PCI Express 3.0 Signal Quality testing for Add-in Cards using Tektronix MSO/DPO/DSA70K (12.5Ghz or Higher) Series Real Time Oscilloscopes

Version 0.9

Index

Revision History

Version	Date	Summary of Change(s)	Contributors
0.9	5/30/2012	Initial Draft	Sarah Boen, Steve Bright, Kalev Sepp, Jit Lim

1. Overview

This document contains the procedure for testing Generation-3 PCI Express add-in cards that support 8.0 GT/s using Tektronix MSO/DSA/DPO70K(12.5Ghz or higher) real time oscilloscopes.

This document provides the details on

1. Using revision 3.0 Compliance Base Board (CBB) test fixture to gather add-in-card waveforms for the data lanes at 2.5 GT/s, 5.0 GT/s, and 8 GT/s.
2. Analyzing the data to test the add-in-card against the 3.0 PCI-SIG Card Electro-mechanical (CEM) specification electrical requirements using SIGTEST.

2. Hardware Requirements

2.1 Oscilloscope:

This document is developed using Tektronix digital storage oscilloscopes, Model# MSO/DSA/DPO70K (12.5GHz or higher)/ and 50GS/s sample rate.

Probes/Cables:

One pair of matched SMA cables: Matched 50 Ohm Coaxial SMA cables (Tek P/N 174-4944-xx) with (2) right angle SMA to SMP adapter (Part Number: 71L-19K2-32K1-00101D from Rosenberger).

One pair of SMP to SMP Cables for toggling through the compliance patterns.

Note: If using the AFG3K for DUT toggle use SMP to SMP right angle adapters (Part Number: 71L-19K2-32K1-00101D from Rosenberger) and SMA to BNC Cables.

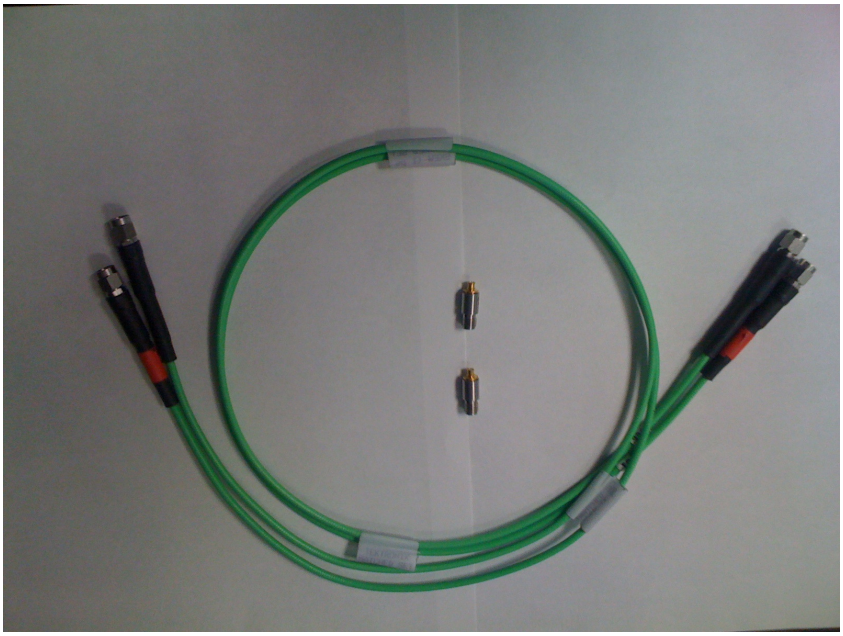

Figure 1. Matched pair SMA cable and SMP to SMA Adapters.

2.2 Termination Load:

SMP, Female, Straight, 50 Ohms (Part Number: MMTL4991 from Fairview Microwave Inc)

Figure 2. 50 Ohm Termination Load

When data signal lanes are terminated using 50 Ohm loads, it drives the particular lane into compliance mode.

Note: All lanes except the lane under test must be terminated with 50 Ohm terminations for all testing described in this document.

2.3 Adapters:

2 SMA (Male) - SMA (Male) Adapters, 2 SMA (Female)-SMP (Male) Adapters, SMA Power splitter and BNC-SMA Adapter for cable de-skewing.

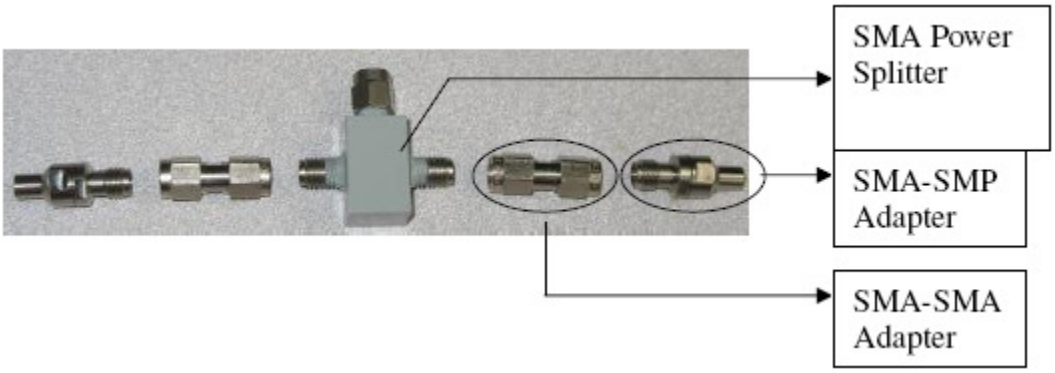

Figure 3. Miscellaneous components required for cable de-skew etc

2.4 SMA TekConnects:

2 TCA-SMA Adapters or 2 TCA-292MM Adapters to connect SMA end of cables to the scope.

Figure 4. TCA-SMA Adapter and TCA-292MM Adapter

2.5 Revision 3.0 Compliance Base Board (CBB):

Compliance fixtures can be ordered from PCISIG at:
http://www.pcisig.com/specifications/order_form

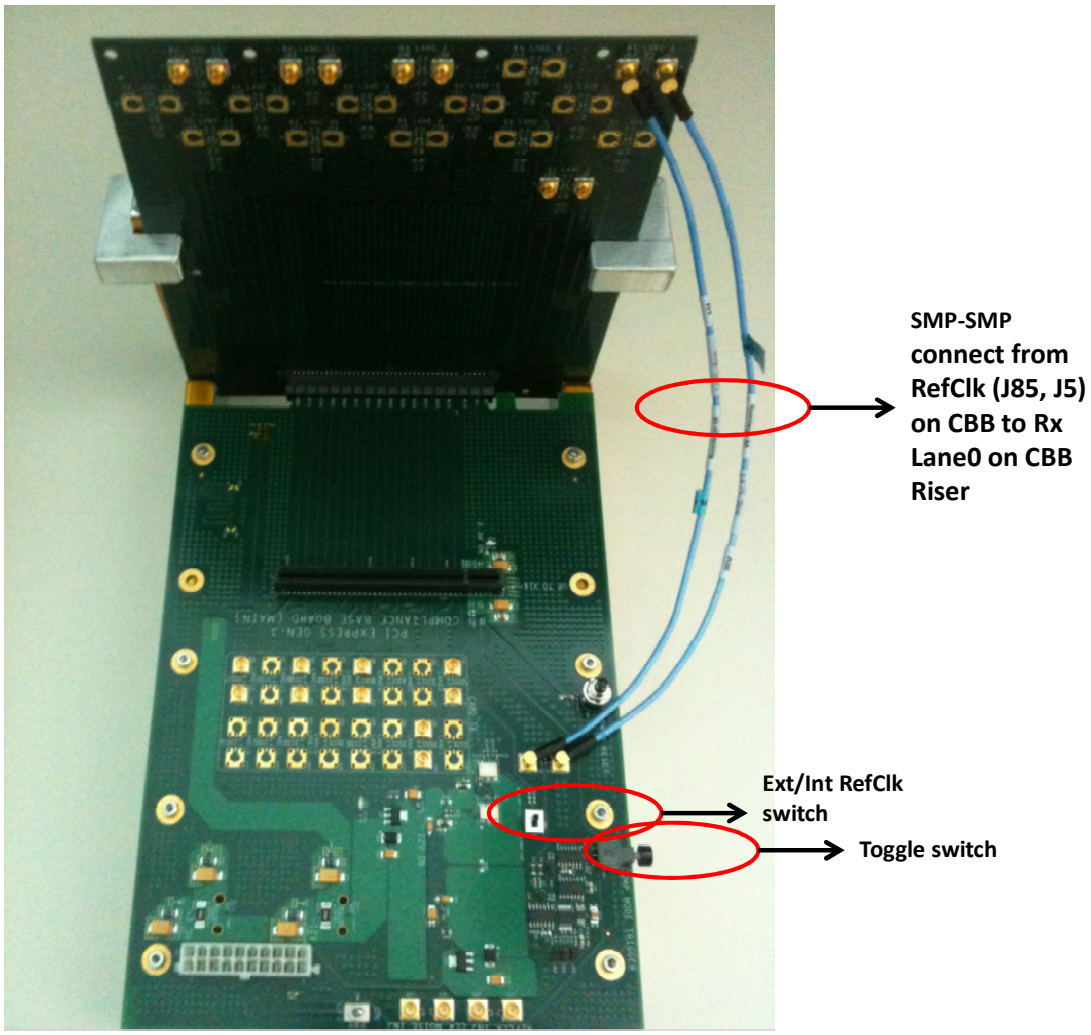

Figure 5. Gen-3 PCIE Compliance Base Board and Riser

2.6 ATX Power Supply:

ATX power supply with hard drive as load.

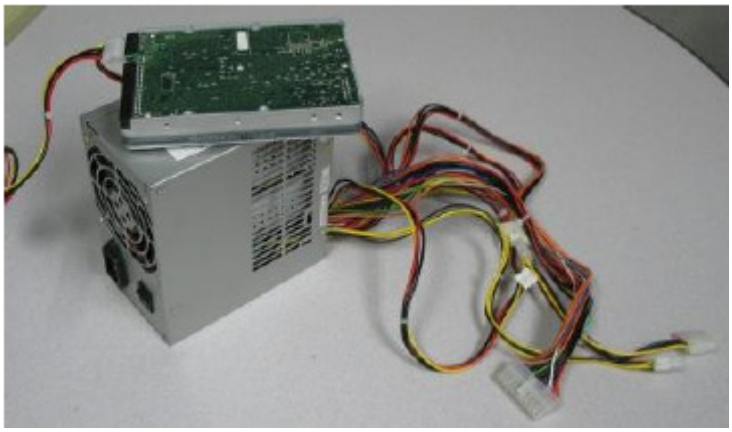

Figure 6. ATX Power Supply for CBB

2.7 Test PC Computer:

1.5 GHz or faster processor with 1GB or more memory, loaded with Microsoft Windows XP Professional operating system or later.

3. SIGTEST Software Tool Requirement

SIGTEST post processing analysis tool available to Serial Enabling Group (SEG) members can be downloaded from www.pcisig.org

4. Test Setup

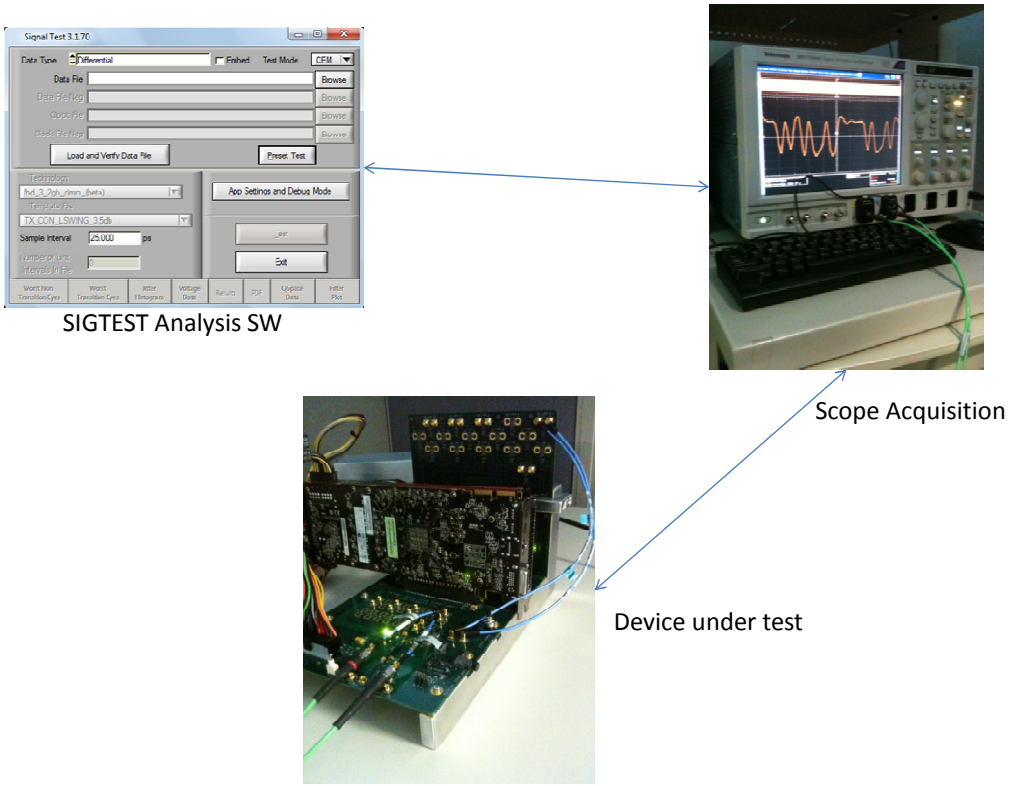

Figure 7. Connection Example

Note: Post-processing tool Sigtest can also be run on the scope.

The procedure described in this document assumes the following toggle order:

Default	2.5GT/s Compliance Pattern
First Toggle	5GT/s (-3.5dB) mode
Second Toggle	5GT/s (-6dB) mode
Third Toggle	8GT/s (Preset 1) mode

Fourth Toggle	8GT/s(Preset 2) mode
Fifth Toggle	8GT/s(Preset 3) mode
Sixth Toggle	8GT/s(Preset 4) mode
Seventh Toggle	8GT/s(Preset 5) mode
Eighth Toggle	8GT/s(Preset 6) mode
Ninth Toggle	8GT/s(Preset 7) mode
Tenth Toggle	8GT/s(Preset 8) mode
Eleventh Toggle	8GT/s(Preset 9) mode
Twelfth Toggle	8GT/s(Preset 10) mode

If this is not the toggle order for the add-in-card under test, then the procedure should be modified accordingly.

1. Perform scope calibration and cable de-skew as described in Appendix A.
2. Connect the SMA ends of two SMA-SMP cables to channels 1 and 2 (Through SMA TekConnects shown in Figure 4). These channels will be used for capturing signaling from a data lane.
3. Make the SMA connections tight using a torque-wrench. (7-10 in lbs)

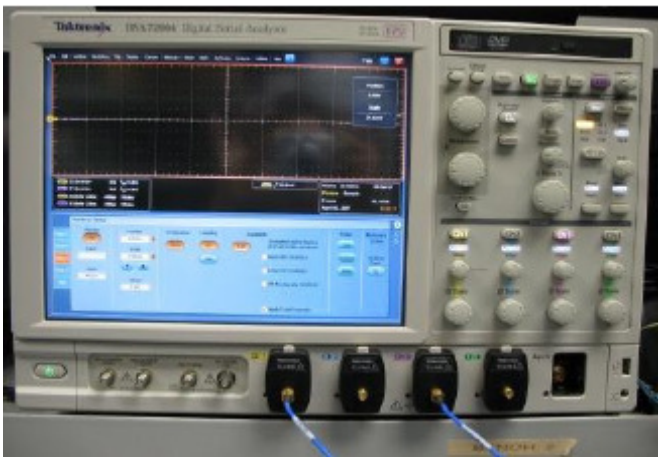

Figure 8. Setup for Add-in Card Measurement

4. Make sure that the hard-drive is connected to the ATX power supply as load. Connect the 2x10 connector of ATX power supply into the power connector on CBB. Make sure that the CBB power on switch is in off state.
5. Connect the SMP to SMP cable from RX Lane 0 to J85 and J5 on the CBB in order to use the 100MHz clock on the CBB to toggle the DUT. Make sure that the switch is turned to Board Ref Clk. See Appendix A for AFG configuration for DUT toggle.
6. Insert Add-in-card into the PCI Express connector on the CBB.
7. Make sure that all the TX data lanes on CBB except the lane being tested are terminated with 50 Ohm terminations.
8. Insert the SMP ends of cables from Ch1 and Ch2 into the data TX lane zero pair on the CBB. **Please make sure that the SMP ends of the cables are fully inserted into the SMP connectors on the fixture.**

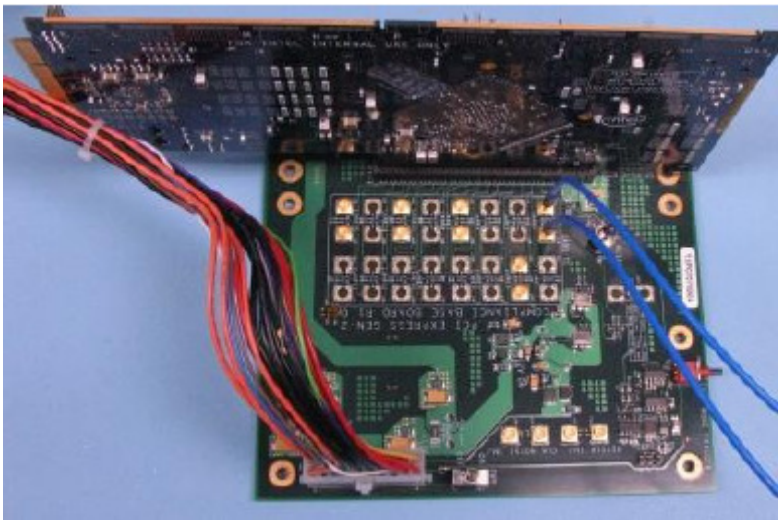

Figure 9. CBB lane 0 connected to SMP end of cables

9. Turn on the ATX and CBB power.

5. Scope Configuration Gen 1

1. Click on the channel buttons Ch1 and Ch2 (Shown in Figure 16 and Figure 17). Turn off Ch1 and Ch2.
2. Press the Run/Stop button on the front panel of the scope
3. Under the Trigger section on the front panel of the scope select the Edge Button and select the Trigger source as Ch1
4. For best accuracy, the amplitude of Ch1 and Ch2 should be adjusted so that both waveforms are around full scale. This takes advantage of full range of A/D converters in the oscilloscope. If the amplitude is greater than 10 divisions, clipping will occur and measurement results will not be valid.

Figure 10. Single Ended Data full scale without clipping

Adjust the scale for Ch1 and Ch2 channels (Using the Vert->Vertical Setup menu option) so that the waveforms come as close as possible to the top and bottom edges of the display without leaving the display. Also make sure that position, offset is set to zero for both channels. Refer to Figure 11 and Figure 12.

Note: The Vert->Vertical Setup menu option allows finer adjustments than the vertical scale knobs and must be used for optimal adjustments.

5. Set function Math1= Ch1-Ch2

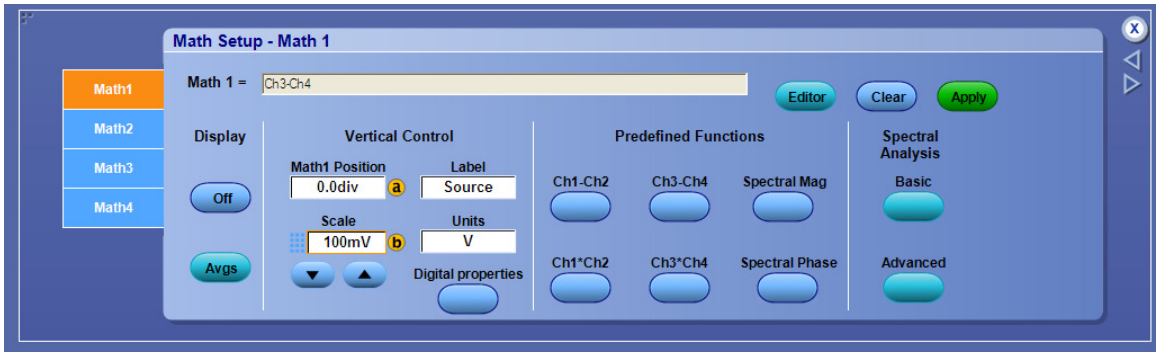

Figure 11. Math Function set-up to get differential signal (MSO/DSA72004 Scope)

6. Make sure that the position is zero for Math1 function as shown in Figure 14 and Figure 15.

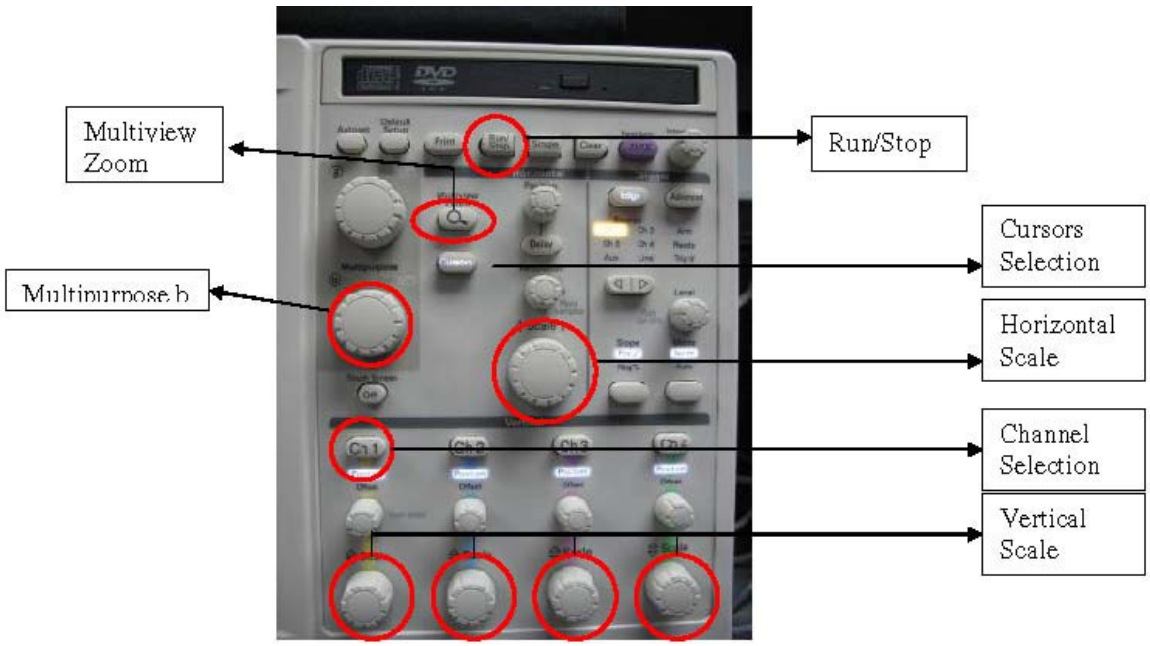

Figure 12. MSO/DSA72004 Scope Front Panel

7. Make sure that only Math1 waveform is visible on scope screen and that all the channels are turned off.
8. Stop the acquisition using the "Run/Stop" button on the front panel.
9. Make sure that the pattern on the scope is Compliance pattern as specified by PCIE Base Specification 3.0. By default the compliance pattern is sent at 2.5GT/s. Use the cursors button (Shown in Figure 16 and Figure 17) to place cursors on a pair of adjacent crossover locations that are closest together to make sure that the unit-interval (UI) is around 400ps (for 2.5 GT/s).
   Note: If the UI is not around 400ps then click Run/Stop button to start the acquisition and press the toggle button on CBB till the UI is around 400ps.

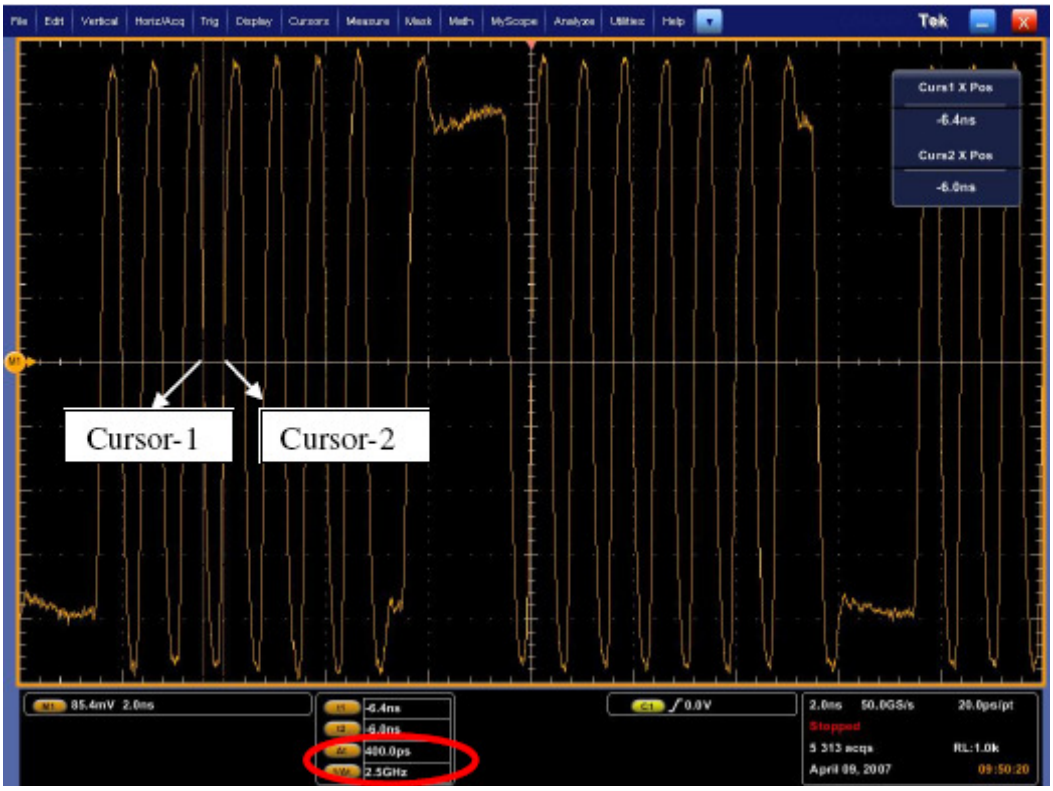

Figure 13. CMM at 2.5GT/s

10. Start the acquisition using the "Run/Stop" button on the front panel.
    - Measurements at 2.5GT/s:
        i. For MSO/DPO/DSA72004 scope, adjust time base (Horizontal Scale) so that Sampling Rate is 25GS/s which is equivalent to 40ps sampling interval.

Select the Menu “Horz/Acq->Horizontal/Acquisition Setup” from main menu.

Set the “Record Length” to 20 Million points.

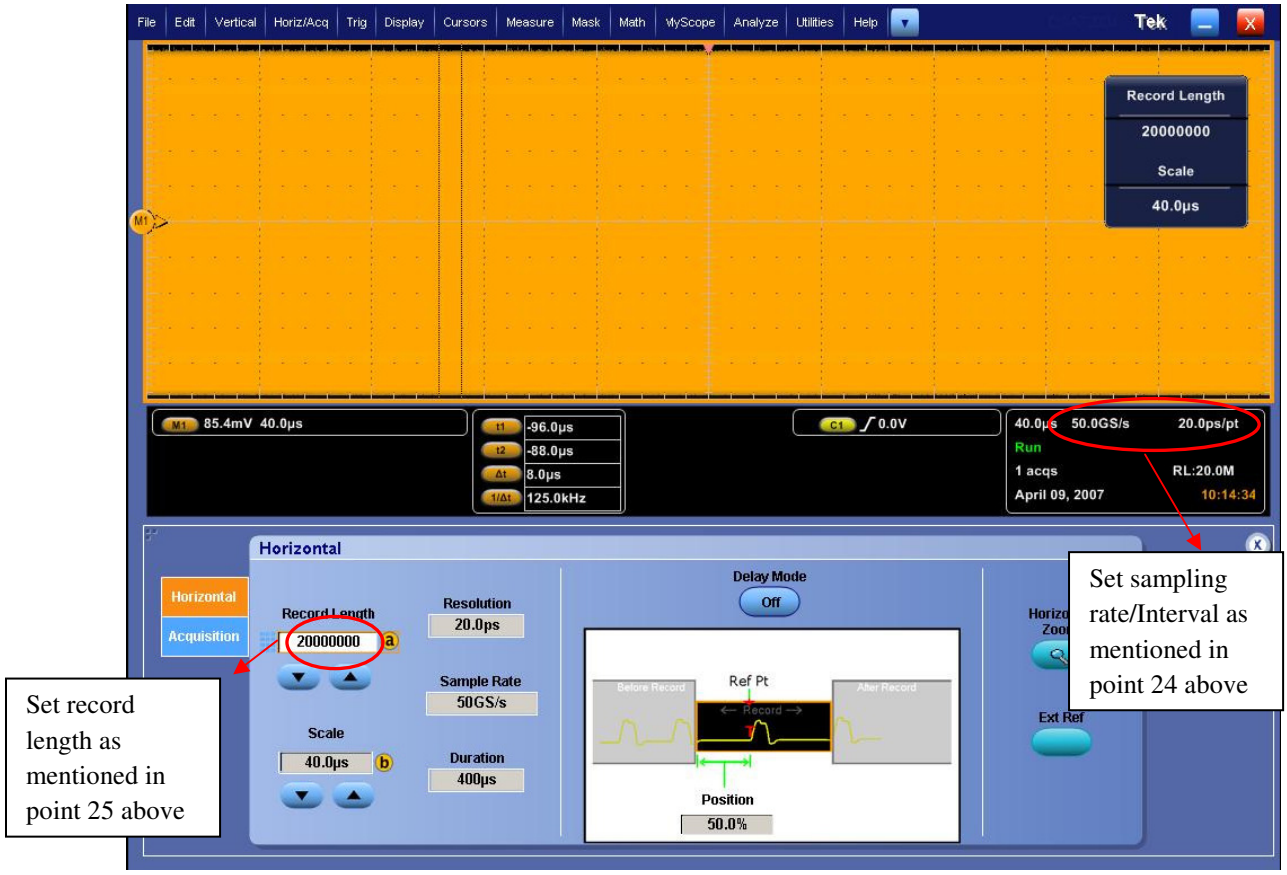

Figure 14. Scope settings for waveform capture

11. Click the Multiview Zoom button on scope front panel, use Multipurpose b knob (Refer Figure 16 and Figure 17) to increase the Zoom factor to a value where you can see the zoomed waveform clearly. Refer to Figure 21.

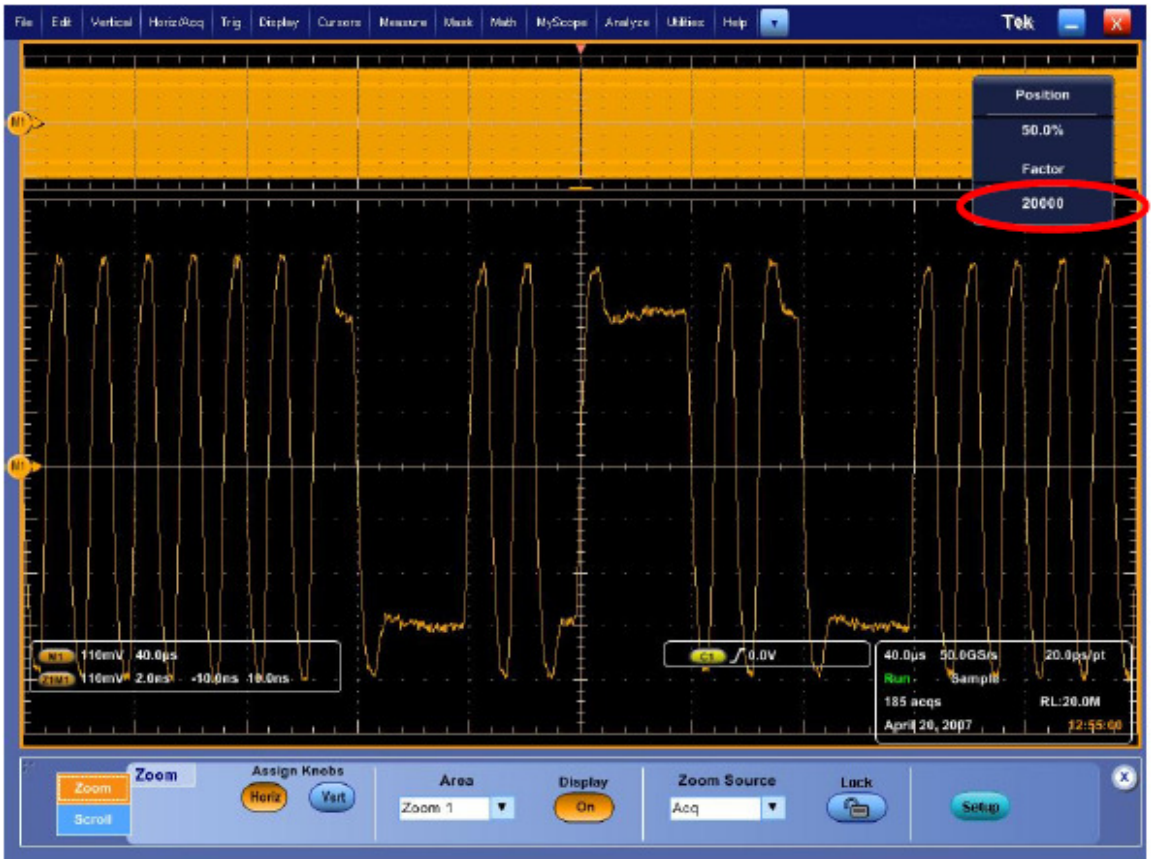

Figure 15. Adjust the zoom factor

12. Wait till scope updates the display.
13. Stop the acquisition using the “Run/Stop” button on the front panel.
14. From Menu select, File->Save As-> Waveform.

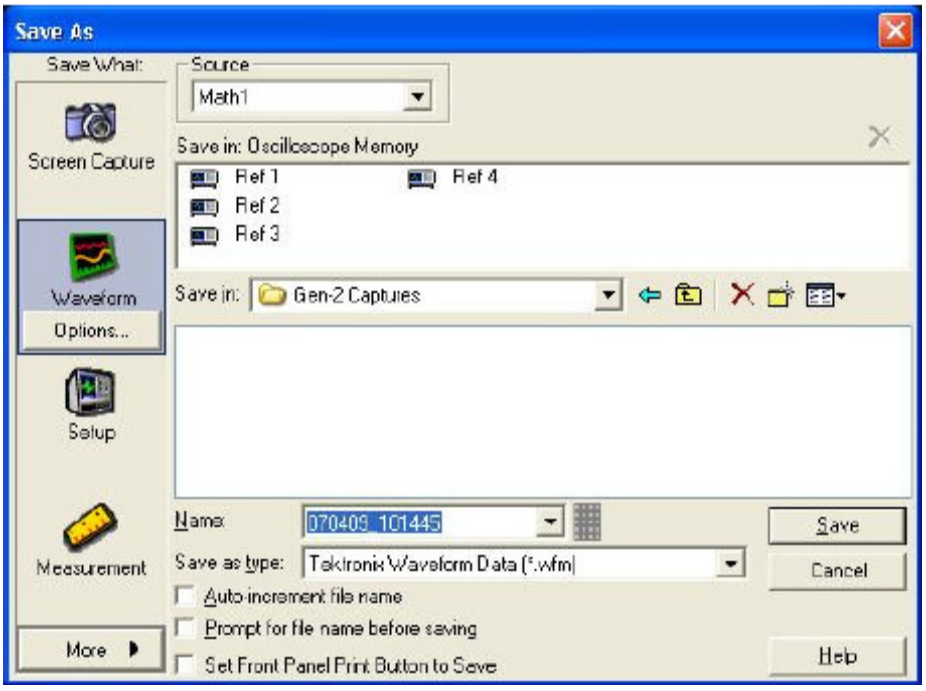

Figure 16. Saving Data waveform

15. Select source as “Math1”.
16. Select file storage path in “Save in” option.
17. Write name of the file to be saved in “Name”.
18. Save the waveform file as .wfm.
19. Click on Run/Stop button to start the acquisition.
20. Move the SMP cable pair ends to next lanes to be tested and repeat steps 28-34.

6. Scope Configuration Gen 2

1. After all the waveforms have been captured at Gen-1 speed, press the compliance mode toggle button on CBB (Shown in Figure 5) to change the compliance mode to: Gen-2 /-3.5db.
2. Click on Run/Stop button to stop the acquisition.
3. Use the cursors button (Shown in Figure 16 and Figure 17) to place cursors on a pair of adjacent crossover locations that are closest together to make sure that the unit-interval (UI) is around 200ps (for 5 GT/s).
   Note: If the UI is not around 200ps then press the toggle button on CLB till the UI is around 200ps. Refer Figure 23.
4. Select Ch1 and Ch2.
5. Click on Run/Stop button to start the acquisition.
6. Adjust the scale for Ch1 and Ch2 channels (Using the Vert->Vertical Setup menu option) so that the waveforms come as close as possible to the top and bottom edges of the display without leaving the display. Make sure that the scale for Ch1 and Ch2 is adjusted to the same value and position, offset is set to zero for both channels
7. Deselect Ch1, Ch2 and make sure that only Math1 is visible on scope screen.
8. Select the Menu “Horz/Acq->Horizontal/Acquisition Setup” from main menu and set the “Record Length” to 10 Million points.
9. Repeat steps 28-34 on all data lanes to be tested at 5GT/s -3.5dB de-emphasis mode.

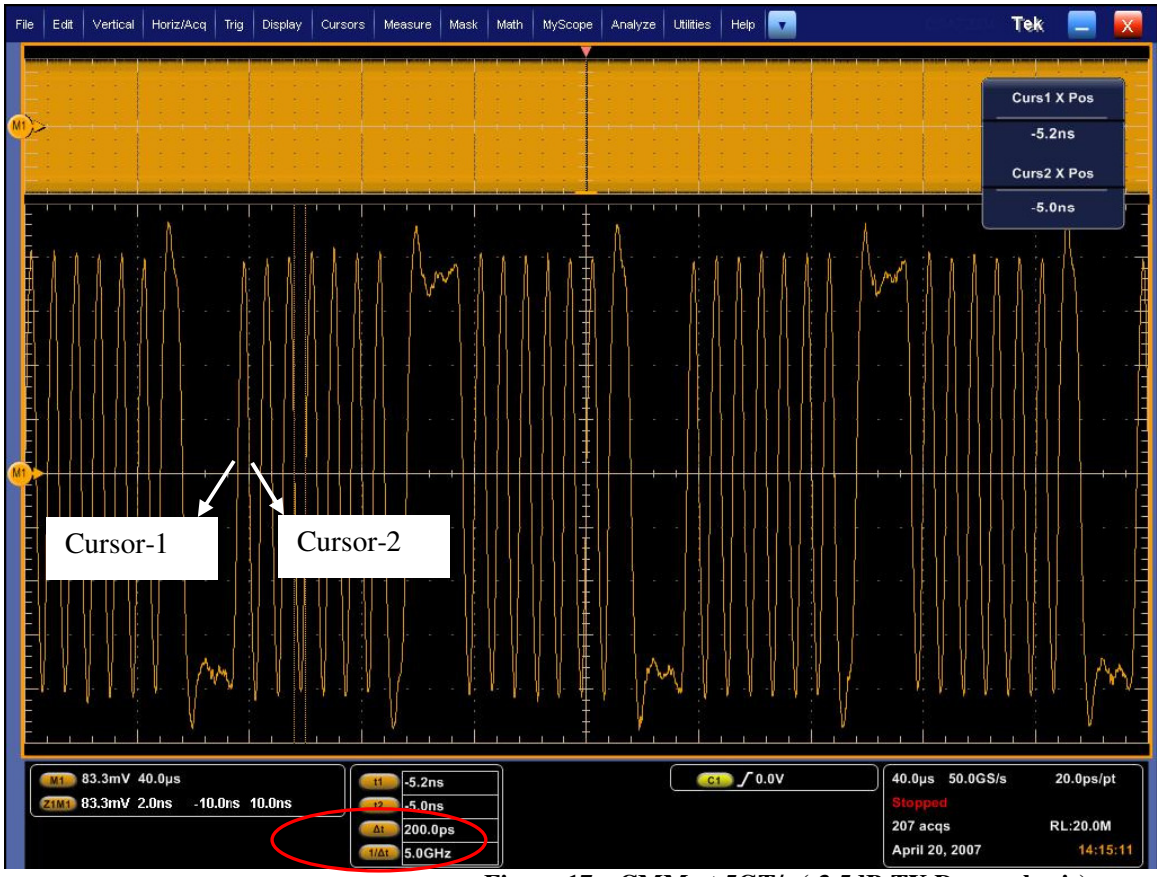

Figure 17. CMM at 5GT/s (-3.5dB TX De-emphasis)

10. Click Run/Stop to start the acquisition.
11. Press the "Toggle Switch" on the CBB one more time to change mode to Gen-2/ -6 dB.
12. Use the cursors button (Shown in Figure 16 and Figure 17) to place cursors on a pair of adjacent crossover locations that are closest together to make sure that the unit-interval (UI) is around 200ps (for 5 GT/s).
    Note: If the UI is not around 200ps then press the toggle button on CLB till the UI is around 200ps. Refer to Figure 24.
13. Select Ch1 and Ch2.
14. Adjust the scale for Ch1 and Ch2 channels (Using the Vert->Vertical Setup menu option) so that the waveforms come as close as possible to the top and bottom edges of the display without leaving the display. Make sure that the scale for Ch1 and Ch2 is adjusted to the same value and position, offset is set to zero for both channels
15. Deselect Ch1, Ch2 and make sure that only Math1 is visible on scope screen.
16. Select the Menu "Horz/Acq->Horizontal/Acquisition Setup" from main menu and For Gen-2 5GT/s captures, set the "Record Length" to 10 Million points.
17. Repeat steps 28-34 on all data lanes to be tested at 5GT/s -6 dB de-emphasis mode.

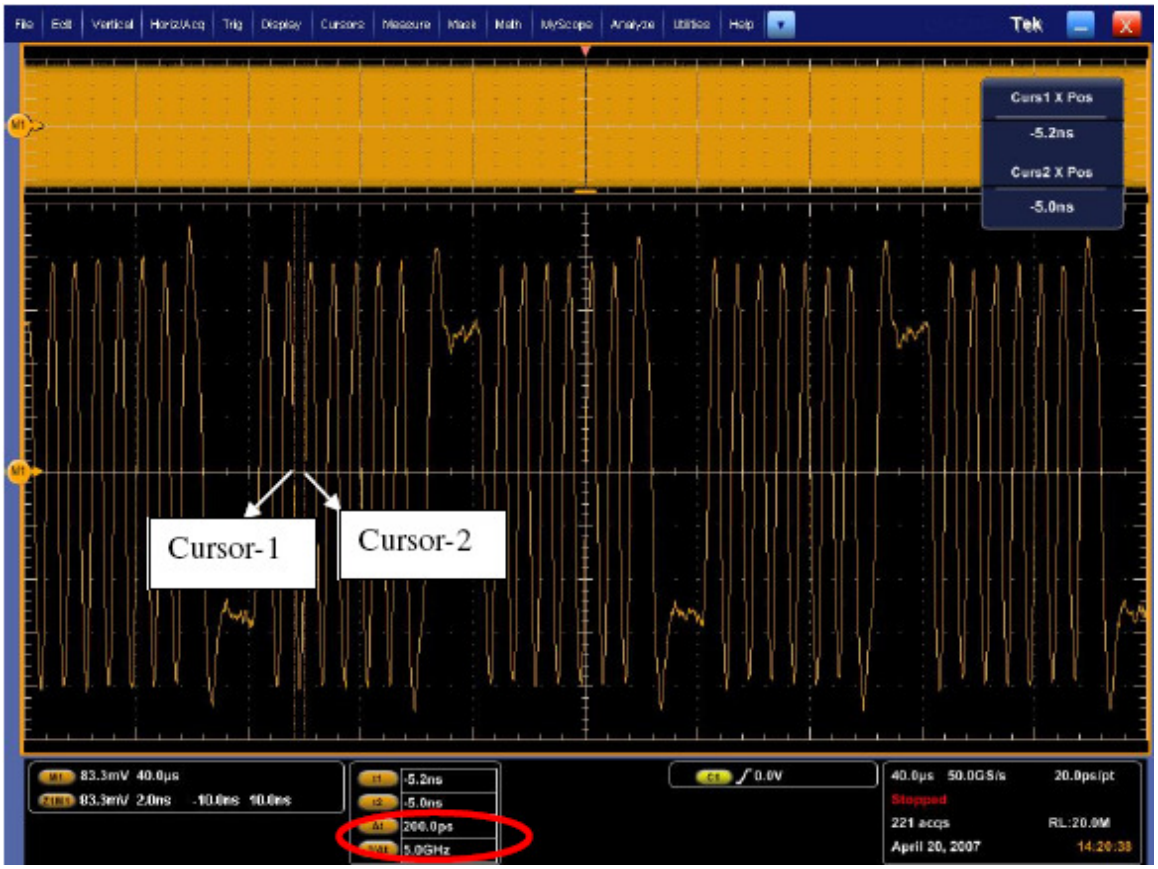

Figure 18. CMM at 5GT/s (-6dB TX De-emphasis)

7. Scope Configuration Gen 3

1. After all the waveforms have been captured at Gen-1 and Gen-2 speeds, press the compliance mode toggle button on CBB to change the compliance mode to: Gen-3.
2. Click on the channel buttons Ch1 and Ch2.
3. Under the Trigger section on the front panel of the scope select the Edge Button and select the Trigger source as Ch1.
4. For best accuracy, the amplitude of Ch1 and Ch2 should be adjusted so that both waveforms are around full scale. This takes advantage of full range of A/D converters in the oscilloscope. If the amplitude is greater than 10 divisions, clipping will occur and measurement results will not be valid.
    - NOTE: When changing presets at 8GT/s the waveform amplitude will change. Make sure to check for clipping between the DUT toggle states. It is also recommended to check for clipping around the 64 1s and 64 0s that are in the compliance pattern at 8GT/s.
    - In order to see the 64 1s and 0s pattern set up a width trigger on the scope as shown in Figure X

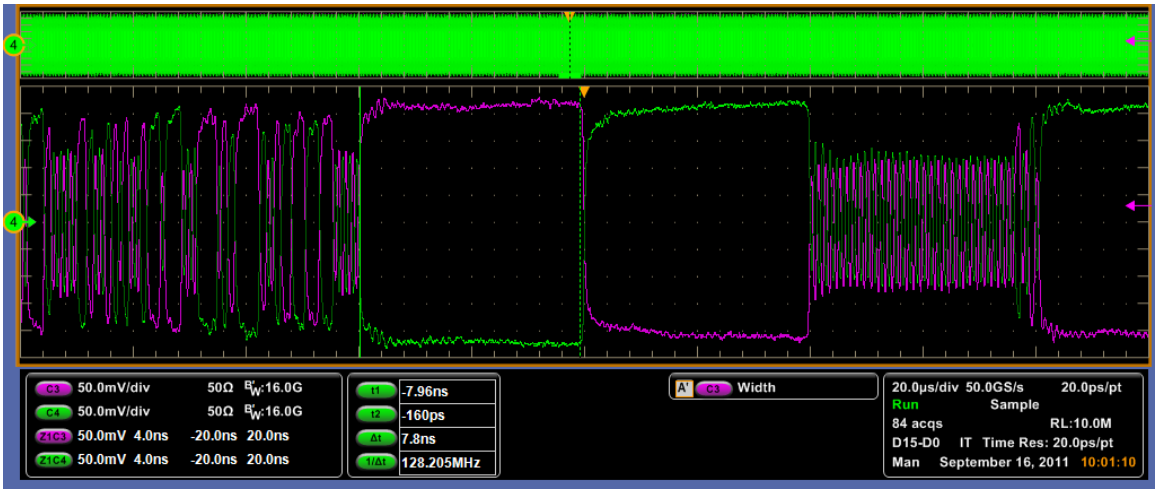

Figure 19. Single Ended Data scale adjusted to full scale without any clipping Gen 3

Adjust the scale for Ch1 and Ch2 channels (Using the Vert->Vertical Setup menu option) so that the waveforms come as close as possible to the top and bottom edges of the display without leaving the display. Also make sure that position, offset is set to zero for both channels. Refer to Figure 11 and Figure 12.

Note: The Vert->Vertical Setup menu option allows finer adjustments than the vertical scale knobs and must be used for optimal adjustments.

5. De-select single ended data channels Ch1 and Ch2

6. Click on, Math-> Math Setup
7. Set function Math1= Ch1-Ch2
8. Make sure that the position is zero for Math1.

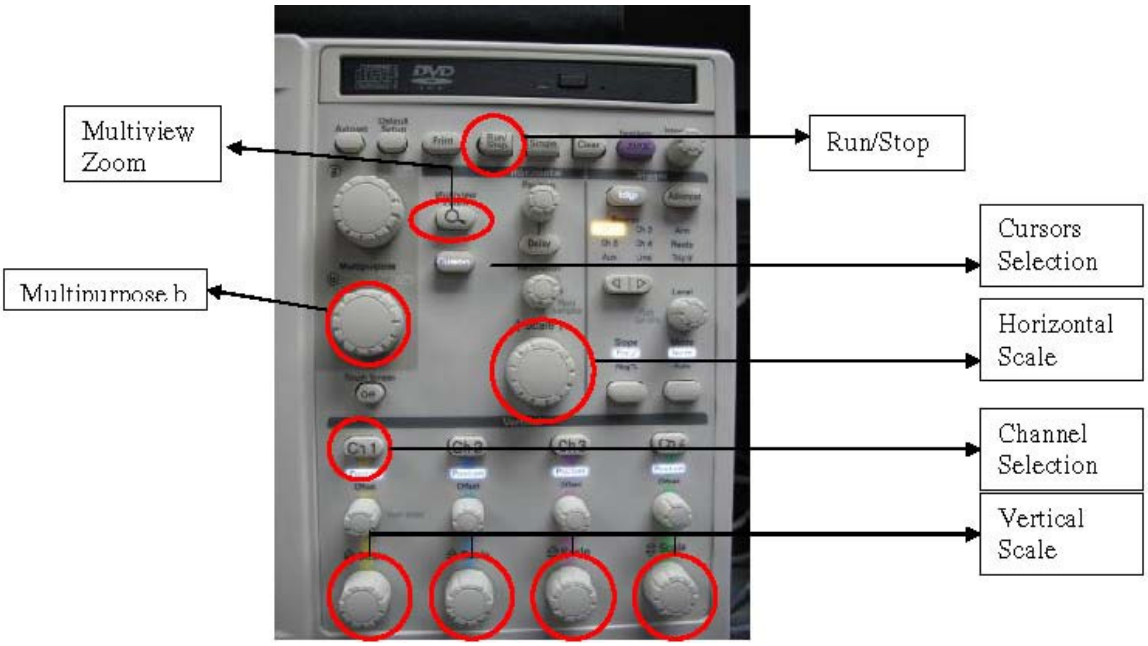

Figure 20. MSO/DSA72004 Scope Front Panel

9. Make sure that only Math1 waveform is visible on scope screen and that all the channels are turned off.
10. Start the acquisition using the "Run/Stop" button on the front panel.
11. Select the Menu "Horz/Acq->Horizontal/Acquisition Setup" from main menu
12. For Gen-3 10GT/s captures, set the "Record Length" to 10 Million points.
13. Click the Multiview Zoom button on scope front panel, use Multipurpose b knob to increase the Zoom factor to a value where you can see the zoomed waveform clearly.
14. Place cursors on a pair of adjacent crossover locations that are closest together to make sure that the unit-interval (UI) is around 125ps (for 8 GT/s).
    Note: If the UI is not around 125ps then click Run/Stop button to start the acquisition and press the toggle button on CLB till the UI is around 125ps.

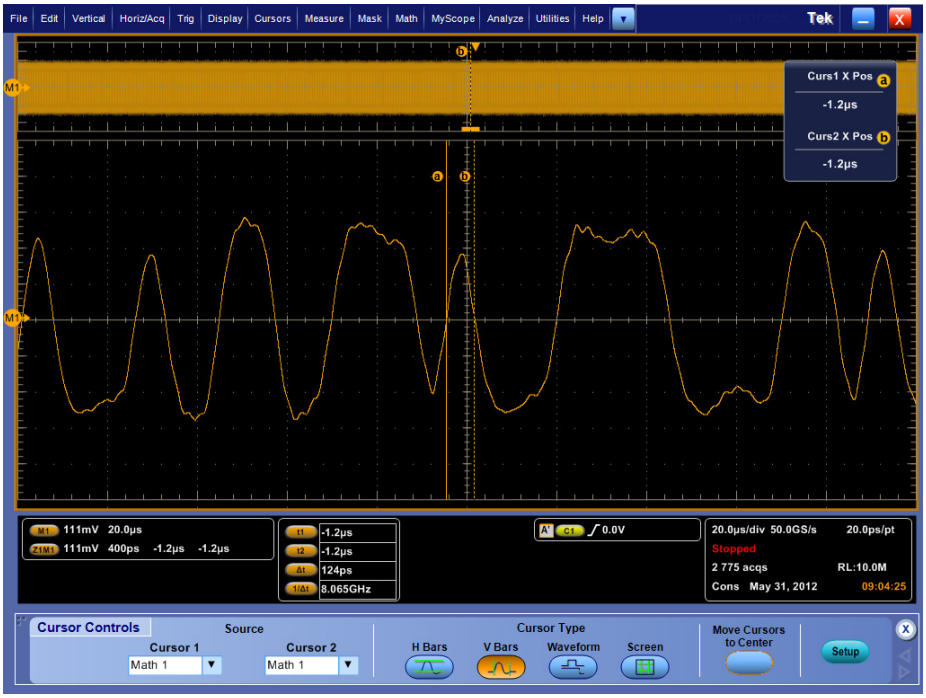

Figure 21. Gen3 Screen Capture

15. Stop the acquisition using the "Run/Stop" button on the front panel.
16. From Menu select, File->Save As-> Waveform.

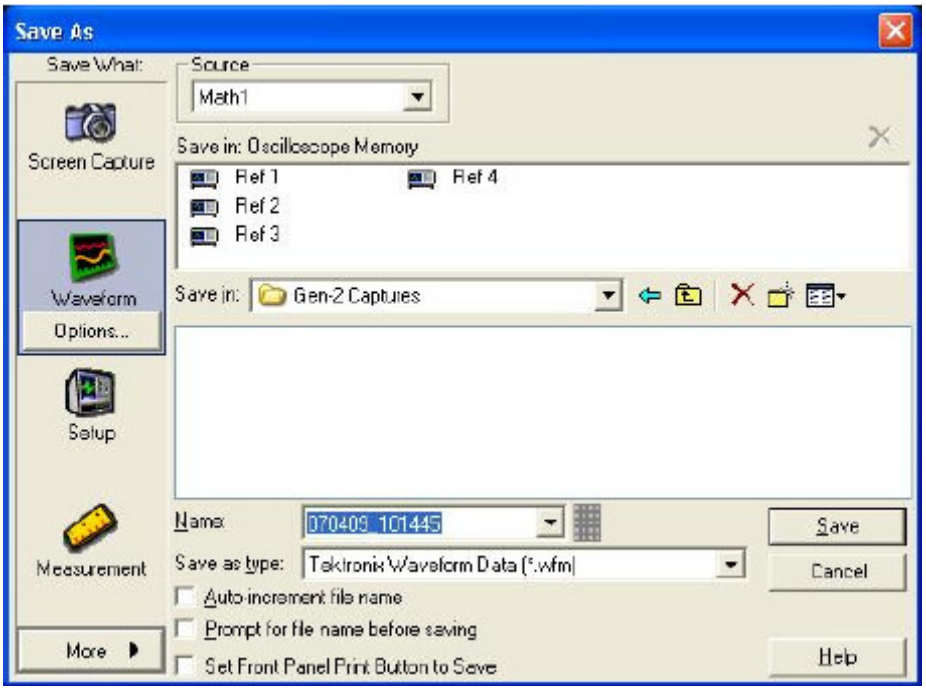

Figure 22. Saving Data waveform

17. Select source as “Math1”.
18. Select file storage path in “Save in” option.
19. Write name of the file to be saved in “Name”.
20. Save the waveform file as .wfm.
21. Click on Run/Stop button to start the acquisition.
22. Push the toggle swtich to test other Gen3 presets or move the SMP cable pair ends to next lanes to be tested.

    NOTE:

    *The June 4, 2012 guidance is to test **Jiiter** for Presets 0, 7, and 8.*

    x1 Cards – Lane 0

    x4 Cards – Lanes 0/4

    x8 Cards - Lanes 0/4/7

    x16 Cards – Lanes 0/4/7/11/15

    *The June 4, 2012 guidance is to test all **Presets** only for Lane 0.*

8. Using SigTest for Gen 1

1. Open the SIGTEST application (Version 3.1.1) installed on Computer
2. Select “Differential” as data type
3. Use the browse button to open the saved 2.5GT/s “*.wfm” differential data file.
4. Click on “Verify Valid Data File”
   Note: When .wfm files are selected the tool automatically updates the sample interval. For all other text based formats like .csv, .txt please enter the sample interval before clicking “Verify Valid Data File”

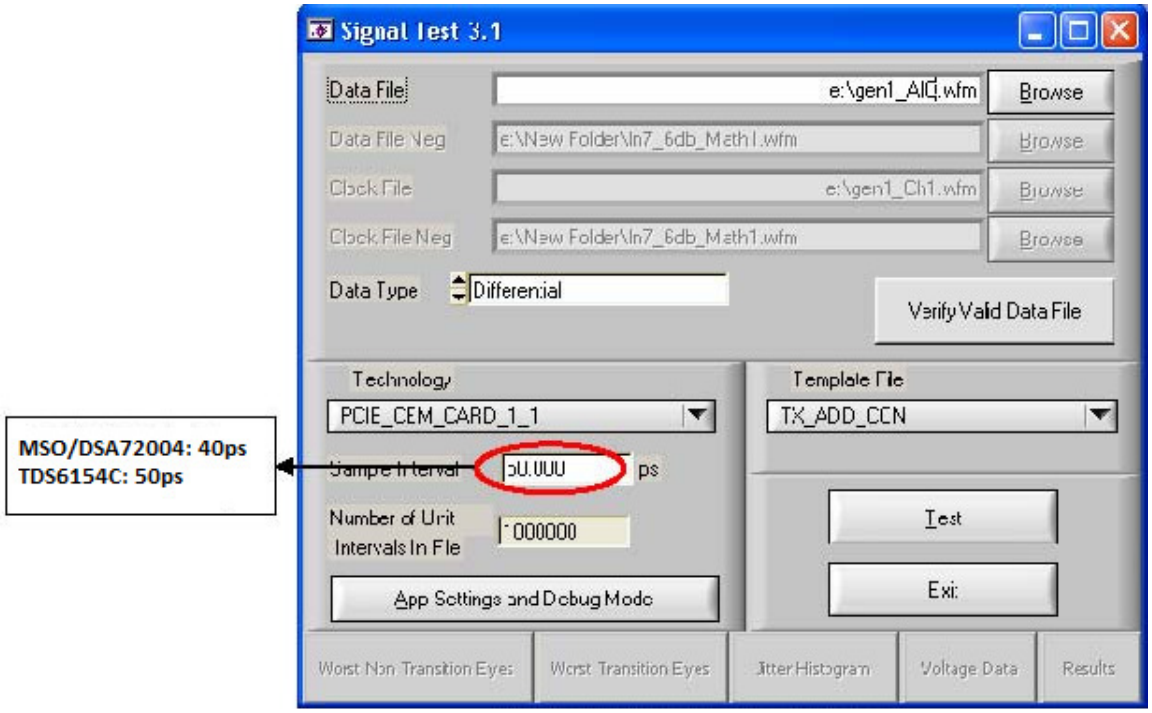

Figure 23. SIGTEST main window

5. Under the “Technology” drop-down select “PCIE_CEM_CARD_1_1” and under the “Template File” drop-down select “TX_ADD_CON”
6. Click on “Test”
7. Window showing test results will pop-up.
8. Repeat above steps for all the 2.5GT/s data files captured.

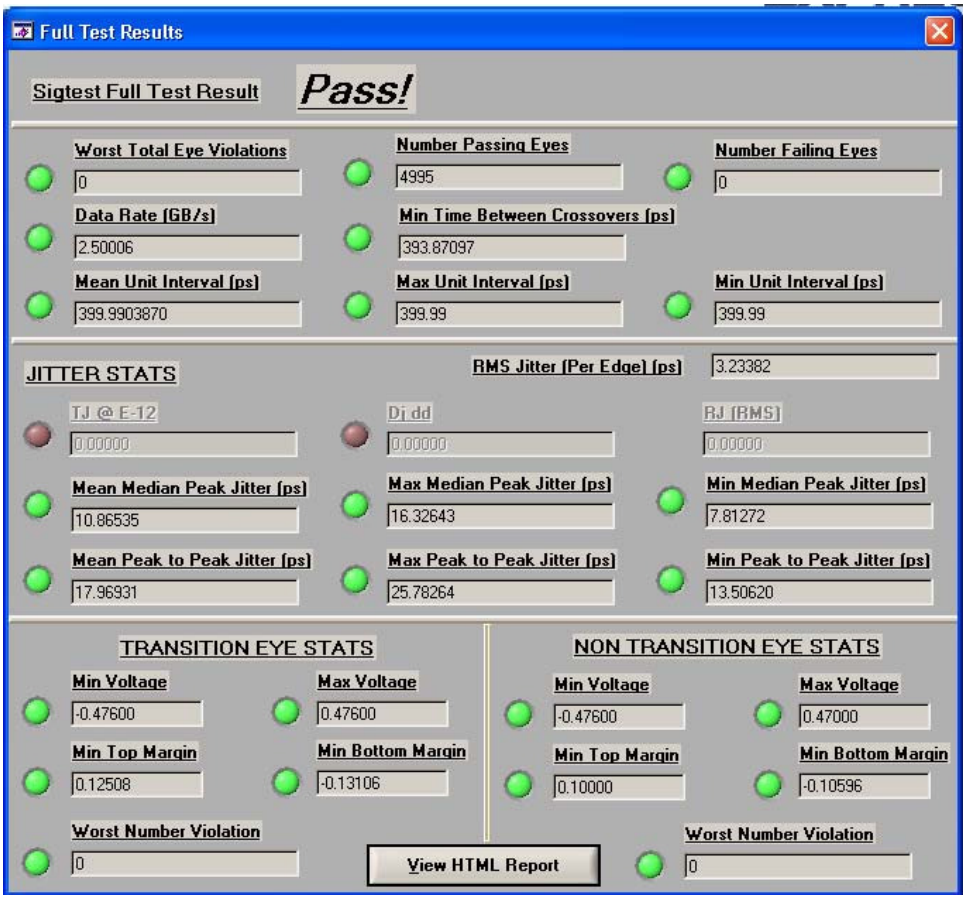

Figure 24. Results window

9. Using SigTest for Gen 2

1. Open the SIGTEST application (Version 3.1.1) installed on Computer
2. Select “Differential” as data type
3. Use the browse button to open the saved 5GT/s 3.5dB “.wfm” data file.
4. Click on “Verify Valid Data File”
   Note: When .wfm files are selected the tool automatically updates the sample interval. For all other text based formats like .csv, .txt please enter the sample interval before clicking “Verify Valid Data File”

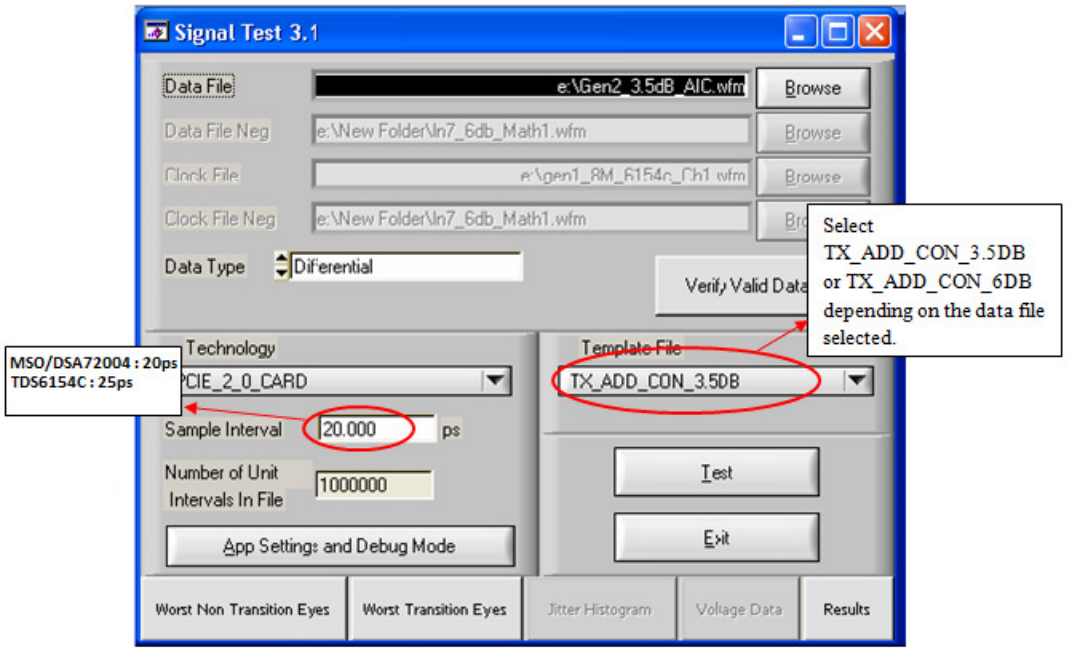

Figure 25. SIGTEST main window

5. Verify that the sample interval is updated to 20ps for MSO/DSA72004 scope where as it is updated to 25ps for TDS6154C.
6. Under the “Technology” drop-down select “PCIE_2_0_CARD”
7. Under the “Template File” drop-down select:
   - “TX_ADD_CON_3.5DB”
8. Click on “Test”
9. Window showing test results will pop-up.
10. Repeat above steps for all the data files captured.
11. Repeat above steps for data files captured at -6dB de-emphasis, by selecting the “Template File”:
    - “TX_ADD_CON_6DB”

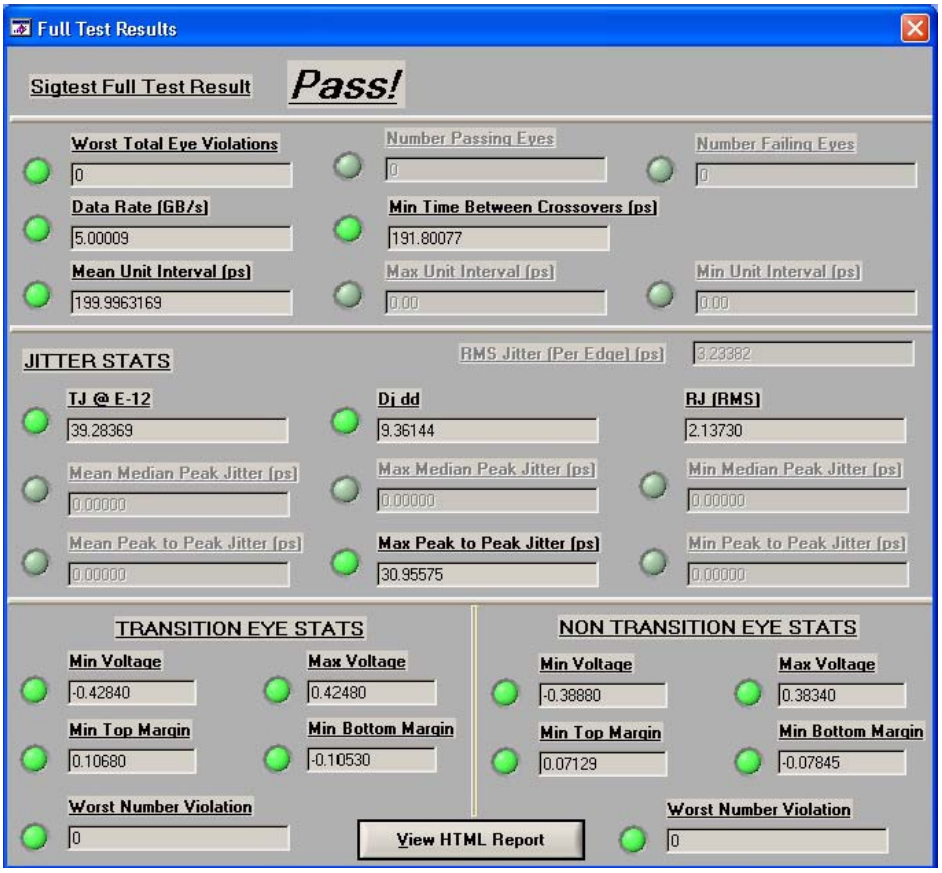

Figure 26. SIGTEST Jitter Results

10. Using SigTest for Gen 3

1. Open the SIGTEST application (Version 3.1.70 or later) installed on Computer or Scope.
2. Select “Differential” as data type.
3. Select the “Embed” checkbox since SigTest will Embed the Compliance Channel
4. Use the browse button to open the saved desired 8GT/s “.wfm” data file.
5. Click on “Load and Verify Data File”
   Note: When .wfm files are selected the tool automatically updates the sample interval. For all other text based formats like .csv, .txt please enter the sample interval before clicking “Verify Valid Data File”

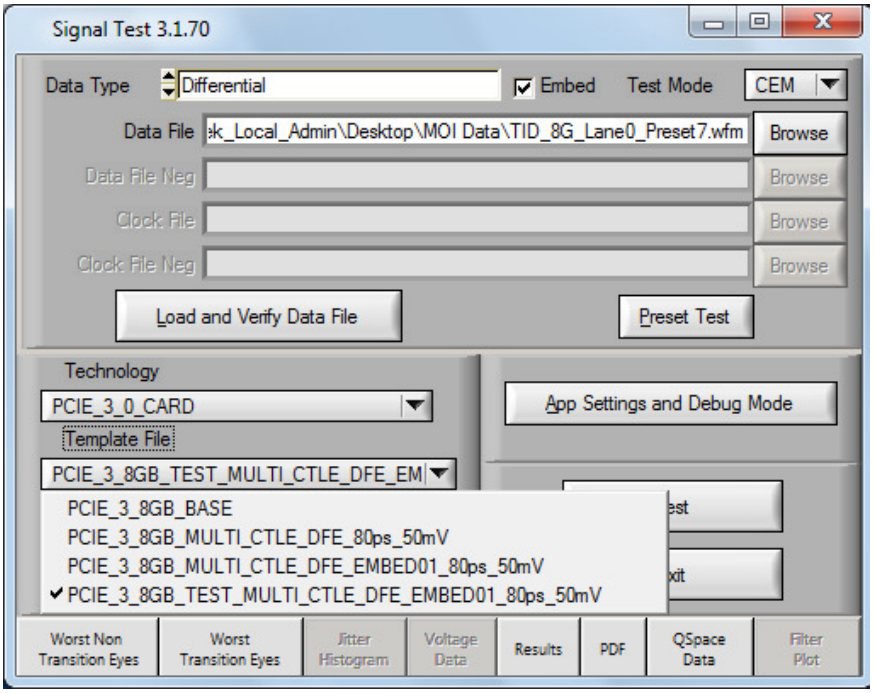

Figure 27. SIGTEST main window

6. Verify that the sample interval is updated to 20ps for MSO/DSA72004
7. Under the “Technology” drop-down select “PCIE_3_0_CARD”
8. Under the “Template File” drop-down select:
   - “PCIE_3_8GB_TEST_MULTI_CTLE_DFE_EMBED01_80ps_50mV” since SigTest is embedding the Compliance Channel
9. Click on “Test”
10. Window showing test results will pop-up.
11. Repeat above steps for all the required pre-sets and lanes.

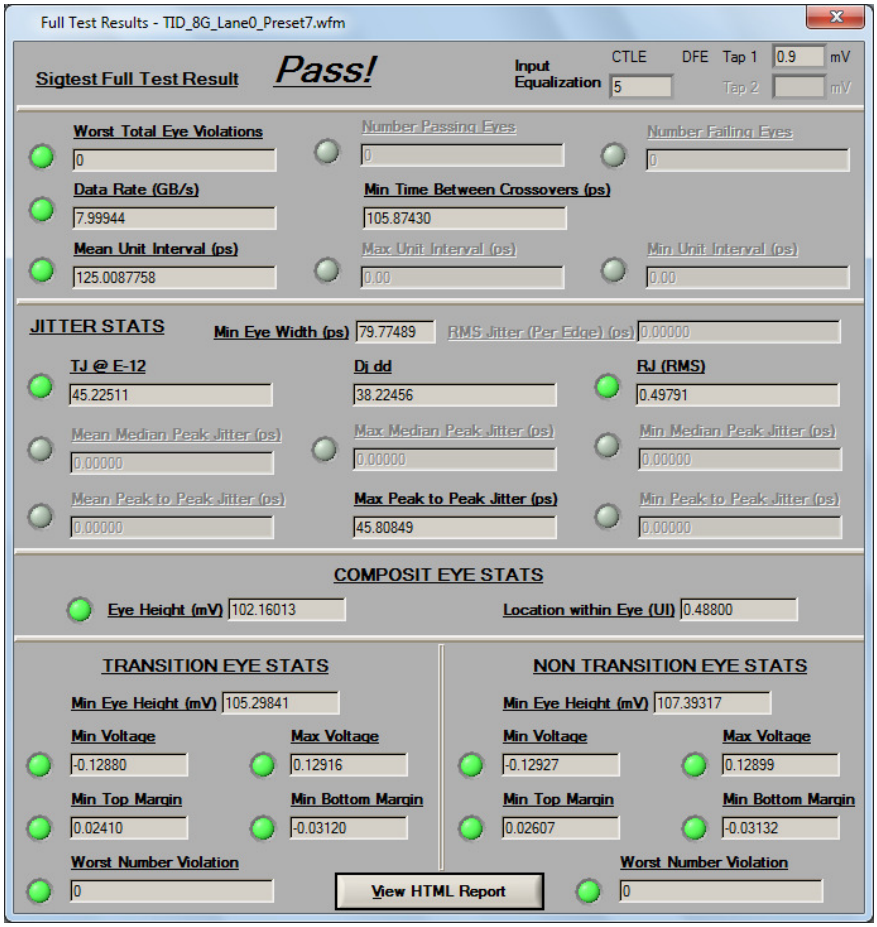

Figure 28. SIGTEST Jitter Results

11. Gen3 Preset Test

1. Run SigTest v3.1.70 or later.
2. Select “Data Type: Differential” and “Preset Test”.

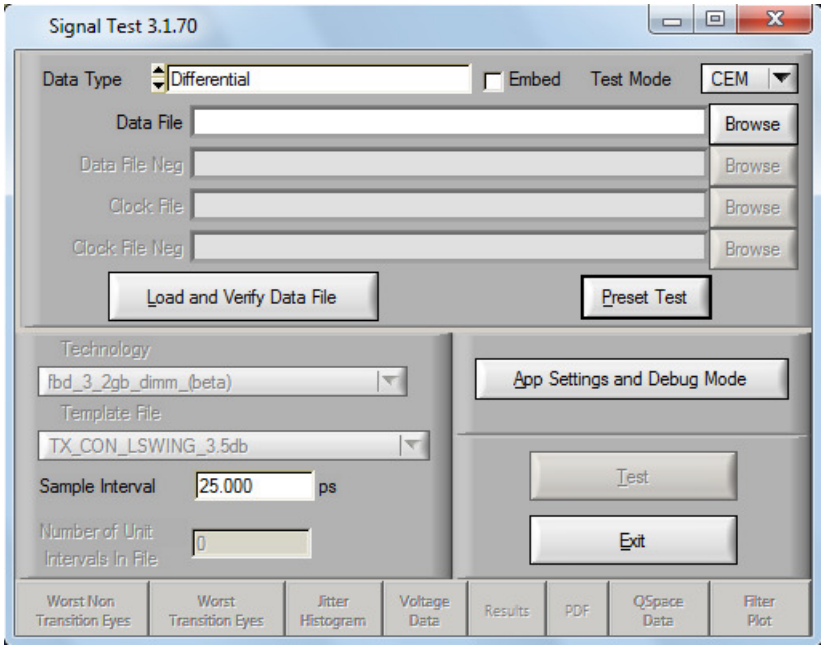

Figure 29. SIGTEST Preset Menu

3. Select “P4” then “Browse” for the corresponding P4 .wfm file, then “Test”
4. Repeat for the remaining presets.

   Note: All the presets have to be analyzed before the results are valid since there is a dependency on other preset values.

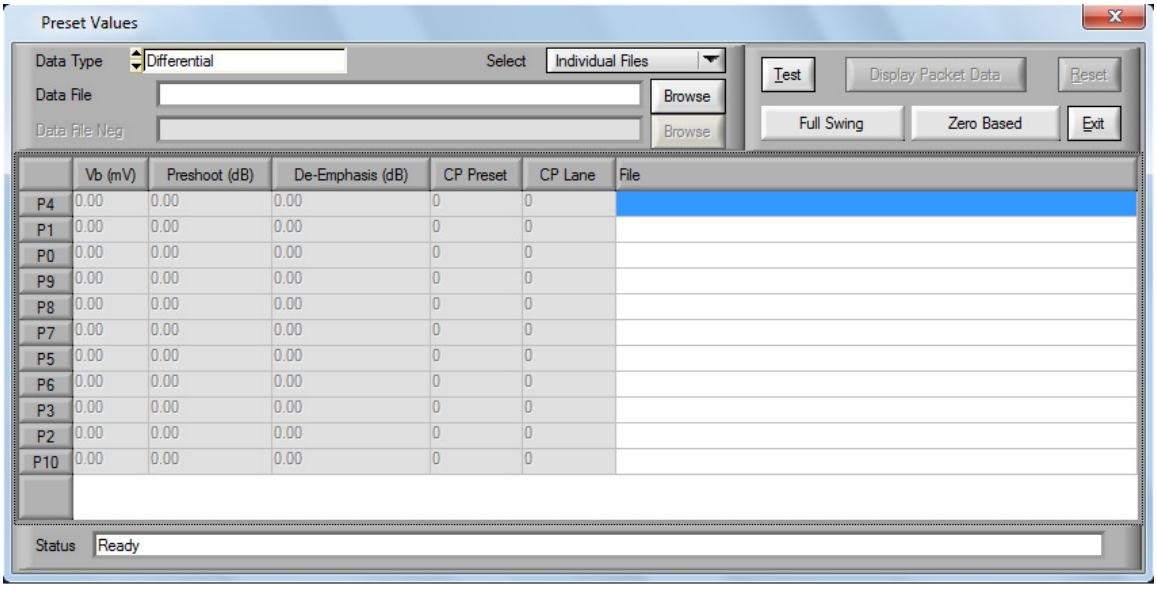

Figure 30. SIGTEST Preset analysis menu

5. Ensure that the Preset selection on the left matches the .WFM data on the right.
6. The Preset test results are shown below.

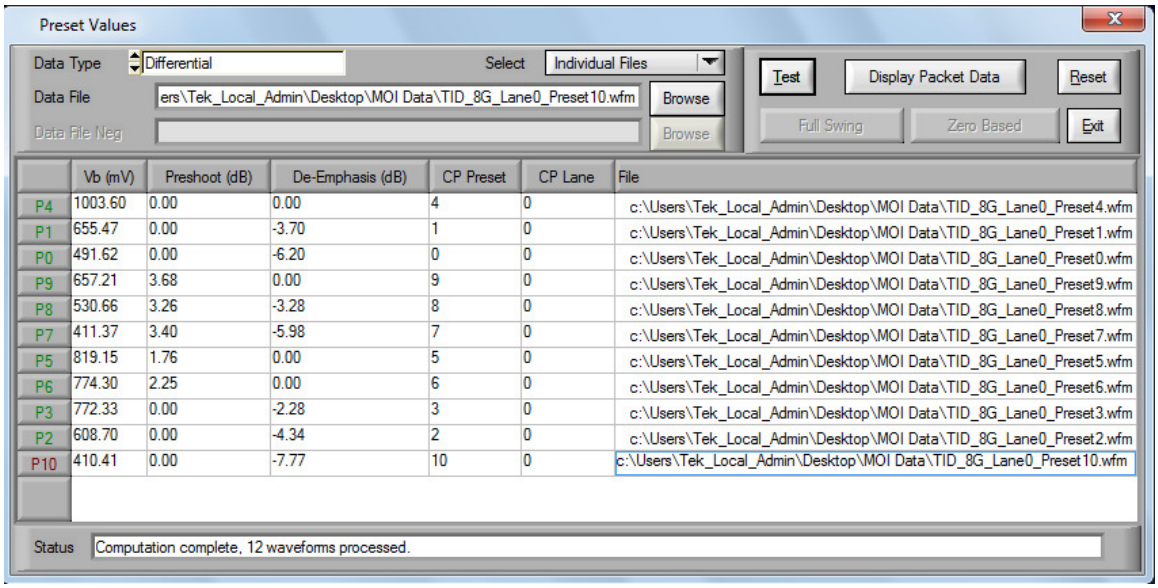

Figure 31. SIGTEST Preset results

12. Appendix A: Scope/Probe/Cable Calibration

Before beginning any test or data acquisition, the oscilloscope must be warmed, calibrated, and cables de-skewed. This section includes the procedure for calibrating the scope and de-skewing the cables.

Calibration can be performed in the following order:

1. Signal Path Compensation compensates the signal pathways for gain and offset errors.
2. Cable de-skew compensates for timing differences between two cables.

   Once these calibrations are performed, they are not permanent. It's recommended the signal path compensation be performed once a week and whenever the ambient temperature of the oscilloscope has changed by more than 5° C, whereas the cable de-skews can be performed before starting any measurements using the scope and cables.

12.1 Signal Path Compensation:

This type of calibration can be done through the scope's utilities menu.
Select Utilities->Instrument calibration.

Figure 32. Select Calibration Menu

To perform this operation, all input cables to the scope channels must be disconnected. Ensure the Tektronix TCA-SMA input adapters are installed in channels 1 and 3 and nothing is connected to the scope inputs.
This prevents transient voltages from leaking into the input amplifiers and ADC's that could adversely affect the quality of the calibration routine. Click on the "Calibrate" button. It takes about 10 minutes to get the calibration result. Final status should be "Pass"

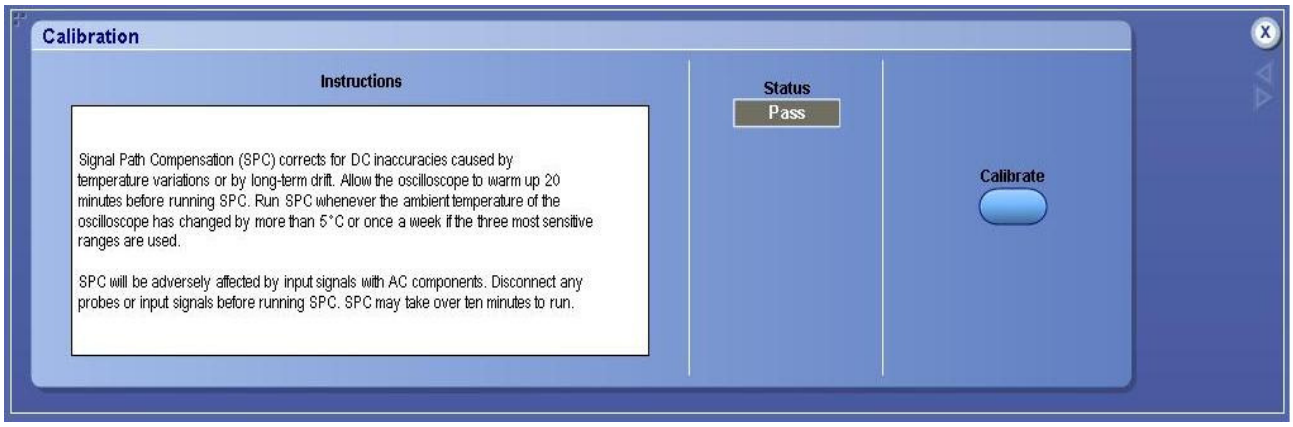

Figure 33. Signal Path Compensation

12.2 Cable De-skew:

Use the following procedure to compensate for timing differences between SMA-SMP cables:
This procedure is performed on a pair of cables at a time.

1. Connect SMA TekConnects to channels 1 and 3 of the scope.
2. Click “Default Setup”
3. Connect the SMA end of the SMA-SMP cable pair to the channels Ch1 and Ch3 of the scope through SMA TekConnects. Use torque-wrench to tighten the connection. (7-10 in lbs)
4. Select the two channels using Ch1 and Ch3 buttons on scope front panel.
5. Make sure that channels Ch2 and Ch4 are de-selected.
6. Connect the power splitter to the “Fast Edge” output of the scope.
   Refer to Figure 31.

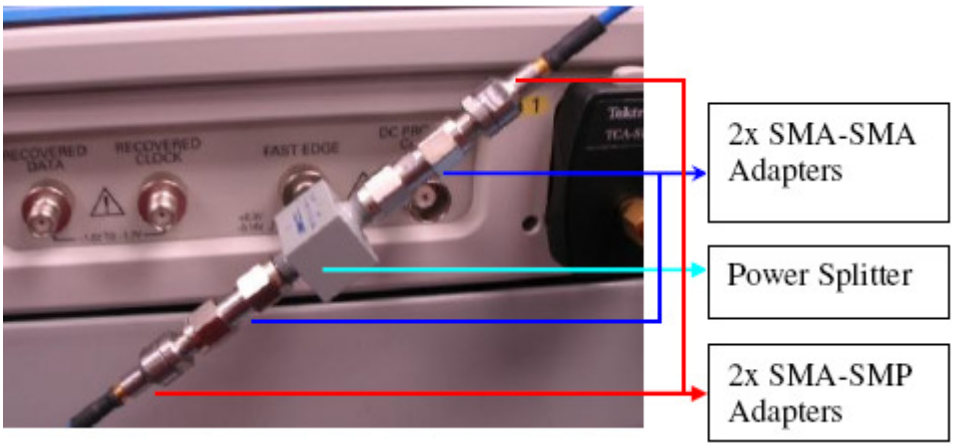

Figure 34. Cable de-skew connections

7. Connect two SMA (male)-SMA (Male) adapters to two outputs of the power splitter. Refer to Figure 31.
8. Connect SMA (Female)-SMP (Male) adapter to the two SMA adapters. Refer to Figure 31.
9. Tighten all the connection joints using torque-wrench. (7-10 in lbs)
10. Connect SMP ends of the cables from Ch1 and Ch3 to these adapters.
11. Click on scope “Autoset” button on front panel
12. Click “Ok” on the confirmation window.
13. Adjust the Vertical Scale (Increase it without any clipping) and Position controls for each channel so that the signals overlap and are centered on the display.
14. Click Horiz/Acq->Horizontal/Acquisition Setup.
15. Click on “Acquisition” tab. Refer to Figure 32.
16. Select “Average” acquisition mode.
17. Keep the “# of Wfms” as default which is 16.

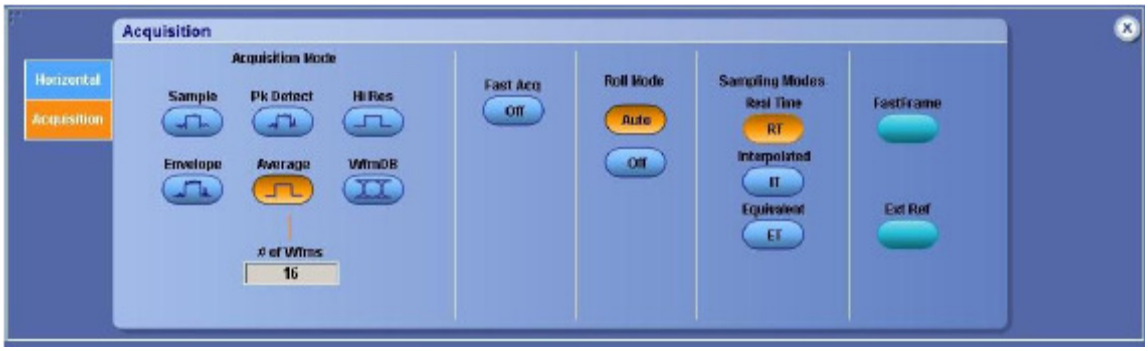

Figure 35. Setting Average

18. Adjust the Horizontal Position so that a rising edge is triggered at the center of the display.
19. Adjust the horizontal Scale (Lower time/pt) so that the differences in the channel delays are clearly visible. Refer to Figure 33.

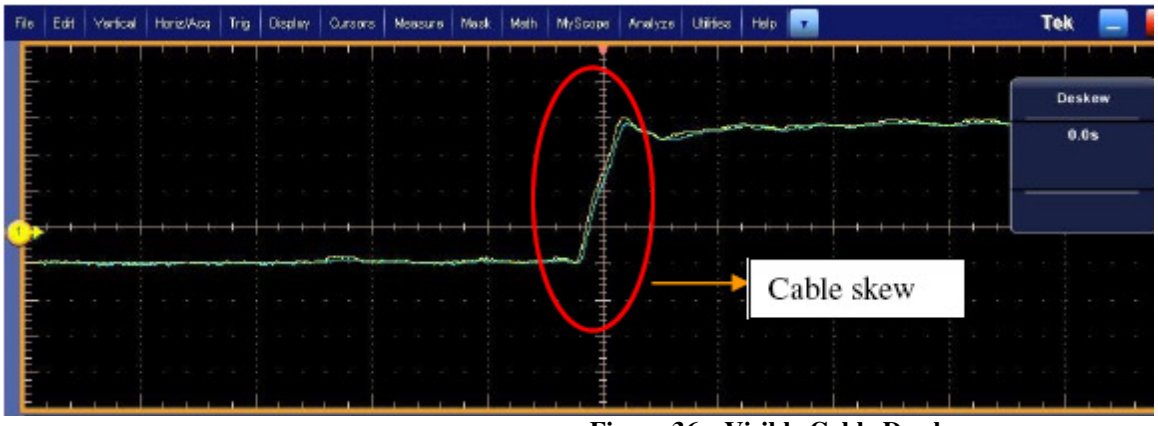

Figure 36. Visible Cable De-skew

20. Adjust the horizontal Position again so that the first rising edge is exactly at the center of the display. The short length (Electrical length) cable is connected to this channel.
21. Select Vertical -> Deskew from the scope menu to open the Deskew control window.
22. Select one of the slower channels.
23. Adjust the de-skew time for the slower channel so that its signal aligns with that of the fastest channel. The de-skew adjustment range is ±75 ns.

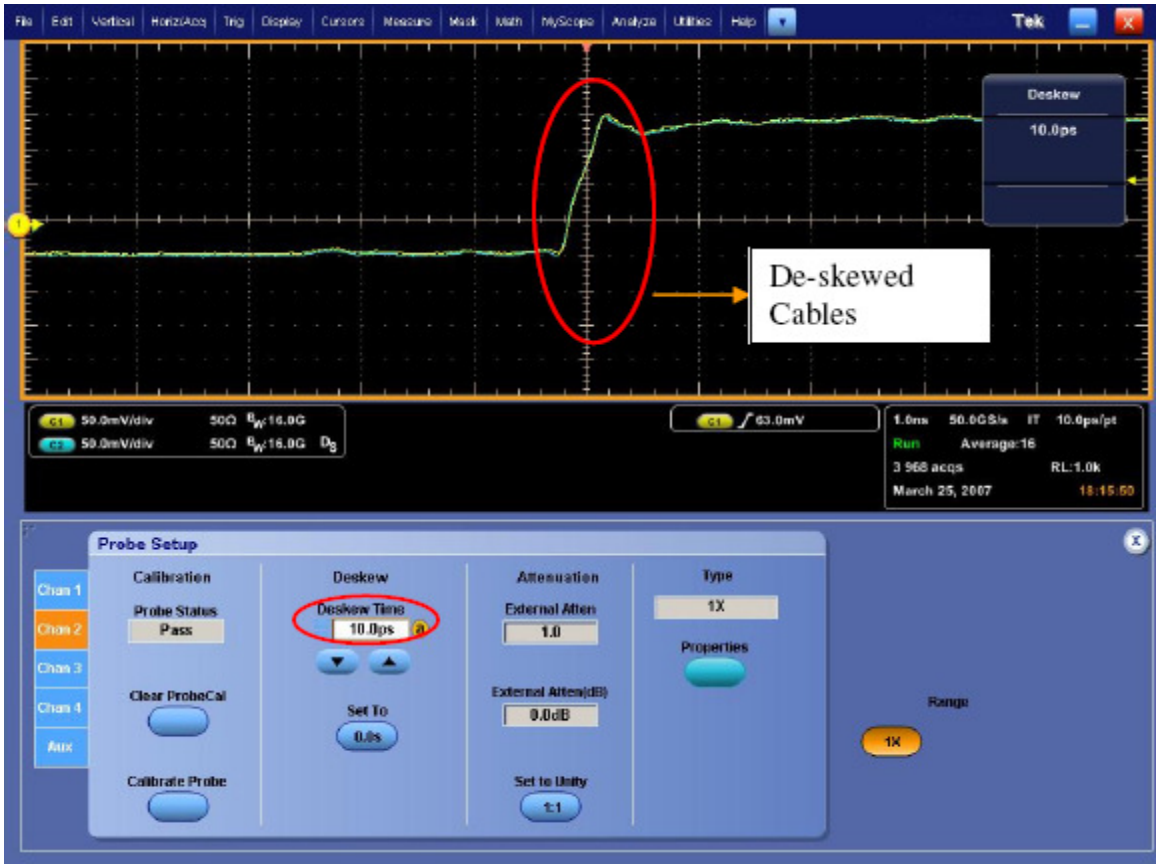

Figure 37. Cable Skew Adjusted

24. Remove the SMP ends of cables attached to Ch1 and Ch3 from cable de-skew attachment. Keep the SMA end of cables attached to Ch1 and Ch3.
25. Click Horiz/Acq->Horizontal/Acquisition Setup.
26. Click on “Acquisition” tab. Refer to Figure 32.
27. Select “Sample” acquisition mode.

13. Appendix B: Abbreviations

PCIE	Peripheral Component Interconnect Express
Gen-2	Generation-2 PCI Express
CLB	Compliance Load Board
SMP	Sub-miniature Type P connector
SMA	Sub-miniature Type A connector
UI	Unit Interval

14. Appendix C: List of Figures