Keysight U7246A/U7246B SD UHS-I Card Compliance Test Application

Methods of Implementation

KEYSIGHT TECHNOLOGIES

Notices

Manual Part Number

U7246-97000

Software Version

Version 1.45.0000

Edition

March 2017

Keysight Technologies
1900 Garden of the Gods Road
Colorado Springs, CO 80907 USA

Warranty

THE MATERIAL CONTAINED IN THIS DOCUMENT IS PROVIDED "AS IS," AND IS SUBJECT TO BEING CHANGED, WITHOUT NOTICE, IN FUTURE EDITIONS. FURTHER, TO THE MAXIMUM EXTENT PERMITTED BY APPLICABLE LAW, KEYSIGHT DISCLAIMS ALL WARRANTIES, EITHER EXPRESS OR IMPLIED WITH REGARD TO THIS MANUAL AND ANY INFORMATION CONTAINED HEREIN, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. KEYSIGHT SHALL NOT BE LIABLE FOR ERRORS OR FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH THE FURNISHING, USE, OR PERFORMANCE OF THIS DOCUMENT OR ANY INFORMATION CONTAINED HEREIN. SHOULD KEYSIGHT AND THE USER HAVE A SEPARATE WRITTEN AGREEMENT WITH WARRANTY TERMS COVERING THE MATERIAL IN THIS DOCUMENT THAT CONFLICT WITH THESE TERMS, THE WARRANTY TERMS IN THE SEPARATE AGREEMENT WILL CONTROL.

Technology Licenses

The hardware and/or software described in this document are furnished under a license and may be used or copied only in accordance with the terms of such license.

U.S. Government Rights

The Software is “commercial computer software,” as defined by Federal Acquisition Regulation (“FAR”) 2.101. Pursuant to FAR 12.212 and 27.405-3 and Department of Defense FAR Supplement (“DFARS”) 227.7202, the U.S. government acquires commercial computer software under the same terms by which the software is customarily provided to the public. Accordingly, Keysight provides the Software to U.S. government customers under its standard commercial license, which is embodied in its End User License Agreement (EULA), a copy of which can be found at http://www.keysight.com/find/sweula. The license set forth in the EULA represents the exclusive authority by which the U.S. government may use, modify, distribute, or disclose the Software. The EULA and the license set forth therein, does not require or permit, among other things, that Keysight: (1) Furnish technical information related to commercial computer software or commercial computer software documentation that is not customarily provided to the public; or (2) Relinquish to, or otherwise provide, the government rights in excess of these rights customarily provided to the public to use, modify, reproduce, release, perform, display, or disclose commercial computer software or commercial computer software documentation. No additional government requirements beyond those set forth in the EULA shall apply, except to the extent that those terms, rights, or licenses are explicitly required from all providers of commercial computer software pursuant to the FAR and the DFARS and are set forth specifically in writing elsewhere in the EULA. Keysight shall be under no obligation to update, revise or otherwise modify the Software. With respect to any technical data as defined by FAR 2.101, pursuant to FAR 12.211 and 27.404.2 and DFARS 227.7102, the U.S. government acquires no greater than Limited Rights as defined in FAR 27.401 or DFAR 227.7103-5 (c), as applicable in any technical data.

Safety Notices

CAUTION

A CAUTION notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.

WARNING

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

SD UHS-I—An Overview

The Keysight Technologies SD compliance test tool supports compliance tests for SD cards Default Speed, High Speed, SDR 12/25/50/104, and DDR 50.

SD UHS-I Card Compliance Test Application — At A Glance

The Keysight U7246A/U7246B SD UHS-I Card Compliance Test Application is a test solution that covers bus output timing analysis, threshold level tests and current consumption tests of the SD (Secure Digital) specifications, specifically version 3.0. The software helps you test SD device under test compliance with the Keysight 9000 or 90000A Series Infiniium Digital Storage Oscilloscope.

There are two main categories of test modes:

- SD Card Tests - These tests are based on the SD compliance specification and are compared to corresponding compliance test limits.
- Work Place Holder - Allows control of the SD Compliance test board.

The SD UHS-I Card Compliance Test Application:

- Lets you select individual or multiple tests to run.
- Lets you identify the device being tested and its configuration.
- Shows you how to make oscilloscope connections to the device under test.
- Automatically checks for proper oscilloscope configuration.
- Automatically sets up the oscilloscope for each test.
- Allows you to determine the number of trials for each test, with the new multi trial run capability.
- Provides detailed information of each test that has been run. The result of maximum twenty five worst trials can be displayed at any one time.
- Creates a printable HTML report of the tests that have been run.

The minimum number of probes required for the tests are:

- Bus Output Timing Tests - 2x InfiniiMax probes
- Current Consumption Tests - 1x InfiniiMax probe and 1x current probe

Required Equipment and Software

In order to run the SD UHS-I automated tests, you need the following equipment and software:

- 9000 or 90000A Series Infiniium Digital Storage Oscilloscope. Keysight recommends using 2.5 GHz or higher bandwidth oscilloscope.
- The minimum version of the Infiniium Oscilloscope Software (see the U7246A/U7246B SD Card UHS-I Compliance Test Application release notes).
- U7246A/U7246B SD UHS-I Card Compliance Test Application.
- Two 1169A, 1168A, 1134A, 1132A, or 1131A InfiniiMax probe amplifiers
- Two E2678A differential socketed probe head
- One N278xA current probe with N2779A power supply and E2697A high impedance adapter
- One SD Compliance test board:

SD compliance test board TD-BD-SDCMPT

Note: Available from Tokyo Electron Device - Japan only

or

SD UHS-I compliance test fixture kit BIT-SD-TFK-0001

Note: Available from BitifEye Digital Test Solutions

http://www.bitifeye.com/cms/front_content.php?idart=205

- Keyboard, qty = 1, (provided with the Keysight Infiniium oscilloscope).
- Mouse, qty = 1, (provided with the Keysight Infiniium oscilloscope).

Below are the required licenses:

- U7246A/U7246B SD UHS-I Card Compliance Test Application license.
- E2688A Serial Data Analysis and Clock Recovery software license.

In This Book

This manual describes the tests that are performed by the SD UHS-I Card Compliance Test Application in more detail.

NOTE Refer to the “SD Specifications Part 1 Physical Layer Specification Version 3.01”, which can be found at https://www.sdcard.org/ for the values assigned to various parameters in the tests described in Chapter 3, “SD UHS-I Compliance Test Procedures”.

Contact Keysight

For more information on SD UHS-I Card Compliance Test Application or other Keysight Technologies' products, applications and services, please contact your local Keysight office. The complete list is available at:

www.keysight.com/find/contactus

Phone or Fax

United States:
(tel) 800 829 4444
(fax) 800 829 4433

Canada:
(tel) 877 894 4414
(fax) 800 746 4866

China:
(tel) 800 810 0189
(fax) 800 820 2816

Europe:
(tel) 31 20 547 2111

Japan:
(tel) (81) 426 56 7832
(fax) (81) 426 56 7840

Korea:
(tel) (080) 769 0800
(fax) (080) 769 0900

Latin America:
(tel) (305) 269 7500

Taiwan:
(tel) 0800 047 866
(fax) 0800 286 331

Other Asia Pacific Countries:
(tel) (65) 6375 8100
(fax) (65) 6755 0042
E-mail: tm_ap@keysight.com

Contents

1 Installing the SD UHS-I Compliance Test Application

Installing the Software

1. Make sure you have the minimum version of Infiniium Oscilloscope Software (see the U7246A/U7246B SD Card UHS-I Compliance Test Application release notes).
2. To obtain the SD UHS-I Compliance Test Application, go to Keysight website: http://www.keysight.com/find/scope-apps-sw/.
3. The link for SD UHS-I Compliance Test Application will appear. Double-click the link and follow the instructions to download and install the application software.

Installing the License Key

1. Request a license code from Keysight by following the instructions on the Entitlement Certificate.
   You will need the oscilloscope's "Option ID Number", which you can find in the **Help>About Infiniium...** dialog box.
2. After you receive your license code from Keysight, choose **Utilities>Install Option License....**
3. In the Install Option License dialog, enter your license code and click **Install License**.
4. Click **OK** in the dialog that tells you to restart the Infiniium oscilloscope application software to complete the license installation.
5. Click **Close** to close the Install Option License dialog.
6. Choose **File>Exit**.
7. Restart the Infiniium oscilloscope application software to complete the license installation.

2 Preparing to Take Measurements

Before running the SD UHS-I automated tests, you should calibrate the oscilloscope and probe. After the oscilloscope and probe have been calibrated, you are ready to start the SD UHS-I Compliance Test Application and perform the measurements.

Calibrating the Oscilloscope

If you haven't already calibrated the oscilloscope and probe, see Chapter 4, "Calibrating the Infiniium Oscilloscope and Probe".

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

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

Starting the SD UHS-I Compliance Test Application

1 The SD Compliance Test board is required for SD card testing. The test board provides the SD card with a power supply, clock, and command/data transition. The test tool software must be installed on the Keysight Infiniium oscilloscope. Connect USB A-B cable to the Keysight Infiniium oscilloscope to be used in the automated test.

2 To start the SD UHS-I Compliance Test Application, from the Infiniium Oscilloscope's main menu, choose **Analyze>Automated Test Apps>U7246A/U7246B SD Card UHS-I Test App**.

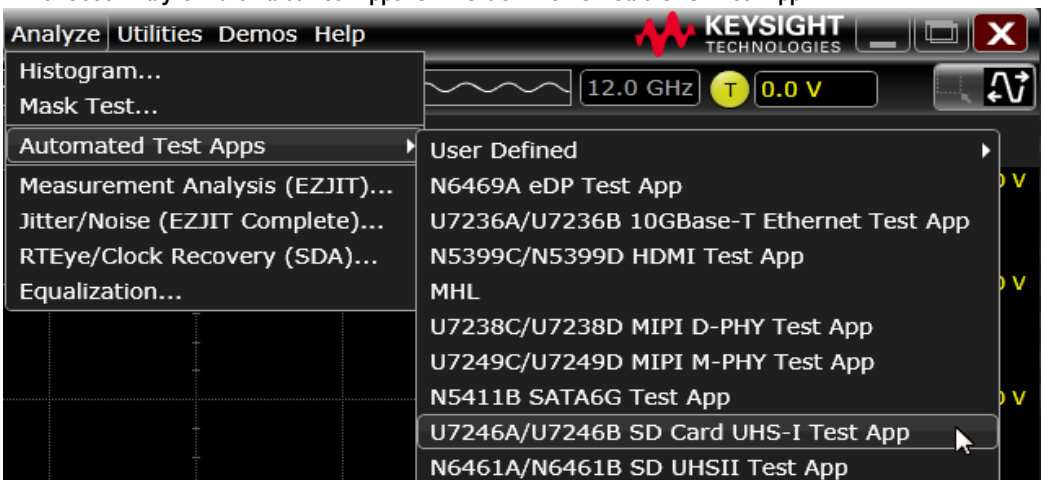

Figure 1 Starting the SD UHS-I Compliance Test Application

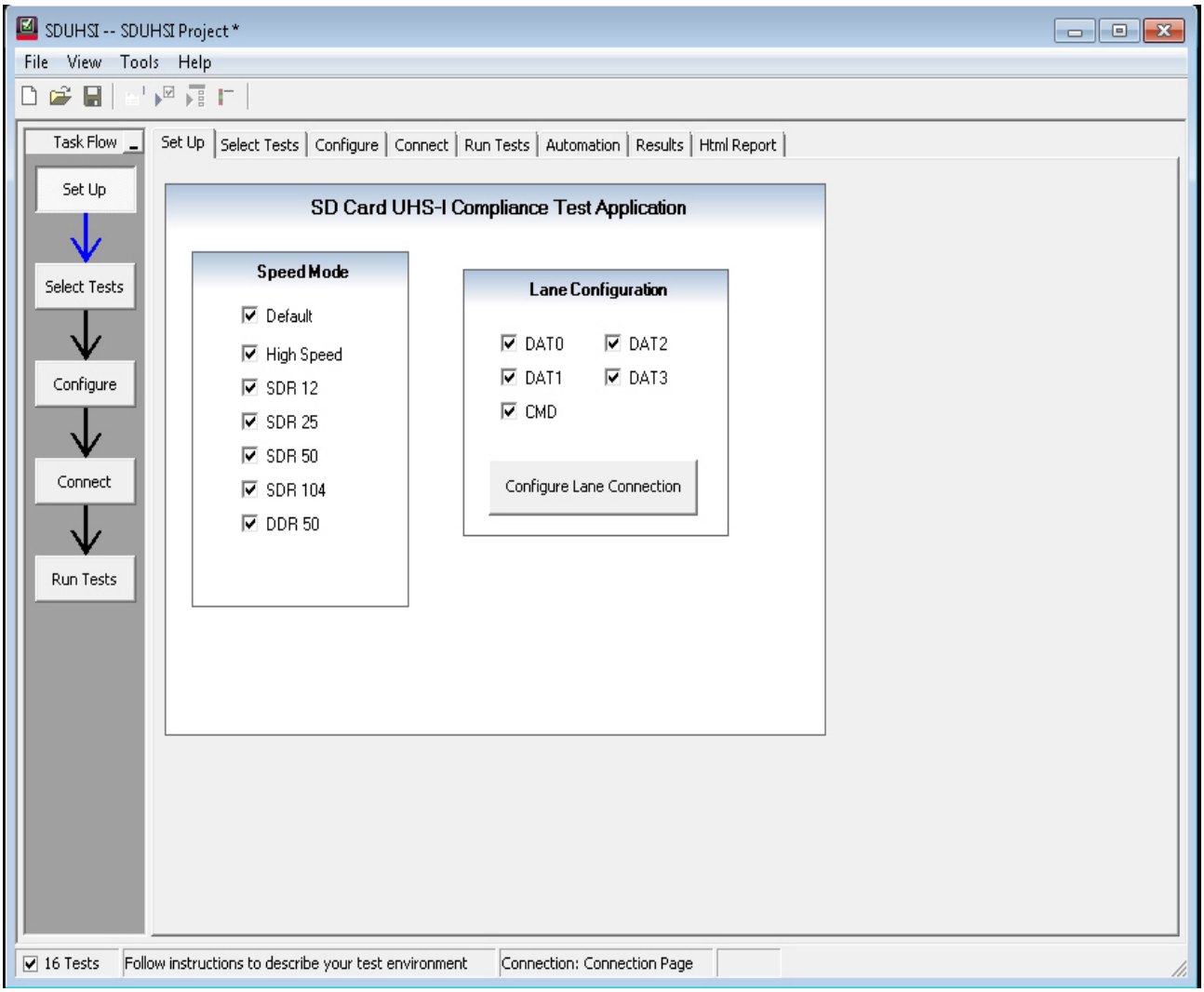

Figure 2 The SD UHS-I Compliance Test Application's Default Window

Figure 2 shows the SD UHS-I Compliance Test Application main window. The task flow pane, and the tabs in the main pane, show the steps you take in running the automated tests:

Tab	Description
Set Up	Lets you identify and set up the test environment.
Select Tests	Lets you select the tests you want to run. The tests are organized hierarchically so you can select all tests in a group. After tests are run, status indicators show which tests have passed, failed, or not been run, and there are indicators for the test groups.
Configure	Lets you configure test parameters (i.e., channels used in the test, voltage levels).
Connect	Shows you how to connect the oscilloscope to the device-under-test for the tests to be run.

Tab	Description
Run Tests	Starts the automated tests. If the connections to the device-under-test need to be changed while multiple tests are running, the tests pause, show you how to change the connection, and wait for you to confirm that the connections have been changed before continuing.
Automation	Lets you construct scripts of commands that drive execution of the application.
Results	Contains more detailed information about the tests that have been run. You can change the thresholds at which marginal or critical warnings appear.
HTML Report	Shows a compliance test report that can be printed.

3 SD UHS-I Compliance Test Procedures

SD UHS-I Compliance Test Item Coverage

The Keysight SD UHS-I Compliance Test Application covers the SD specification Part 1 of the Physical Test Specification for Card Version 3.00.

6-1-1 Threshold Levels

- Output High Voltage, V_{OH} – **Default**
- Output Low Voltage, V_{OL} – **Default**
- Output High Voltage, V_{OH} – **High Speed**
- Output Low Voltage, V_{OL} – **High Speed**

6-1-4 Current Consumption

- Current Consumption Write – **Default**
- Current Consumption Read – **Default**
- Current Consumption Write – **High Speed**
- Current Consumption Read – **High Speed**

6-1-6 Bus Timing

Reduced Connection Mode: Bus Output Timing **DAT0**/**DAT1**/**DAT2**/**DAT3** and **CMD**

- $t_{ODLAY\ MAX}$ – **Default**
- $t_{ODLAY\ MIN}$ – **Default**
- t_{ODLAY} – **High Speed**
- t_{OH} – **High Speed**

6-2-1 Threshold Levels

- Output High Voltage, V_{OH} – **SDR 12**
- Output Low Voltage, V_{OL} – **SDR 12**
- Output High Voltage, V_{OH} – **SDR 25**
- Output Low Voltage, V_{OL} – **SDR 25**
- Output High Voltage, V_{OH} – **SDR 50**
- Output Low Voltage, V_{OL} – **SDR 50**
- Output High Voltage, V_{OH} – **SDR 104**
- Output Low Voltage, V_{OL} – **SDR 104**
- Output High Voltage, V_{OH} – **DDR 50**
- Output Low Voltage, V_{OL} – **DDR 50**

6-2-5 Current Consumption

- Current Consumption Write – **SDR 12**
- Current Consumption Read – **SDR 12**
- Current Consumption Write – **SDR 25**
- Current Consumption Read – **SDR 25**
- Current Consumption Write – **SDR 50**
- Current Consumption Read – **SDR 50**
- Current Consumption Write – **SDR 104**
- Current Consumption Read – **SDR 104**
- Current Consumption Write – **DDR 50**

- Current Consumption Read – **DDR 50**

6-2-8 Output Drivers

Precision Measurement Mode: Bus Output Timing for **DAT0**/**DAT1**/**DAT2**/**DAT3** and **CMD**

- Rise Time – **SDR50**
- Fall Time – **SDR50**
- Rise/Fall Time Mismatch – **SDR50**
- Rise Time – **SDR104**
- Fall Time – **SDR104**
- Rise/Fall Time Mismatch – **SDR104**

6-2-11 CMD/DAT Output Fixed Timing For SDR

- t_{ODLAY} – **SDR12**
- t_{OH} – **SDR12**
- t_{ODLAY} – **SDR25**
- t_{OH} – **SDR25**
- t_{ODLAY} – **SDR50**
- t_{OH} – **SDR50**

6-2-12 CMD/DAT Output Variable Timing for SDR

- t_{OP} – **SDR104**
- t_{ODW} – **SDR104**

6-2-14 CMD/DAT Input and Output Timing for DDR

- $t_{ODLAY2X\ MAX}$ – **DDR50**
- $t_{ODLAY2X\ MIN}$ – **DDR50**

Threshold Levels Tests

- Output High Voltage, V_{OH} – **Default**
- Output Low Voltage, V_{OL} – **Default**
- Output High Voltage, V_{OH} – **High Speed**
- Output Low Voltage, V_{OL} – **High Speed**
- Output High Voltage, V_{OH} – **SDR12**
- Output Low Voltage, V_{OL} – **SDR12**
- Output High Voltage, V_{OH} – **SDR25**
- Output Low Voltage, V_{OL} – **SDR25**
- Output High Voltage, V_{OH} – **SDR50**
- Output Low Voltage, V_{OL} – **SDR50**
- Output High Voltage, V_{OH} – **SDR104**
- Output Low Voltage, V_{OL} – **SDR104**
- Output High Voltage, V_{OH} – **DDR50**
- Output Low Voltage, V_{OL} – **DDR50**

Test Procedure

Output High Voltage, V_{OH}

1. Set V_{DD} to 2.7 V and according to the test you select, set the appropriate speed mode (**Default**/**High Speed**/**SDR12**/**SDR25**/**SDR50**/**SDR104**/**DDR50**).
2. Trigger on “Random” test pattern during the READ operation.
3. For **DAT0**/**DAT1**/**DAT2**/**DAT3** data line, acquire 10,000 unit intervals (UI) on the waveform to perform measurements.
   For CMD Lane, acquire 1000 UI on the waveform to perform measurements.
4. Generate the Eye patterns from the acquired waveforms.
5. Use the **Histogram** feature on the Infiniium Oscilloscope to measure the Output High Voltage. Record the minimum value as V_{OH}.
6. Report V_{OH} as the resultant value in the final test results.

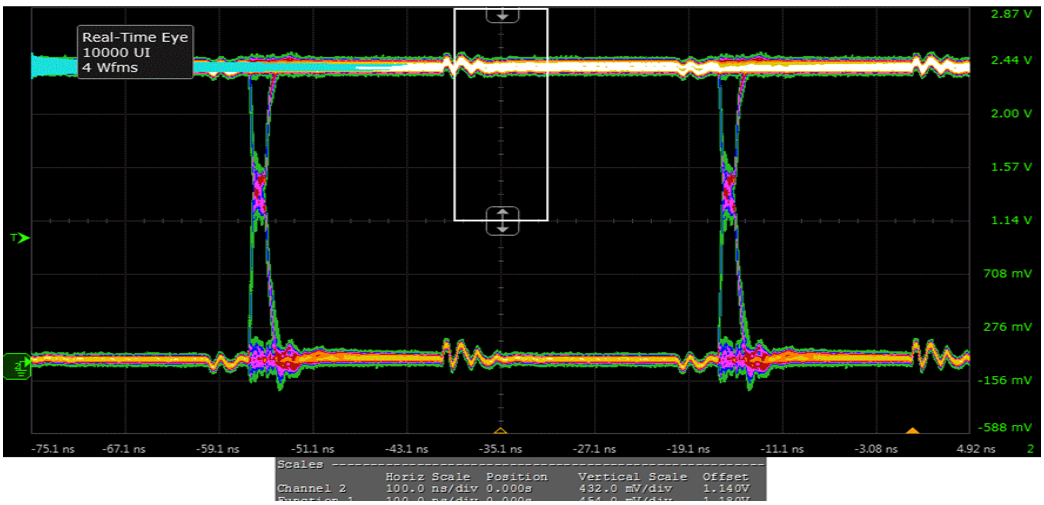

Figure 3 Output High Voltage, V_{OH}

Output Low Voltage, V_{OL}

1. Set V_{DD} to 3.6 V and according to the test you select, set the appropriate speed mode (**Default**/**High Speed**/**SDR12**/**SDR25**/**SDR50**/**SDR104**/**DDR50**).
2. Trigger on “Random” test pattern during the READ operation.
3. For **DAT0**/**DAT1**/**DAT2**/**DAT3** data line, acquire 10,000 unit intervals (UI) on the waveform to perform measurements.
   For **CMD** Lane, acquire 1000 UI on the waveform to perform measurements.
4. Generate the Eye patterns from the acquired waveforms.
5. Use the **Histogram** feature on the Infiniium Oscilloscope to measure the Output Low Voltage. Record the maximum value as V_{OL}.
6. Report V_{OL} as the resultant value in the final test results.

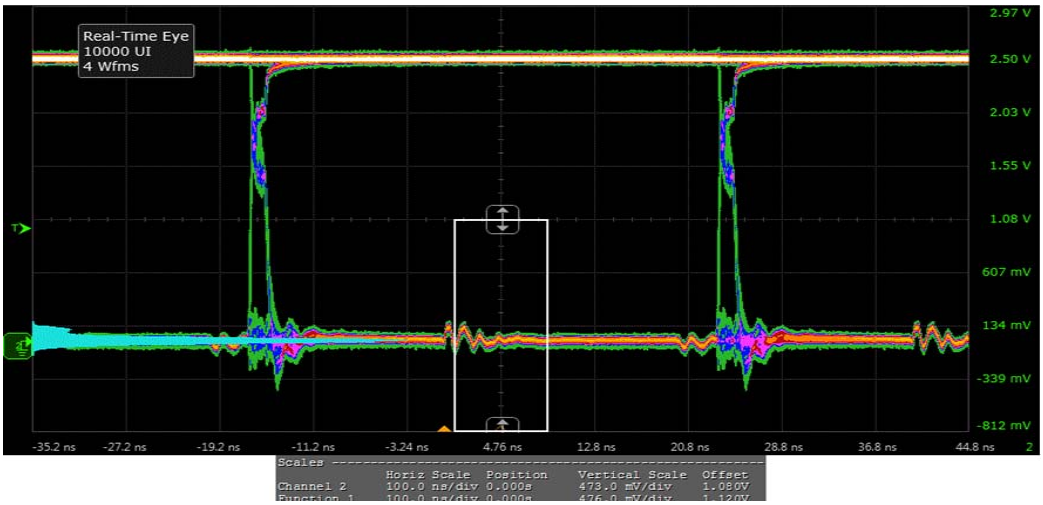

Figure 4 Output Low Voltage, V_{OL}

Current Consumption Tests

- Current Consumption Write – **Default**
- Current Consumption Read – **Default**
- Current Consumption Write – **High Speed**
- Current Consumption Read – **High Speed**
- Current Consumption Write – **SDR12**
- Current Consumption Read – **SDR12**
- Current Consumption Write – **SDR25**
- Current Consumption Read – **SDR25**
- Current Consumption Write – **SDR50**
- Current Consumption Read – **SDR50**
- Current Consumption Write – **SDR104**
- Current Consumption Read – **SDR104**
- Current Consumption Write – **DDR50**
- Current Consumption Read – **DDR50**

Test Procedure

1. Set V_{DD} to 3.6 V and according to the test you select, set the appropriate speed mode (**Default**/**High Speed**/**SDR12**/**SDR25**/**SDR50**/**SDR104**/**DDR50**).
2. Trigger on “Toggle” test pattern during either WRITE or READ operation depending on the test you have selected.
3. Measure V_{dd} pin Current V_{avg} value for the entire 1s waveform.
4. Report V_{avg}/N (mA) and check against the specification value for Pass/Fail (where N is the number of loop coils used with the current probe).

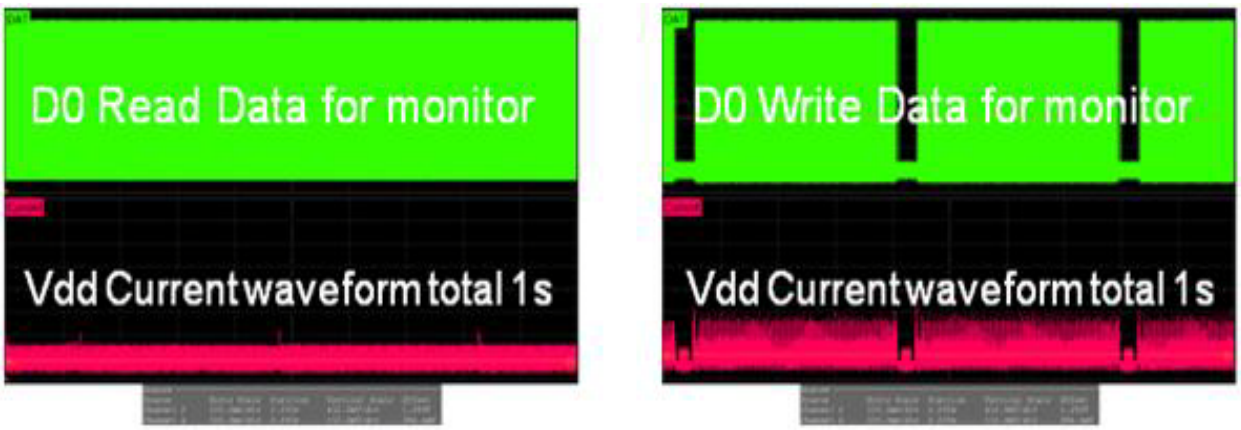

Figure 5 Current Consumption Read and Current Consumption Write

Output Drivers Tests

Precision Measurement Mode: Bus Output Timing for **DAT0**/**DAT1**/**DAT2**/**DAT3** and **CMD**

- Rise Time – **SDR50**
- Fall Time – **SDR50**
- Rise/Fall Time Mismatch – **SDR50**
- Rise Time – **SDR104**
- Fall Time – **SDR104**
- Rise/Fall Time Mismatch – **SDR104**

Test Procedure

1. Set V_{DD} to 2.7 V and according to the test you select, set the appropriate speed mode (**SDR50**/**SDR104**).
2. Trigger on “Random” test pattern during the READ operation.
3. For **DAT0**/**DAT1**/**DAT2**/**DAT3** data line, acquire 1000 unit intervals (UI) on the waveform to perform measurements.
   For **CMD** Lane, acquire 100 UI on the waveform to perform measurements.
4. Measure the Output Rise Time between $V_{OL\ max}$ (0.45 V) and $V_{OH\ min}$ (1.4 V) through the entire acquired waveform.
5. Measure the Output Fall Time between $V_{OH\ min}$ (1.4 V) and $V_{OL\ max}$ (0.45 V) through the entire acquired waveform.
6. Report Rise Time, Fall Time and the ratio of Rise/Fall Time value for Pass/Fail.

Bus Timing Tests (Default)

Reduced Connection Mode: Bus Output Timing **DAT0**/**DAT1**/**DAT2**/**DAT3** and **CMD**

- $t_{ODLAY\ MAX}$ – **Default**
- $t_{ODLAY\ MIN}$ – **Default**

Test Procedure

Output Delay Time, $t_{ODLAY\ MAX}$

1 Set V_{DD} to 2.7 V and the speed mode to **Default**.
2 Trigger on "Random" test pattern during the READ operation.
3 Acquire 10,000 unit intervals (UI) on the waveform to perform measurements.
4 Generate Eye patterns from the acquired waveform.
5 Each reference amplitude is as follows:
$V_{IL(max)} = 0.25 \times V_{DD} = 0.675$ V
$V_{IH(min)} = 0.625 \times V_{DD} = 1.6875$ V
$V_{OL(max)} = 0.125 \times V_{DD} = 0.3375$ V
$V_{OH(min)} = 0.75 \times V_{DD} = 2.025$ V

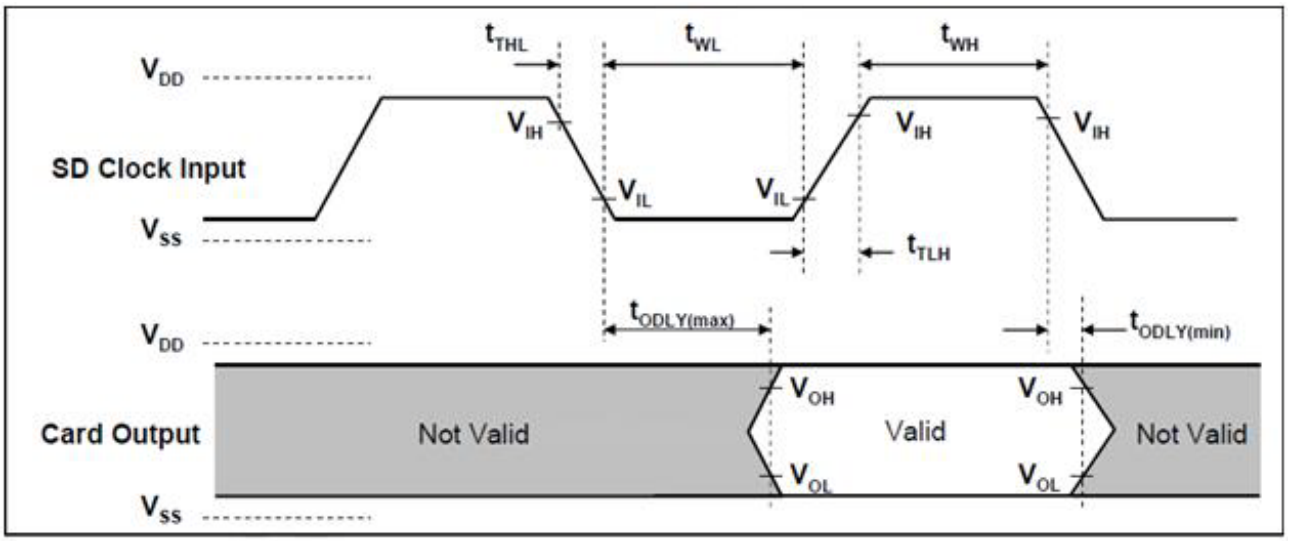

Figure 6 Card output timing (Speed mode - Default)

6 Use the **Histogram** feature on the Infiniium Oscilloscope to measure the value for $t_{VIL\ MAX}$. Place the Histogram window at $V_{IL\ (max)}$ and $V_{IH\ (min)}$ on the CLK falling edge waveform. Record the maximum value as $t_{VIL\ MAX}$ (CLK Falling Edge).

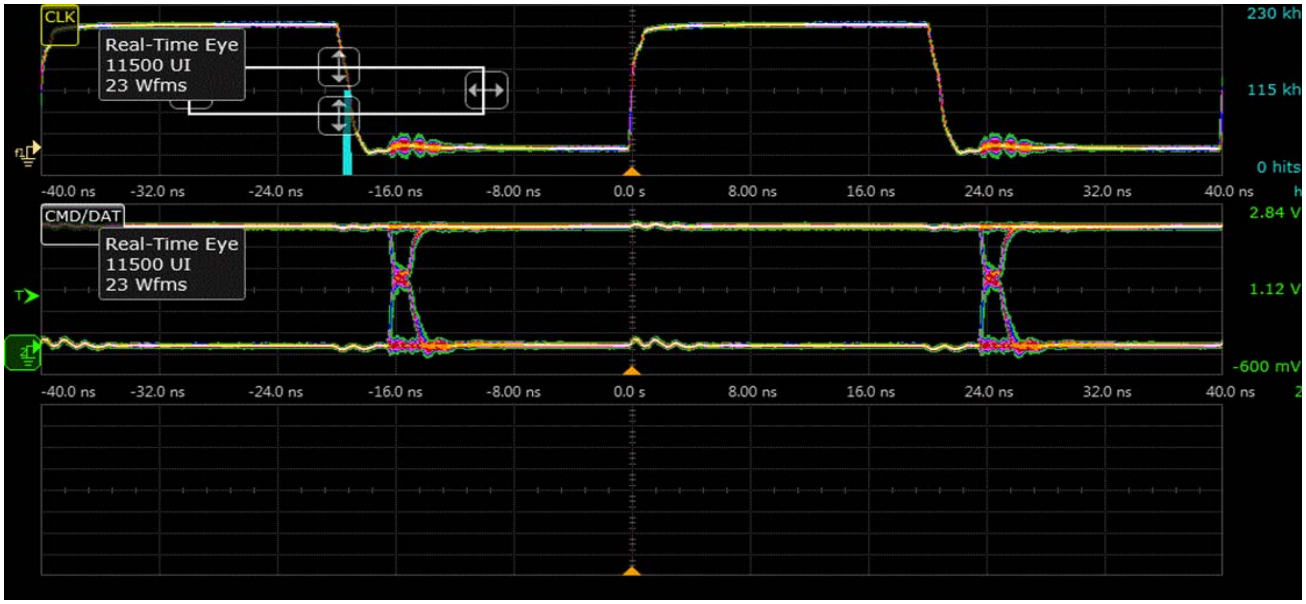

Figure 7 tVIL MAX (CLK Falling Edge)

7 Place the Histogram window at $V_{OL(max)}$ and $V_{OH(min)}$ on Data/CMD waveform to determine the worst Eye opening position (right edge of the Histogram). Record the maximum value as $t_{VO\ Max}$ (Eye Diagram Edges).

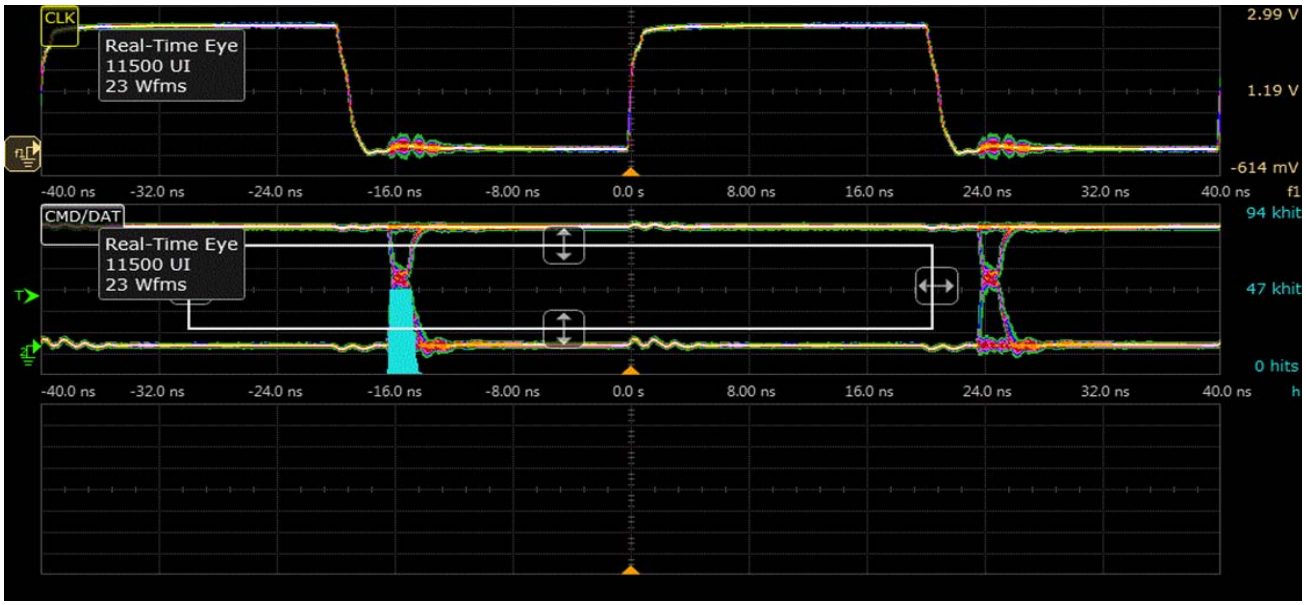

Figure 8 $t_{VO\ Max}$ (Eye Diagram Edges)

8 Measure delta time of $t_{VIL\ MAX}$ (CLK Falling edge) to $t_{VO\ MAX}$ (Eye Diagram Edges). Record the resultant value as $t_{ODLAY\ MAX}$.

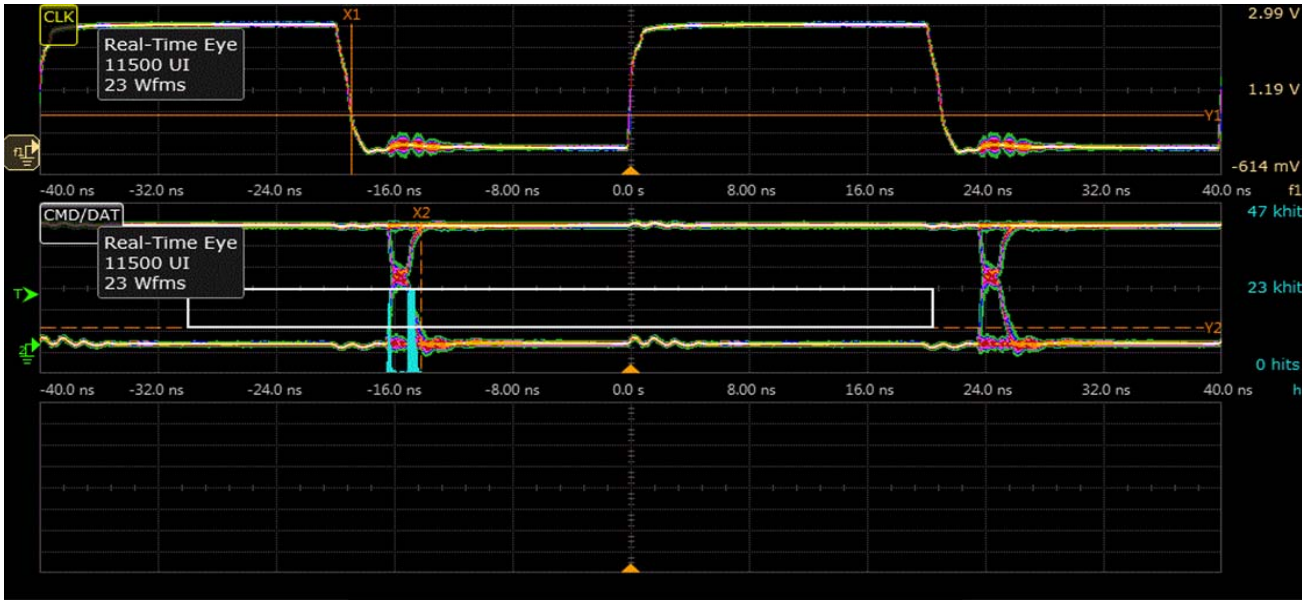

Figure 9 $t_{ODLAY\ MAX}$

9 Report the resultant value of $t_{ODLAY\ MAX}$ as the final test result.

Output Delay Time, $t_{ODLAY\ MIN}$

1 Set V_{DD} to 2.7 V and the speed mode to **Default**.

2 Trigger on “Random” test pattern during the READ operation.

3 Acquire 10,000 unit intervals (UI) on the waveform to perform measurements.

4 Generate Eye patterns from the acquired waveform.

5 Each reference amplitude is as follows:
$V_{IL(max)} = 0.25 \times V_{DD} = 0.675$ V
$V_{IH(min)} = 0.625 \times V_{DD} = 1.6875$ V
$V_{OL(max)} = 0.125 \times V_{DD} = 0.3375$ V
$V_{OH(min)} = 0.75 \times V_{DD} = 2.025$ V

6 Use the **Histogram** feature on the Infiniium Oscilloscope to measure the value for $t_{VIH\ MIN}$. Place the Histogram window at $V_{IL\ (max)}$ and $V_{IH\ (min)}$ on the CLK falling edge waveform. Record the minimum value as $t_{VIH\ MIN}$ (CLK Falling Edge).

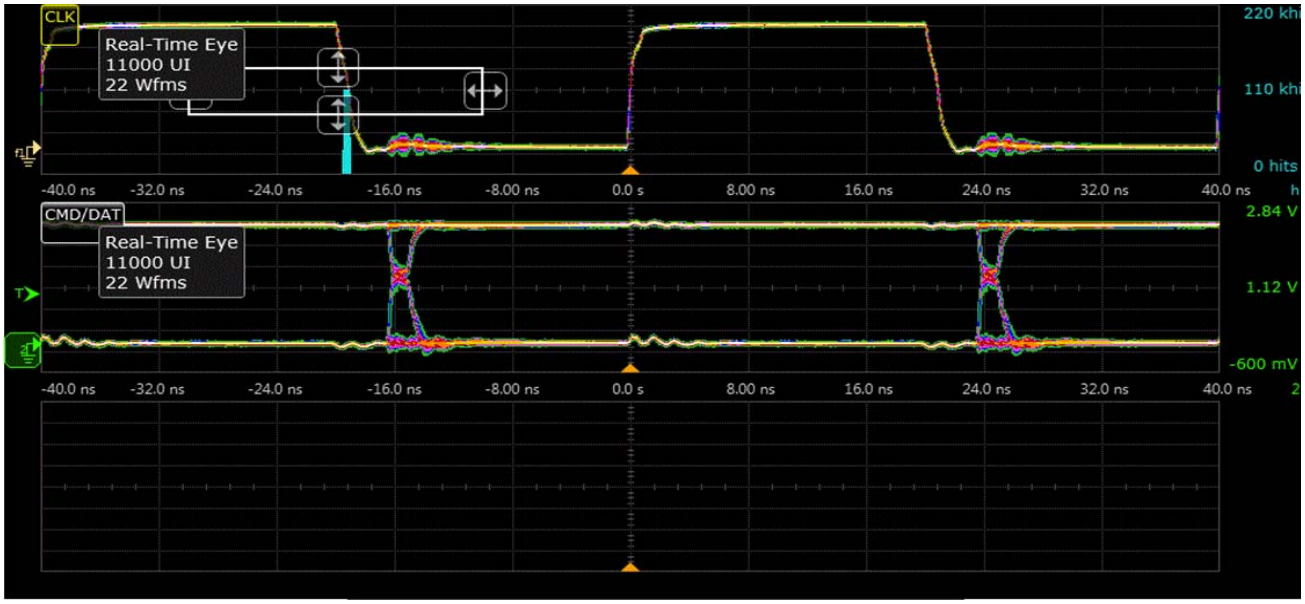

Figure 10 $t_{VIH\ MIN}$ (CLK Falling Edge)

7 Place the Histogram window at $V_{OL(max)}$ and $V_{OH(min)}$ on Data/CMD waveform to determine the worst Eye opening position (left edge of the Histogram). Record the minimum value as $t_{VO\ MIN}$ (Eye Diagram Edges).

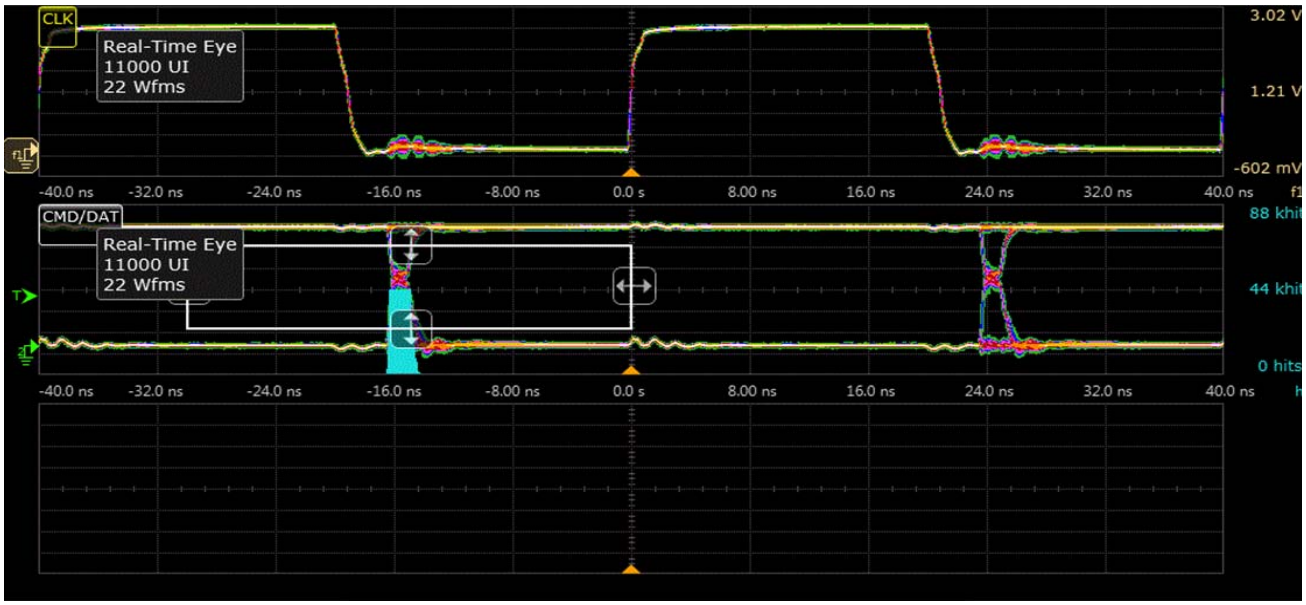

Figure 11 $t_{VO\ MIN}$ (Eye Diagram Edges)

8 Measure delta time of $t_{VIH\ MIN}$ (CLK Falling edge) to $t_{VO\ MIN}$ (Eye Diagram Edges). Record the resultant value as $t_{ODLAY\ MIN}$.

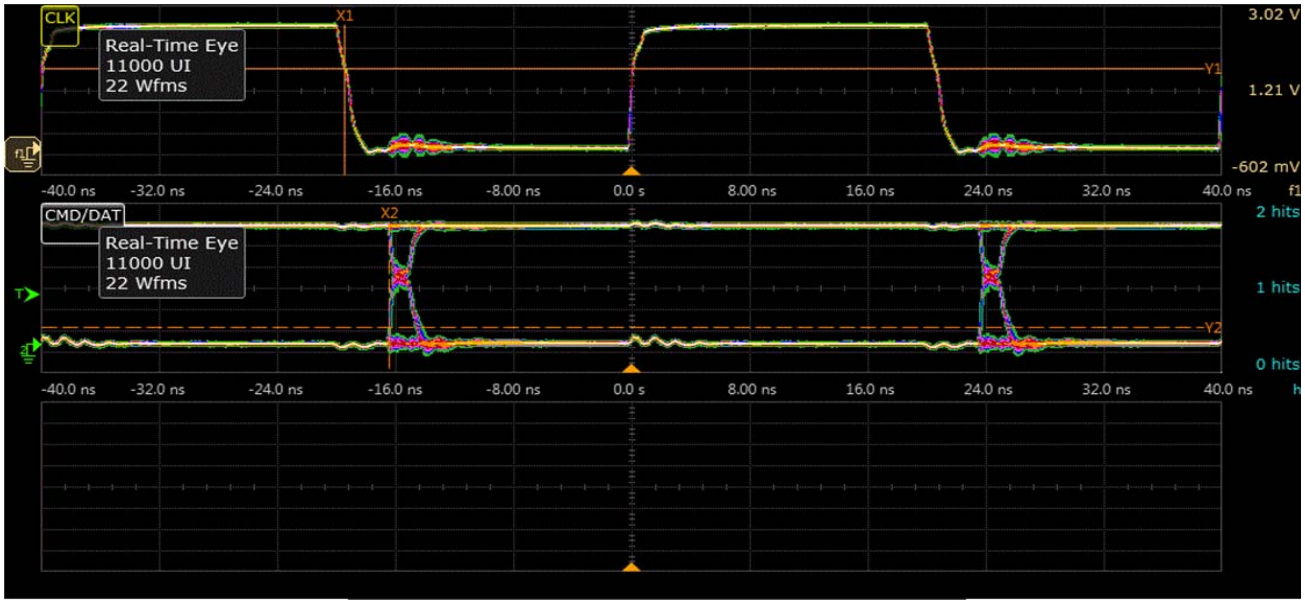

Figure 12 $t_{ODLAY\ MIN}$

9 Report the resultant value of $t_{ODLAY\ MIN}$ as the final test result.

Bus Timing Tests (High-Speed)

Reduced Connection Mode: Bus Output Timing **DAT0**/**DAT1**/**DAT2**/**DAT3** and **CMD**

- t_{ODLAY} – **High Speed**
- t_{OH} – **High Speed**

Test Procedure

Output Delay Time, t_{ODLAY}

1 Set V_{DD} to 2.7 V and the speed mode to **High Speed**.
2 Trigger on "Random" test pattern during the READ operation.
3 Acquire 10,000 unit intervals (UI) on the waveform to perform measurements.
4 Generate Eye patterns from the acquired waveform.
5 Each reference amplitude is as follows:
$50\% V_{DD} = 0.5 \times V_{DD} = 1.35$ V
$V_{OL(max)} = 0.125 \times V_{DD} = 0.3375$ V
$V_{OH(min)} = 0.75 \times V_{DD} = 2.025$ V

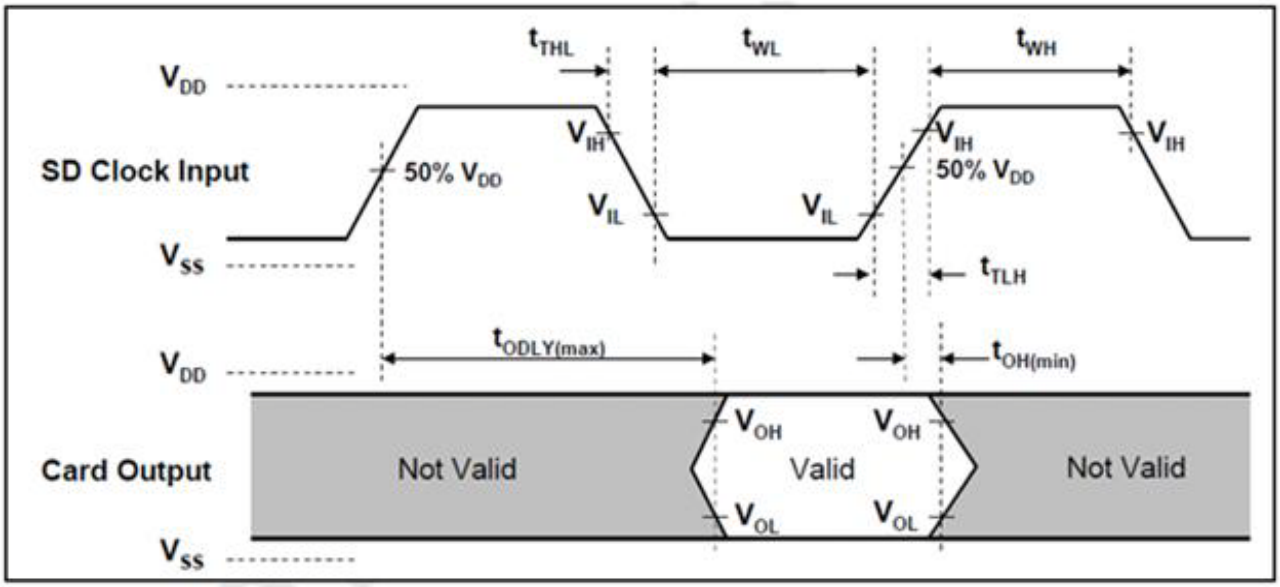

Figure 13 Card Output timing (High Speed mode)

6 Use the **Histogram** feature on the Infiniium Oscilloscope to measure the value for $t_{VDD50\%}$. Place the Histogram window at 50% V_{DD} on the CLK rising edge waveform. Record the mode value as $t_{VDD50\%}$ (CLK Rising Edge).

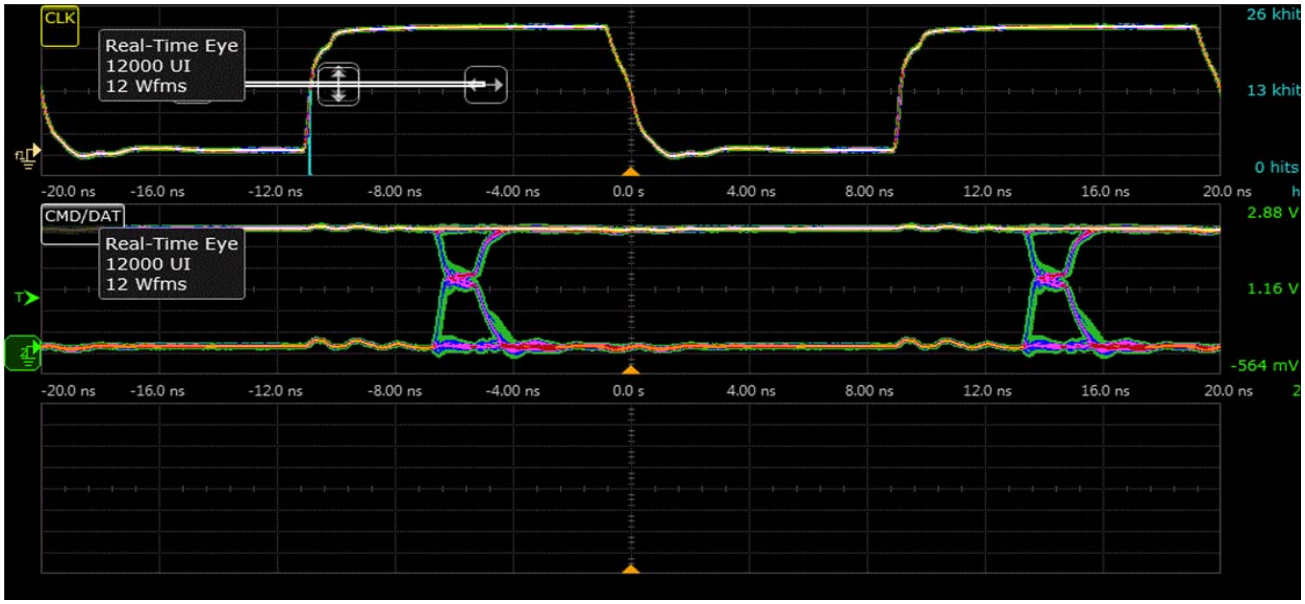

Figure 14 tVDD50% (CLK Rising Edge)

7 Place the Histogram window at $V_{OL(max)}$ and $V_{OH(min)}$ on Data/CMD waveform to determine the worst Eye opening position (right edge of the Histogram). Record the maximum value as t_{VO} (Eye Diagram Edges).

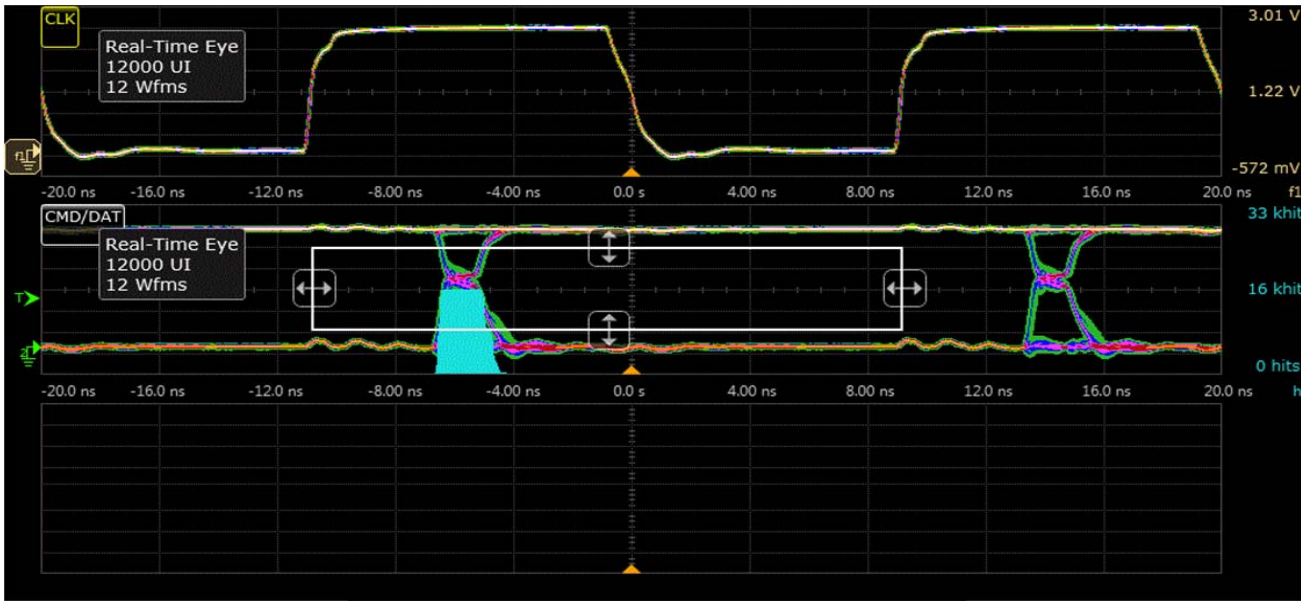

Figure 15 t_{VO} (Eye Diagram Edges)

8 Measure delta time between $t_{VDD50\%}$ (CLK Rising edge) to t_{VO} (Eye Diagram Edges). Record the resultant value as t_{ODLAY}.

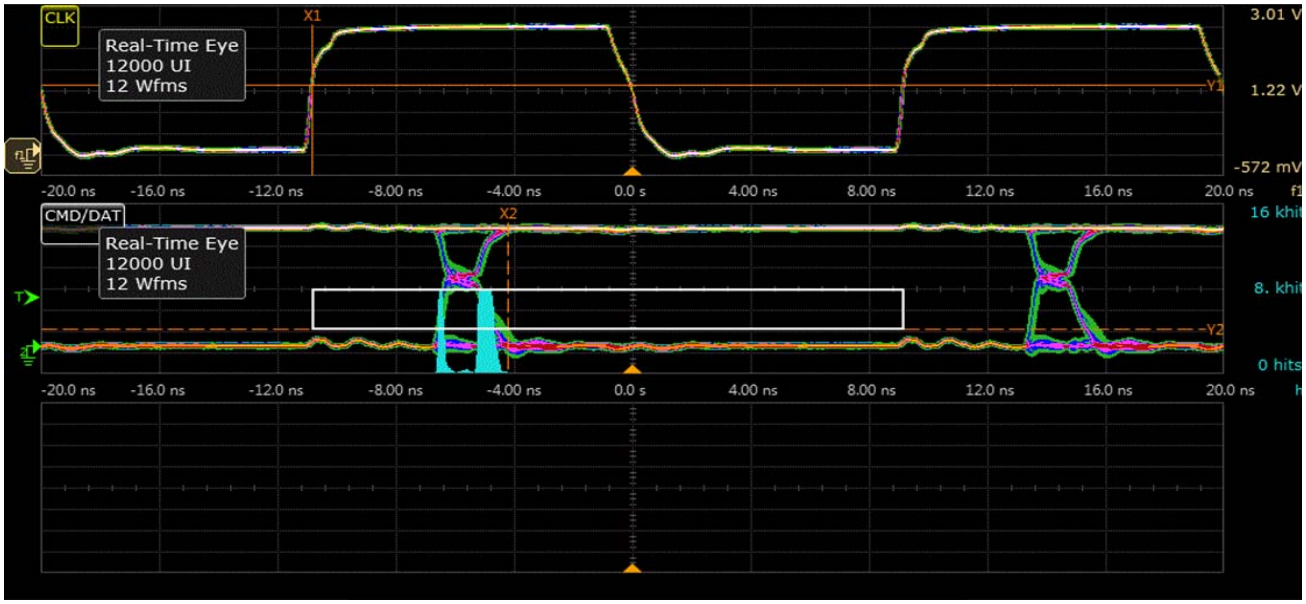

Figure 16 t_{ODLAY}

9 Report the resultant value of t_{ODLAY} as the final test result.

Output Hold Time, t_{OH}

1 Set V_{DD} to 2.7 V and the speed mode to **High Speed**.

2 Trigger on “Random” test pattern during the READ operation.

3 Acquire 10,000 unit intervals (UI) on the waveform to perform measurements.

4 Generate Eye patterns from the acquired waveform.

5 Each reference amplitude is as follows:
50% V_{DD} = 0.5 x V_{DD} = 1.35 V
$V_{OL(max)}$ = 0.125 x V_{DD} = 0.3375 V
$V_{OH(min)}$ = 0.75 x V_{DD} = 2.025 V

6 Use the **Histogram** feature on the Infiniium Oscilloscope to measure the value for $t_{VDD50\%}$. Place the Histogram window at 50% V_{DD} on the CLK rising edge waveform. Record the mode value as $t_{VDD50\%}$ (CLK Rising Edge).

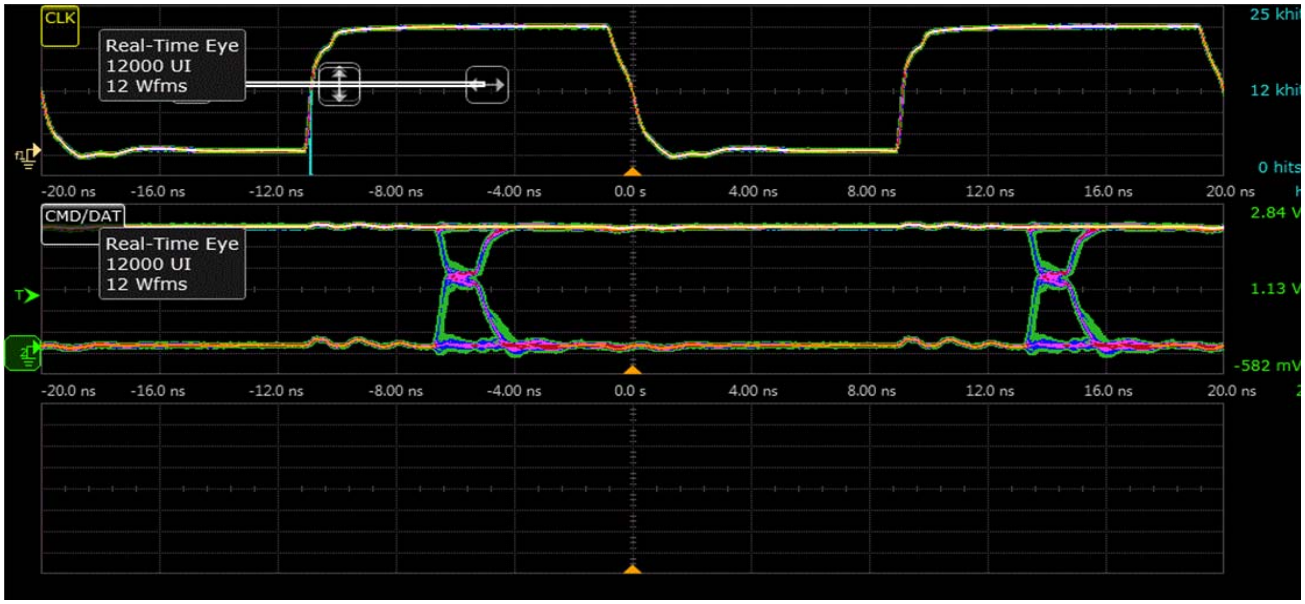

Figure 17 $t_{VDD50\%}$ (CLK Rising Edge)

7 Place the Histogram window at $V_{OL(max)}$ and $V_{OH(min)}$ on Data/CMD waveform to determine the worst Eye opening position (left edge of the Histogram). Record the minimum value as t_{VO} (Eye Diagram Edges).

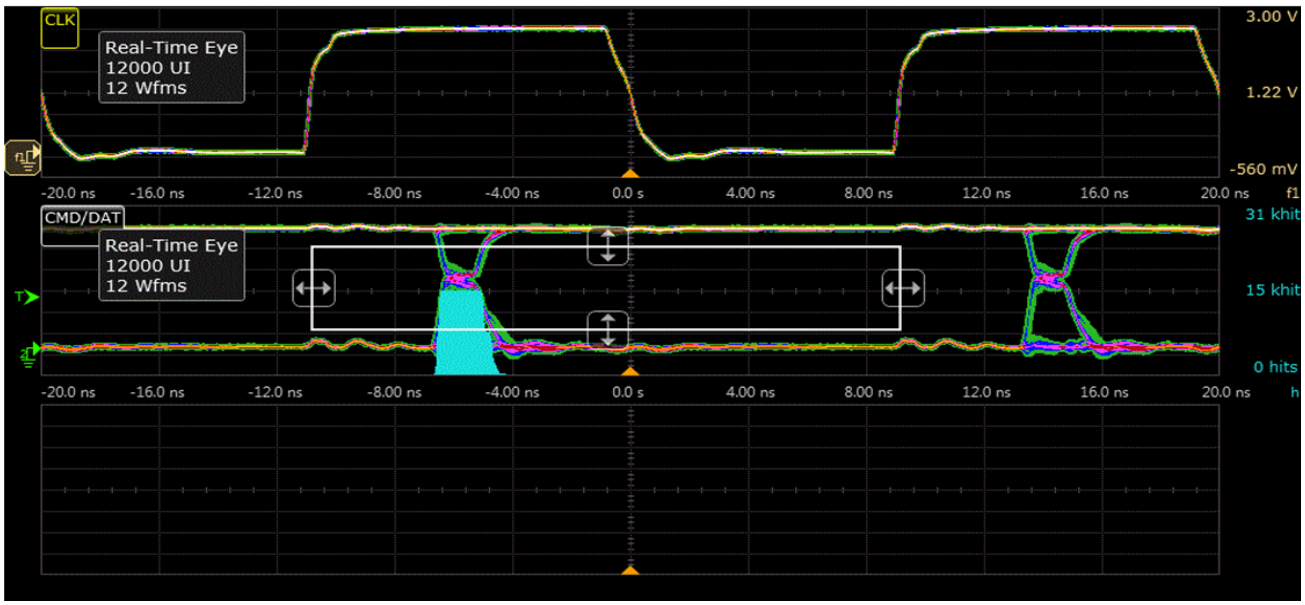

Figure 18 t_{VO} (Eye Diagram Edges)

8 Measure delta time between $t_{VDD50\%}$ (CLK Rising edge) to t_{VO} (Eye Diagram Edges). Record the resultant value as t_{OH}.

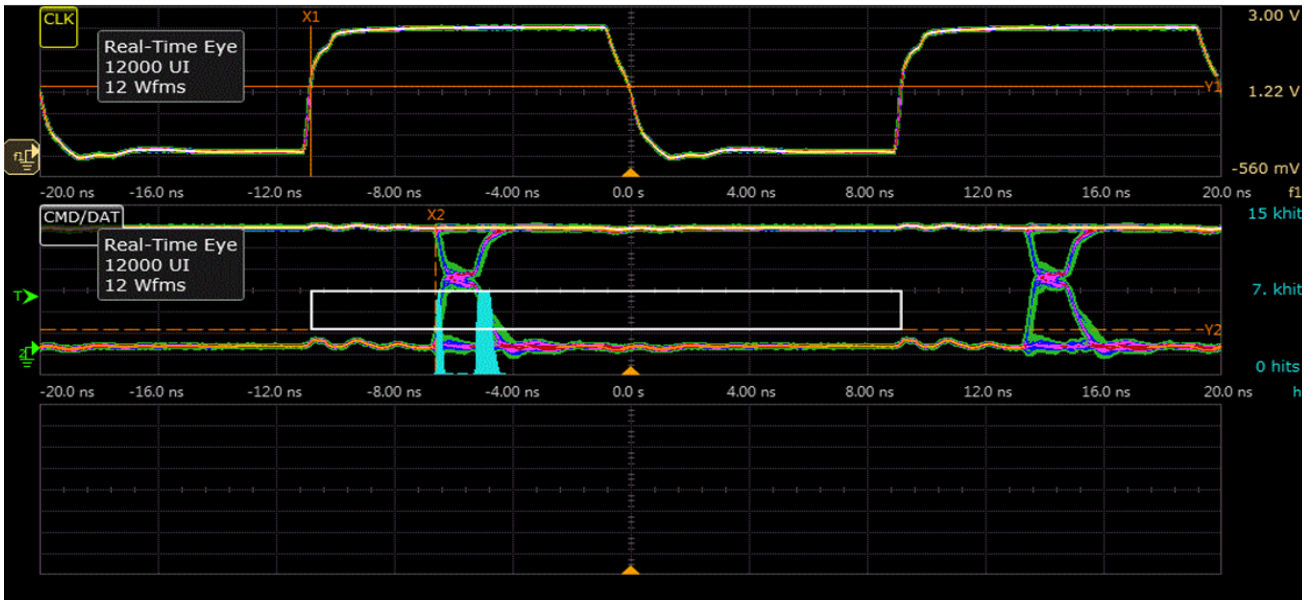

Figure 19 t_{OH}

9 Report the resultant value of t_{OH} as the final test result.

CMD/DAT Output Fixed Timing for SDR Tests

Reduced Connection Mode: Bus Output Timing **DAT0**/**DAT1**/**DAT2**/**DAT3** and **CMD**.

- t_{ODLAY} – **SDR12**
- t_{OH} – **SDR12**
- t_{ODLAY} – **SDR25**
- t_{OH} – **SDR25**
- t_{ODLAY} – **SDR50**
- t_{OH} – **SDR50**

Test Procedure

Output Delay Time, t_{ODLAY}

1. Set V_{DD} to 2.7 V and according to the test you select, set the appropriate speed mode (**SDR12**/**SDR25**/**SDR50**).
2. Trigger on “Random” test pattern during the READ operation.
3. Acquire 10,000 unit intervals (UI) on the waveform to perform measurements.
4. Generate Eye patterns from the acquired waveform.
5. Each reference amplitude is as follows:
   V_{CT} = 0.975 V
   $V_{OL(max)}$ = 0.45 V
   $V_{OH(min)}$ = 1.40 V

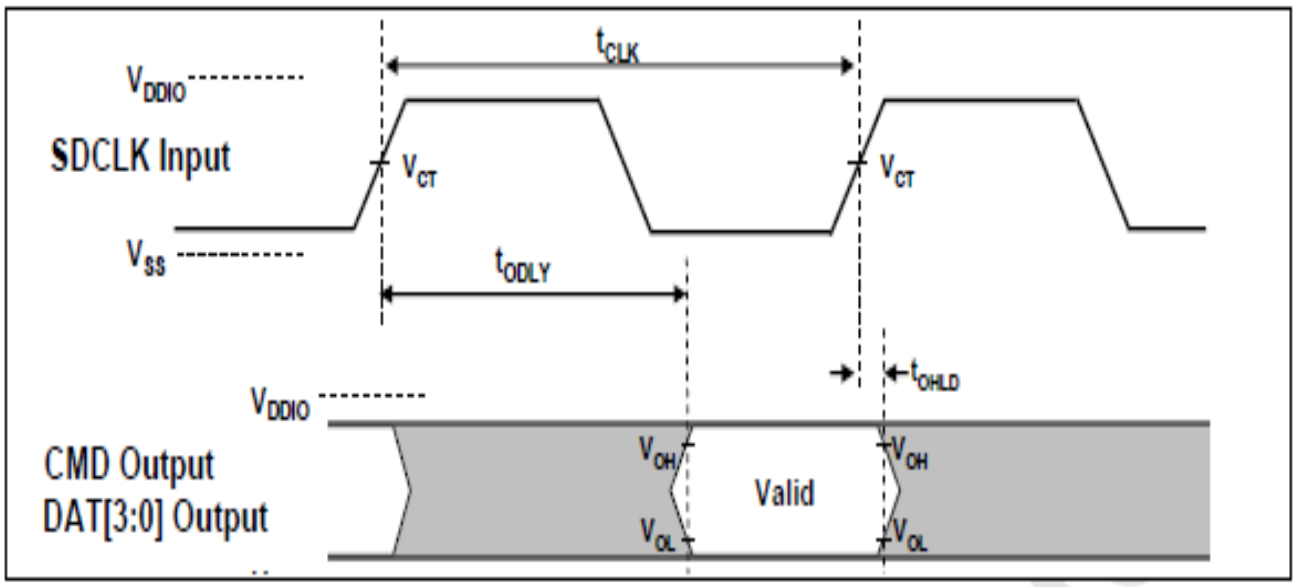

Figure 20 Output Timing of the Fixed Data Window

6. Use the **Histogram** feature on the Infiniium Oscilloscope to measure the value for t_{VCT}. Place the Histogram window at V_{CT} on the CLK rising edge waveform. Record the mode value as t_{VCT} (CLK Rising Edge).

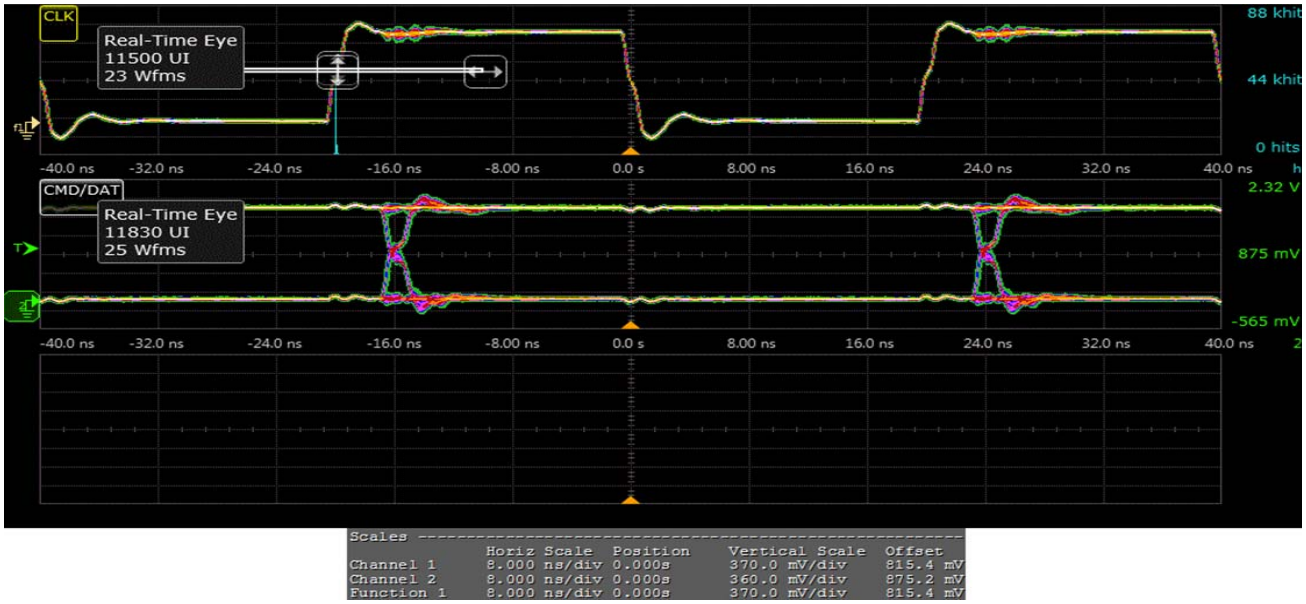

Figure 21 t_{VCT} (CLK Rising Edge)

7 Place the Histogram window at $V_{OL(max)}$ and $V_{OH(min)}$ on Data/CMD waveform to determine the worst Eye opening position (right edge of the Histogram). Record the maximum value as t_{VO} (Eye Diagram Edges).

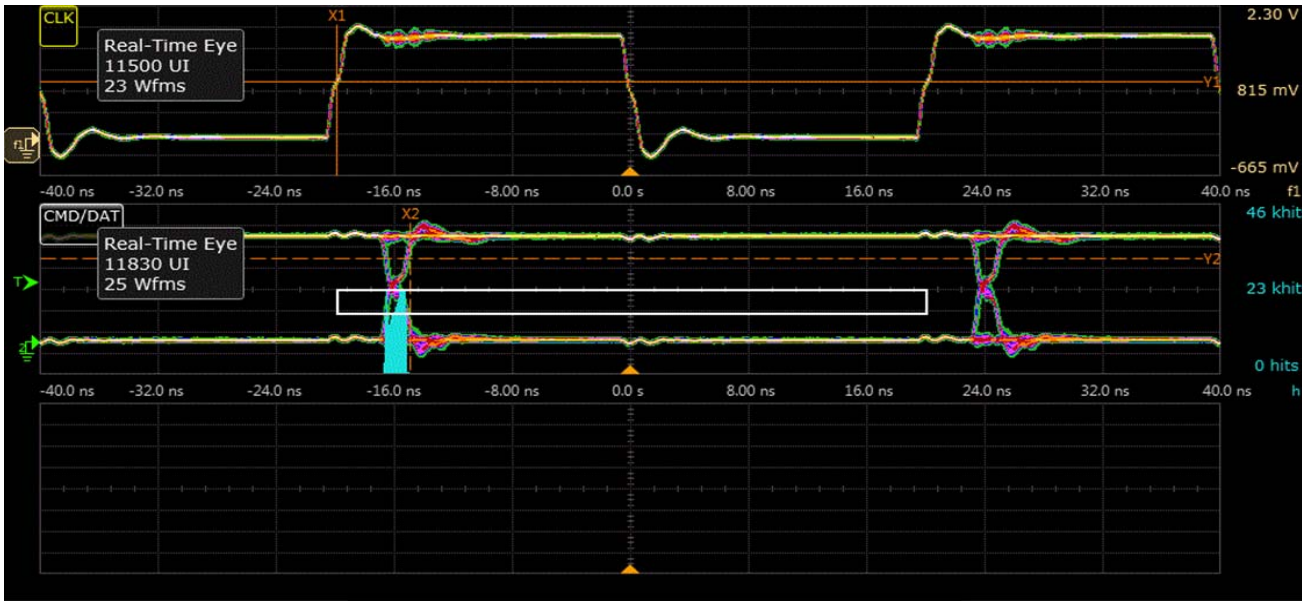

Figure 22 t_{VO} (Eye Diagram Edges)

8 Measure delta time between t_{VCT} (CLK Rising edge) and t_{VO} (Eye Diagram Edges). Record the resultant value as t_{ODLAY}.

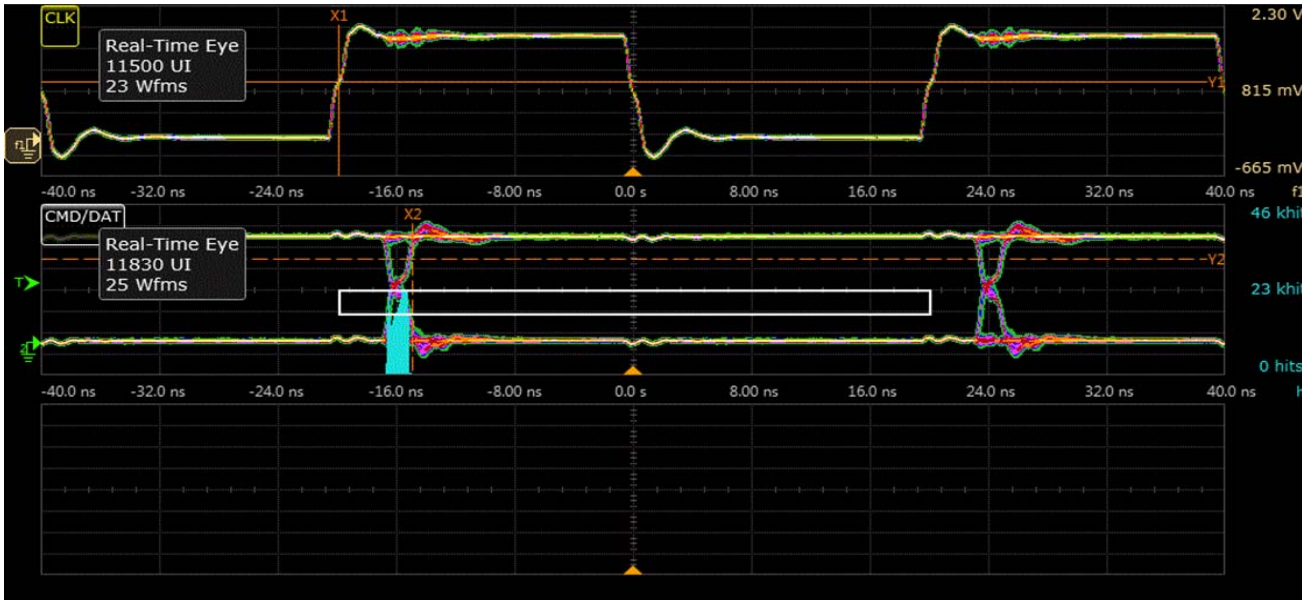

Figure 23 t_{ODLAY}

9 Report the resultant value of t_{ODLAY} as the final test result.

Output Hold Time, t_{OH}

1 Set V_{DD} to 2.7 V and according to the test you select, set the appropriate speed mode (**SDR12**/**SDR25**/**SDR50**).

2 Trigger on “Random” test pattern during the READ operation.

3 Acquire 10,000 unit intervals (UI) on the waveform to perform measurements.

4 Generate Eye patterns from the acquired waveform.

5 Each reference amplitude is as follows:
V_{CT} = 0.975 V
$V_{OL(max)}$ = 0.45 V
$V_{OH(min)}$ = 1.40 V

6 Use the **Histogram** feature on the Infiniium Oscilloscope to measure the value for t_{VCT}. Place the Histogram window at V_{CT} on the CLK rising edge waveform. Record the mode value as t_{VCT} (CLK Rising Edge).

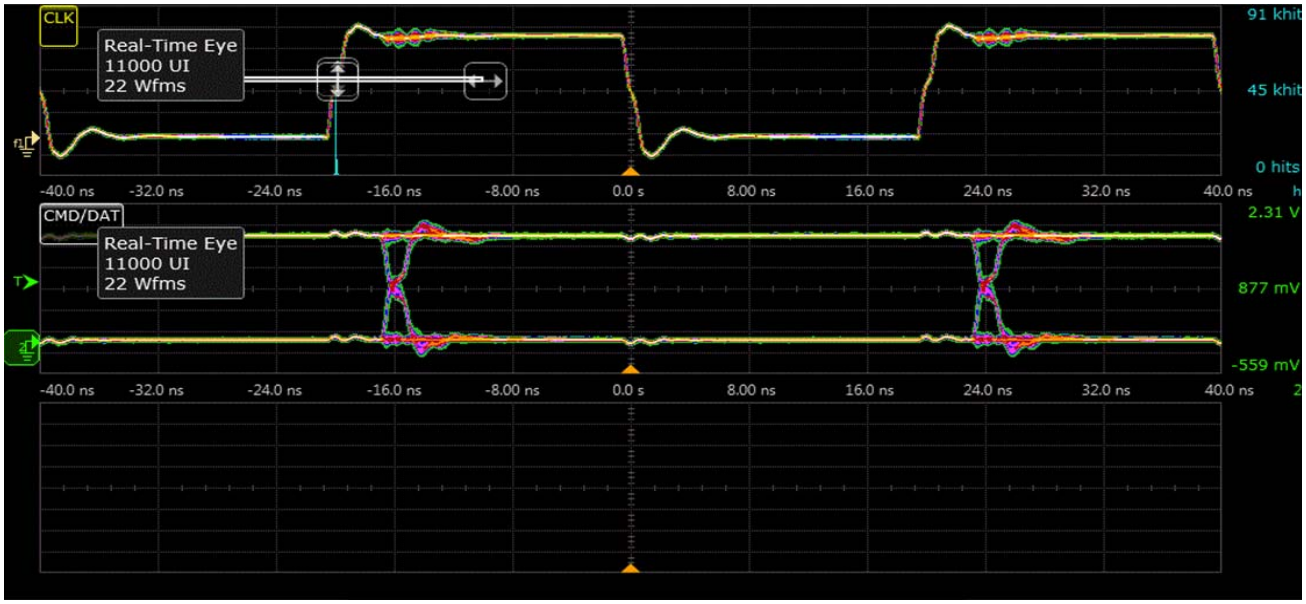

Figure 24 t_{VCT} (CLK Rising Edge)

7 Place the Histogram window at $V_{OL(max)}$ and $V_{OH(min)}$ on Data/CMD waveform to determine the worst Eye opening position (left edge of the Histogram). Record the minimum value as t_{VO} (Eye Diagram Edges).

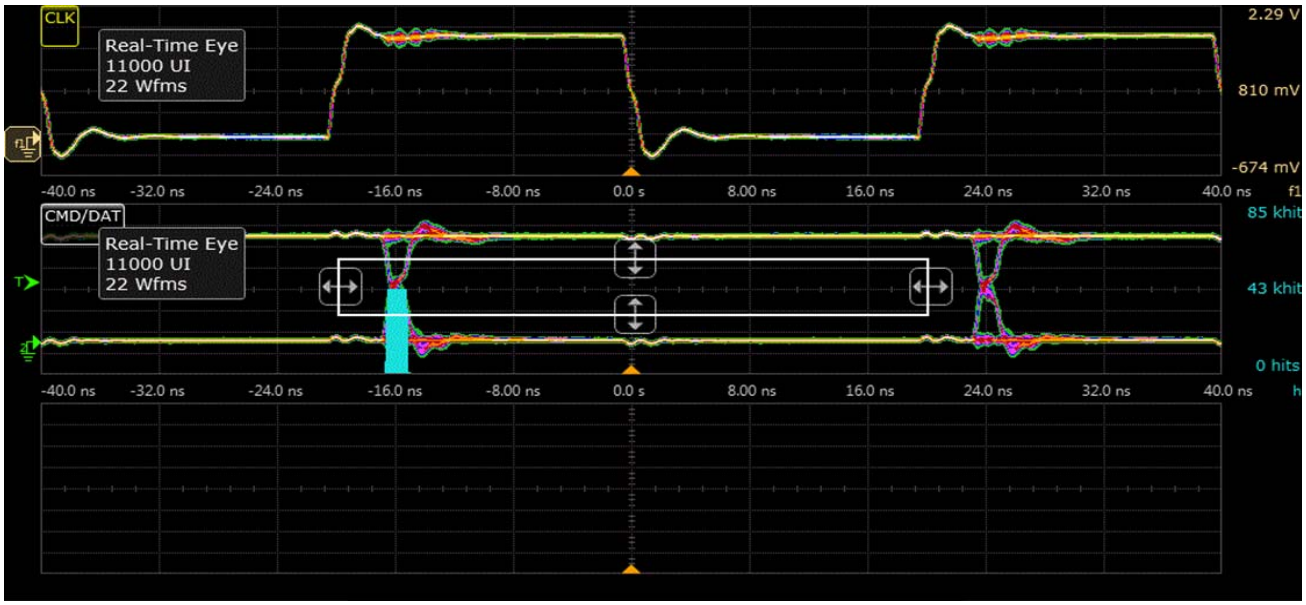

Figure 25 t_{VO} (Eye Diagram Edges)

8 Measure delta time between t_{VCT} (CLK Rising edge) and t_{VO} (Eye Diagram Edges). Record the resultant value as t_{OH}.

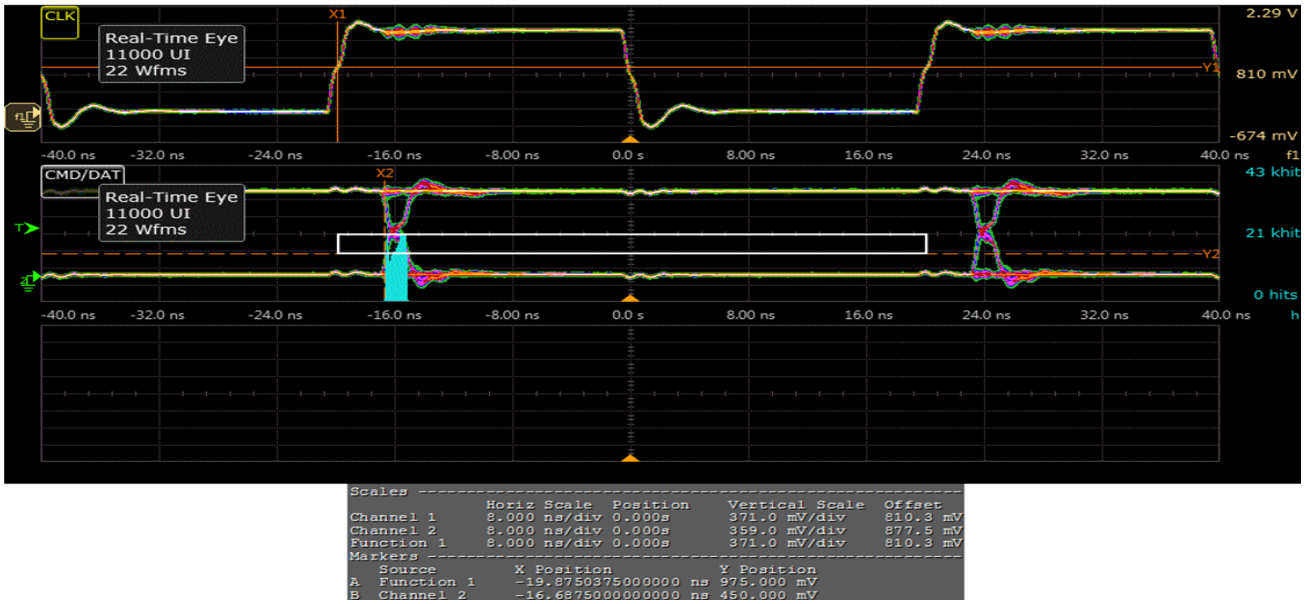

Figure 26 t_{OH}

9 Report the resultant value of t_{OH} as the final test result.

CMD/DAT Output Variable Timing for SDR Tests

- t_{OP} – **SDR104**
- t_{ODW} – **SDR104**

Test Procedure

Output Valid Window Drift, t_{OP}

1 Set V_{DD} to 2.7 V and select the speed mode to **SDR104**.
2 Trigger on “Random” test pattern during the READ operation.
3 Acquire 10,000 unit intervals (UI) on the waveform to perform measurements.
4 Generate Eye patterns from the acquired waveform.
5 Each reference amplitude is as follows:
V_{CT} = 0.975 V
$V_{OL(min)}$ = 0.45 V
$V_{OH(max)}$ = 1.40 V

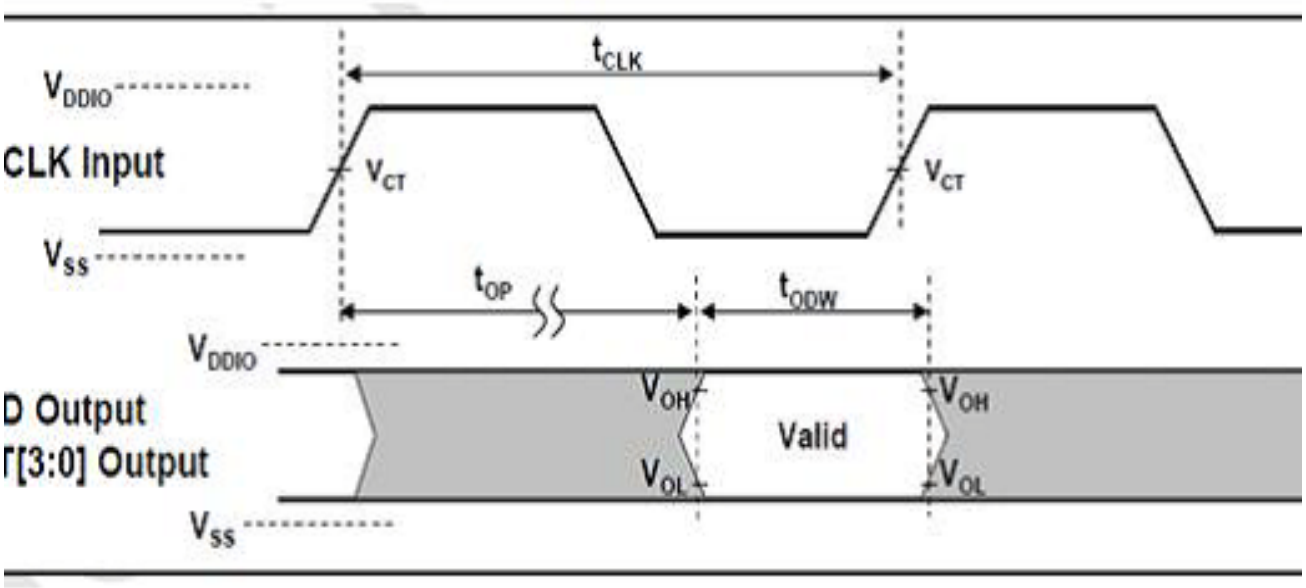

Figure 27 Output Timing of the Variable Data Window

6 Use the **Histogram** feature on the Infiniium Oscilloscope to measure the value for t_{VCT}. Place the Histogram window at V_{CT} on the CLK rising edge waveform. Record the mode value as t_{VCT} (CLK Rising Edge).

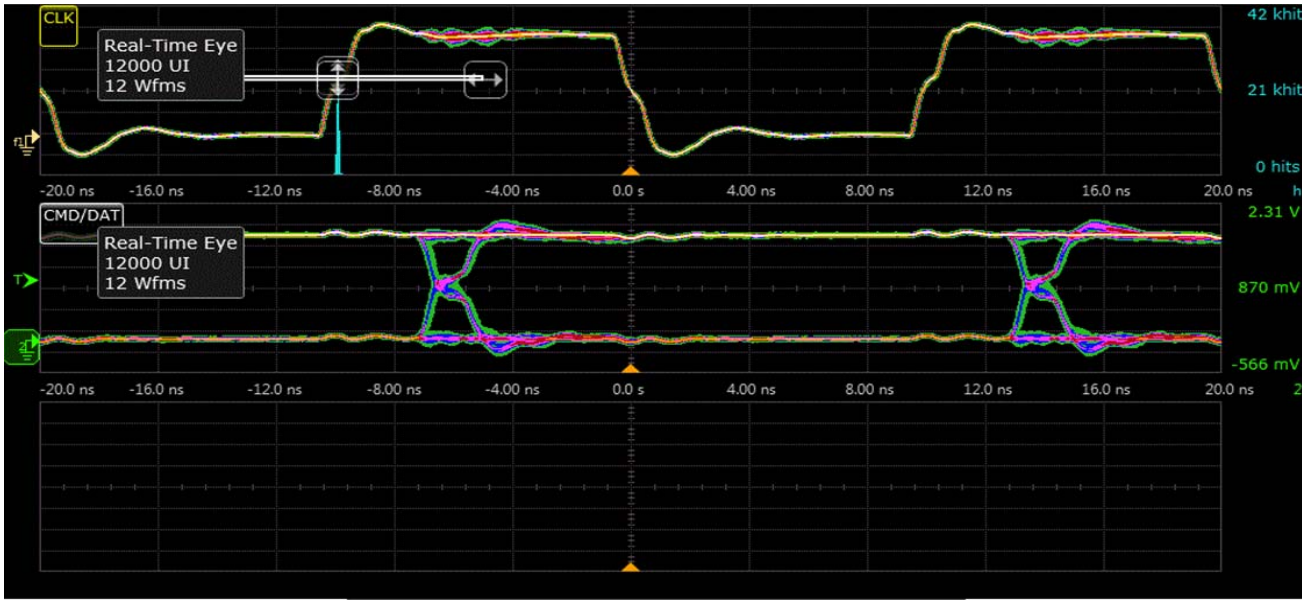

Figure 28 t_{VCT} (CLK Rising Edge)

7 Place the Histogram window at $V_{OL(max)}$ and $V_{OH(min)}$ on Data/CMD waveform to determine the worst Eye opening position (right edge of the Histogram). Record the maximum value as t_{VO} (Eye Diagram Edges).

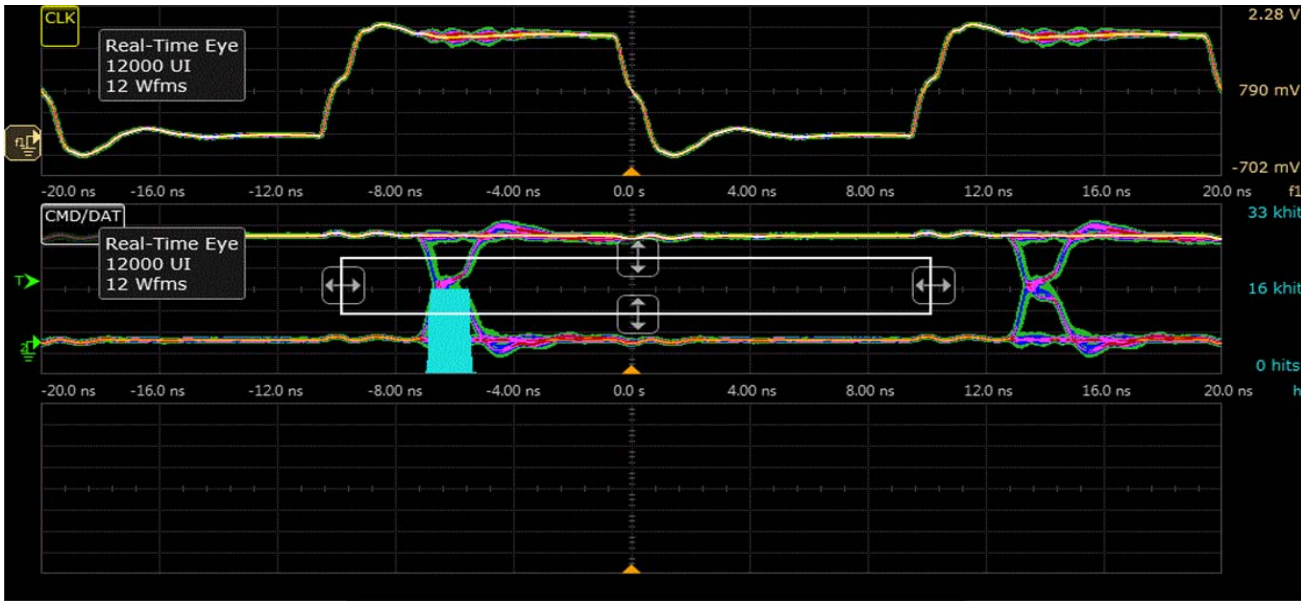

Figure 29 t_{VO} (Eye Diagram Edges)

8 Measure delta time between t_{VCT} (CLK Rising edge) and t_{VO} (Eye Diagram Edges). Record the resultant value as t_{OP}.

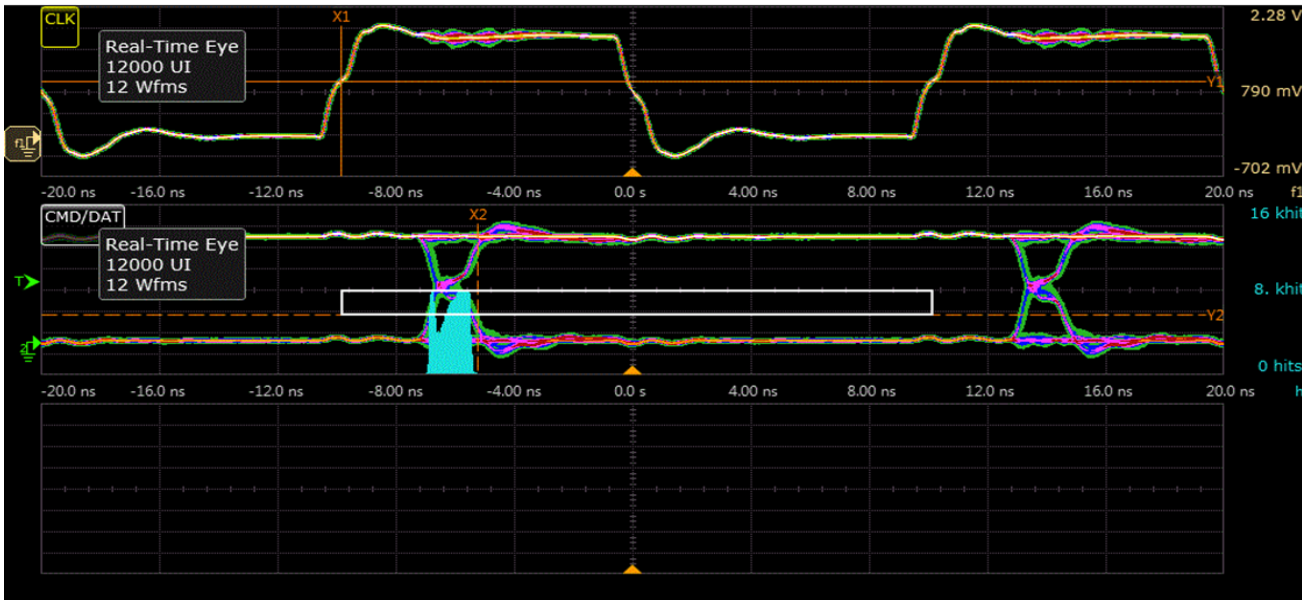

Figure 30 t_{OP}

9 Report the resultant value of t_{OP} as the final test result.

Output Valid Data Window, t_{ODW}

1 Set V_{DD} to 2.7 V and select the speed mode to **SDR104**.

2 Trigger on “Random” test pattern during the READ operation.

3 Acquire 10,000 unit intervals (UI) on the waveform to perform measurements.

4 Generate Eye patterns from the acquired waveform.

5 Each reference amplitude is as follows:
V_{CT} = 0.975 V
$V_{OL(min)}$ = 0.45 V
$V_{OH(max)}$ = 1.40 V

6 Use the **Histogram** feature on the Infiniium Oscilloscope to measure the value for t_{VO} (Eye Diagram Left Edges) and t_{VO} (Eye Diagram Right Edges).

7 Place the Histogram window at $V_{OL(max)}$ and $V_{OH(min)}$ on Data/CMD waveform to determine the worst Eye opening position (right edge of the Histogram). Record the maximum value as t_{VO} (Eye Diagram Left Edges).

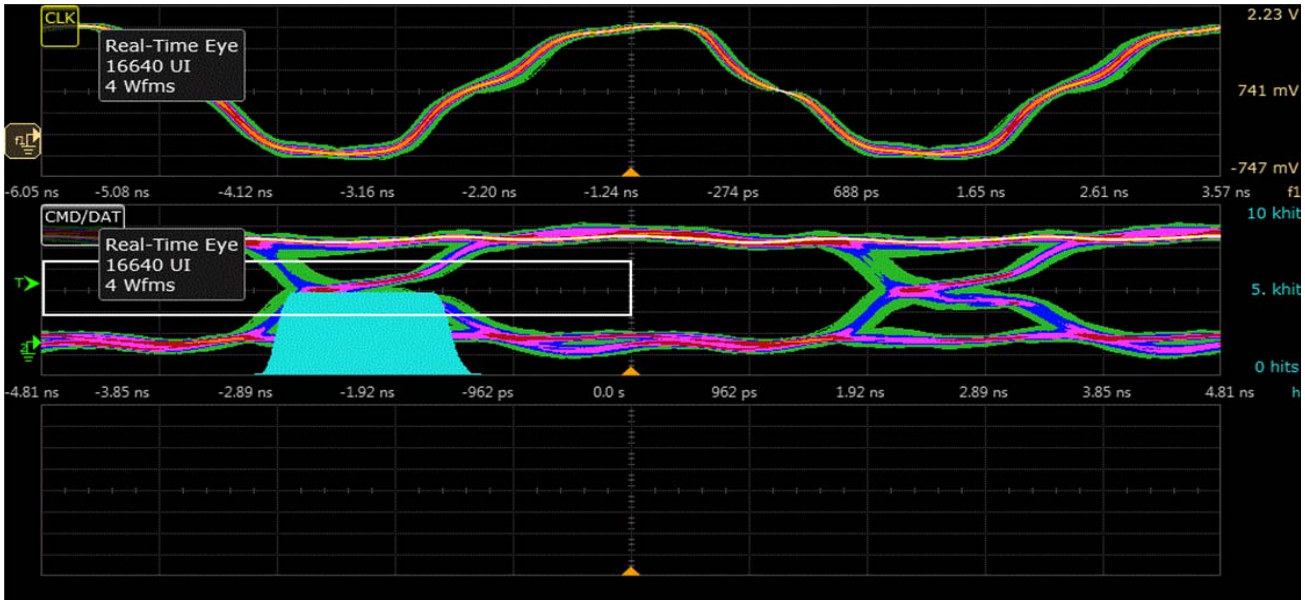

Figure 31 tVO (Eye Diagram Left Edges)

8 Place the Histogram window at $V_{OL(max)}$ and $V_{OH(min)}$ on Data/CMD waveform to determine the worst Eye opening position (left edge of the Histogram). Record the minimum value as t_{VO} (Eye Diagram Right Edges).

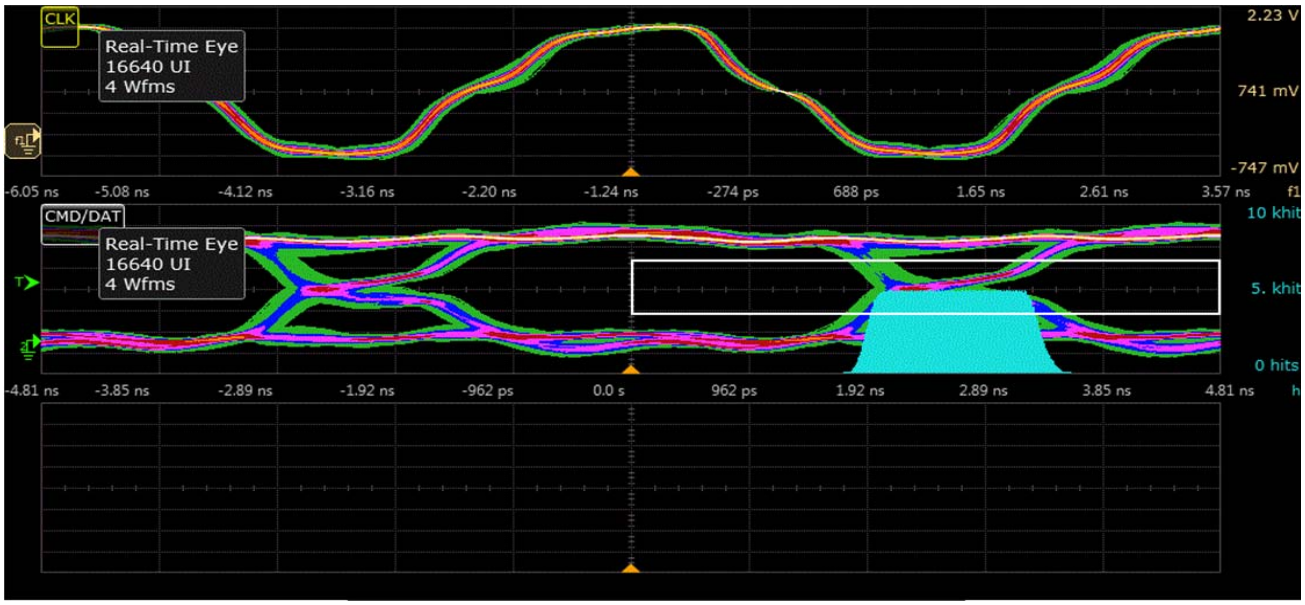

Figure 32 t_{VO} (Eye Diagram Right Edges)

9 Measure delta time between t_{VO} (Eye Diagram Left Edges) and t_{VO} (Eye Diagram Right Edges). Record the resultant value as t_{ODW}.

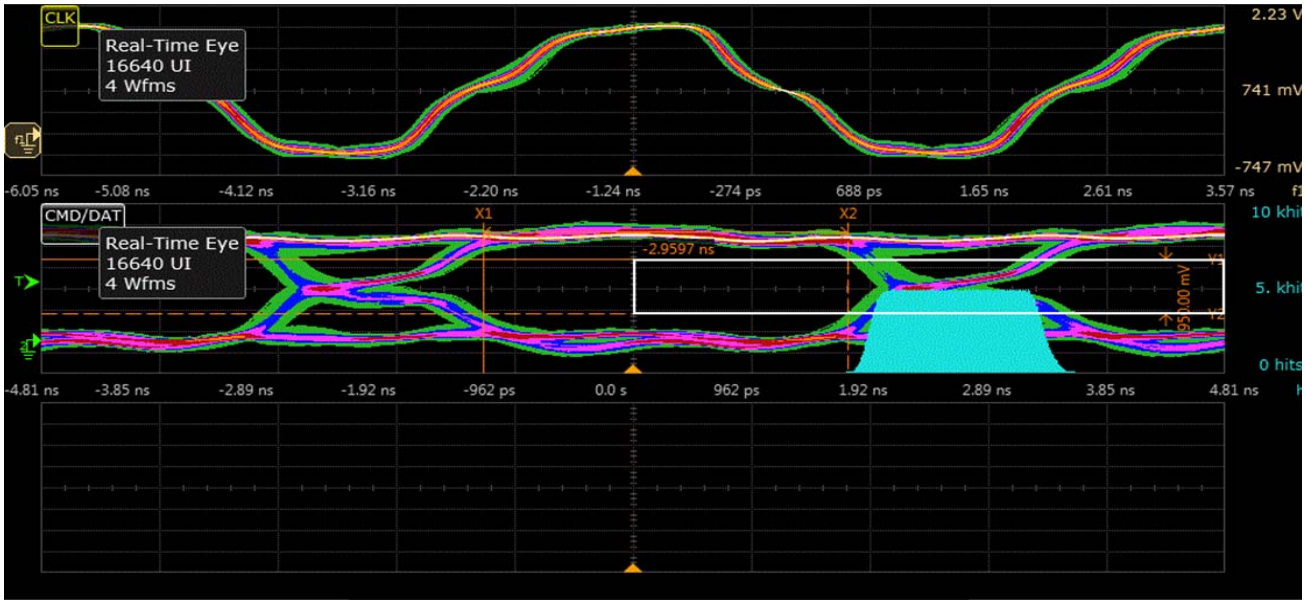

Figure 33 t_{ODW}

10 Report the resultant value of t_{ODW} as the final test result.

CMD/DAT Input and Output Timing for DDR Tests

- $t_{ODLAY2X\_MAX}$ – **DDR50**
- $t_{ODLAY2X\_MIN}$ – **DDR50**

Test Procedure

Output Delay Time, $t_{ODLAY2X\_MAX}$

1 Set V_{DD} to 2.7 V and select the speed mode to **DDR50**.
2 Trigger on “Random” test pattern during the READ operation.
3 Acquire 10,000 unit intervals (UI) on the waveform to perform measurements.
4 Generate Eye patterns from the acquired waveform.
5 Each reference amplitude is as follows:
V_{CT} = 0.975 V
$V_{OL(max)}$ = 0.45 V
$V_{OH(min)}$ = 1.40 V

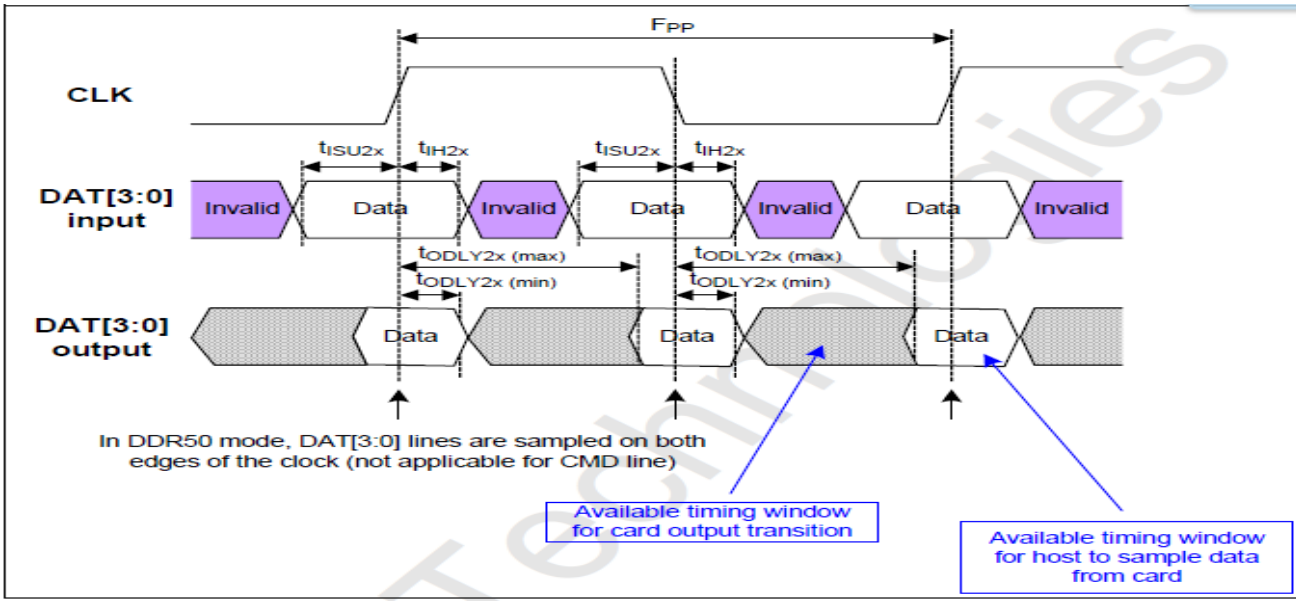

Figure 34 Timing Diagram DAT Inputs/Outputs referenced to CLK in DDR50 speed mode

6 Use the **Histogram** feature on the Infiniium Oscilloscope to measure the values for t_{VCT} (CLK Rising Edge) and t_{VCT} (CLK Falling Edge).
7 Place the Histogram window at V_{CT} on CLK rising edge waveform and record the mode value as t_{VCT} (CLK Rising Edge).

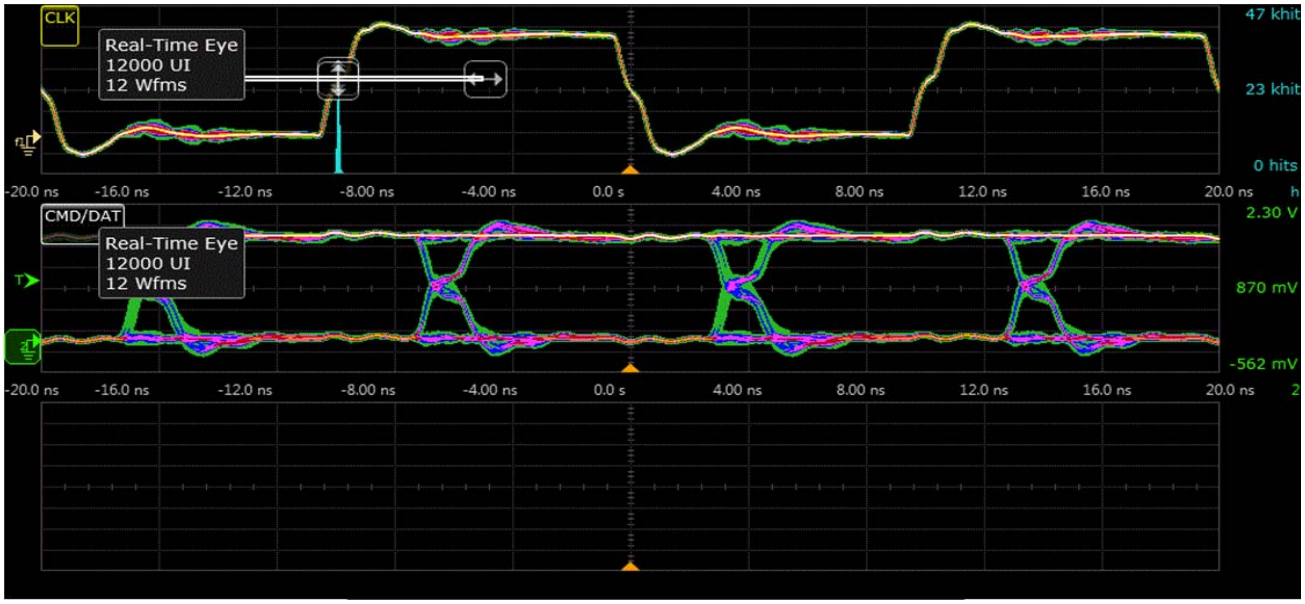

Figure 35 t_{VCT} (CLK Rising Edge)

8 Place the Histogram window at V_{CT} on CLK falling edge waveform and record the mode value as t_{VCT} (CLK Falling Edge).

9 Place the Histogram window at $V_{OL(max)}$ and $V_{OH(min)}$ on Data/CMD waveform to determine the worst Eye opening position. Record the maximum value as t_{VO} at CLK Rise Edge (Eye Diagram Edges).

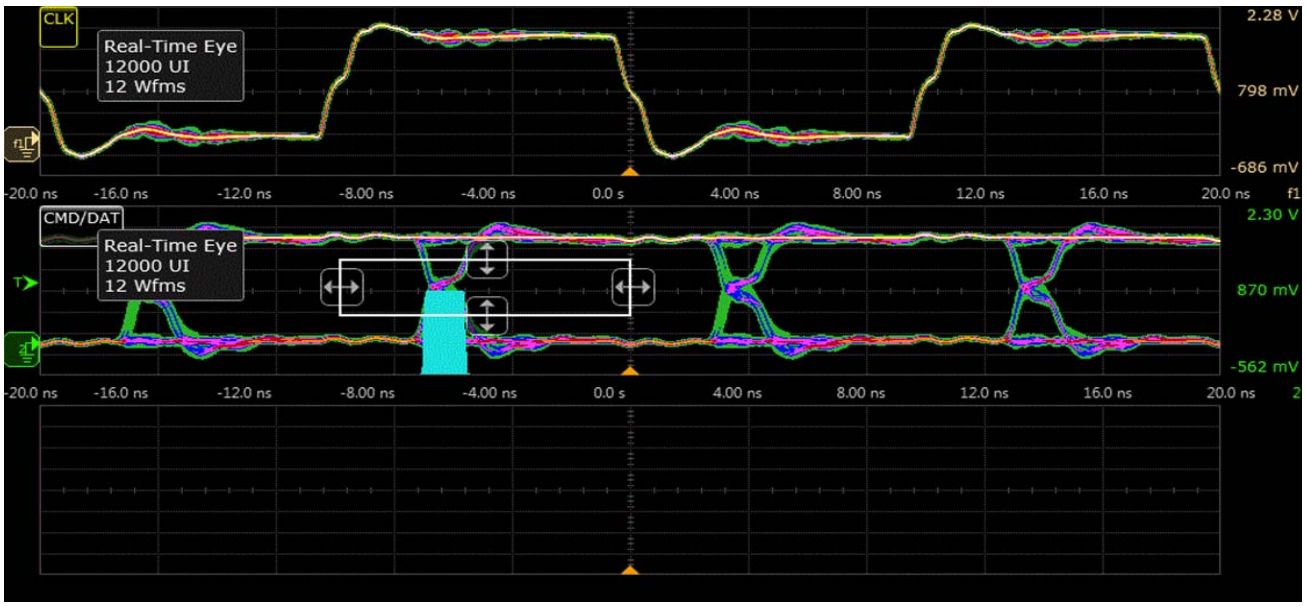

Figure 36 t_{VO} at CLK Rise Edge (Eye Diagram Edges)

10 Place the Histogram window at $V_{OL(max)}$ and $V_{OH(min)}$ on Data/CMD waveform to determine the worst Eye opening position. Record the maximum value as t_{VO} at CLK Fall Edge (Eye Diagram Edges).

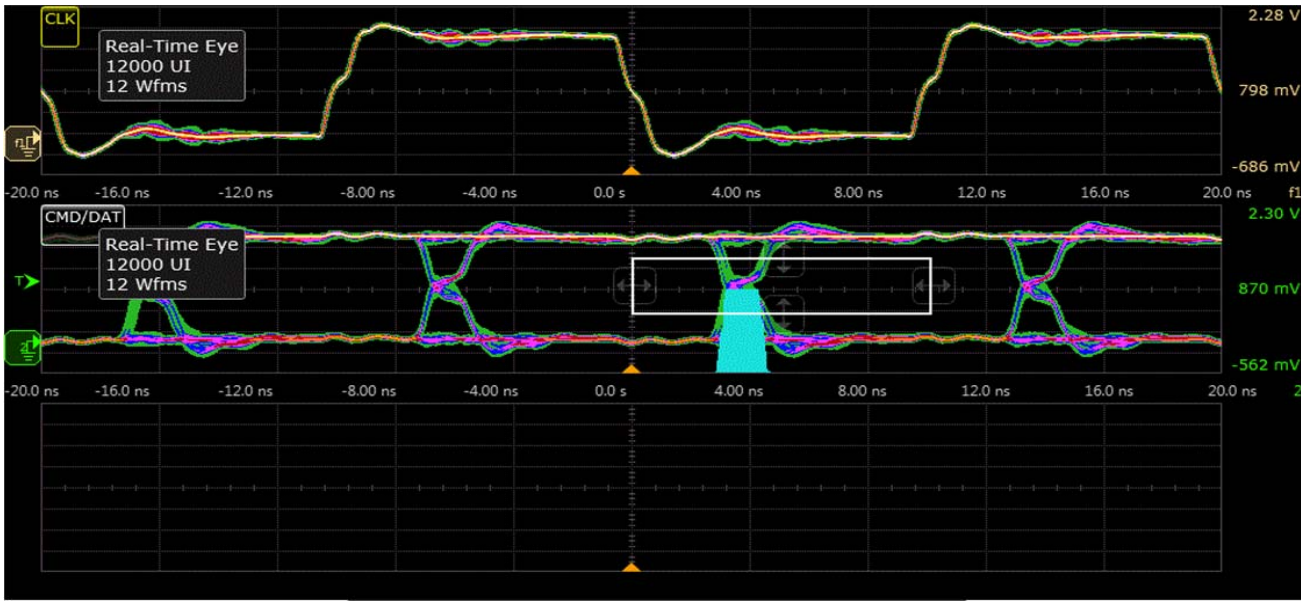

Figure 37 t_{VO} at CLK Fall Edge (Eye Diagram Edges)

11 Measure delta time between t_{VCT} (CLK Rising Edge) and t_{VO} at CLK Rise Edge (Eye Diagram Edges). Record the resultant value as CLK Rise Edge to $t_{ODLAY2X\_MAX}$.

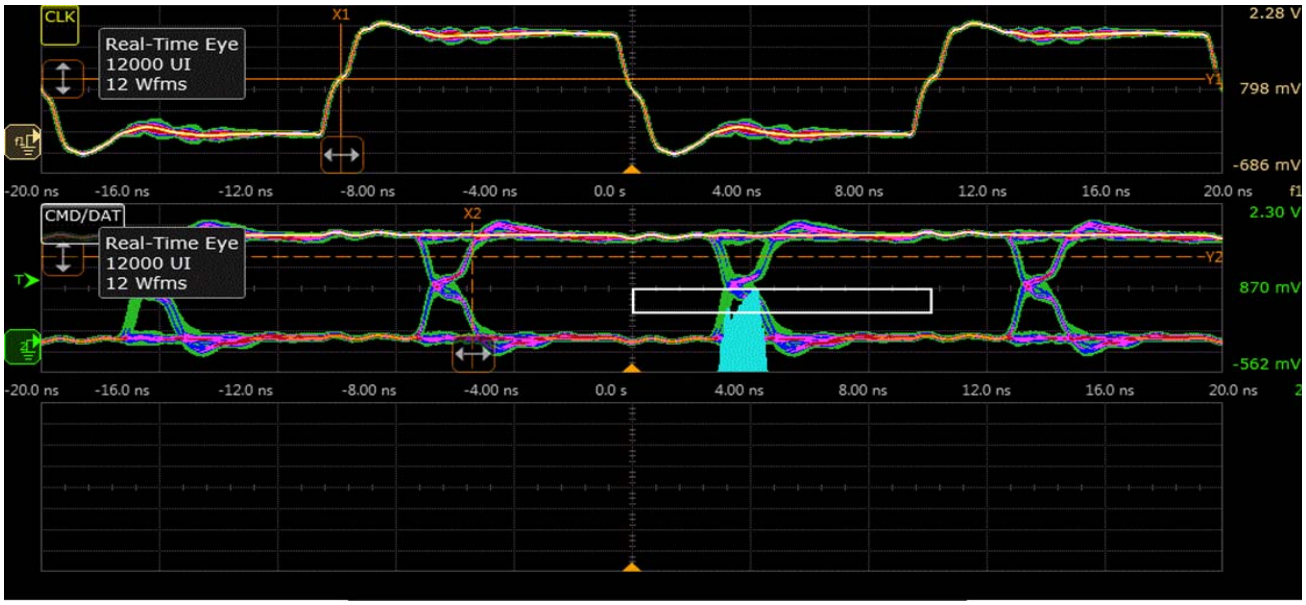

Figure 38 CLK Rise Edge to $t_{ODLAY2X\_MAX}$

12 Measure delta time between t_{VCT} (CLK Falling Edge) and t_{VO} at CLK Fall Edge (Eye Diagram Edges). Record the resultant value as CLK Fall Edge to $t_{ODLAY2X\_MAX}$.

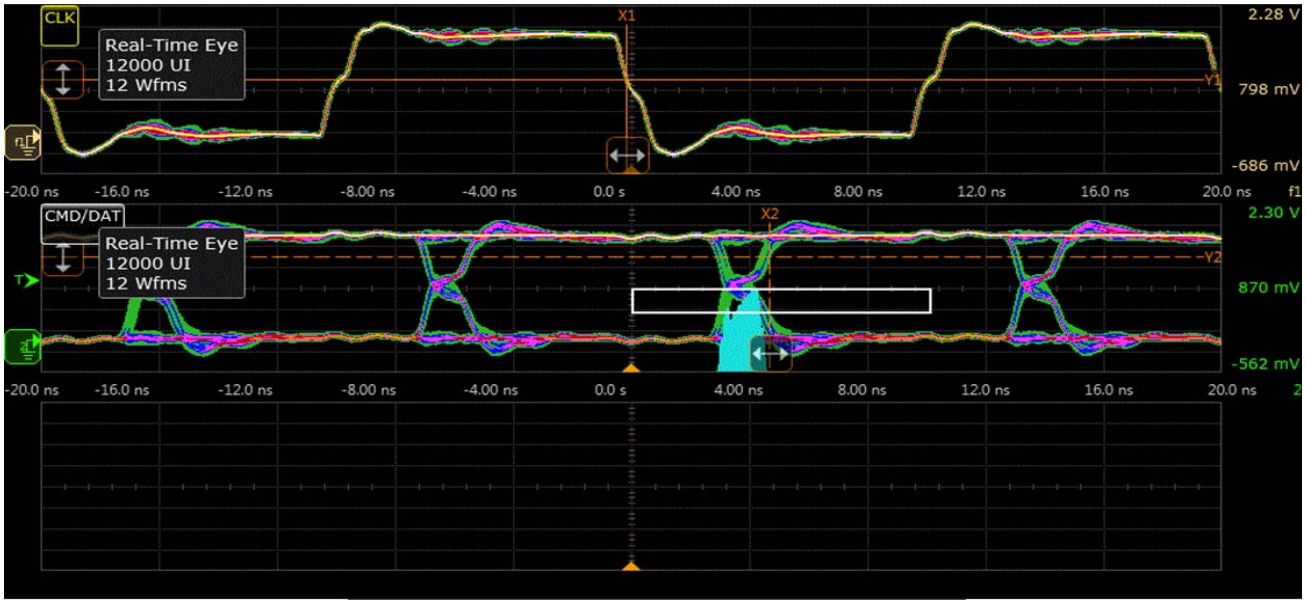

Figure 39 CLK Fall Edge to $t_{ODLAY2X\_MAX}$

13 Measure the worst value for CLK Rise Edge to $t_{ODLAY2X\_MAX}$ and CLK Fall Edge to $t_{ODLAY2X\ MAX}$. Record the resultant value.

14 Report the resultant value as the final test result.

Output Hold Time, $t_{ODLAY2X\_MIN}$

1 Set V_{DD} to 2.7 V and select the speed mode to **DDR50**.

2 Trigger on “Random” test pattern during the READ operation.

3 Acquire 10,000 unit intervals (UI) on the waveform to perform measurements.

4 Generate Eye patterns from the acquired waveform.

5 Each reference amplitude is as follows:
V_{CT} = 0.975 V
$V_{OL(max)}$ = 0.45 V
$V_{OH(min)}$ = 1.40 V

6 Use the **Histogram** feature on the Infiniium Oscilloscope to measure the values for t_{VCT} (CLK Rising Edge) and t_{VCT} (CLK Falling Edge).

7 Place the Histogram window at V_{CT} on CLK rising edge waveform and record the mode value as t_{VCT} (CLK Rising Edge).

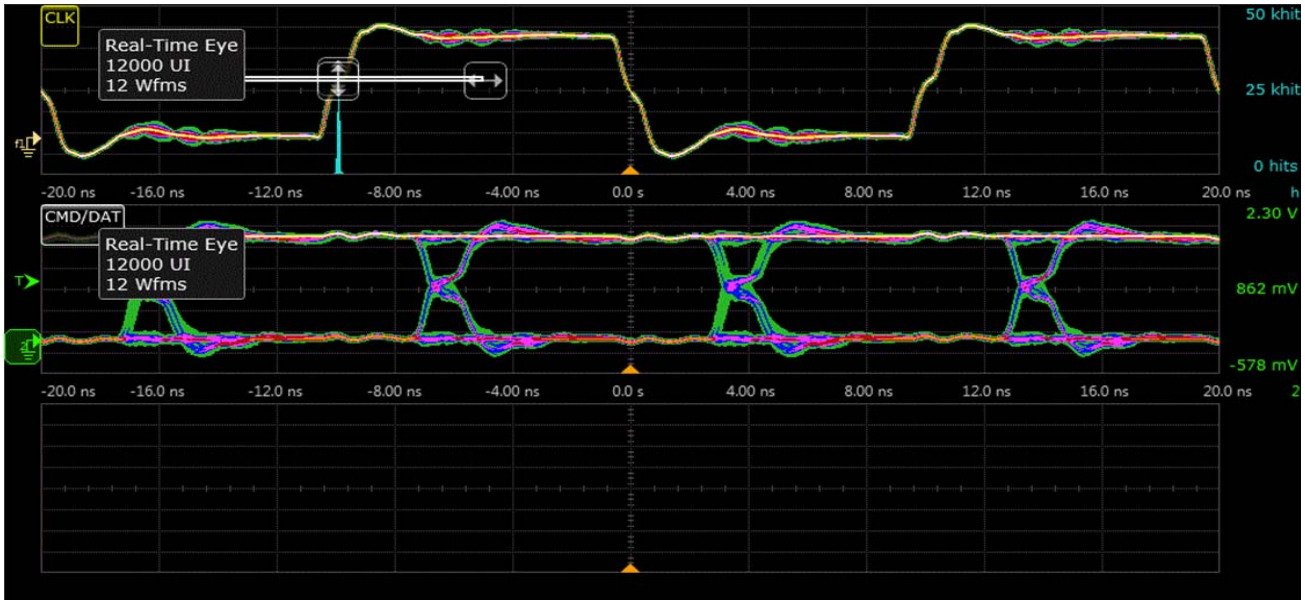

Figure 40 tVCT (CLK Rising Edge)

8 Place the Histogram window at V_{CT} on CLK falling edge waveform and record the mode value as t_{VCT} (CLK Falling Edge).

9 Place the Histogram window at $V_{OL(max)}$ and $V_{OH(min)}$ on Data/CMD waveform to determine the worst Eye opening position. Record the minimum value as t_{VO} at CLK Rise Edge (Eye Diagram Edges).

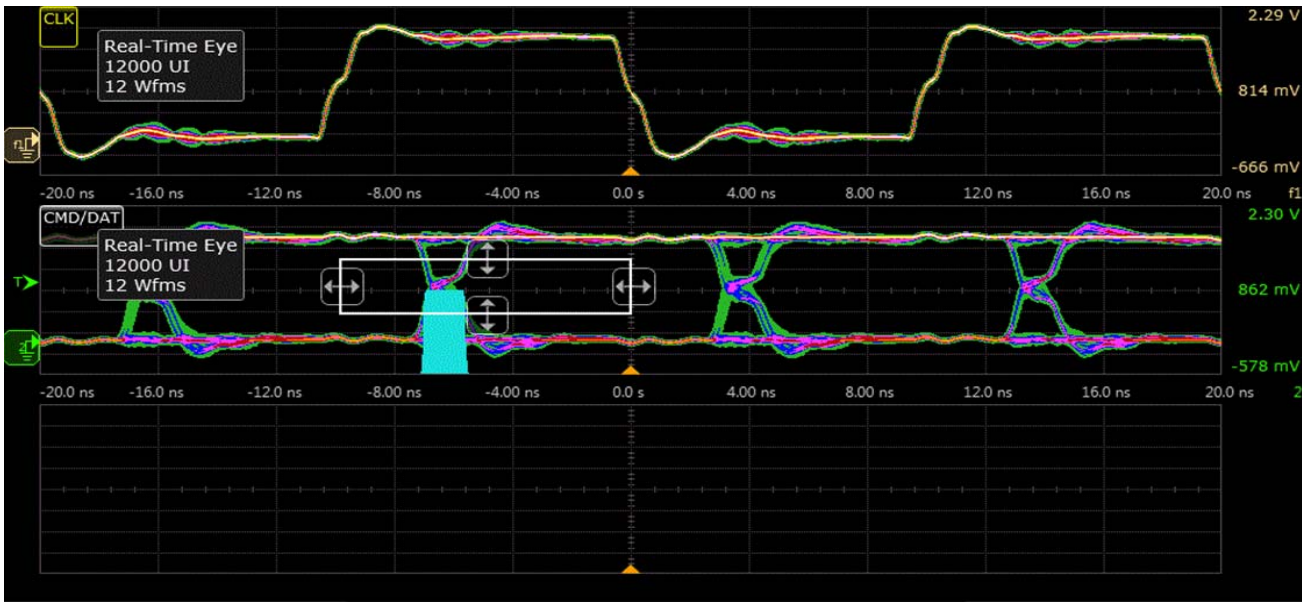

Figure 41 t_{VO} at CLK Rise Edge (Eye Diagram Edges)

10 Place the Histogram window at $V_{OL(max)}$ and $V_{OH(min)}$ on Data/CMD waveform to determine the worst Eye opening position. Record the minimum value as t_{VO} at CLK Fall Edge (Eye Diagram Edges).

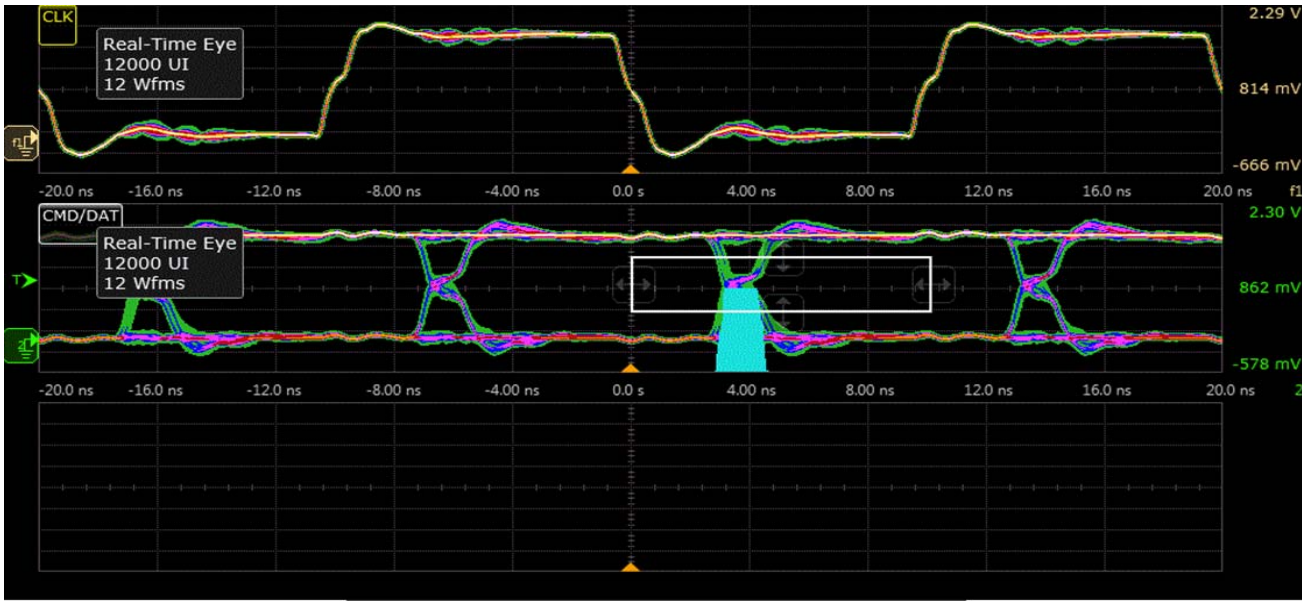

Figure 42 t_{VO} at CLK Fall Edge (Eye Diagram Edges)

11 Measure delta time between t_{VCT} (CLK Rising Edge) and t_{VO} at CLK Rise Edge (Eye Diagram Edges). Record the resultant value as CLK Rise Edge to $t_{ODLAY2X\_MIN}$.

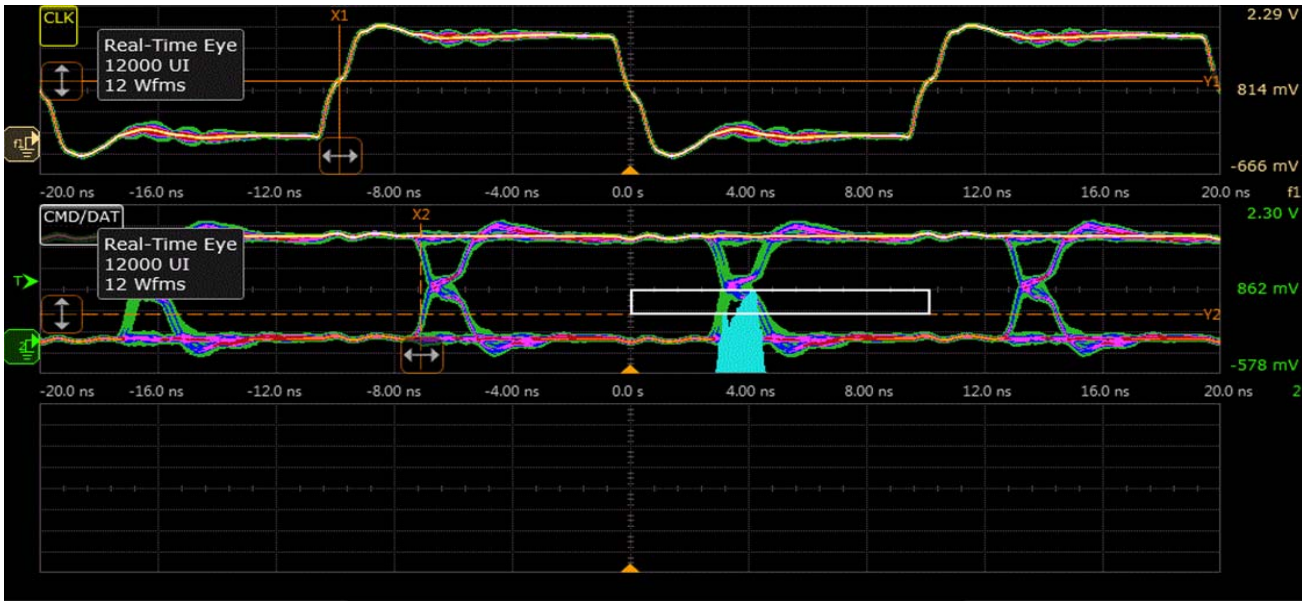

Figure 43 CLK Rise Edge to $t_{ODLAY2X\_MIN}$

12 Measure delta time between t_{VCT} (CLK Falling Edge) and t_{VO} at CLK Fall Edge (Eye Diagram Edges). Record the resultant value as CLK Fall Edge to $t_{ODLAY2X\_MIN}$.

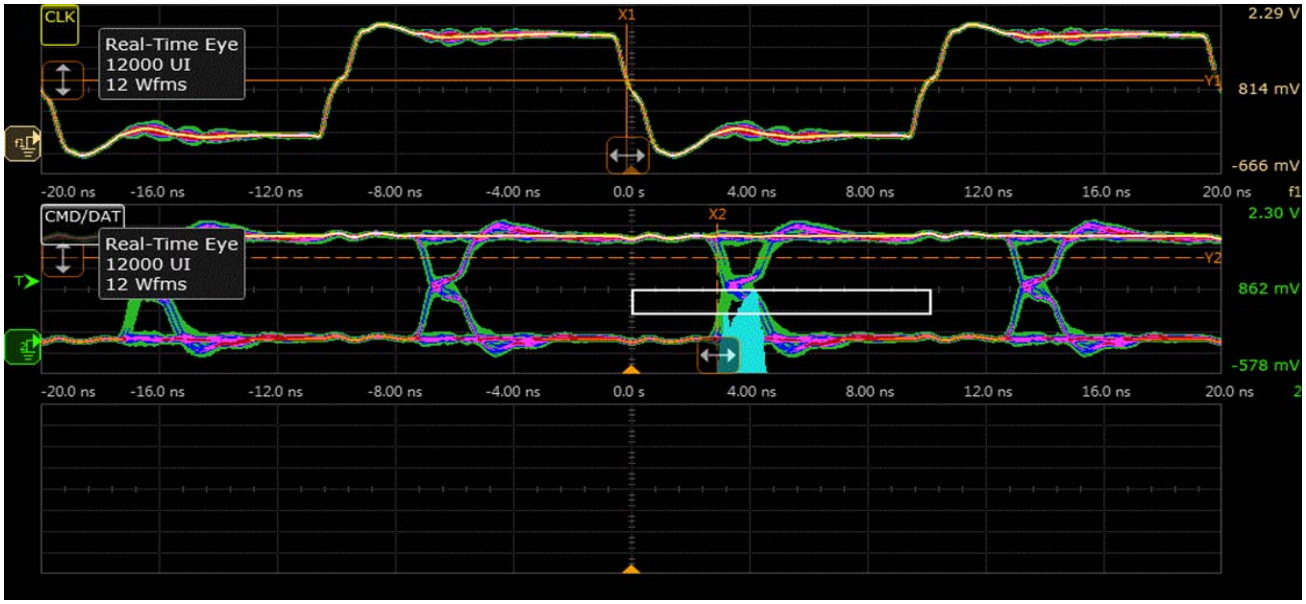

Figure 44 CLK Fall Edge to $t_{ODLAY2X\_MIN}$

13 Measure the worst value for CLK Rise Edge to $t_{ODLAY2X\_MIN}$ and CLK Fall Edge to $t_{ODLAY2X\ MIN}$. Record the resultant value.

14 Report the resultant value as the final test result.

4 Calibrating the Infiniium Oscilloscope and Probe

This section describes the Keysight Infiniium Digital Storage Oscilloscope calibration procedures.

Required Equipment for Oscilloscope Calibration

To calibrate the Infiniium Oscilloscope in preparation for running the SD UHS-I automated tests, you need the following equipment:

- Keyboard, qty = 1, (provided with the Keysight Infiniium Oscilloscope).
- Mouse, qty = 1, (provided with the Keysight Infiniium Oscilloscope).
- Precision 3.5 mm BNC to SMA male adapter, Keysight p/n 54855-67604, qty = 2 (provided with the Keysight Infiniium Oscilloscope).
- Calibration cable (provided with the 90000A Series Infiniium Oscilloscopes). Use a good quality 50 Ω BNC cable.

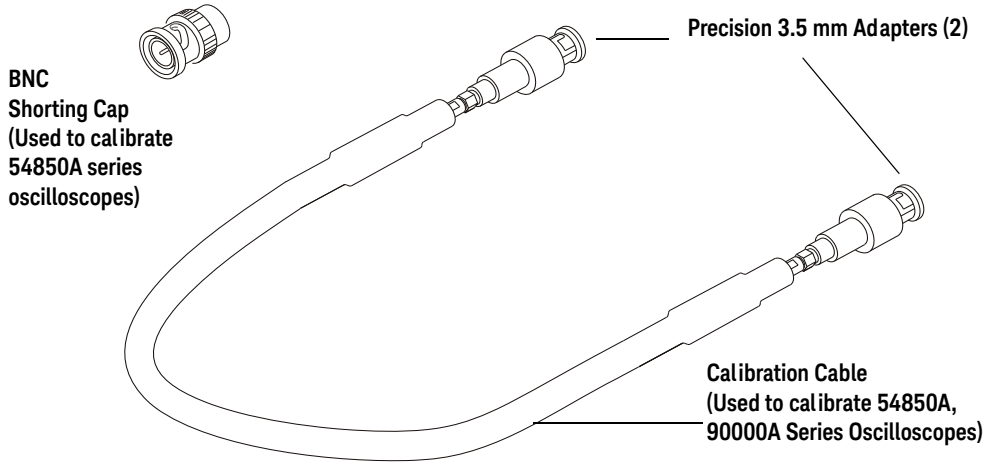

Figure 45 Accessories Provided with the Keysight Infiniium Oscilloscope

Internal Calibration

This process performs an internal diagnostic and calibration cycle for the Oscilloscope. For the Keysight Oscilloscope, this is referred to as Calibration. This Calibration takes about 20 minutes. Perform the following steps:

1 Set up the Oscilloscope with the following steps:
   a Connect the keyboard, mouse and power cord to the rear of the Oscilloscope.
   b Plug in the power cord.
   c Turn on the Oscilloscope by pressing the power button located on the lower left of the front panel.
   d Allow the Oscilloscope to warm up at least 30 minutes prior to starting the calibration procedure in step 3 below.

2 Locate and prepare the accessories required for the internal calibration:
   a Locate the BNC shorting cap.
   b Locate the calibration cable.
   c Locate the two Keysight precision SMA/BNC adapters.
   d Attach one SMA adapter to the other end of the calibration cable - hand tighten snugly.
   e Attach another SMA adapter to the other end of the calibration cable - hand tighten snugly.

3 Referring to Figure 46 below, click **Utilities>Calibration** menu to open the **Calibration** dialog box.

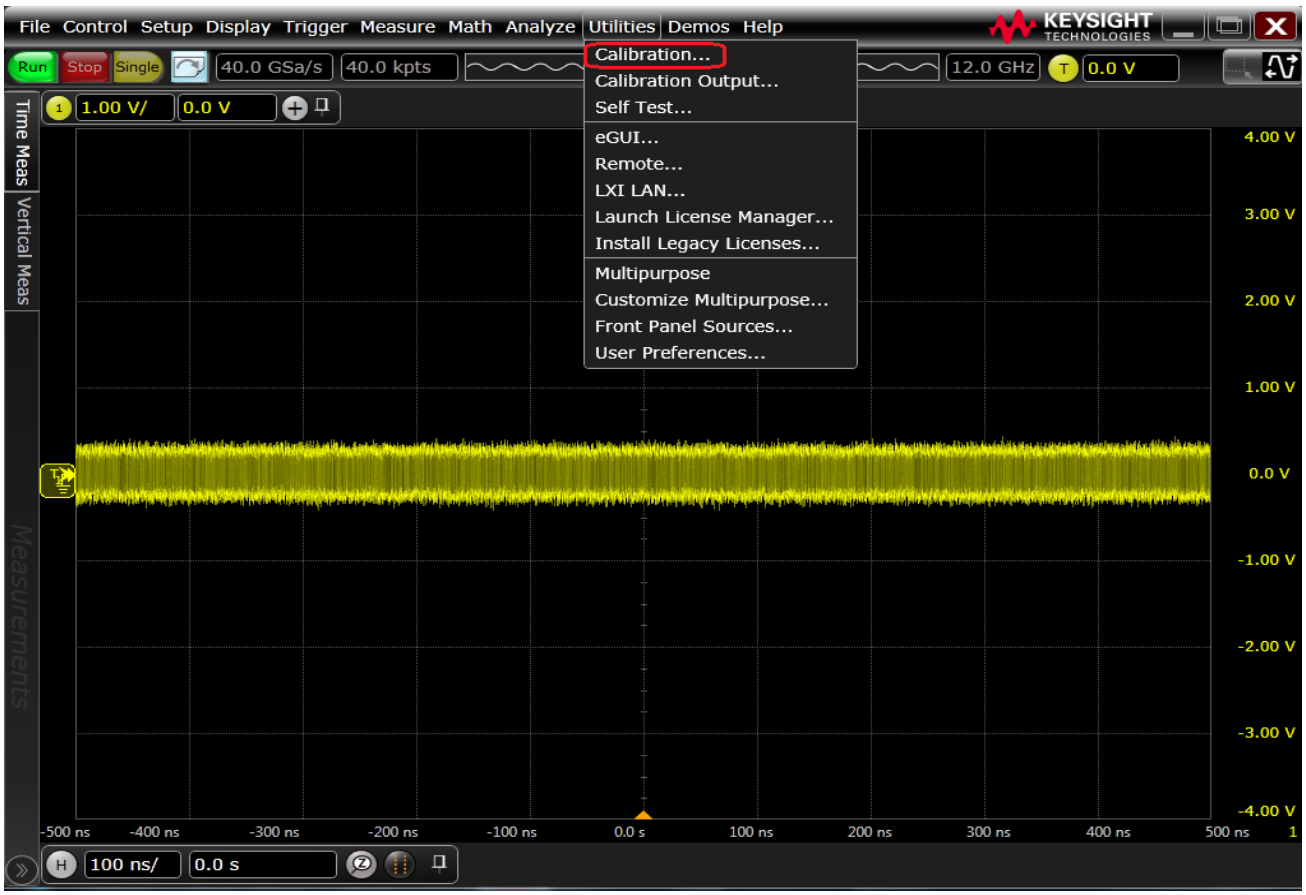

Figure 46 Accessing the Calibration menu

4 Referring to Figure 47 below, perform the following steps to start the calibration:

a Uncheck the **Cal Memory Protect** checkbox.

b Click the **Start** button to begin the calibration.

Figure 47 Oscilloscope Calibration Process

c During the calibration of Channel 1, if you are prompted to perform a Time Scale Calibration, as shown in Figure 48 below.

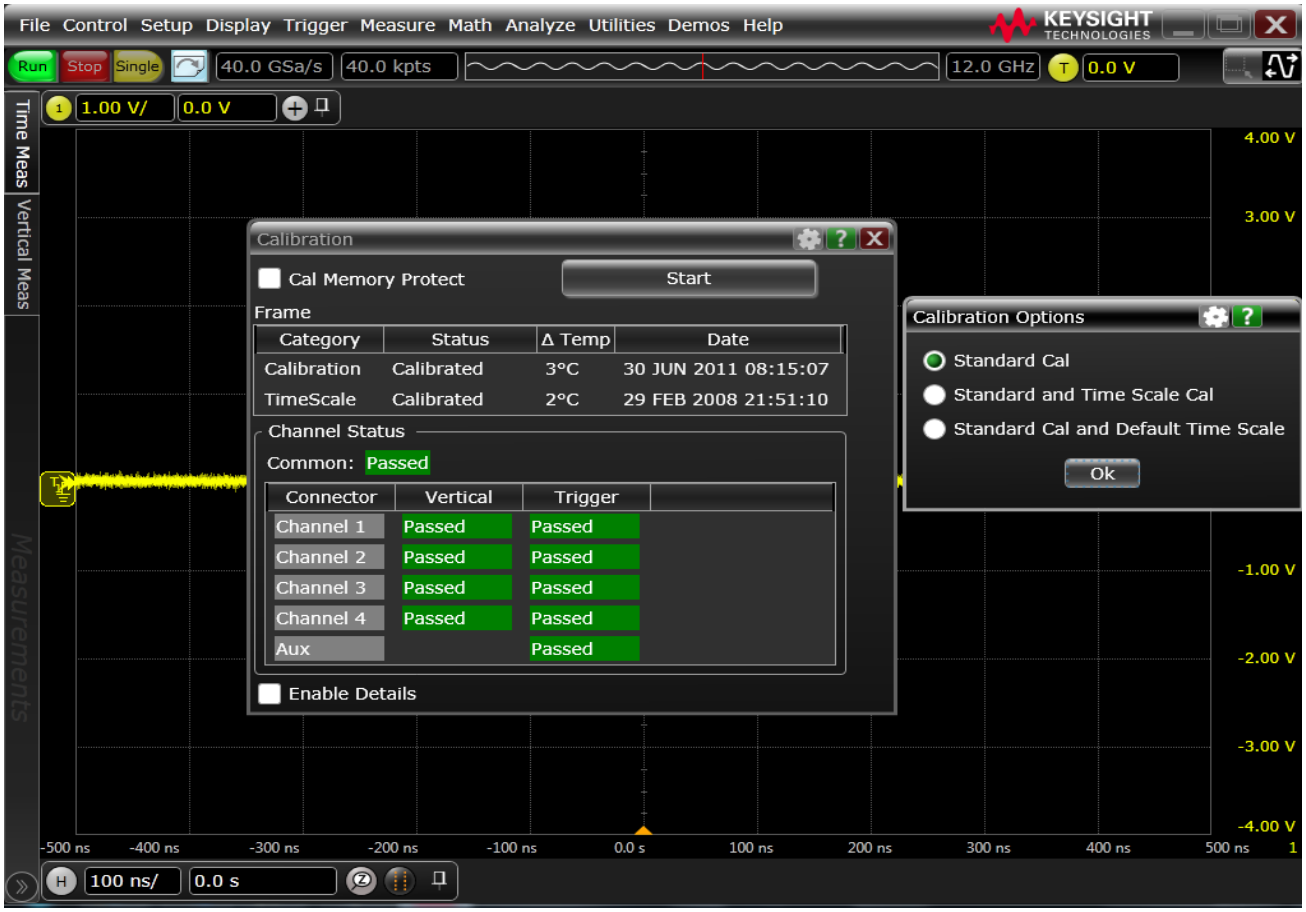

Figure 48 Calibration Options to perform Time Scale Calibration

d Select the **Standard Cal and Default Time Scale** radio button to continue the calibration using the factory default calibration factors.

e When the calibration procedure is complete, you will be prompted with a **Calibration Complete** message. Click the **OK** button to close this window.

f Confirm that the Vertical and Trigger Calibration Status for all Channels passed.

g Click the **Close** button to close the calibration window. The internal calibration is completed.

NOTE

These steps do not need to be performed every time a test is run. However, if the ambient temperature changes more than 5 degrees Celsius from the calibration temperature, this calibration should be performed again. The delta between the calibration temperature and the present operating temperature is shown in the **Utilities>Calibration** menu.

Required Equipment for Probe Calibration

Before performing SD UHS-I tests, you must calibrate the probes. Calibration of the solder-in probe heads consist of a vertical calibration and a skew calibration. The vertical calibration should be performed before the skew calibration. Both calibrations should be performed for best probe measurement performance.

The calibration procedure requires the following parts.

- BNC (male) to SMA (male) adapter
- Deskew fixture
- 50 Ω SMA terminator

Probe Calibration

Connecting the Probe for Calibration

For the following procedure, refer to Figure 49 below.

1. Connect BNC (male) to SMA (male) adapter to the deskew fixture on the connector closest to the yellow pincher.
2. Connect the 50 Ω SMA terminator to the connector farthest from yellow pincher.
3. Connect the BNC side of the deskew fixture to the Aux Out BNC of the Infiniium Oscilloscope.
4. Connect the probe to an Oscilloscope Channel.
5. To minimize the wear and tear on the probe head, it should be placed on a support to relieve the strain on the probe head cables.
6. Push down the back side of the yellow pincher. Insert the probe head resistor lead underneath the center of the yellow pincher and over the center conductor of the deskew fixture. The negative probe head resistor lead or ground lead must be underneath the yellow pincher and over one of the outside copper conductors (ground) of the deskew fixture. Make sure that the probe head is approximately perpendicular to the deskew fixture.
7. Release the yellow pincher.

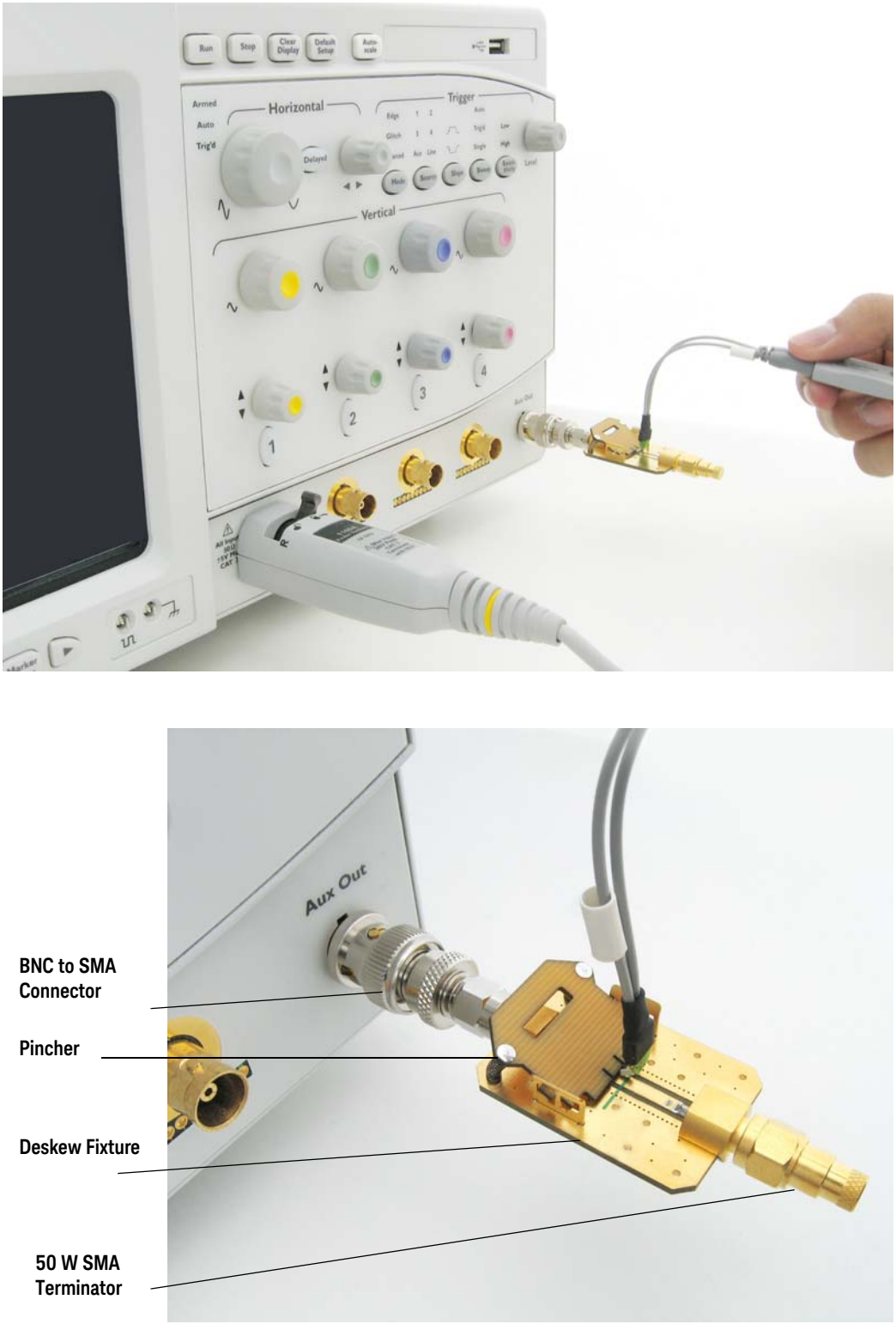

Figure 49 Solder-in Probe Head Calibration Connection Example

Verifying the Connection

1 On the Infiniium Oscilloscope, press the autoscale button on the front panel.

2 Set the volts per division to 100 mV/div.

3 Set the horizontal scale to 1.00 ns/div.

4 Set the horizontal position to approximately 3 ns. You should see a waveform similar to that in Figure 50 below.

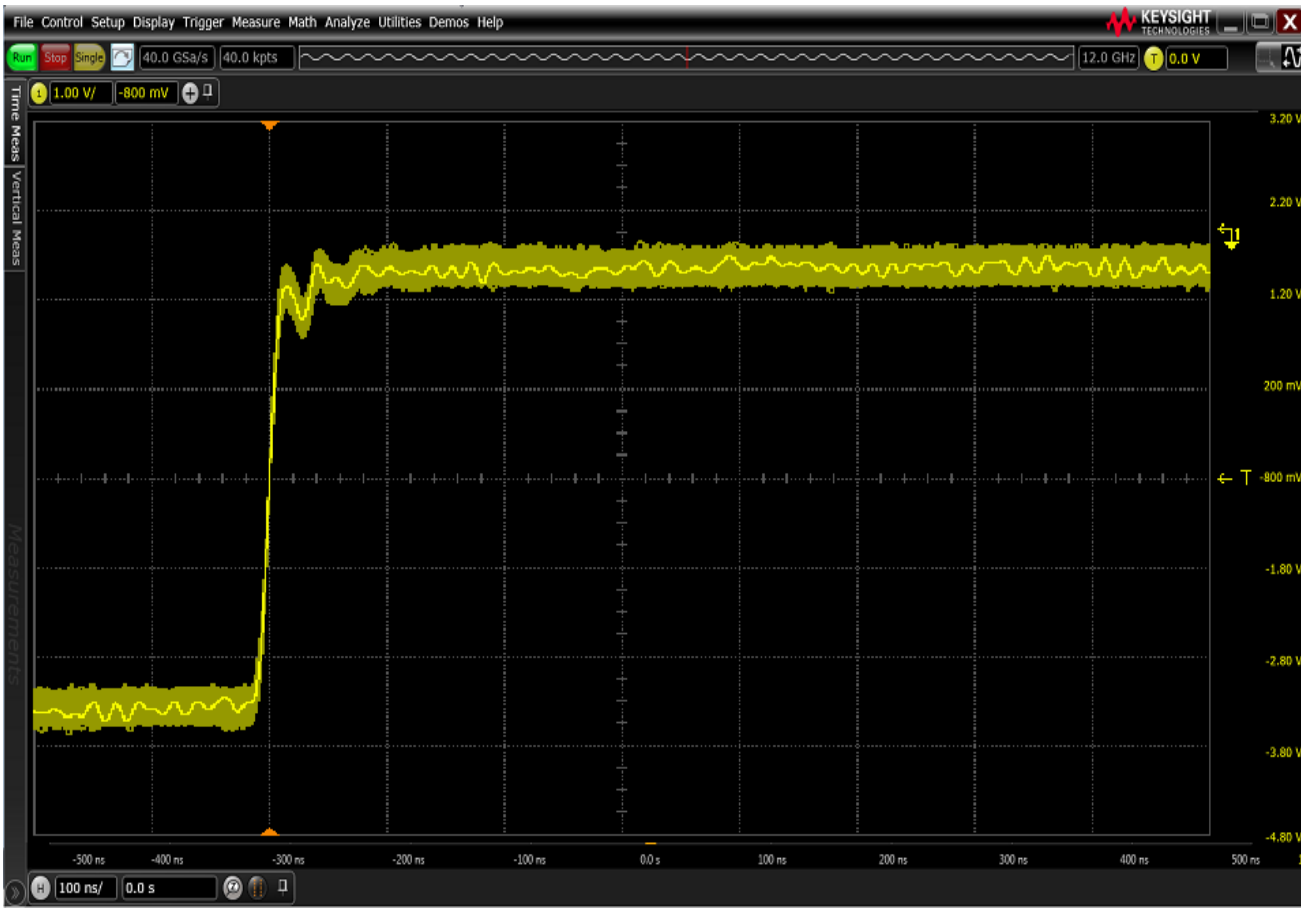

Figure 50 Example of a Good Connection Waveform

5 If you see a waveform similar to that of Figure 51 below, then you have a bad connection and should check all of your probe connections.

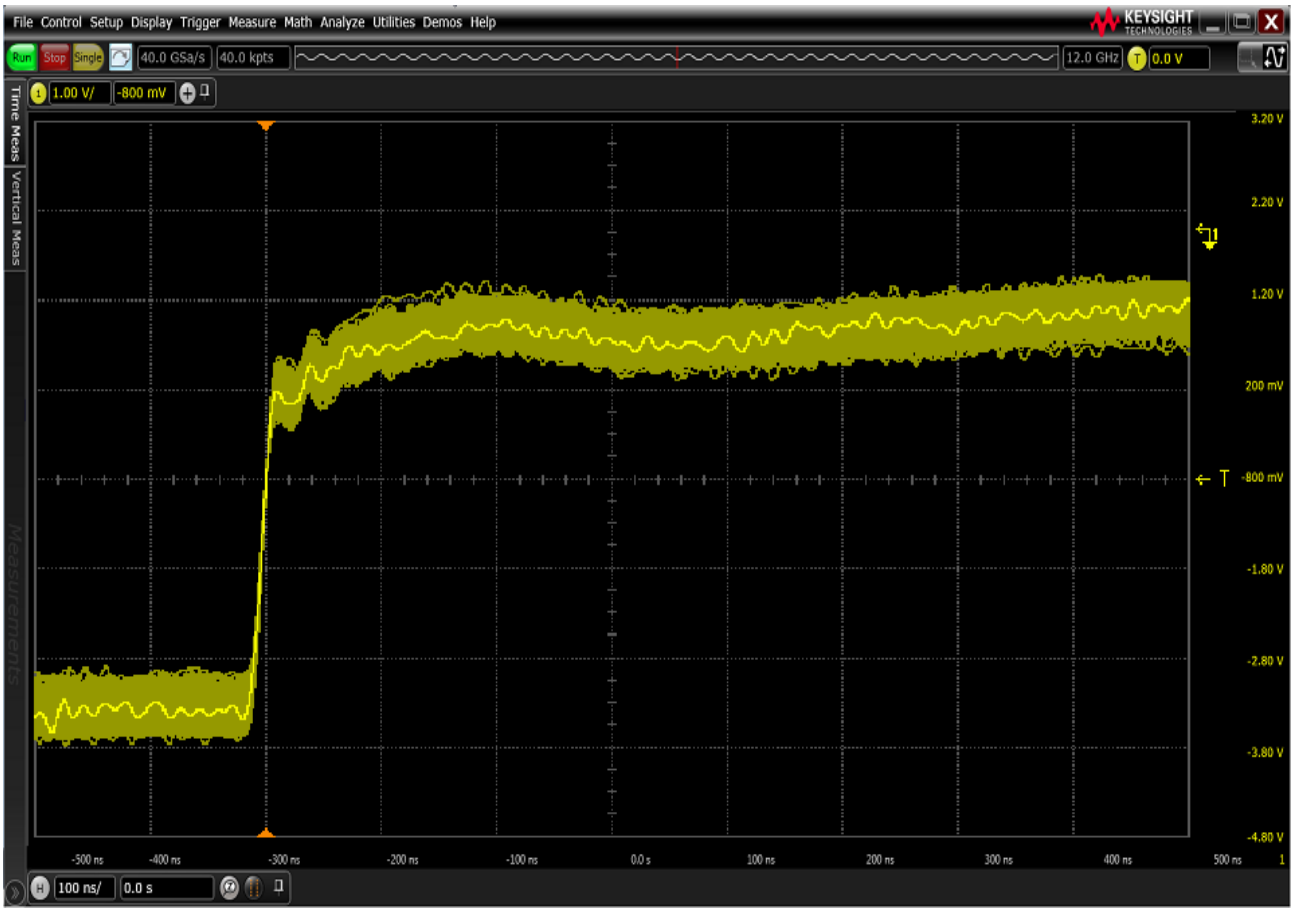

Figure 51 Example of a Bad Connection Waveform

Running the Probe Calibration and Deskew

1 On the Infiniium Oscilloscope in the **Setup** menu, select the Channel connected to the probe, as shown in Figure 52.

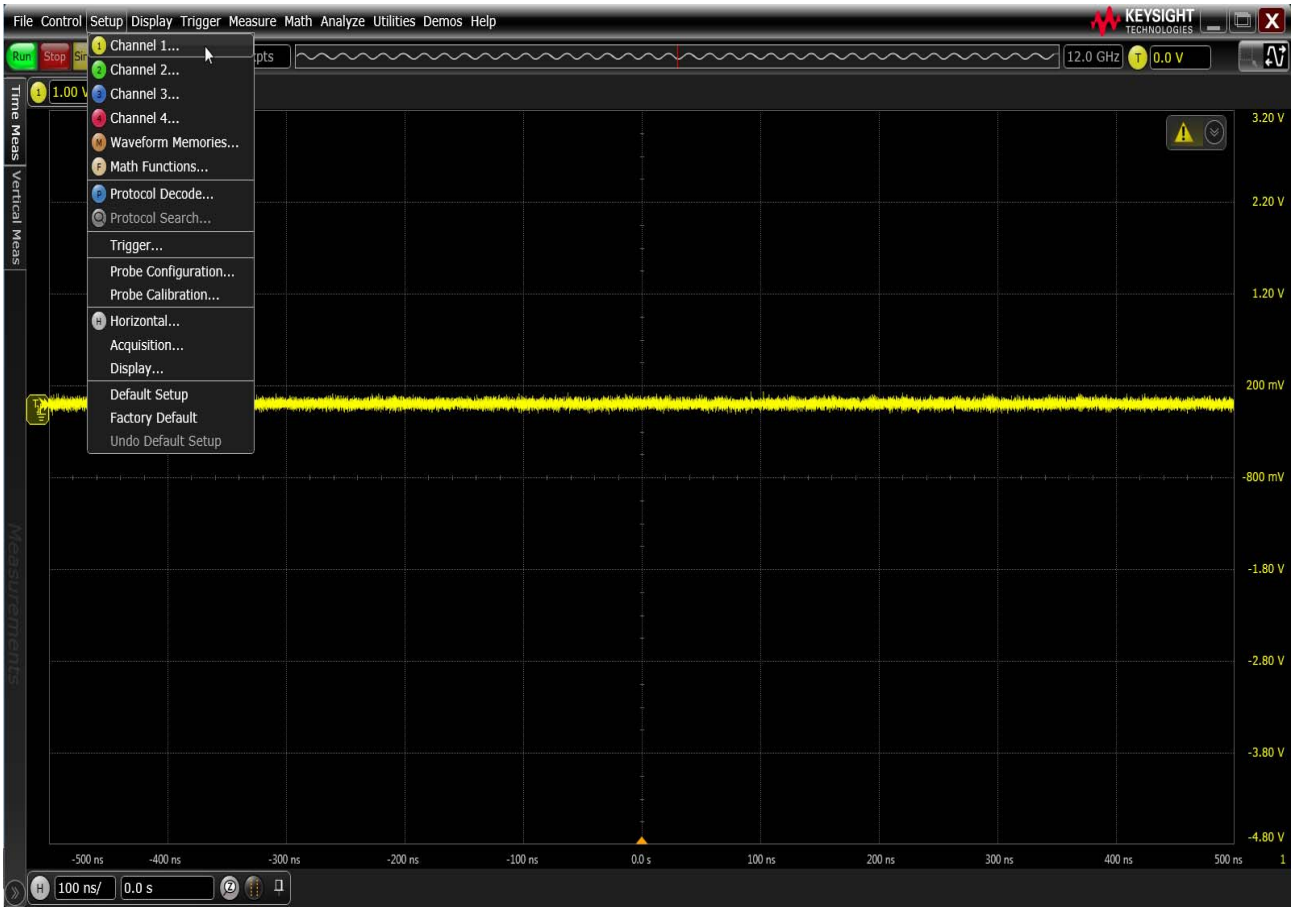

Figure 52 Selection of Channel Setup Dialog from the Setup menu

2 In the **Channel** dialog box, select the **Probe...** button, as shown in Figure 53.

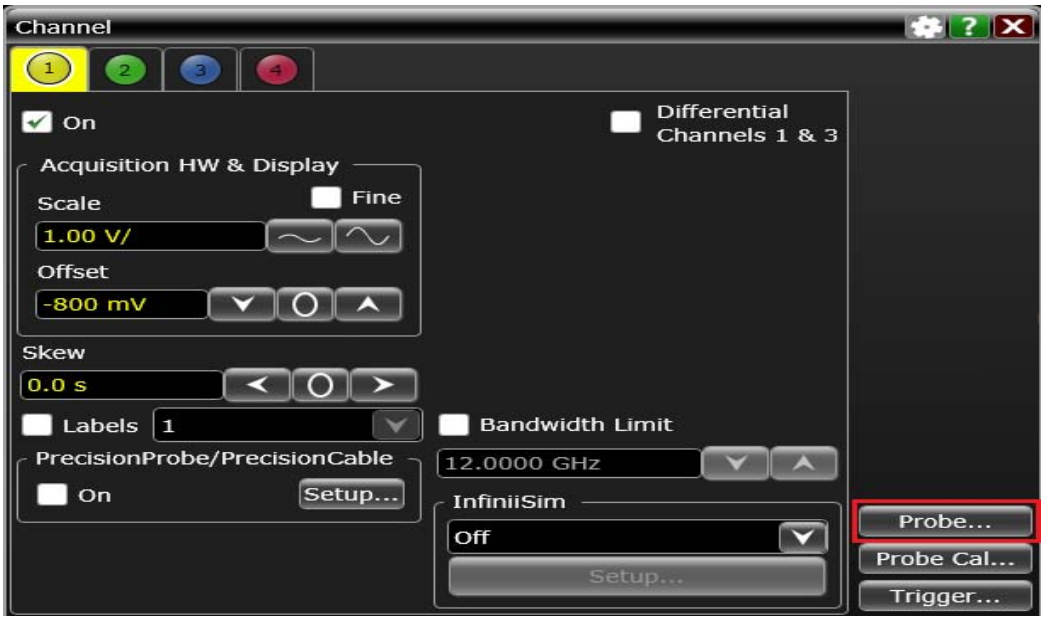

Figure 53 Channel Dialog Box

3 In the **Probe Configuration** dialog, click the **Uncalibrated** button (either for **Atten/Offset** or for **Skew**) in the **Calibration Status** area, as shown in Figure 54.

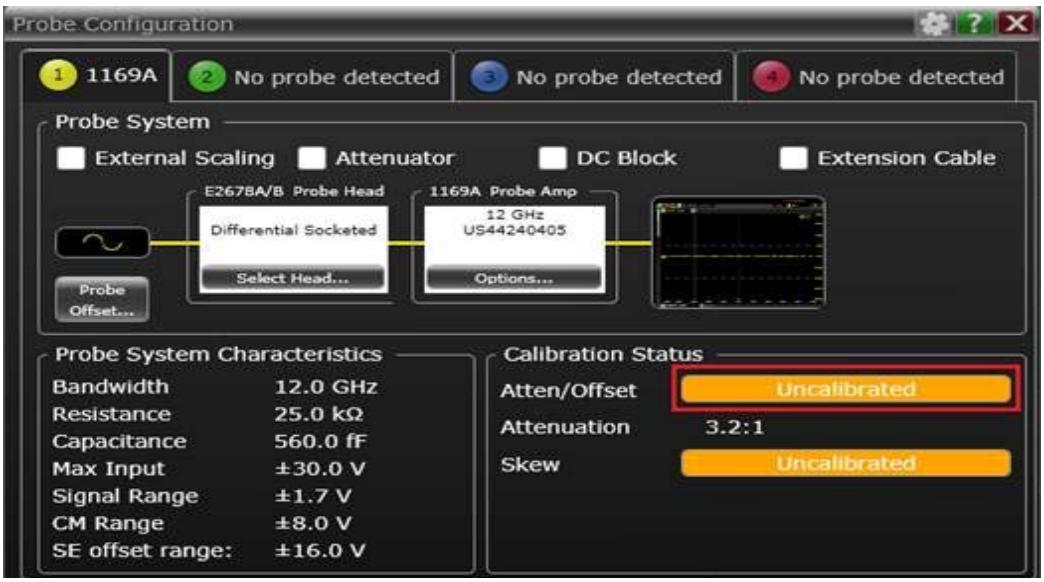

Figure 54 Probe Setup dialog

4 In the **Probe Calibration** dialog box, click the **Start Atten/Offset Cal...** button in the **DC Attenuation/Offset Cal** area and follow the on-screen instructions for the vertical calibration procedure. Refer to Figure 55.

5 Once the vertical calibration has successfully completed, click the **Start Skew Cal...** button in the **Skew Calibration** area and follow the on-screen instructions for skew calibration. Refer to Figure 55.

Figure 55 Probe Calibration dialog

At the end of each calibration, the Oscilloscope prompts you if the calibration was or was not successful.

Verifying the Probe Calibration

If you have successfully calibrated the probe, it is not necessary to perform this verification. However, if you want to verify that the probe was properly calibrated, the following procedure will help you verify the calibration.

The calibration procedure requires the following parts:

- BNC (male) to SMA (male) adapter
- SMA (male) to BNC (female) adapter
- BNC (male) to BNC (male) 12 inch cable such as the Keysight 8120-1838
- Keysight 54855-61620 calibration cable (Infiniium Oscilloscopes with bandwidths of 6 GHz and greater only)
- Keysight 54855-67604 precision 3.5 mm adapters (Infiniium Oscilloscopes with bandwidths of 6 GHz and greater only)
- Deskew fixture

For the following procedure, refer to Figure 56.

1. Connect BNC (male) to SMA (male) adapter to the deskew fixture on the connector closest to the yellow pincher.
2. Connect the SMA (male) to BNC (female) to the connector farthest from the yellow pincher.
3. Connect the BNC (male) to BNC (male) cable to the BNC connector on the deskew fixture to one of the unused Oscilloscope Channels. For Infiniium Oscilloscopes with bandwidths of 6 GHz and greater, use the 54855-61620 calibration cable and the two 54855-64604 precision 3.5 mm adapters.
4. Connect the BNC side of the deskew fixture to the Aux Out (or Cal Out) BNC of the Infiniium Oscilloscope.
5. Connect the probe to an Oscilloscope Channel.
6. To minimize the wear and tear on the probe head, it should be placed on a support to relieve the strain on the probe head cables.
7. Push down on the back side of the yellow pincher. Insert the probe head resistor lead underneath the center of the yellow pincher and over the center conductor of the deskew fixture. The negative probe head resistor lead or ground lead must be underneath the yellow pincher and over one of the outside copper conductors (ground) of the deskew fixture. Make sure that the probe head is approximately perpendicular to the deskew fixture.
8. Release the yellow pincher.
9. On the Oscilloscope, press the autoscale button on the front panel.
10. Select **Setup** menu and choose the Channel connected to the BNC cable from the pull-down menu.
11. Select the **Probe Cal...** button.
12. Select the **Calibrated Skew** radio button.
13. Click the **Start Skew Cal...** button and follow the on-screen instructions.
14. Once the skew calibration is completed, close all dialog boxes.

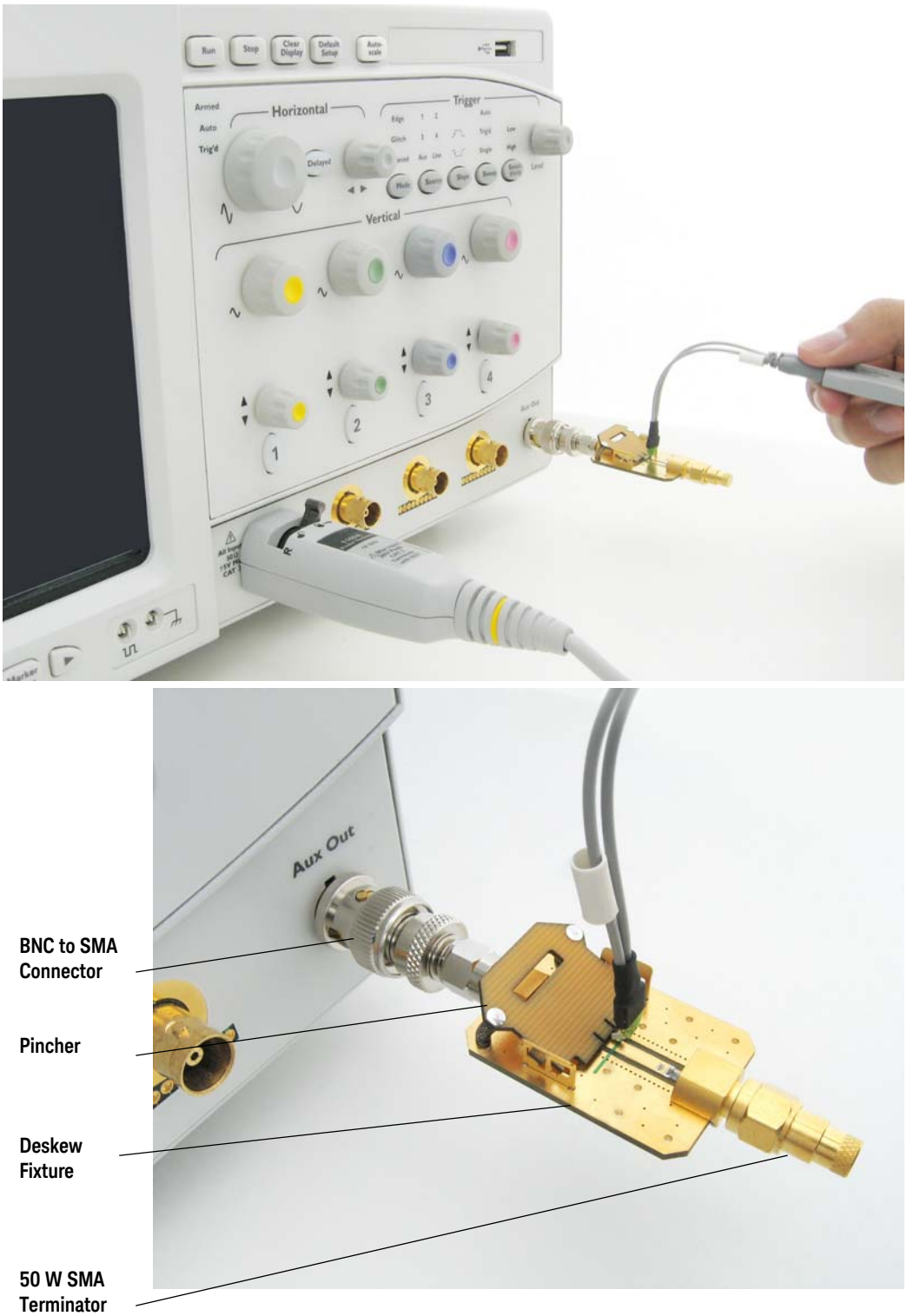

Figure 56 Example of Probe Calibration Verification Connection

15 Set the vertical scale for the displayed channels to 100 mV/div.

16 Set the horizontal range to 1.00 ns/div.

17 Set the horizontal position to approximately 3 ns.

18 Change the vertical position knobs of both channels until the waveforms overlap each other.

19 Click the **Setup** menu and choose **Acquisition...**.

20 In the **Acquisition** dialog box, select **Enabled** for **Averaging**. When you close the dialog box, you should see waveforms similar to that in Figure 57.

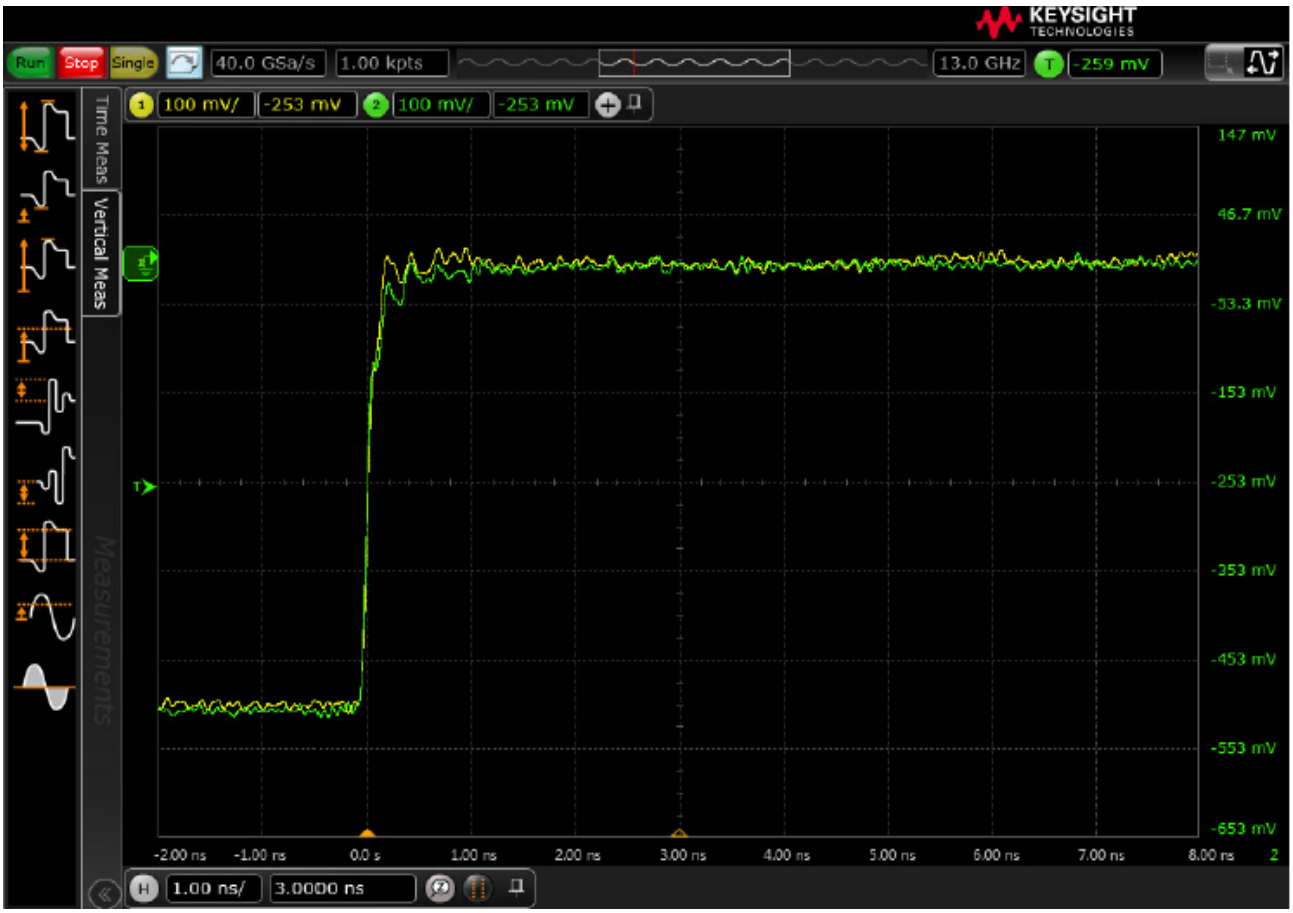

Figure 57 Example of a Calibration Probe Waveform

NOTE

Each probe is calibrated with the Oscilloscope Channel to which it is connected. Do not switch probes between Channels or other Oscilloscopes, or it will be necessary to calibrate them again. It is recommended that the probes be labeled with the Channel on which they were calibrated.

Index