Configure Oscilloscope for Remote Control

1. From the menu bar, choose **Utilities → Utilities Setup...**
2. Open the **Remote** tab and set Remote Control to **TCP/IP**.
3. Verify that the oscilloscope shows an IP address.

Add Connection to QualiPHY

1. On the host PC, download and run **QualiPHYInstaller.exe**.
2. Start QualiPHY and click the **General Setup** button.
3. On the **Connection** tab, click **Scope Selector**.
4. Click **Add** and choose the connection type. Enter the oscilloscope IP address from Step 3 above. Click **OK**.
5. When the oscilloscope is properly detected, it appears on the Scope Selector dialog. Select the connection, and click **OK**.

QualiPHY is now ready to control the oscilloscope.

Select Connection

Multiple oscilloscopes may be accessible to a single remote host. In that case, go to General Setup and use the Scope Selector at the start of the QPHY session to choose the correct connection.

QualiPHY tests the oscilloscope connection when starting a test. The system warns you if there is a connection problem.

Using QualiPHY

This section provides an overview of the QualiPHY user interface and general procedures. For detailed information about the QPHY-HDMI2 software option, see [QPHY-HDMI2 Testing](#).

Accessing the Software

Once QualiPHY is installed and activated, it can be accessed from the oscilloscope menu bar by choosing **Analysis > QualiPHY**, or by double-clicking the **QualiPHY desktop icon** on a remote computer.

The QualiPHY framework dialog illustrates the overall software flow, from general set up through running compliance tests. Work from left to right, making all desired settings on each sub-dialog.

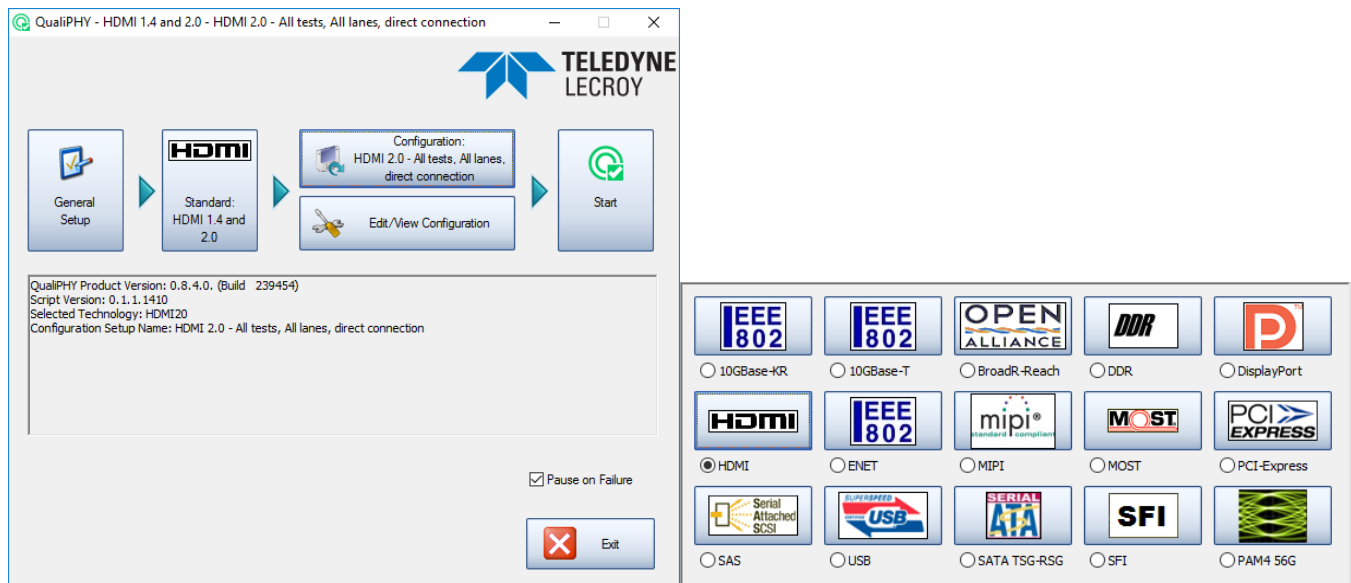


Figure 1 - QualiPHY framework dialog and Standard selection menu

The sub-dialogs are organized into tabs each containing configuration controls related to that part of the process. These are described in more detail in the following sections.

If **Pause on Failure** is checked, QualiPHY prompts to retry a measure whenever a test fails.

Report Generator launches the manual report generator dialog.

The **Exit** button at the bottom of the framework dialog closes the QualiPHY application.

General Setup

The first sub-dialog contains general system settings. These remain in effect for each session, regardless of Standard, until changed.

Connection tab

Shows **IP Address** of the test oscilloscope (local host 127.0.0.1 if QualiPHY is run from the oscilloscope). The **Scope Selector** allows you to choose the oscilloscope used for testing when several are connected to the QualiPHY installation. See [Set Up Remote Control](#) for details.

Session Info tab

Optional information about the test session that may be added to reports, such as: **Operator Name**, **Device Under Test (DUT)**, **Temperature** (in °C) of the test location, and any additional **Comments**. There is also an option to **Append Results** or **Replace Results** when continuing a previous session.

To optimize report generation, enter at least a DUT name at the beginning of each session.

Report tab

Settings related to automatic report generation. Choose:

- **Reporting behavior of:**
 - o “Ask to generate a report after tests,” where you’ll be prompted to create a new file for each set of test results.
 - o “Never generate a report after tests,” where you’ll need to manually execute the Report Generator to create a report.
 - o “Always generate a report after tests,” to autogenerate a report of the latest test results.
- **Default** report output type of XML, HTML, or PDF.
- A generic **Output file name**, including the full path to the report output folder.

Optionally, check **Allow style sheet selection in Report Generator** to enable the use of a custom .css when generating reports. The path to the .css is entered on the Report Generator dialog.

Report Generator launches the Report Generator dialog, which contains the same settings as the Report tab, only applied to individual reports.

Advanced tab

This tab launches the **X-Replay Mode** dialog. See [X-Replay Mode](#).

About tab

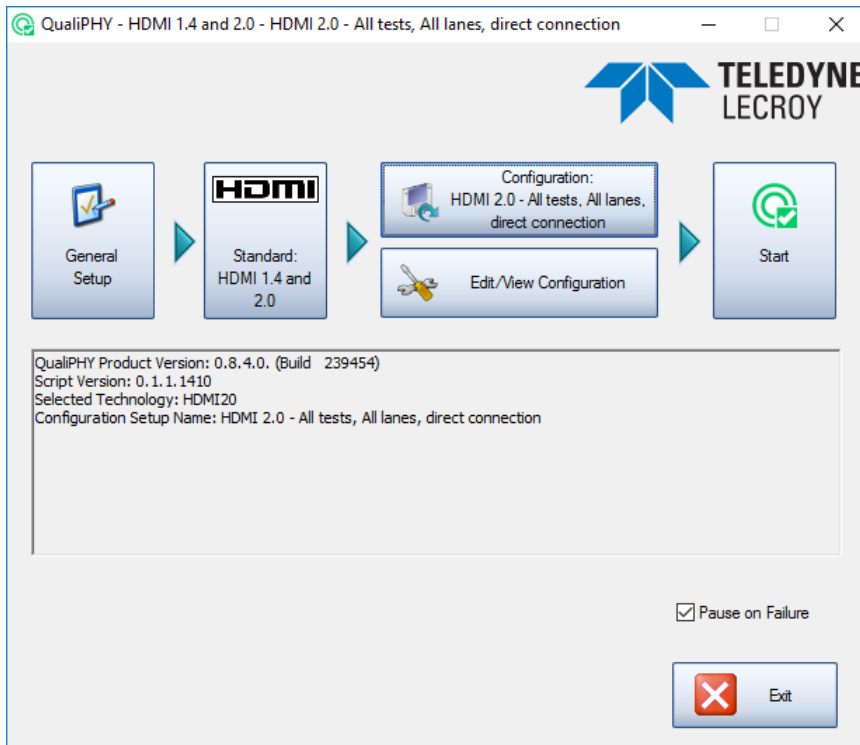
Information about your QualiPHY installation.

QualiPHY Test Process

Once general system settings are in place, these are the steps for running test sessions.

Set Up Test Session

1. Connect the oscilloscope to the DUT.
2. Access the QualiPHY software to display the framework dialog.



3. If running QualiPHY remotely, click **General Setup** and open the **Scope Selector** to select the correct oscilloscope connection.
4. If you have more than one component activated, click **Standard** and select the desired standard to test against. Otherwise, your one activated component will appear as the default selection.

Note: Although all the QualiPHY components appear on this dialog, only those selected when installing QualiPHY are enabled for selection now.

5. Click the **Configuration** button and select the test configuration to run. These pre-loaded configurations are set to run all the required tests and provide a quick, easy way to begin compliance testing. See [QPHY-HDMI2 Test Configurations](#) for a description of configurations.

You can also create custom configurations for internal compliance tests by copying and modifying the pre-loaded configurations. See [Customizing QualiPHY](#) for details.

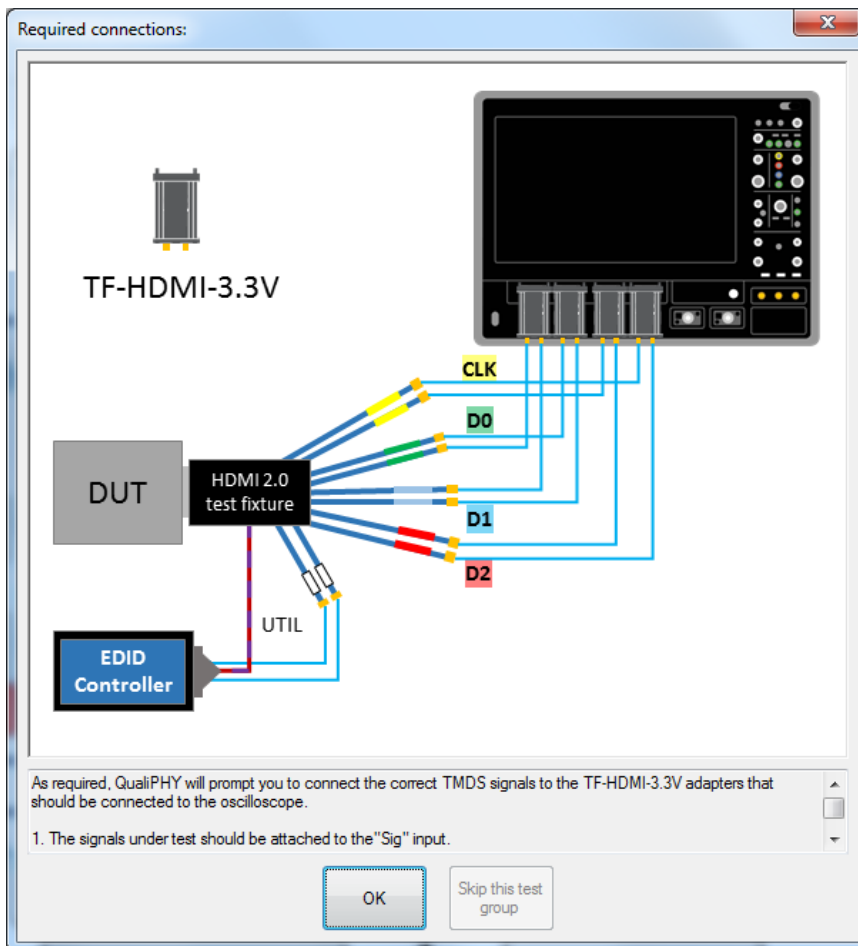
6. **Close** the Edit/View Configuration dialog to return to the framework dialog.

Run Tests

1. On the framework dialog, click **Start** to begin testing.

When tests are in progress, this button changes to **Stop**. Click it at any time to stop the test in process. You'll be able to resume from the point of termination or from the beginning of the test.

2. Follow the pop-up window prompts. QualiPHY guides you step-by-step through each of the tests described in the standard specification, including diagrams of the connection to the DUT for each required test mode.



3. When all tests are successfully completed, both progress bars on the framework dialog are completely green and the message "All tests completed successfully" appears. If problems are encountered, you'll be offered options to:
 - **Retry** the test from the latest established point defined in the script
 - **Ignore and Continue** with the next test
 - **Abort Session**

Run Reports

The QualiPHY software automates report generation. On the framework dialog, go to **General Setup > Report** to pre-configure reporting behavior. You can also manually launch the **Report Generator** from the framework dialog once a test is run.

The Report Generator offers the same selections as the Report tab, only applied to each report individually, rather than as a system setting. This enables you to save reports for each test session, rather than overwrite the generic report file. There are also options to link a custom style sheet (.xslt) to the report, or to Exclude Informative Results.

The Test Report includes a summary table with links to the detailed test result pages.

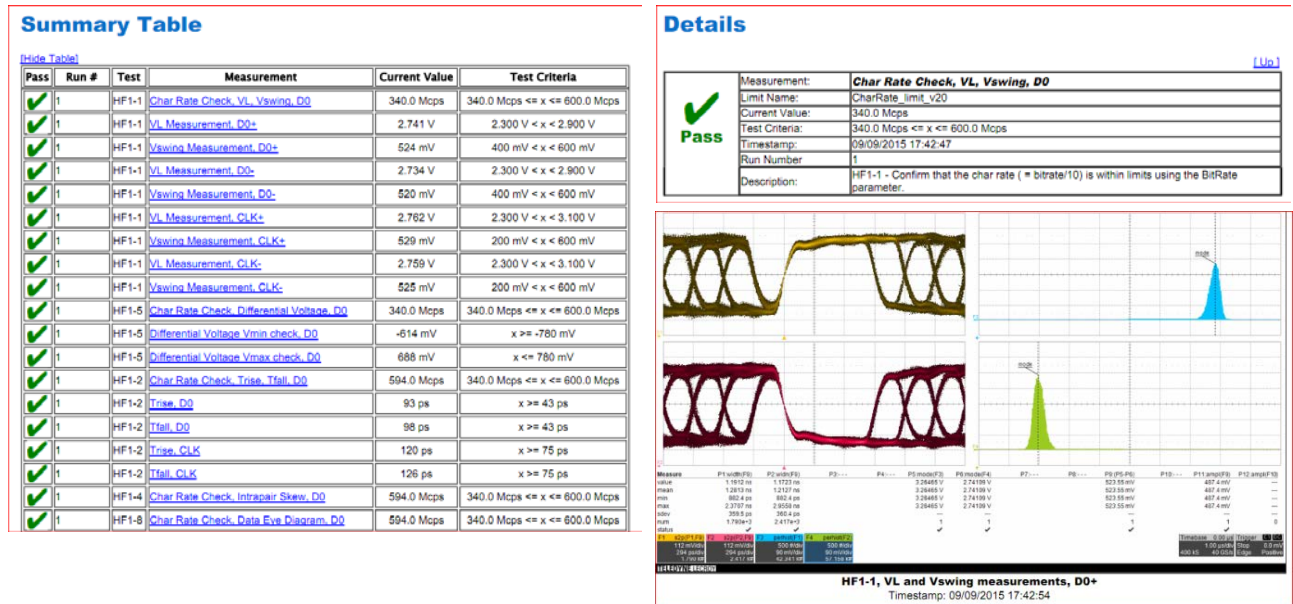


Figure 2 - The Test Report Summary Table and Details pages

Reports are output to the folder D:\QPHY\Reports, or C:\LeCroy\QPHY\Reports if QualiPHY is installed on a remote PC.

You can add your own logo to the report by replacing the file *\\QPHY\\StyleSheets\\CustomerLogo.jpg.

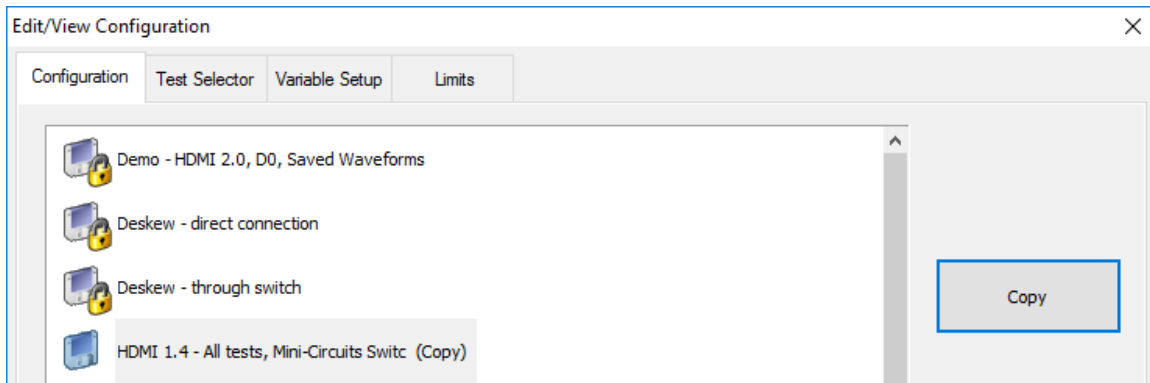
The recommended maximum size is 250x100 pixels at 72 ppi, 16.7 million colors, 24 bits. Use the same file name and format.

Customizing QualiPHY

The pre-loaded configurations cannot be modified. However, you can create your own test configurations by copying one of the standard test configurations and modifying it.

Copy Configuration

1. Access the QualiPHY framework dialog and select a **Standard**.
2. Click **Edit/View Configuration** and select the configuration upon which to base the new configuration. This can be a pre-loaded configuration or another copy.
3. Click **Copy** and enter a name and description. Once a custom configuration is defined, it appears on the Configuration tab followed by "(Copy)."



4. Select the new configuration from the list, then follow the procedures below to continue making changes.

Note: If any part of a configuration is changed, the Save As button on the Configuration tab becomes active. If a custom configuration is changed, the Save button will also become active to apply the changes to the existing configuration, rather than create a new one.

Select Tests

On the **Test Selector** tab, select/deselect the tests that make up the configuration. Each test is defined by the HDMI standard. A description of each test is displayed when it is selected.

To loop any of the tests in this configuration, select the test from the list, then choose to **Loop the highlighted test** until stopped or enter the number of repetitions.

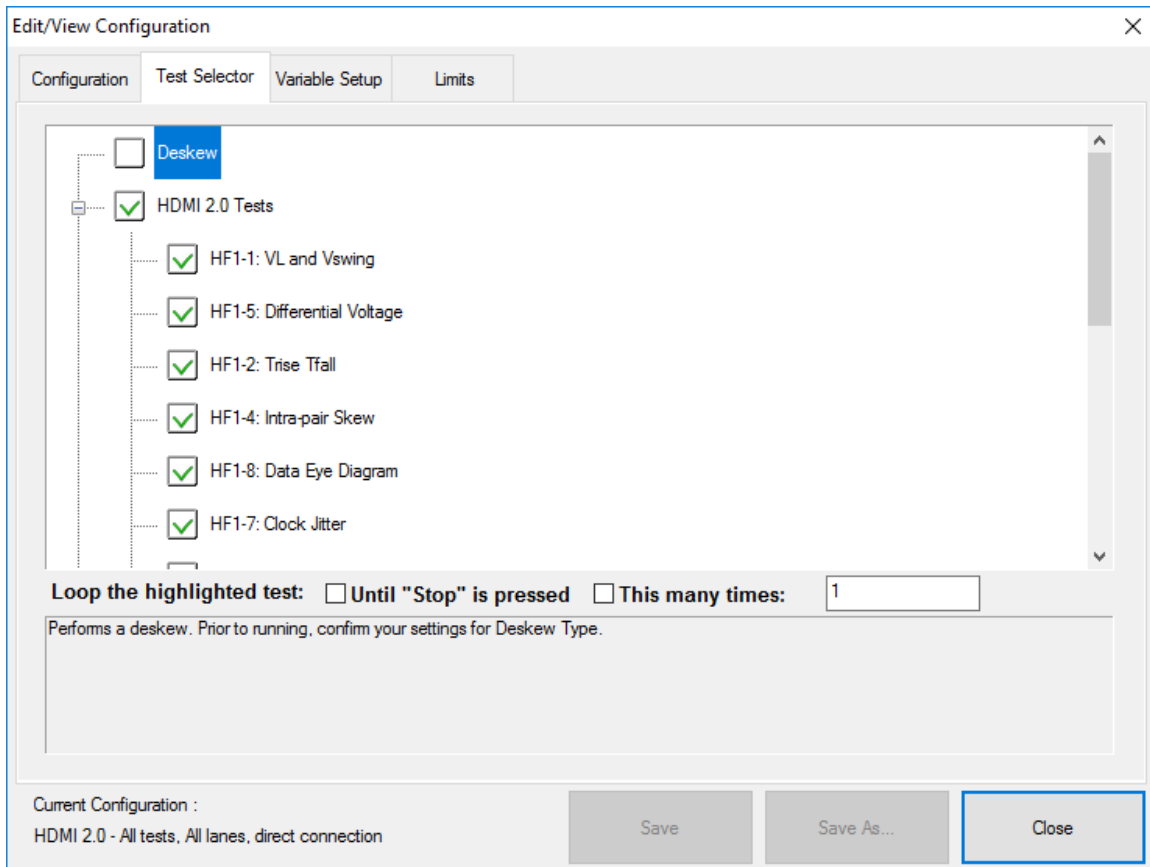


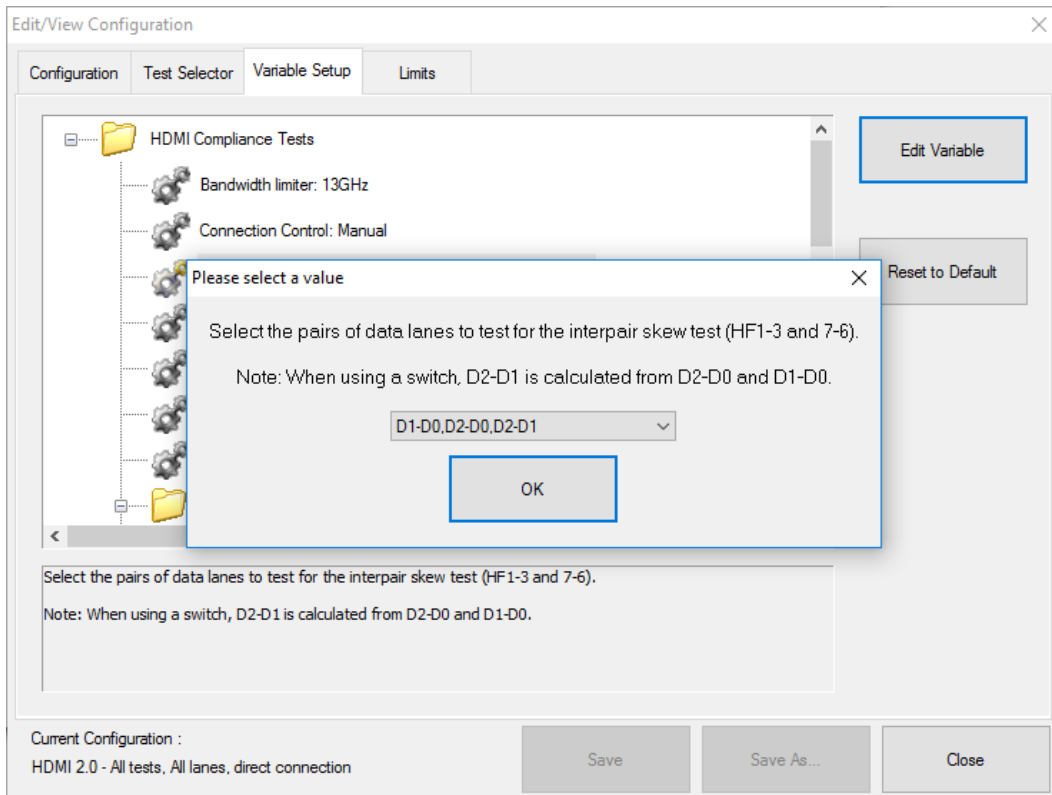
Figure 3 – Configuration Test Selector tab

Edit Variables

The Variable Setup tab contains a list of test variables. See [QPHY-HDMI2 Variables](#) for descriptions.

To modify a variable:

1. Select the variable on the Variable Setup tab, then click **Edit Variable**. (You can also choose to Reset to Default at any time.)
2. The conditions of this variable appear on a pop-up. Choose the new condition to apply.



Edit Test Limits

The Limits tab shows the Limit Set currently associated with the configuration. Any limit set can be associated with a custom configuration by selecting it in this field.

The Limits Manager shows the settings for every test limit in a limit set. Those in the default set are the limits defined by the standard.

To create a custom limit set:

1. On the Limits tab, click **Limits Manager**.
2. With the default set selected, click **Copy Set** and enter a name.

Note: You can also choose to copy and/or modify another custom set that has been associated with this configuration.

3. Double click the limit to be modified, and in the pop-up enter the new values.

Limits manager

Selected Limit Set:
Default

Copy Set Rename Set Delete Set

This is a parent Set!

List of available Limits for the selected set:

Name	Set	Comparison Method	Reference	Unit	Grain
VL_range_limit_data_v20	Default	A < x < B	2.3 2.9	V	1.000000e-003
VL_range_limit_clock_v20	Default	A < x < B	2.3 3.1	V	1.000000e-003

Define Limit

Name	Set	Compare Method	Reference A	Reference B	Unit	Grain
Vswing_range_limit_data_v20	Default	A < x < B	0.4	0.6	V	0.001

OK Cancel

Interpair_skew_limit_v20	Default	x < A	20	% ...	1.000000e-002
Intrapair_skew_limit_v20	Default	x < A	15	% ...	1.000000e-002
Differential Vmax limit v20	Default	x <= A	.78	V	1.000000e-003

Import Limits Export Limits Edit Limit

Close

You can also **Import Limits** from a .csv file. Navigate to the file location after clicking the button.

Tip: Likewise, Export Limits creates a .csv file from the current limit set. You may wish to do this and copy it to format the input .csv file.

X-Replay Mode

The X-Replay mode window is an advanced (“developer”) view of QualiPHY. The tree in the upper-left frame enables you to navigate to processes in the HDMI test script, in case you need to review the code, which appears in the upper-right frame.

Two other particularly useful features are:

- A **list of recent test sessions** in the lower-left frame. While you can only generate a report of the current test session in the QualiPHY wizard, in X-Replay Mode you can generate a report for any of these recent sessions. Select the session and choose **Report > Create Report** from the menu bar.
- An **event log is shown** the bottom-right frame. The frame can be split by dragging up the lower edge. The bottom half of this frame now shows the **raw Python output**.

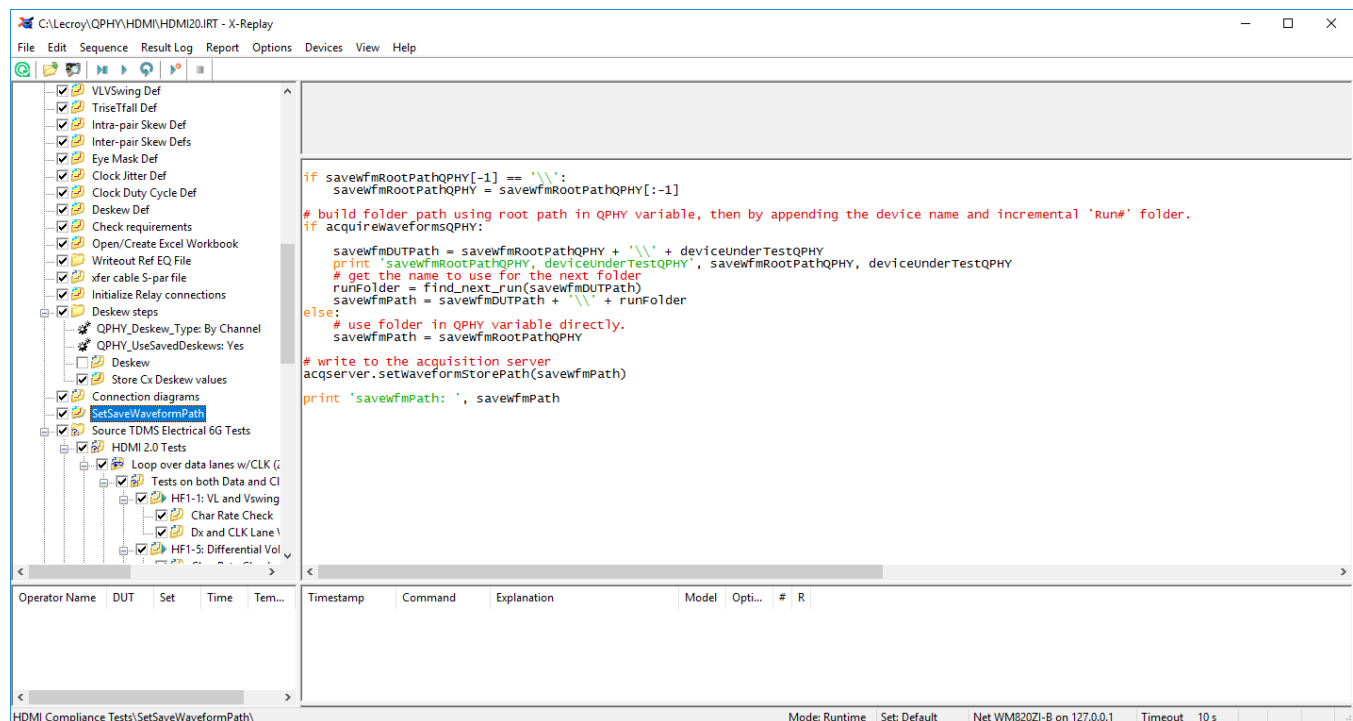


Figure 4 – X-Replay Mode window

QPHY-HDMI2 Testing

Test Preparation

Before beginning any test or data acquisition, warm the oscilloscope for at least 20 minutes.

Calibration is performed automatically by the oscilloscope software; no manual calibration is required. Calibration is run again if the temperature of the oscilloscope changes by more than a few degrees.

Required Test Modes

The QPHY-HDMI2 script requires that you place the DUT (Device Under Test) in the required test modes. The script will prompt you to do so before each specific test, but it is recommended that you ensure the DUT is capable of being placed in the required test modes before beginning testing.

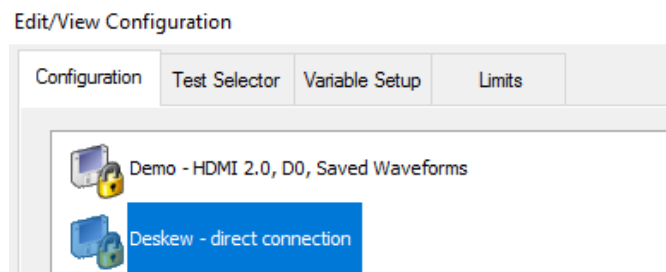
Physical Setup

The Teledyne LeCroy direct measurement solution uses SMA cables to connect two differential signals at one time to the oscilloscope channels through the TF-HDMI-3.3V SIG input. SMA cables are also used to terminate the unused signal onto the TERM inputs. See the description of each test for specific set up information.

Deskewing Input Channels, Cables and/or Switches

In order to achieve the highest accuracy possible, a deskewing step is required. Deskewing (or simply “deskew”) corrects for any difference in the path lengths connecting each signal input to the oscilloscope. When properly deskewed, differences in these path lengths are corrected, avoiding potential measurement errors. Improperly deskewed inputs can result in higher than expected intra-pair and inter-pair skew measurements, incorrect differential rise and fall times, higher than expected AC Common Mode noise measurements, excess eye diagram closure, excess jitter, etc.

The Deskew configurations will guide you through an initial deskew procedure. We highly recommend that you deskew after making your probe connections and before any HDMI tests.



Some higher bandwidth Teledyne LeCroy oscilloscopes (e.g., WaveMaster series) include the unique FastEdge output signal and trigger type to facilitate deskewing. The test script uses this output as a signal source in conjunction with the FastEdge trigger to measure the arrival time of the FastEdge through each channel. Deskew values are stored to file and recalled into each channel's Deskew setting, which is located in the Pre-processing section of the channel configuration dialog.

There are three basic kinds of deskew that are performed:

1. Deskew only the oscilloscope's inputs
2. Deskew input cabling + oscilloscope inputs
3. Deskew input switches, cabling and oscilloscope inputs.

In the QPHY-HDMI2 script, methods 1 and 2 are handled by the “By Channel” deskew method. Method 3 is handled using “By Lane”.

Deskew Oscilloscope Inputs Only

When wishing only to correct for timing differences between the oscilloscope input connectors and the internal digitizing hardware, the deskew reference plane is the point where the input signal is plugged into the oscilloscope. This type of deskew is used in the case where the test fixture is being connected directly to the oscilloscope inputs.

To do this deskew, disconnect all signals, and use a single cable connected to the FastEdge output. When the software prompts you to plug a cable into an input channel, simply change the connection from one channel to the next **using the same cable**. The result is a deskew of the input path through the TF-HDMI-3.3V adapter and the oscilloscope's internal circuitry. The script will store to file time offsets between the FastEdge signal and the trigger time. Skew with respect to channel 1 will be used during testing, such that the deskew setting for C1 = 0. The deskew settings for other channels are with respect to the value measured for C1. Deskew values that are small (picoseconds) will result.

Deskew through Input cabling + Oscilloscope inputs

When timing differences between the cables used to connect the DUT to the oscilloscope are not of interest and are to be removed (which is usually the case), then a slightly different deskew procedure is performed. This type of deskew is used in the case where the test fixture is being connected to the oscilloscope via cables.

Leave the cables connected to the oscilloscope, and disconnect them from the DUT. When the software prompts you to plug a cable into an input channel (e.g., C2), leave the cable plugged into C2, and connect the other end of the cable into the FastEdge connect. (Don't forget to torque properly!) The result is a deskew of the input path through the cables specific to each channel, through the TF-HDMI-3.3V adapter, and the oscilloscope's internal circuitry. The script will store to file the time offsets between the FastEdge signal and the trigger. Skew with respect to channel 1 will be used during testing, such that the deskew setting for C1 = 0. The deskew settings for other channels are with respect to the value measured for C1. Deskew values depend on cable lengths used, but if the cables are of the same nominal length (but are not specifically "matched cables"), then channel deskew values can be as high as several tens of picoseconds.

Tip: Label the cables and input adapters with the number of the channel to which they are connected.

Deskew through Input switches, Input cabling + Oscilloscope inputs

When using a switch matrix to route inputs from the test fixture to the oscilloscope, there are two choices. One is to perform a deskew as described below, the other is to **de-embed** the switch matrix and attached cables via S-parameter de-embedding feature of the QualiPHY-HDMI script. **Do not do both**, since this will essentially "Double correct" for any skew.

Note: The S-parameter de-embedding performed by the VirtualProbe feature of the oscilloscope will correct for both loss and skew, since S-parameters include both magnitude and phase information.

If choosing to use de-embedding to perform the "By Channel" method deskew, take care to not have any overlap in the reference planes of the deskew and of the S-parameters. If choosing to only deskew the switches, set the "Deskew Type" variable to "By Lane", and make sure the variable "De-embed switches?" is set to "No".

To perform a deskew through the switches, disconnect the signals from the DUT, but leave all cabling through the switches and into the oscilloscope connected. Connect a cable to the FastEdge output. When prompted, connect the output of this cable to the appropriate switch input. For example, when prompted to connect signal "D2+", connect the FastEdge signal to the D2+ input of the switch matrix (or to the cable connected to this input.) The script will store to file the time offsets between the FastEdge signal and the trigger time. It will also store an appropriate signal path descriptor, such as "D1+C1". During testing, the script will program the oscilloscope with the appropriate skew values for the lane/line under test. Skew with respect to channel 1 will be used during testing, such that the deskew setting for

C1 = 0. The deskew settings for other channels are with respect to the value measured for C1. Deskew values will depend on any variations in the cabling to and from the switch matrix and through any interconnecting cables.

Important: Use a torque wrench at each step in the deskew process. If a torque wrench is not used, the accuracy can easily be off by several picoseconds.

De-embedding

QualiPHY-HDMI2 includes the capability to de-embed the test fixture (TPA) as well as any switch matrix and/or cables that sit between the lane under test and the oscilloscope. De-embedding is accomplished by using the VirtualProbe software capability to emulate the effects of the TPA/switches S-parameters. To de-embed, you must provide the Touchstone files containing the complete S-parameters.

Note: De-embedding the TPA or the switch is not a requirement of the HDMI 2.0 Generic CTS, nor is it explicitly recommended. However, you may wish to de-embed if the DUT's performance is on the pass/fail boundary.

TPA

For the TPA (test fixture), this is a 4-port S-parameter file (.s4p), which would be s-parameters that represent any of the main link differential pairs. This file is specific to the TPA in use and should be requested from your TPA vendor if required.

Switch/Cable

For switches/cables, one two-port file (.s2p) is needed for each signal path that connects a single TPA output (such as Lane0) to an oscilloscope channel. The S2P file can be of any part of the path between the TPA output and the oscilloscope channel that you wish to de-embed. For a complete de-embedding, make your S-parameter measurements are from the cable connecting to the TPA outputs (if used) to the end of the cable that is attached to the oscilloscope channel.

The S2P file connecting Lane "N" of polarity "M" to oscilloscope channel "X" must be named using the following syntax:

switchD{N}{M}-C{X}

Example filenames are shown in the table. (Note that S2P files are needed to route lane D0 to both C1/C2 and to C3/C4. The routing to C3/C4 is needed for the inter-pair skew testing.)

S-parameter filename	Corresponding signal path
switchD0+C1.s2p	D0 (+) to oscilloscope channel C1
switchD0-C2.s2p	D0 (-) to oscilloscope channel C2
switchD1+C3.s2p	D1 (+) to oscilloscope channel C3
switchD1-C4.s2p	D1 (-) to oscilloscope channel C4
switchD2+C1.s2p	D2 (+) to oscilloscope channel C1
switchD2-C2.s2p	D2 (-) to oscilloscope channel C2
switchCLK+C3.s2p	CLK (+) to oscilloscope channel C3
switchCLK-C4.s2p	CLK (-) to oscilloscope channel C4
switchD0+C3.s2p	D0 (+) to oscilloscope channel C1
switchD0-C4.s2p	D0 (-) to oscilloscope channel C2

Preparing to De-embed

Prior to performing de-embedding within QualiPHY, it is good practice to examine the touchstone files with an S-parameter viewer in order to confirm that the S-parameters are “healthy”.

Set up the de-embedding in VirtualProbe and examine the de-embedding manually. This separate step will allow you to confirm that S-parameters for the TPA or switch are being properly read-in and yield reasonable results.

After confirming the de-embedding in VirtualProbe, configure QualiPHY to perform the de-embedding.

QPHY-HDMI2 Test Configurations

Test configurations include variable settings, limit sets, and test selections. All utilize the Default limit set. See [QPHY-HDMI2 Variables](#) for a description of each variable and its default value. See the [QPHY-HDMI2 Limit Sets](#) for more information about the default test limits.

Demo - HDMI 2.0, D0, Saved Waveforms

Performs all measurements except inter-pair skew on lane D0 using saved waveforms.

Deskew - Direct Connection

Performs the deskew step only, using "By channel" Deskew Type. Use this either when deskewing only the oscilloscope inputs, or if the input cables are not matched cables. Results are stored to file for later use.

Deskew - Through Switch

Performs the deskew step when connected to a switch matrix, using "By channel" Deskew Type.

Note: Change Deskew Type to:"By lane" if you ARE NOT de-embedding the switch matrix using its S-parameters, and you wish to set the reference plane for the deskew at the inputs to the switch matrix or output of the TPA-P. Leave "By channel" if you ARE de-embedding the switch matrix, or you do not want to include the switch delay in the deskew.

HDMI 1.4 - All Tests, Mini-Circuits Switch

Runs all HDMI 2.0 transmitter tests using a mini-circuit switch, with the variable settings Data Lane 0, no switch de-embedding, no TPA de-embedding, and no remote Host Program Control (the oscilloscope is the controller).

HDMI 1.4 - D0 Only, Direct Connection

Runs all HDMI 2.0 transmitter tests with the variable settings Data Lane 0, no switch de-embedding, no TPA de-embedding, and no remote Host Program Control (the oscilloscope is the controller).

HDMI 2.0 - All Tests, All Lanes, Direct Connection

Runs all HDMI 2.0 transmitter tests on all lanes.

HDMI 2.0 - All Tests, Mini-Circuits Switch

Runs all HDMI 2.0 transmitter tests on all lanes using the Mini-Circuits switch matrix to route the signals to the oscilloscope

HDMI 2.0 - D0 Only, Direct Connection

Runs all HDMI 2.0 transmitter tests except for inter-pair skew on Lane D0 only.

QPHY-HDMI2 Test Descriptions for HDMI 2.0

These are the standard HDMI 2.0 transmitter compliance tests as per HDMI 2.0 Generic CTS V8

Test HF1-1: Source TMDS Electrical – 6G VL and Vswing

HF1-1 performs the VL and VSwing test specified in section 7.1.1 of the HDMI 2.0b Generic CTS (v8). The tests are performed on the TMDS data lanes selected by the user, as well as the clock lane. After confirming that the bitrate is between 340 and 600 Mcps, VL and VSwing are measured and compared to the limits defined in the Generic CTS.

VL is the mode of the voltage distribution observed during the last 2 bits of 'HLLL' sequences. Similarly, VH is the mode for 'LHHH' sequences. VSwing = VH-VL.

Requirement

Single-ended, low level voltage range, VL:

Data Signals 0,1,2: $(AV_{cc} - 600 \text{ mV}) \leq VL \leq (AV_{cc} - 400 \text{ mV})$

Clock Signal: $(AV_{cc} - 1000 \text{ mV}) \leq VL \leq (AV_{cc} - 200 \text{ mV})$

Single-ended, swing voltage, VSwing:

Data Signals 0,1,2: $400 \text{ mV} \leq V_{\text{Swing}} \leq 600 \text{ mV}$

Clock Signal: $200 \text{ mV} \leq V_{\text{Swing}} \leq 600 \text{ mV}$

Reference: [HDMI: Table 7-1] Source TMDS Electrical – 6G – VL Requirements

Methodology

1. Connect TPA-P adapter to Source DUT HDMI output connector.
2. Connect TF-HDMI-3.3V to TMDS_DATA0+.
3. Configure the EDID, which indicates all Video Formats necessary for this test.
4. Configure the Source DUT to output a video format with lowest supported TMDS character rate above 340 Mcps up to 600 Mcps.
5. Capture 1000 or more repetitions, triggered at the vertical mid-point of the High-to-Low transition of an H-L-L-L bit sequence. Each capture must be of duration 3*Tbit.
6. Display the voltage (vertical) histogram on the oscilloscope, with the histogram data accumulated only from the last 2 bits of the H-L-L-L sequence.
7. Read the VL value as the most common low-level voltage shown on the histogram.
8. Capture 1,000 or more repetitions, triggered at the vertical mid-point of the Low-to-High transition of an L-H-H-H bit sequence. Each capture shall be of duration 3*Tbit.
9. Display the voltage (vertical) histogram on the Oscilloscope, with the histogram data accumulated only from the last 2 bits of the L-H-H-H sequence.
10. Read the VH value as the most common high-level voltage shown on the histogram.
11. Calculate Vswing = VH – VL.

13. If measured signal is Data Channel, then:

- If ($V_L < 2.30\text{ V}$) OR ($2.90\text{ V} < V_L$), then FAIL.
- If ($V_{\text{swing}} < 400\text{ mV}$) or ($600\text{ mV} < V_{\text{swing}}$), then FAIL.

14. If measured signal is Clock Channel, then:

- If ($V_L < 2.30\text{ V}$) OR ($3.10\text{ V} < V_L$), then FAIL.
- If ($V_{\text{swing}} < 200\text{ mV}$) or ($600\text{ mV} < V_{\text{swing}}$), then FAIL.

15. Repeat the test for the remaining untested TMDS signals.

HF1-2: Source TMDS Electrical – 6G TRise, TFall

HF1-2 performs the Trise and Tfall tests specified in section 7.1.1 of the HDMI 2.0b Generic CTS (v8). The tests are performed on the selected TMDS data and clock lanes. After confirming that the bitrate is between 340 and 600 Mcpc, Trise and Tfall are measured and compared to the limits defined in the Generic CTS.

Rise and fall times are measured using the Rise@level and Fall@level parameters, between 20% and 80% of the VL and VH levels (see info for test HF1-1). The values used for Trise and Tfall are the modes of the distributions of Rise@level and Fall@level measurements, respectively.

Requirement

Rise/Fall time: Data (20% to 80%): ≥ 42.5 ps

Rise/Fall time: Clock (20% to 80%): ≥ 75 ps

Reference: [HDMI 2.0: Table 6-2] Source AC Characteristics at TP1

Methodology

1. Connect TPA-P adapter to Source DUT HDMI output connector.
2. Configure the EDID, which indicates Video Formats necessary for this test.
3. Configure Source DUT to output a video format and pixel size with highest DUT-supported TMDS character rate.
4. For each of the TMDS clock and data pairs, perform the following:
 - a. Accumulate at least 10,000 triggered waveforms.
 - b. Measure TRise as the mode of the sampled edge times from 20% to 80% of the differential swing voltage rising edge.
 - c. Measure TFall as the mode of the sampled edge times from 80% to 20% of the differential swing voltage on the falling edge.
 - *In the case of Data Signals:*
 - d. If (TRise < 42.5 ps) then FAIL.
 - e. If (TFall < 42.5 ps) then FAIL.
 - *In the case of Clock Signals:*
 - f. If (TRise < 75 ps) then FAIL.
 - g. If (TFall < 75 ps) then FAIL.
5. Repeat the test for all of the remaining untested pairs.

HF1-3: Source TMDS Electrical – 6G Inter-Pair Skew

HF1-3 performs the Inter-Pair skew test specified in section 7.1.1 of the HDMI 2.0b Generic CTS (v8). After confirming that the bitrate is between 340 and 600 Mcpc, the skew between selected pairs of data lanes is measured during a sequence of unscrambled Control Period encoded characters, then compared to the limits defined in the Generic CTS. Tskew is the mean of the skew measurements taken for a set of '1010' sequences found in the control period.

Requirement

Inter-pair skew must not exceed $0.20 \cdot T_{\text{character}}$.

Reference: [HDMI 2.0: 6.1.2.4] Scrambler Synchronization Control Periods

Methodology

1. Connect TPA-P adapter to Source DUT HDMI output connector.
2. Connect two TF-HDMI-3.3V to the data signal TMDS_DATA0.
3. Connect the other two TF-HDMI-3.3V to data signal TMDS_DATA1.
4. Configure the EDID, which indicates all Video Formats necessary for this test.
5. Configure Source DUT to output an HDMI signal with a video format and pixel size with highest supported TMDS character rate.
6. Capture and find a sequence of unscrambled Control Period encoded characters on each TMDS channel. Measure Tskew between two TMDS channels (TMDS_DATA0 and TMDS_DATA1).
7. If ($T_{\text{skew}} > 0.2 \cdot T_{\text{character}}$), then FAIL.
8. Repeat the test for remaining untested combinations of TMDS_DATAx channels pairs.

HF1-4: Source TMDS Electrical Intra-Pair Skew

HF1-4 performs the Intra-Pair skew test specified in section 7.1.1 of the HDMI 2.0b Generic CTS (v8). The test is performed on the TMDS data lanes selected by the user, as well as the clock lane. After confirming that the bitrate is between 340 and 600 Mcpc, the skew between the (+) and (-) lines of a TMDS signal is measured and compared to the limits defined in the Generic CTS.

Tskew is the mode of the distribution of at least 10,000 skew measurements between the rising edge of the (+) line and the corresponding falling edge on the (-) line of the differential pair under test, using 50% crossing levels.

Requirement

Intra-pair skew between TMDS DATA pairs must not exceed $0.15 \times \text{Tbit}$.

Reference: [HDMI 2.0: Table 6-2] AC Characteristics at TP1

Methodology

1. Connect TPA-P adapter to the Source DUT HDMI output connector.
2. Configure the EDID, which indicates all Video Formats necessary for this test.
3. Connect the first TF-HDMI-3.3V to TMDS_DATA0+.
4. Connect the second TF-HDMI-3.3V to TMDS_DATA0-.
5. Configure Source DUT to output a video format and pixel size with highest supported TMDS character rate.
6. Set the trigger on TMDS_DATA0+ rising edge.
7. Display the waveform of TMDS_DATA0+ and DATA0-. Accumulate 10,000 or more triggers. Find the closest falling edge of DATA0- (either preceding or following DATA0+ rising edge) and determine the most common 50% crossing point of that TMDS_DATA0- falling edge using a horizontal (time) Histogram method.
8. Measure skew from trigger point to most common 50% crossing point of TMDS_DATA0-. If (skew > $0.15 \times \text{Tbit}$) then FAIL.
9. Repeat the test for all remaining TMDS differential pairs.

HF1-5: Source TMDS Electrical – 6G Differential Voltage

HF1-5 performs the Differential Voltage test specified in section 7.1.1 of the HDMI 2.0b Generic CTS (v8). The test is performed on the TMDS data lanes selected by the user. After confirming that the bitrate is between 340 and 600 Mcpc, the minimum and maximum differential voltage is measured, and compared to the limits defined in the Generic CTS.

The minimum and maximum voltage of the waveform is measured using the Max and Min parameters. An eye diagram is also rendered.

Requirement

Maximum Differential Voltage: 780 mV

Minimum Differential Voltage: 780 mV

Reference: [HDMI 2.0: Table 6-2] AC Characteristics at TP1

Methodology

1. Connect TPA-P adapter to Source DUT HDMI output connector.
2. Connect TF-HDMI-3.3V as follows:
 - a. D0+ to the signal input of the TF-HDMI-3.3V adapter connected to channel 1
 - b. D0- to the signal input of the TF-HDMI-3.3V adapter connected to channel 2
 - c. CLK+ to the signal input of the TF-HDMI-3.3V adapter connected to channel 3
 - d. CLK- to the signal input of the TF-HDMI-3.3V adapter connected to channel 4
3. Configure TMDS Clock signal as trigger.
4. Configure the EDID, which indicates all Video Formats necessary for this test.
5. Configure the Source DUT to output a Video Format supported by the DUT with the lowest TMDS Character Rate above 340 Mcsc up to 600 Mcsc.
6. For this TMDS character rate, perform the following:
 - a. Capture the waveform and process it with the oscilloscope. Process with the CRU to display the data Eye Diagram.
 - b. Memory length set to 16 M samples per-channel.
 - c. Set the Sampling Rate to greater than or equal to 40 GS/s
7. If any part of the waveform exceeds Maximum/Minimum Differential Voltage (± 780 mV), then FAIL.
8. Change configuration as follows:
 - a. D1+ to the signal input of the TF-HDMI-3.3V adapter connected to channel 1
 - b. D1- to the signal input of the TF-HDMI-3.3V adapter connected to channel 2
 - c. D2+ to the signal input of the TF-HDMI-3.3V adapter connected to channel 3
 - d. D2- to the signal input of the TF-HDMI-3.3V adapter connected to channel 4
9. Follow steps 3 through 7.

HF1-6: Source TMDS Electrical - 6G Clock Duty Cycle and Clock Rate

HF1-6 performs the Clock Duty Cycle and Frequency tests specified in section 7.1.1 of the HDMI 2.0b Generic CTS (v8). This test is performed only on the TMDS clock lane. After confirming that the bitrate is between 340 and 600 Mcpc, the minimum and maximum duty cycle are measured for at least 1000 cycles, along with the clock frequency, and compared to the limits defined in the Generic CTS. The Duty@level parameter is used with the levels at 50%.

Requirement

Clock duty cycle must be at least 40% and not more than 60%.

TMDS Clock Rate must be between 85 MHz and 150 MHz.

Reference: [HDMI 2.0: Table 6-2] AC Characteristics at TP1

Methodology

1. Connect TPA-P adapter to Source DUT HDMI output connector.
2. Configure the EDID, which indicates all Video Formats necessary for this test.
3. Configure Source DUT to output a video format and pixel size with highest supported TMDS clock frequency.
4. Connect two TF-HDMI-3.3V to TMDS Clock.
5. Display the waveform of 1 clock period.
6. Configure the oscilloscope: trigger source is the TMDS Clock rising edge, turn on infinite persistence, measurement is duty cycle, capture at least 10,000 or more triggers.
7. Measure minimum duty cycle (Tduty(MIN)) as earliest crossing of the TMDS_CLOCK falling edge. If (Tduty(MIN) < 40%), then FAIL.
8. Measure maximum duty cycle (Tduty(MAX)) as the latest crossing of the TMDS_CLOCK falling edge. If (Tduty(MAX) > 60%), then FAIL.
9. Measure the Tc (period of clock).
10. If ($1/Tc < 85 \text{ MHz}$) OR ($1/Tc > 150 \text{ MHz}$), then FAIL.
11. Repeat the test for a Video Format and Pixel size with the lowest DUT-supported TMDS character rate above 340 Mcsc up to 600 Mcsc.

HF1-7: Source TMDS Electrical – 6G Clock Jitter

HF1-7 performs the Clock Jitter test specified in section 7.1.1 of the HDMI 2.0b Generic CTS (v8). This test is performed only on the TMDS clock lane. After confirming that the bitrate is between 340 and 600 Mcpc, a persistence map showing the jitter on rising edges is formed, and a pk-pk jitter value is determined by finding the maximum extent of a 1mV horizontal slice centered at 0V. The value is compared to the limit of defined in the Generic CTS. This test is performed after applying the 4-port Worst Cable Emulator and Reference Cable Equalizer using the VirtualProbe feature.

Requirement

TMDS differential clock jitter must not exceed $0.3 \times \text{Tbit}$.

Reference: [HDMI 2.0: Table 6-4] HDMI Source Jitter Characteristics at TP2_EQ

Single-Ended Swing Voltage for Clock channel: $200 \text{ mV} \leq V_{\text{swing}} \leq 600 \text{ mV}$

Reference: [HDMI 2.0: Table 6-1] DC Characteristics at TP1.

Test Methodology

1. Connect TPA-P adapter to the Source DUT HDMI output connector.
2. Connect the EDID, which indicates all Video Formats necessary for this test.
3. Connect two TF-HDMI-3.3V test fixtures to each line of the TMDS Clock pair.
4. Configure the digital oscilloscope and CRU: evaluate 16 M samples per channel (can be acquired with a single capture or with multiple smaller captures).
5. Configure Source DUT to output one video format with a TMDS character rate of 594 Mcsc. If this TMDS Rate is not supported, then the highest DUT-supported TMDS character is used. For this TMDS character rate, perform the following:
 - a. Capture the waveform and process it with the oscilloscope using a sample rate greater or equal to 40 GS/s.
 - b. Measure the TP1 differential swing voltage (V_s).
 - c. If ($V_s > 1200 \text{ mV}$) OR ($V_s < 400 \text{ mV}$), then FAIL.
6. Apply the Worst Cable Emulator (Note: this setup may be applied in the oscilloscope after the process of 6.a).
7. For this TMDS character rate, perform the following:
 - a. Capture the waveform and process it with the CRU by the oscilloscope.
 - b. Apply the Reference Cable Equalizer for 3.4 Gbps – 6 Gbps to display the waveform.
 - c. Measure the TP2_EQ Clock jitter as the difference between the farthest left sampling point and the furthest right sampling point within the measurement box below:

Vertical setting = $V_c = 0 \text{ V} \pm 1 \text{ mV}$
 - d. If Clock jitter exceeds $0.3 \times \text{Tbit}$, then FAIL.

HF1-8: Source TMDS Electrical – 6G Data Eye Diagram

HF1-8 performs the Data Eye Diagram Mask test specified in section 7.1.1 of the HDMI 2.0b Generic CTS (v8). This test is performed only on the TMDS data lanes. After confirming that the bitrate is between 340 and 600 Mcpc, an eye diagram is rendered and compared to a mask. The eye diagram is shifted horizontally to find a position where there are no mask hits. This test is performed after applying the 4-port Worst Cable Emulator and Reference Cable Equalizer using the VirtualProbe feature, first with ports 1 & 3 of the Worst Cable Emulator attached to the (+) line and ports 2 & 4 attached to the (-) line, then with ports 1 & 3 of the Worst Cable Emulator attached to the (-) line and ports 2 & 4 attached to the (+) line.

Requirement

Allowable Total Data Jitter: (1-H) Tbit

H defines in Figure 6-4 Eye Diagram at TP2_EQ

Reference: [HDMI: Table 6-4] HDMI Source Jitter Characteristics at TP2_EQ. Refer to the “Eye Diagram at TP2_EQ” on [HDMI 2.0: Figure 6-4].

Methodology

1. Connect TPA-P to Source DUT HDMI output connector.
2. Connect the first TF-HDMI-3.3V to TMDS Clock, and configure as the trigger.
3. Connect the TF-HDMI-3.3V as follows:
 - a. Any D0+ to the signal input of the TF-HDMI-3.3V adapter connected to channel 1
 - b. Any D0- to the signal input of the TF-HDMI-3.3V adapter connected to channel 2
 - c. CLK+ to the signal input of the TF-HDMI-3.3V adapter connected to channel 3
 - d. CLK- to the signal input of the TF-HDMI-3.3V adapter connected to channel 4
4. Configure Source DUT to output one video format with a TMDS character rate of 594 Mcsc. If this TMDS Rate is not supported, then the highest DUT-supported TMDS character is used.
5. Apply the Worst Cable Emulator under the condition that the Worst Cable Emulator causes delay on all TMDS DATA positive (+) lines against negative (-) lines.

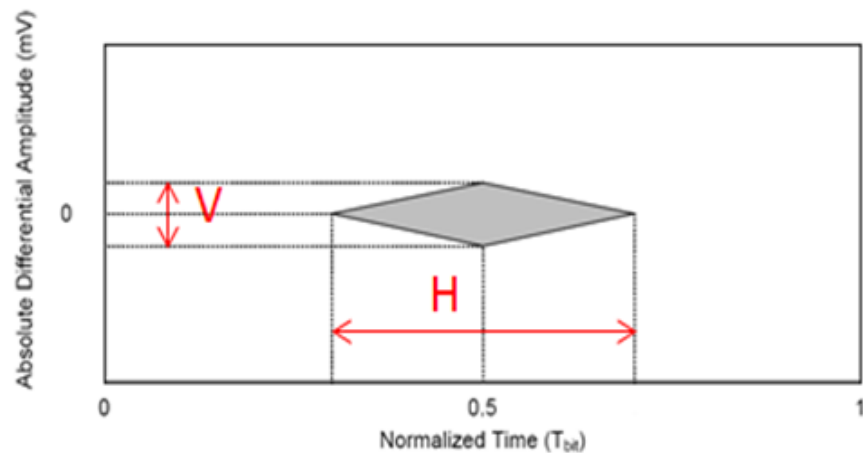
Note: this setup may be applied in the oscilloscope after the process of 6.a.

6. For this TMDS Character Rate, perform the following:
 - a. Capture the waveform and process it with the CRU by the oscilloscope.
 - b. Apply the Reference Equalizer for 3.4 Gbps – 6 Gbps to display the data eye diagram.
 - i. Set the Memory length to 16M samples per channel.
 - ii. Set the Sampling Rate to greater than or equal to 40 GS/s.

Continued

- c. Compare the data eye to the TP2_EQ Eye Diagram Mask shown in the following figure.

TMDS Bit Rate (Gbps)	H (Tbit)	V (mV)
3.71	0.6	335
4.46	0.56	295
5.94	0.4	150
Others	See [HDMI2.0: Table 6-5]	



- d. Shift the mask left or right through one entire Tbit to determine if any horizontal position has no capture points within the eye mask. No vertical shifting is allowed.
 - e. If no shifted position exists where no part of the waveform touches or crosses into the data eye, then FAIL.
7. Repeat the test after applying Worst Cable Emulator under the condition that the Worst Cable Emulator causes delay on all TMDS DATA negative (-) lines against positive (+) lines.
 8. Change the connections in order to test each data lane in sequence, repeating the steps above to make Eye Diagram measurement.

QPHY-HDMI2 Test Descriptions for HDMI 1.4b

These are the standard HDMI 1.4b transmitter compliance tests as per HDMI_CTS_1_4b.pdf.

Test 7-2: TMDS-VL

This test confirms that DC voltage levels on the HDMI link are within specified limits for each TMDS signal.

Requirement

Single-ended, low level output voltage, VL:

If attached Sink supports only ≤ 165 MHz: $(AV_{cc} - 600 \text{ mV}) \leq VL \leq (AV_{cc} - 400 \text{ mV})$

If attached Sink supports > 165 MHz: $(AV_{cc} - 700 \text{ mV}) \leq VL \leq (AV_{cc} - 400 \text{ mV})$

Reference: [HDMI: Table 4-15] Source DC Characteristics at TP1

Methodology

1. Connect TPA-P adapter to Source DUT HDMI output connector.
2. Connect TF-HDMI-3.3V to TMDS_DATA0+.
3. Configure the EDID to indicate only 27 MHz formats (480 p and 576 p, no Deep Color support) with the 640 x 480 p Established Timings bit set.
4. Control the Source DUT to output a video format with lowest supported TMDS clock frequency (typically 27 MHz).
5. Capture 1000 or more repetitions, triggered at the vertical mid-point of the High-to-Low transition of an H-L-L-L bit sequence. Each capture must be of duration $3 \times T_{bit}$.
6. Display the voltage (vertical) histogram on the oscilloscope, with the histogram data accumulated only from the last 2-bits of the H-L-L-L sequence.
7. Read the VL value as the most common low-level voltage shown on the histogram.
8. If $(VL > 2.90 \text{ V})$ OR $(VL < 2.70 \text{ V})$ then capture 10,000 repetitions, triggered at mid-point of waveform, of duration $\geq 2 \times T_{bit}$ to get proper histograms.
9. Display the voltage (vertical) histogram on the oscilloscope. If $(VL > 2.90 \text{ V})$ OR $(VL < 2.70 \text{ V})$ then FAIL.
10. Repeat the test for all eight TMDS signals.
11. If CDF field Source_Above_165, then switch to an EDID that additionally indicates:
 - a. Support for 1080 p 50 Hz and 60 Hz
 - b. Deep Color 36-bits/pixel
 - c. Max_TMDS_Clock of 225 MHz (value = $225/5 = 45$)
12. Repeat test sequence above still using lowest clock rate format. If $(VL > 2.90 \text{ V})$ OR $(VL < 2.60 \text{ V})$ then FAIL.
13. Repeat the test for all eight TMDS signals.

Test 7-4: TMDS TRise, TFall

This test confirms that the rise times and fall times on the TMDS differential signals fall within the limits of the specification.

Requirement

75 ps $\leq$ Rise Time or Fall Time

Reference: [HDMI: Table 4-16] Source AC Characteristics at TP1

Methodology

1. Connect TPA-P adapter to Source DUT HDMI output connector.
2. Configure Source DUT to output a video format and pixel size with highest supported TMDS clock frequency.
3. Accumulate at least 10,000 triggered waveforms.
4. Measure TRISE as the mode of the sampled edge times from 20% to 80% of the differential swing voltage rising edge.
5. Measure TFALL as the mode of the sampled edge times from 80% to 20% of the differential swing voltage on the falling edge.
If (TRISE < 75 ps) then FAIL.
6. Repeat the test for all remaining TMDS clock and data pairs.

Test 7-5: TMDS Over/Undershoot

This test confirms that the differential TMDS signals do not have overshoot or undershoot beyond that allowed by the specified limits (HDMI 1.0 only).

Test 7-6: TMDS Inter-Pair Skew

This test confirms that that any skew between the differential pairs in the TMDS portion of the HDMI link does not exceed the limits in the specification.

Requirement

Inter-pair skew must not exceed $0.20 \cdot T_{PIXEL}$.

Reference: [HDMI: Table 4-16] Source AC Characteristics at TP1

Methodology

1. Connect TPA-P adapter to Source DUT HDMI output connector.
2. Connect the first TF-HDMI-3.3V to TMDS_DATA0.
3. Connect the second TF-HDMI-3.3V to TMDS_DATA1.
4. Configure Source DUT to output an HDMI signal with a video format and pixel size with highest supported TMDS clock frequency.
5. Capture (trigger) or find a sequence of Control Period encoded characters. Either 10-bit or 20-bit trigger may be used.
6. Measure TIPSKEW:

For 10-bit Trigger	For 20-bit Trigger
Find the first bit of the TMDS character on the two TMDS channels. The CTL encoding pattern 1101010100 corresponds to: TMDS_DATA0: HSYNC=1, VSYNC=0 TMDS_DATA1: CTL0=1, CTL1=0 (any Preamble) TMDS_DATA2: CTL2=1, CTL3=0 (Data Island Preamble) If it is difficult to capture using the above patterns, then any of the following (Control Period) patterns may be used: 0010101011 1101010100 0010101010 1101010101 Examine second channel for any valid CTL code and measure TIPSKEW between channels.	Find the first bit of the following 20-bit sequence on the TMDS channels. For Channel 0: 0010101011 0011001101 For Channel 0: 0010101010 0011001101 For Channel 0: 1101010101 0011001101 For Channel 1: 0010101010 1100110010 For Channel 2: 0010101011 0011001101 Examine second channel for the appropriate sequence and measure TIPSKEW between channels.

If $TIPSKEW > 0.2 \cdot T_{CHARACTER}$ then FAIL.

7. Repeat the test for remaining combinations of TMDS_DATAx pairs.

Test 7-7: TMDS Intra-Pair Skew

This test confirms that any skew within any one differential pair in the TMDS portion of the HDMI link does not exceed the limits in the specification.

Requirement

Intra-pair skew between TMDS DATA pairs must not exceed $0.15 \times \text{TBIT}$.

Reference: [HDMI: Table 4-16] Source AC Characteristics at TP1

Methodology

1. Connect TPA-P adapter to the Source DUT HDMI output connector.
2. Connect the first TF-HDMI-3.3V to TMDS_DATA0+.
3. Connect the second TF-HDMI-3.3V to TMDS_DATA0-.
4. Configure Source DUT to output a video format and pixel size with highest supported TMDS clock frequency.
5. Set the trigger on TMDS_DATA0+ rising edge.
6. Display the waveform of TMDS_DATA0+ and DATA0-. Accumulate 10,000 or more triggers.
7. Find the closest falling edge of DATA0- (either preceding or following DATA0+ rising edge) and determine the most common 50% crossing point of that TMDS_DATA0- falling edge using a horizontal (time) Histogram method.
8. Measure skew from trigger point to most common 50% crossing point of TMDS_DATA0-. If (skew > $0.15 \times \text{TBIT}$) then FAIL.
9. Repeat the test for all remaining TMDS differential pairs.

Test 7-8: TMDS Clock Duty Cycle

This test confirms that the duty cycle of the differential TMDS clock does not exceed the limits allowed by the specification.

Requirement

Clock duty cycle must be at least 40% and not more than 60%.

Reference: [HDMI: Table 4-16] Source AC Characteristics at TP1

Methodology

1. Connect TPA-P adapter to Source DUT HDMI output connector.
2. Configure Source DUT to output a video format and pixel size with highest supported TMDS clock frequency.
3. Connect TF-HDMI-3.3V to TMDS Clock.
4. Display the waveform of 1 clock period.
5. Configure the oscilloscope as follows: trigger source is the TMDS Clock rising edge, turn on infinite persistence, measurement is duty cycle, capture at least 10,000 or more triggers.
6. Measure minimum duty cycle as earliest crossing of TMDS_CLOCK falling edge.
If (TDUTY(MIN) < 40%, then FAIL.
7. Measure maximum duty cycle as latest crossing of TMDS_CLOCK falling edge.)
If (TDUTY(MAX) > 60%, then FAIL.

Test 7-9: TMDS Clock Jitter

This test confirms that the TMDS Clock does not carry excessive jitter.

Requirement

TMDS differential clock jitter must not exceed $0.25 \times \text{TBIT}$, relative to the ideal Recovery Clock.

Reference: [HDMI: Table 4-16] Source AC Characteristics at TP1

Test Methodology

1. Connect TPA-P adapter to the Source DUT HDMI output connector.
2. Connect two TF-HDMI-3.3V test fixtures to each line of the TMDS Clock pair.
3. Configure the oscilloscope and CRU: evaluate 16 M samples per channel (can be acquired with a single or with multiple smaller captures).
4. Configure Source DUT to output one video format for the first of the following TMDS Clock frequencies supported: 27 MHz (or 25 MHz), 74.25 MHz, 148.5 MHz, or 222.75 MHz..
5. Perform the following:
 - a. Capture the waveform and process it with the oscilloscope.
 - b. If test frequency is ≤ 165 MHz, then set Sampling Rate ≥ 10 GS/s.
If test frequency is >165 MHz, then set Sampling Rate ≥ 20 GS/s.
 - c. Measure Clock jitter as difference between farthest left sampling point and farthest right sampling point, at Vertical setting = VC = $0 \text{ V} \pm 20 \text{ mV}$. If Clock jitter exceeds $0.25 \times \text{TBIT}$ then FAIL.
6. Repeat Steps 4 and 5 for remaining supported test frequencies. Only one video format/pixel-size combination is required per TMDS clock rate.

Test 7-10: TMDS Data Eye Diagram

This test confirms that the differential signal on each TMDS differential data pair has an “eye opening” (region of valid data) that meets or exceeds the limits on eye opening in the specification.

Requirement

Refer to the “Eye Diagram Mask at TP1 for Source Requirements.

Reference: [HDMI: Figure 4-18] Eye Diagram Mask at TP1

Methodology

1. Connect TPA-P-TDR to Source DUT HDMI output connector.
2. Connect the first TF-HDMI-3.3V to TMDS Clock and configure as trigger.
3. Connect the second TF-HDMI-3.3V to TMDS_DATA0.
4. Connect 50 Ohm pull-ups to each of the non-probed TMDS lines to 3.3 V.
5. Configure Source DUT to output one video format for the first of the following TMDS clock frequencies supported: 27 MHz (or 25 MHz), 74.25 MHz, 148.5 MHz, or 222.75 MHz.
6. Capture the waveforms on the oscilloscope. Process with the CRU to display the data eye diagram.
 - a. Set memory length to 16 M samples per-channel.
 - b. If test frequency is ≤ 165 MHz then set Sampling Rate ≥ 10 GS/s.
If test frequency is > 165 MHz then set Sampling Rate ≥ 20 GS/s.
7. Compare the data eye to the TP1 Eye Diagram Mask. If any part of the waveform exceeds either the high or low maximum voltage (± 780 mV), then FAIL.
8. Shift the mask left or right through one entire TBIT to determine if any horizontal position has no capture points within eye mask. No vertical shifting is allowed. If no shifted position exists where no part of the waveform touches or crosses into the data eye, then FAIL.
9. Measure the data jitter at the zero crossing point. Measurement box vertical setting: $0\text{ V} \pm 5\text{ mV}$. If data jitter $> 0.3 \cdot \text{TBIT}$, then FAIL.
10. Repeat Steps 5 through 9 for the remaining supported TMDS clock frequencies, plus the highest DUT-supported frequency (if not already covered). Only one video format/pixel-size combination is required per TMDS clock rate.
11. Repeat the test for remaining TMDS_DATA pairs.

QPHY-HDMI2 Variables

Root Variables

Bandwidth Limiter

Bandwidth limiter to configure on input channels. Typically set to 13 GHz. See the oscilloscope channel dialog's Bandwidth selector for allowed values (including Full).

Connection Control

Selects how the connections to the oscilloscope will be made:

- Manual: the user will be prompted to connect signals to the oscilloscope as necessary.
- Mini-Circuits Switches: the QualiPHY script will automatically control two Mini-Circuits RF switch boxes to route the appropriate signals from the TPA-P to the oscilloscope.

Note: The switch boxes should be connected via USB to the computer running QualiPHY—typically the oscilloscope.

- Host Program Control: QualiPHY will use the Host Control Sync File protocol to signal host control software when input connections should be changed.

Data Lanes to Test for Inter-Pair Skew

Select the pairs of data lanes to test for the inter-pair skew tests (HF1-3 and 7-6).

Note: When using a switch, D2-D1 is calculated from D2-D0 and D1-D0.

Data Lanes to Test for TMDS Tests

TMDS data lanes to test. (CLK lane is always tested along with the selected data lanes as required).

Waveform Path

Root oscilloscope folder in which to save waveforms. When Use Saved Waveforms is No, acquired waveforms are automatically saved here, with the full path including the DUT name folder plus an auto-incrementing Run# folder (e.g., D:\Waveforms\HDMI\DUT-ABCDE\Run6\). When Use Saved Waveforms is Yes, QualiPHY will retrieve the waveform files (.trc format) from this folder.

Use Saved Waveforms

When Yes, QualiPHY recalls waveform files from the folder specified in Waveform Path. Default is No.

De-embedding Variables

Delay Through Switch (ns)

If de-embedding the switch, the nominal delay in ns. This value is used for the HF1-3 Inter-pair skew test to optimize the alignment.

De-embed TPA?

Enables/disables de-embedding the TPA-P using a 4-port S-parameter touchstone file.

Note: Contact the manufacturer of your TPA-P to get the correct file and determine how the ports in the file map to the physical ports of the TPA-P. De-embedding the TPA-P is optional, and not specified by the HDMI compliance test specification.

Delay Through TPA (ns)

If de-embedding the TPA, the delay through the TPA in ns. This value is used for the HF1-3 Inter-pair skew test to optimize the alignment.

Filename/Path for TPA-P Touchstone File

Full path to the touchstone file for the TPA-P if you are choosing to have it de-embedded.

Note: De-embedding is optional and not specified by the HDMI compliance test specification.

TPA-P Touchstone File Port Mapping

Port mappings, where the entered values are the port numbers in the touchstone file, and map to the TPA-P topology in the following manner:

- a. ABCD, where A goes through to B, and C goes through to D
- b. A and B are inputs to the TPA-P's HDMI connector, with A being a (+) line, and B being a (-) line
- c. C and D are outputs from the TPA-P's SMA cables, with C being a (+) line, and D being a (-) line.

Example: For the choice 1234:

- A=1, B=2, C=3, D=4.
- Ports 1 goes through to port 2, and port 3 goes through to port 4.
- Ports 1 and 3 correspond to the inputs to the HDMI connector for (+) and (-) line, and ports 2 and 4 are the corresponding outputs for 1 differential pair, such as D0.

De-embed Switches

Enables/disables de-embedding of any relays or switches that are in the signal path.

Note: De-embedding is optional and not specified by the HDMI compliance test specification.

Folder for Switch De-embedding S2P Files

Full path to the touchstone files for the switch if you are choosing to have it de-embedded.

Note: De-embedding is optional and not specified by the HDMI compliance test specification.

Host Program Control Variables

Host Program Control Sync Filename

If Use Host Program Control? is set to Yes, specifies the full path to the sync file.

See [Appendix A: Using Host Program Control Mode](#) for more information.

Use Host Program Control

Use a simple, file-based protocol that allows a host computer to interact with QualiPHY during a session, instead of showing messages to a human user. QualiPHY will write a file of the name you specify in UserSyncFile_name, it will contain XML that either contains an error message or specifies a desired state. When the desired state has been set up (possibly automated by another process) the sync file should be deleted. QualiPHY waits for that. When it is deleted, QualiPHY will proceed.

See [Appendix A: Using Host Program Control Mode](#) for more information.

Deskew Steps Variables

Deskew Type

Specifies type of deskew to perform.

By lane: When using a switch matrix to route signals, select "By lane" if you are NOT de-embedding the switch matrix using its S-parameters, and if you wish to set the reference plane for the deskew at the inputs to the switch matrix or output of the TPA-P.

By channel: When not using a switch matrix, or when not wanting to include the switch delay as part of the deskew, choose the "By Channel" option. When using a switch matrix AND using de-embedding of the switch matrix, use this option.

Use Saved Deskew Values

Enables/disables the use of deskew values saved in D:\HDMI\SkewCal\SkewCal.cal when not performing the manual Deskew test step.

HDMI1.4 Test Variables

QPHY_Custom_Freq_List

Comma-delimited list of clock frequencies used in tests 7-9 and 7-10. Only include frequencies from the following list: 25, 27, 74.25, 148.5, 222.75.

DUT TMDS Clock Standard Frequencies

List of standard frequencies tested: 27 MHz (or 25 MHz), 74.25 MHz, 148.5 MHz, 222.75 MHz

Use alternate frequency if the highest DUT-supported frequency is not already covered or if you want to define a custom list of frequencies.

Source_Above_165

Specifies if the CDF field is above 165. Used by the 7-2 VL test.

QPHY-HDMI2 Limit Sets

The default installation of QPHY-HDMI2 contains only one limit set, called “HDMI_Default.” In this script, limits are only used to convey Unit labels. The actual limits for each value tested is encoded in or computed by the script and cannot be changed. The default limits used by QPHY-HDMI2 are specified in version 1.4 of the High Definition Multimedia Interface Compliance Test Specification (HDMI).

Appendix A: Using Host Program Control Mode

Host Program Control Mode (HPC) is a new feature that allows QualiPHY to be started by a user's host program with a number of arguments. Once running, a simple "Sync File" protocol is used by QualiPHY to signal the host program. When the QualiPHY script requires action from the host program, it writes a User Sync File to the disk in .xml format containing several tags. QualiPHY then pauses execution and waits. The host program should set the requested DUT parameters or test system configuration, respond as necessary, then delete the User Sync File. When QualiPHY sees that the User Sync File is deleted, it continues execution.

In the QPHY-HDMI2 script, there are three situations when a Sync File is written out:

1. When the user host program needs to change which signals are connected to the oscilloscope (typically utilized in systems involving an RF switch)
2. When the user host program needs to change the signal type output from the DUT (e.g., the signal's character rate)
3. When an issue (error condition) has occurred

In order to use Host Program Control Mode, the following considerations should be taken into account.

Preparing Special Configuration for Host Control Mode

In QualiPHY, create a custom Configuration that has the variables configured in the way you will need them when you run in Host Program Control Mode. Make sure you save the configuration after editing the variables so that it will be available to refer to when you startup QualiPHY via command line.

Variables that need to be considered to run in HPC are:

- **Host Program Control sync filename**
 - o Definition: Use to specify sync file path.
 - o Default: C:\HDMI_sync_file.xml
 - o Comments: Just use default unless conflict.
- **Use Host Program Control?**
 - o Definition: Set to "Yes" to use the Host Program Control feature, "No" otherwise.
 - o Default: No
 - o Comment: When set to "Yes", QualiPHY will pause execution after it creates a sync file and while it is waiting for the sync file to be deleted.

Host Program Elements Needed to Control the QualiPHY Script

Launching QualiPHY (XReplay)

The Host program needs to launch the QualiPHY program (the actual program is named XReplay.exe) with the following command line, including arguments for HDMI:

```
C:\Program Files (x86)\LeCroy\XReplay\XReplay.exe -A -R -E -WIZARD -TECH:HDMI -CONFIG:HostControlTest -N:IP
```

The path shown above is where the XReplay.exe program (QualiPHY) is placed by the installer.

Arguments are:

-A	Stops all manual user interaction. (Always use)
-R	Causes the test script (HDMI in this case) to be run automatically. (Always use)
-E	Automatically exit when test script is done executing. (Always use)
-WIZARD	Required.
-TECH:HDMI	Sets the technology to test, HDMI in this case.
-CONFIG:HostControlTest	Sets the name of the configuration that will be used; HostControlTest in this case.
-N:IP Address	IP address of the oscilloscope: If QualiPHY is running on the oscilloscope, set to <i>localhost</i> . If QualiPHY is not running on the oscilloscope, set to <i>Host ID</i> or <i>IP Address</i> of the oscilloscope.

Monitoring for QualiPHY Termination

The host program needs to continuously test to see if the QualiPHY process still exists, to be able to know when the QualiPHY test script has completed and take appropriate action.

File Transfer Synchronization

The host synchronization consists of three parts:

1. Waiting for C:\HDMI_sync_file.xml (or other name specified in configuration) to be written by QualiPHY.
2. Reading the file and performing the required actions.
3. Deleting C:\HDMI_sync_file.xml in order to signal QualiPHY that the operation is complete.

Renaming the Test Report

The test report that is created by the QualiPHY test script is always created with the same name (e.g., D:\QPHY\Reports\LeCroyReport.pdf). For this reason, it needs to be renamed after QualiPHY (XReplay) terminates in order to avoid overwriting it the next time QualiPHY is run.

Sample Host Program

This sample VBS host program performs all the essential tasks involved in launching and syncing with the QualiPHY HDMI2 test script. It is shown below and referred to in the text following it.

```
' Sample Host Program Control Script
' September 10, 2015

Set shell = CreateObject("Wscript.Shell")
Set fso = CreateObject("Scripting.FileSystemObject")

WScript.Echo "Launching QualiPHY"
Set qphyProc = shell.Exec("C:\Program Files (x86)\LeCroy\XReplay\XReplay.exe -A -R -E -WIZARD
-TECH:HDMI -CONFIG:HostControlTest -N:172.28.13.164")
fname = "C:\HDMI_sync_file.xml"
Do While qphyProc.Status = 0
    If fso.FileExists(fname) Then
        result = parse_XML(fname, sigtype, connectionsReq, errorcode, detail)
    ' Perform actions based on info in sync file here.
    '
        Wscript.Echo "Deleting sync file"
        fso.DeleteFile(fname)
    Else
        wscript.sleep(500)
    End If
Loop

WScript.Echo "Generating report"

Set qphyProc = shell.Exec("C:\Program Files (x86)\LeCroy\XReplay\XReplay.exe -D -WIZARD")
Do While qphyProc.Status = 0
    wscript.sleep(500)
Loop

WScript.Echo "Renaming report"
fso.MoveFile "D:\QPHY\Reports\LeCroyReport.pdf", "D:\QPHY\Reports\QPHY-HDMI.pdf"
WScript.Echo "Done!"

Function parse_XML(ByVal fname, ByRef sigtype, ByRef connectionsReq, ByRef errorcode, ByRef
detail)
    set xmlDoc=CreateObject("Microsoft.XMLDOM")
    xmlDoc.async="false"
    xmlDoc.load(fname)

    'Set queryNode = xmlDoc.selectSingleNode(".//signal_type[@context = 'General']")
    Set Node = xmlDoc.documentElement.selectSingleNode("signal_type")
    sigtype = Node.text
    Set Node = xmlDoc.documentElement.selectSingleNode("connectionsReq")
    connectionsReq = Node.text
    Set Node = xmlDoc.documentElement.selectSingleNode("error")
    errorcode = Node.text
    Set Node = xmlDoc.documentElement.selectSingleNode("detail")
    detail = Node.text

    set xmlDoc = Nothing
    parse_XML = 0
End Function
```

HPC Sync File

Sync File Tags

The Host Program Control synchronization file includes the following tags:

- **connectionsReq**: Describes the connections that should be made.
 - o When instructed to connect two lanes, connect /route the lanes to the oscilloscope such that (+) lines are to channels C1 and C3, and (-) lines to C2 and C4.)
 - o Example: **“D0,CLK”**: Connect: D0+ to C1, D0- to C2, CLK+ to C3, CLK- to C4
 - o For simplicity, in the HDMI script CLK lines are always input to C3 and C4.
- **signal_type**: Describes the signal type that is required for the test. Examples:
 - o “Lowest, v2.0”: Configure the source to output the lowest supported character rate for HDMI 2.0 operation (between 340 Mcps and 600 Mcps)
 - o “148500000”: Configure the source to output HDMI signals with 148.5 MHz (required for HDMI 1.4)
- **error**: includes an error code. Refer to the “detail” field for information about the error.
- **detail**: Gives additional information, especially in situations where the error code $\neq 0$, which would indicate an issue. Examples:
 - o “Deskew: No signal detected on C2! Please check connections and source.”
 - o “No trigger: Trigger timed out. Is signal present and trigger set correctly?”

Example XML Sync Files

```
<TestConfig>
<signal_type/>
<connectionsReq>init</connectionsReq>
<detail/>
<error>0</error>
</TestConfig>
```

```
<TestConfig>
<signal_type/>
<connectionsReq>D0,CLK</connectionsReq>
<detail>New connections:</detail>
<error>0</error>
</TestConfig>
```

```
<TestConfig>
<signal_type>Lowest, v2.0</signal_type>
<connectionsReq/>
<detail>New signal type</detail>
<error>0</error>
</TestConfig>
```

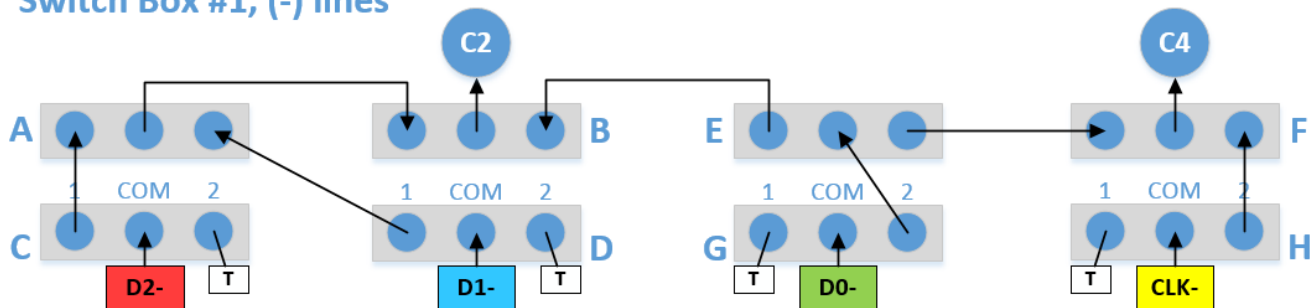
```
<TestConfig>
<signal_type/>
<connectionsReq/>
<detail>No trigger: Trigger timed out. Is signal present and trigger set correctly?
</detail>
<error>3</error>
</TestConfig>
```

Appendix B: Switch Matrix Configuration

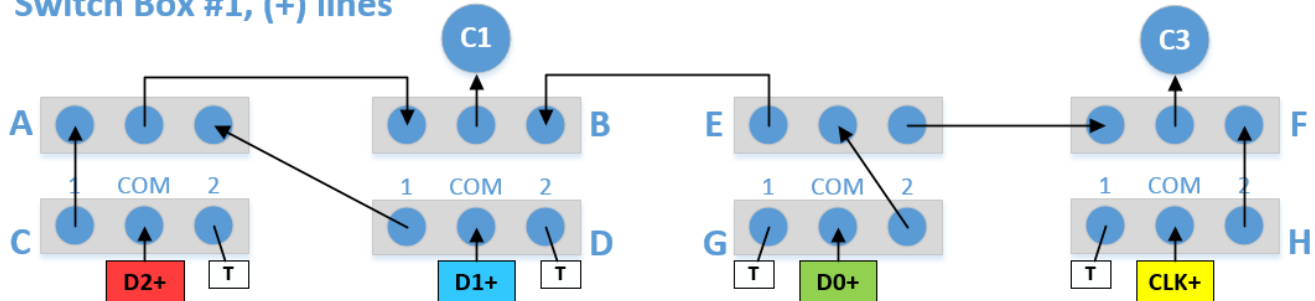
Follow this connection diagram when using Mini-Circuits Model RC-8SPDT-A18 switches to automatically connect TPA outputs to oscilloscope inputs. Note that this connection scheme allows lane D0 to be connected either to C3/C4 for the inter-pair skew tests, or to C1/C2 for all other tests. Lanes D1 and D2 always are routed to C1/C2, and CLK to C3/C4:

HDMI Testing – Switch Configuration

Switch Box #1, (-) lines



Switch Box #1, (+) lines



T = 3.3V pull-up termination



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