LeCroy Corporation

USB3.0 Tx/Rx Electrical Compliance Test Procedure

Version 0.98
September 23, 2011

Referencing USB3.0 Electrical Test Specification v0.9
LeCroy MOI for USB3.0 Rx Test v0.98
(Using LeCroy SDA813Zi-A and PeRT^3 Eagle)

TABLE OF CONTENTS

MODIFICATION RECORD

Feb 23, 2010 Version 0.7
(Initial Release Draft)
David Li

March 18, 2010 Version 0.8
(Revised based on the latest Electrical spec draft)
David Li

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(Revised based on the latest Electrical spec draft)
David Li

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(Revised based on the latest updates to the Electrical Spec draft and to include Oscilloscope measurements using SigTest)
David Li

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(Revised based on the latest updates the USB3.0 Workshop #72 – Eye height measurement method was modified – Host jitter calibration and Host Rx testing setup diagrams are added)
David Li

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(Revised based on the latest updates the USB3.0 Workshop #76 and using new external 2 tap de-emphasis box)
(Added LFPS Test procedures)
David Li

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(Revised based on the latest updates the USB3.0 Workshop #78 and adding Tx compliance testing procedure)
David Li

INTRODUCTION

This document provides the method of implementation for testing the receiver of USB3.0 Devices and Host as described in receiver testing portion of the USB3.0 Electrical Test Specification V0.9. A current copy of this specification can be found at www.USB.org

ACKNOWLEDGMENTS

Creation of this document:
David Li (LeCroy Corp.)

Review and Comments:

USB3.0 Electrical Transmitter Testing:

Detailed Test:

Purpose: Verify that the Device Under Test (DUT) meets the jitter tolerance requirements per USB3.0 specification requirements

References:

- USB3.0 Base Specifications
- USB3.0 Electrical Test Specifications

Resource requirements:

See appendix A

DUT requirements:

- DUT must be able to send LFPS signal after power up
- If DUT does not detect TSEQ after power up, DUT must be able to enter transmit compliance mode and be able to accept LFPS Ping command to transmit CP0 and CP1

Discussion:

USB3.0 Transmitter Testing involves the following test items:

a. LFPS testing
b. SSC* waveform testing using CP1
c. Slew Rate testing with CP1
d. Random Jitter measurement with CP1 (Sigtest needs clock pattern based RJ to calculate TJ)
e. Total Jitter and Deterministic Jitter measurements with CP0
f. Eye Margin testing with CP0

All Transmitter Tests are automated through the LeCroy QualiPHY software which includes setup and connections diagrams and wizard guided instructions.

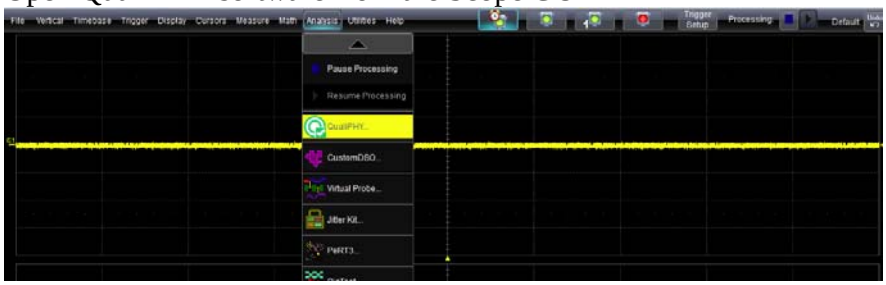
NOTE: SSC is not required to be enabled on a DUT to pass compliance. But if SSC is enabled, it must satisfy the USB3.0 compliance requirements.

The following document describes the test setup, necessary resource requirements, and a step by step test procedure to perform USB3.0 transmitter test.

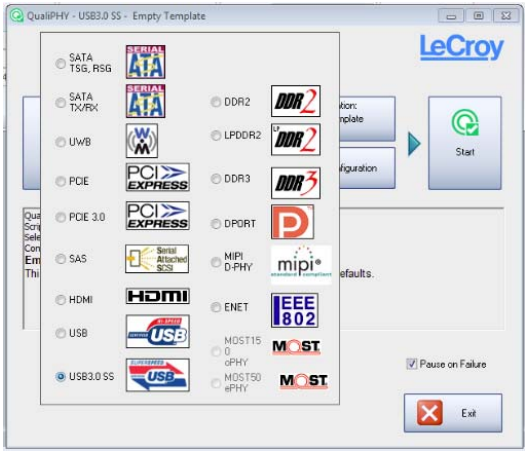
Test Procedure:

Setup QualiPHY for USB3.0 Transmitter Testing

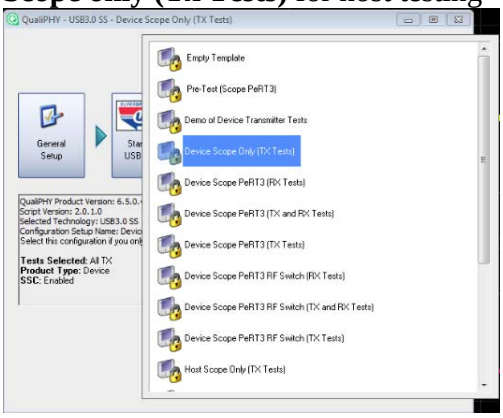
1. Open QualiPHY software from the Scope GUI



2. Under Standards, select **USB3.0 SS**

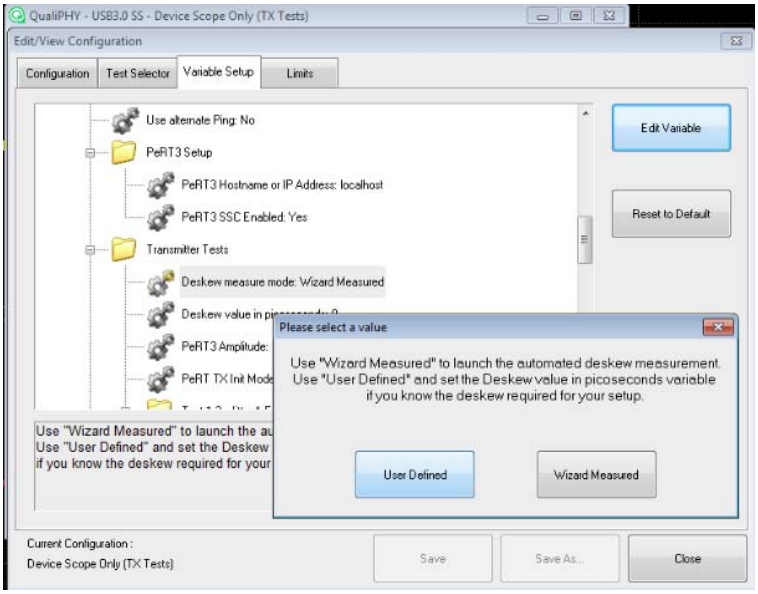


3. Under Configuration, select **Device Scope only (Tx Tests)** for device testing and **Host Scope only (Tx Tests)** for host testing

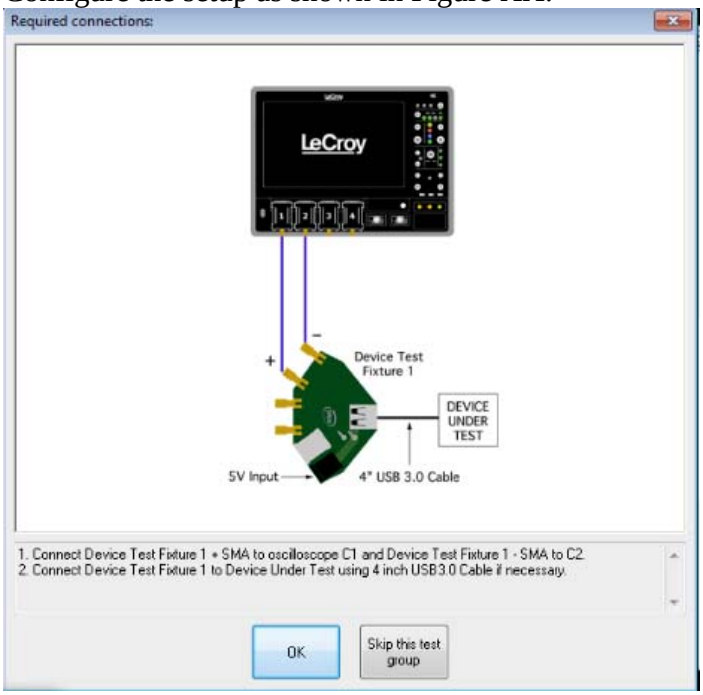


4. Run test

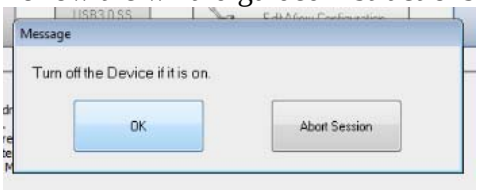
Note: default USB3 test script will ask the user to deskew cables with wizard guided instructions. This can be disabled in QualiPHY under **Variable Setup** and **Deskew Measurement Mode** by selecting **User Defined**.



a. LFSP Testing
   1. Configure the setup as shown in Figure XX.



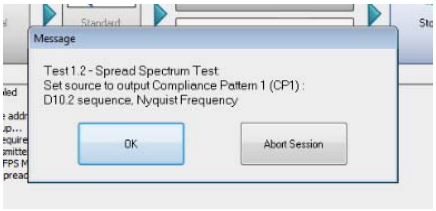
2. Follow the wizard guided instructions and power off the DUT



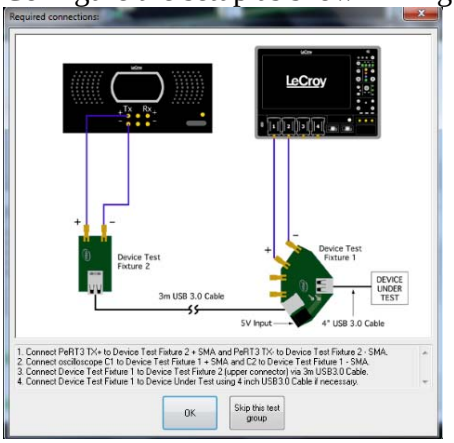
3. Power on the DUT, now the scope trigger has been setup and will automatically capture the first 6 LFPS burst for measurements

b. SSC Testing (not required if DUT SSC is disabled, but if SSC is enabled, testing is required)

1. QualiPHY will ask for DUT to send out CP1. This can be done by controlling the PeRT3 Eagle (also used for Rx testing) to send out LFPS Ping signal and command the DUT to switch from CP0 to CP1

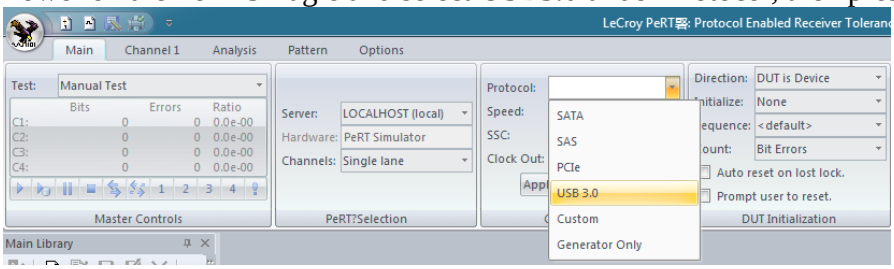


2. Configure the setup as shown in Figure 2.



NOTE: On Device Test Fixture 2, only use the upper port, the lower port is not connected!

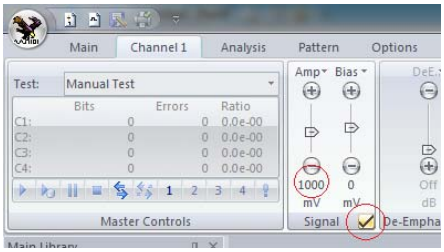
3. Power on the PeRT3 Eagle and select **USB3.0** under Protocol, then press **Apply**



4. Under Initialize, select **Custom Sequence**

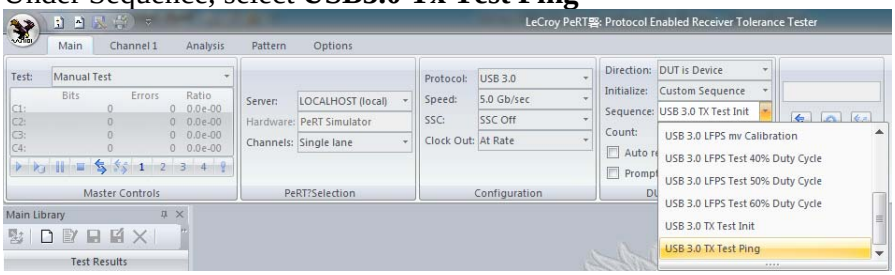
5. Under Sequence, select **USB3.0 Tx Test Init**

6. Go to Channel 1 tab and enable the signal to 1000mV



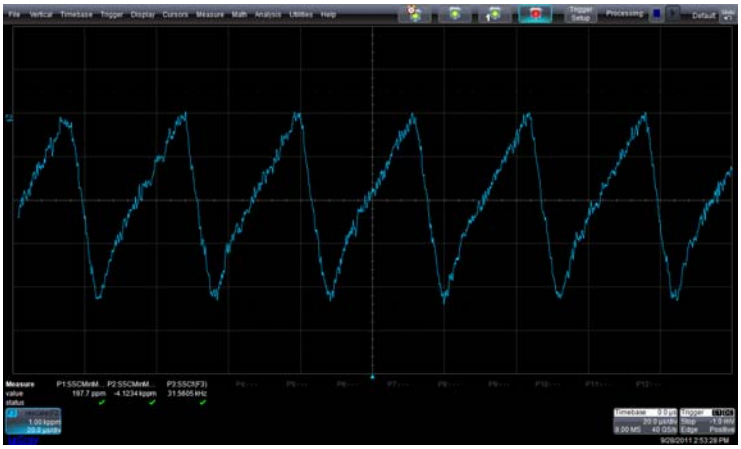
7. Press **Connect** (this is to initialize the instrument prior to transmitting LFPS Ping)

8. Under Sequence, select **USB3.0 Tx Test Ping**



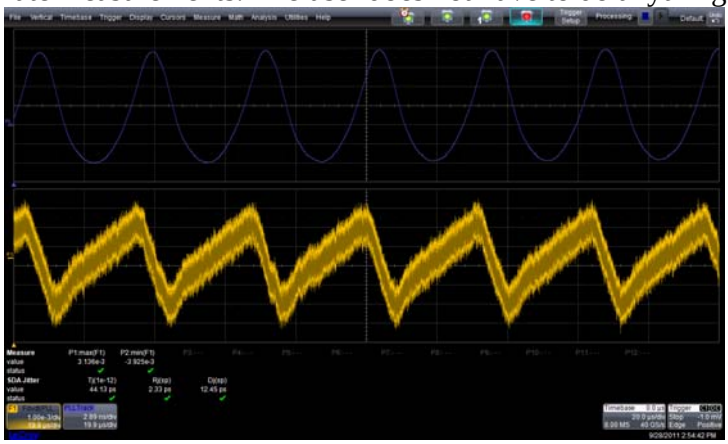
9. Press **Connect** (minimize the PeRT3 software and the Scope software, you should observe the signal in the scope changing patterns every time you press Connect)

10. After DUT is set to send CP1 (1010 patterns), press OK in QualiPHY to continue the test. SSC will be measured first



c. Slew Rate measurements

1. Since the DUT is already sending CP1 pattern, QualiPHY will automatically make slew rate measurements. The user does not have to do anything.



d. RJ measurements with CP1

1. Since the DUT is already sending CP1 pattern, QualiPHY will automatically make RJ measurements. The user does not have to do anything.

e. TJ and DJ measurements with CP0

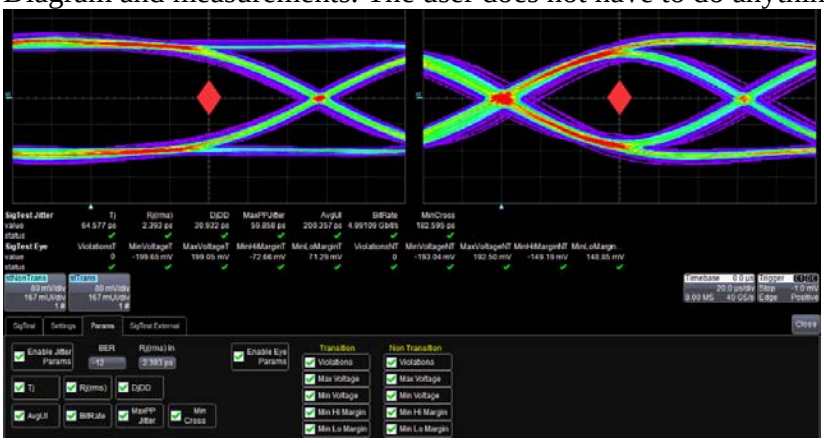
1. QualiPHY will prompt the user to command the DUT to transmit CP0 (this can be done through sending LFPS Ping 8 times by using the PeRT3 Eagle, **or** can be done by power cycling the DUT, whichever one is easier)

2. Press OK after verifying DUT is sending CP0 (scrambled PRBS 11 pattern)

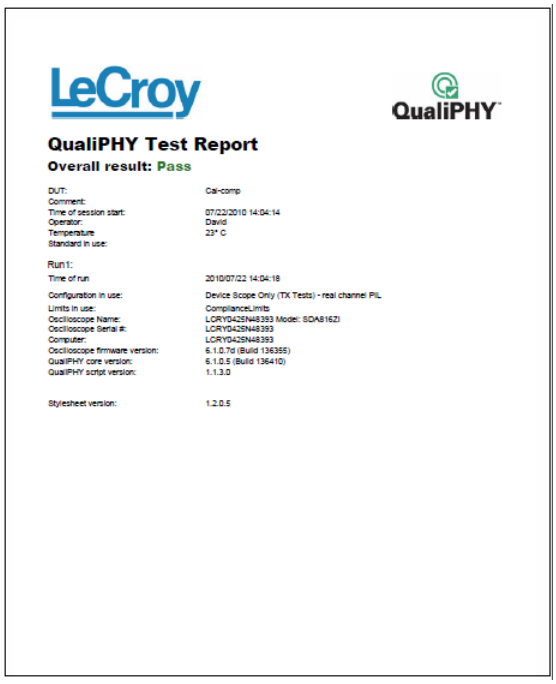
3. QualiPHY will automatically make the required TJ and DJ measurement

f. Eye Measurements

1. Since the DUT is already sending CP0 pattern, QualiPHY will automatically make Eye Diagram and measurements. The user does not have to do anything.



At the end of the test, QualiPHY will ask the user to save the test report. The report can be saved in PDF or HTML formats.



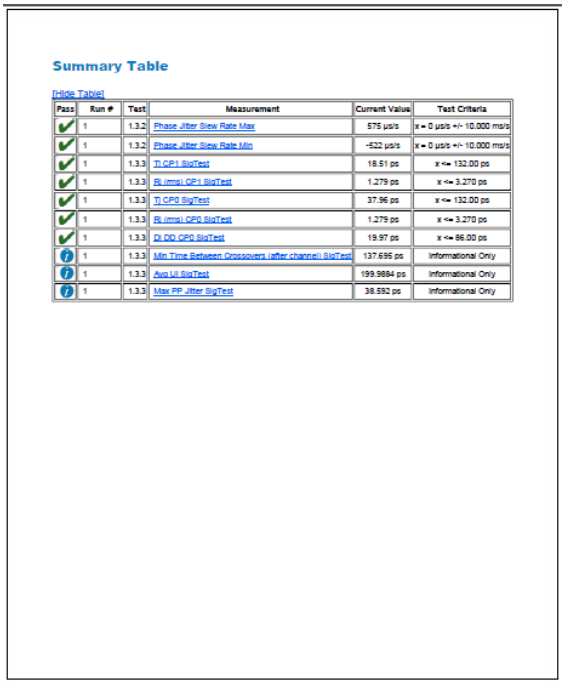
LeCroy

QualiPHY

QualiPHY Test Report

Overall result: Pass

DUT:	Cal-comp
Comment:	
Time of session start:	07/22/2010 14:04:14
Operator:	David
Temperature	23° C
Standard in use:	
Run1:	
Time of run	2010/07/22 14:04:18
Configuration in use:	Device Scope Only (TX Tests) - real channel PIL
Limits in use:	ComplianceLimits
Oscilloscope Name:	LCRY042SN48393 Model: SDA816ZI
Oscilloscope Serial #:	LCRY042SN48393
Computer:	LCRY042SN48393
Oscilloscope firmware version:	6.1.0.7d (Build 136355)
QualiPHY core version:	6.1.0.5 (Build 136410)
QualiPHY script version:	1.1.3.0
Stylesheet version:	1.2.0.5



Summary Table

[Hide Table]

Pass	Run #	Test	Measurement	Current Value	Test Criteria
✔	1	1.3.2	Phase Jitter Slew Rate Max	575 µs/s	x = 0 µs/s +/- 10.000 ms/s
✔	1	1.3.2	Phase Jitter Slew Rate Min	-522 µs/s	x = 0 µs/s +/- 10.000 ms/s
✔	1	1.3.3	TJ CP1 SigTest	18.51 ps	x <= 132.00 ps
✔	1	1.3.3	Rj (rms) CP1 SigTest	1.279 ps	x <= 3.270 ps
✔	1	1.3.3	TJ CP0 SigTest	37.96 ps	x <= 132.00 ps
✔	1	1.3.3	Rj (rms) CP0 SigTest	1.279 ps	x <= 3.270 ps
✔	1	1.3.3	Dj DD CP0 SigTest	19.97 ps	x <= 86.00 ps
ℹ	1	1.3.3	Min Time Between Crossovers (after channel) SigTest	137.695 ps	Informational Only
ℹ	1	1.3.3	Avg UI SigTest	199.9884 ps	Informational Only
ℹ	1	1.3.3	Max PP Jitter SigTest	38.592 ps	Informational Only

USB3.0 Electrical Receiver Testing:

Detailed Test:

Purpose: Verify that the Device Under Test (DUT) meets the jitter tolerance requirements per USB3.0 specification requirements

References:

- USB3.0 Base Specifications
- USB3.0 Electrical Test Specifications

Resource requirements:

See appendix A

Jitter Source Calibration:

- See appendix D for Oscilloscope setup to measure the following:
  - De-Emphasis
  - Signal Amplitude
  - Random Jitter
  - Sinusoidal Jitter

Discussion:

Testing USB3.0 DUT receivers involves 3 main steps:

1) Signal Source Calibration
2) Loopback Initialization
3) Tolerance Testing
   a. LFPS Testing
   b. Jitter Tolerance Sweep

A product must run error free in the specified measurement depth with the required amounts of signal degradation applied.

The following document describes the test setup, necessary resource requirements, and a step by step test procedure to perform USB3.0 receiver test.

Test Procedure:

Step 1: Signal Source Calibration

(The following is a manual procedure for calibration; for the automated calibration procedure, proceed to page xx)

Calibration of Signal Source must meet the parameters described in Table 1:

Calibration Parameters	**Device Setup**	**Host Setup**
De-emphasis	3.0dB	3.0dB
Random Jitter (RJ) ±10% RMS	2.4ps	2.4ps
Sinusoidal Jitter (SJ) +0/-10%pk-pk	33Mhz – 40ps 20Mhz – 40ps 10Mhz – 40ps 4.9Mhz – 40ps 2Mhz – 100ps 1Mhz – 200ps 500khz – 400ps	33Mhz – 40ps 20Mhz – 40ps 10Mhz – 40ps 4.9Mhz – 40ps 2Mhz – 100ps 1Mhz – 200ps 500khz – 400ps
Eye Height +10/-0% pk –pk	145mV	180mV
Total Jitter	85-90ps	85-90ps

Table 1

Test Calibration Setup:

- Setup the test equipment as described in Figure 1a for De-emphasis Calibration :

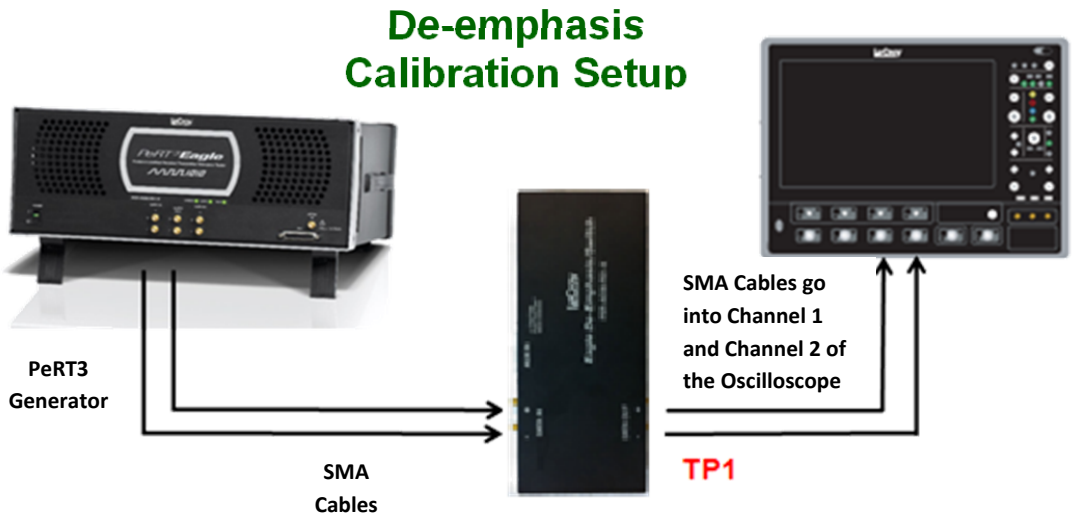


Figure 1a

- Setup the test equipment as described in Figure 1b for Device calibration and Figure 1c for Host calibration:

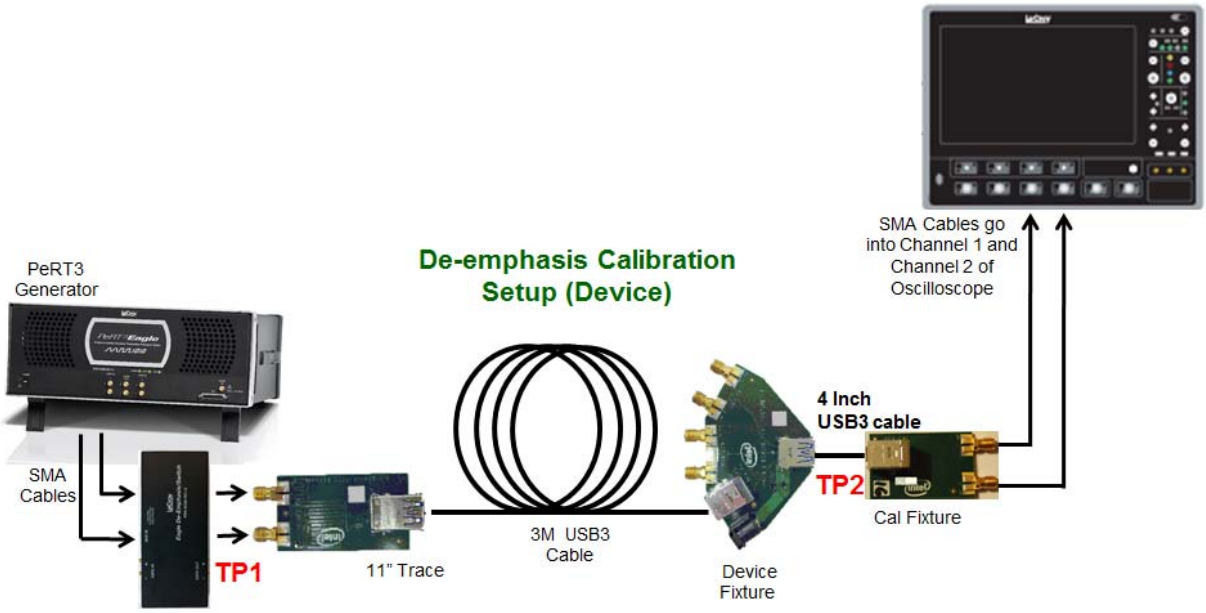


Figure 1b

NOTE: On Device Test Fixture 2, only use the upper port, the lower port is not connected!

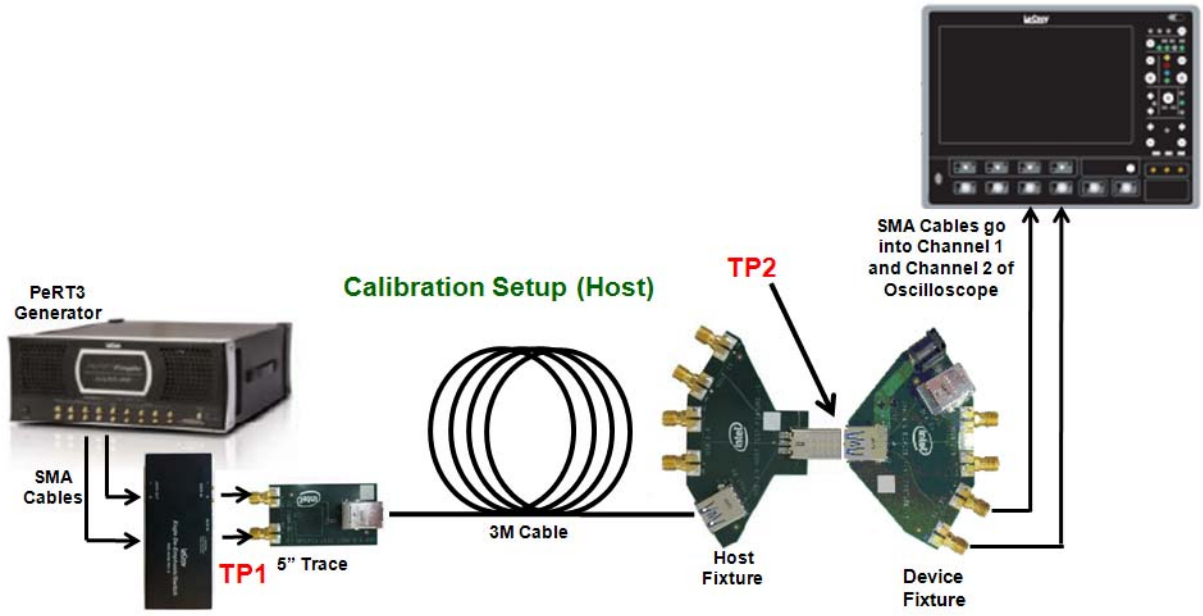


Figure 1c

NOTE: On Device Test Fixture 2, only use the upper port, the lower port is not connected!

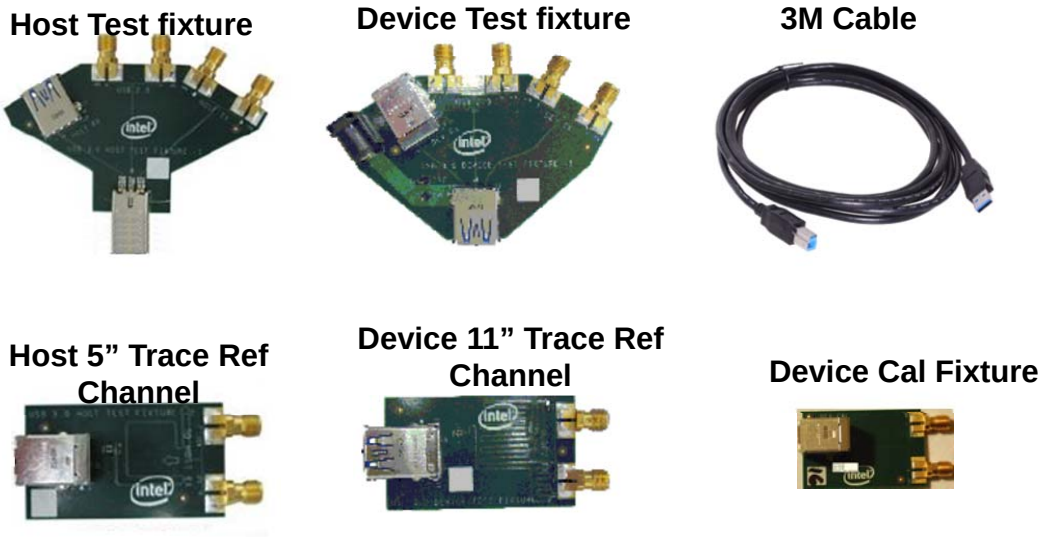


Figure 1d

Signal De-emphasis Calibration:

NOTE: If the LeCroy External De-emphasis box is available, follow the de-emphasis calibration procedure. Otherwise, follow the Pre-emphasis calibration procedure. Both method satisfy compliance test requirements.

De-emphasis calibration procedure:

- Setup the Generator to output proper signal and jitter:
  - Protocol: Generator Only
  - Speed: 5Gb/sec
  - SSC: OFF
  - Press Apply as shown in Figure 2

Figure 2

  - PeRT3 Generator Amplitude = 1000mV (used as a starting point for calibration)
  - PeRT3 De-emphasis setting: -3.0dB
  - Set PeRT3 Pattern to: CP0

- Setup the Oscilloscope for measurements:
  - Connect PeRT3 Tx+ and Tx- to channel 1 and channel 2 of scope at shown in De-emphasis calibration setup (Figure 1a)
  - Adjust channel gain to make sure signal does not clip
  - Setup Math Function 2 to take the difference between Ch1 and Ch2
  - Set signal acquisition to 8MS at 40GS/s
  - Enable measurement **VTxDeRatio**
  - Under **VTxDeRatio** settings, adjust for 5Gbps
  - Take a single trigger and read the measurement (for example: VTxDeRatio = 0.723)
  - The value you're looking for is 3.0 dB + 5/-0% dB or 0.669 to 0.708 on the VTxDeRatio value

Pre-emphasis setting procedure (only if De-emphasis box is not available)**:**

- Setup the Generator to output proper signal and jitter:
  - Protocol: Generator Only
  - Speed: 5Gb/sec
  - SSC: OFF
  - PeRT3 Generator Amplitude = 1000mV (used as a starting point for calibration)
  - Set PeRT3 Pre-emphasis, Amp=4, Dur=9
  - Set PeRT3 Pattern to: CP0

Random Jitter Calibration:

- Setup the Generator to output proper signal and jitter:
  - PeRT3 Generator Amplitude = 1000mV (used as a starting point for calibration)
  - Use the calibrated De-emphasis setting from De-emphasis calibration (ex: -3.0dB)
  - PeRT3 pattern select CP1 as shown in Figure 3:
  - Start by setting PeRT3 HFRJ = 2.4ps RMS

Figure 3

- Setup the Oscilloscope for measurements:
  - Connect PeRT3 Tx+ and Tx- to channel 1 and channel 2 of scope as shown in Calibration Setup (Figure 1b for Device, and Figure 1c for Host)
  - Adjust channel gain to make sure signal does not clip
  - Setup Math Function 2 to take the difference between Ch1 and Ch2
  - Open Sigtest tab under Analysis in the DSO window tabs
  - Apply the following parameters in the SigTest GUI:
    - SigTest tab - Signal Source: select 1 input and DataSource = F1

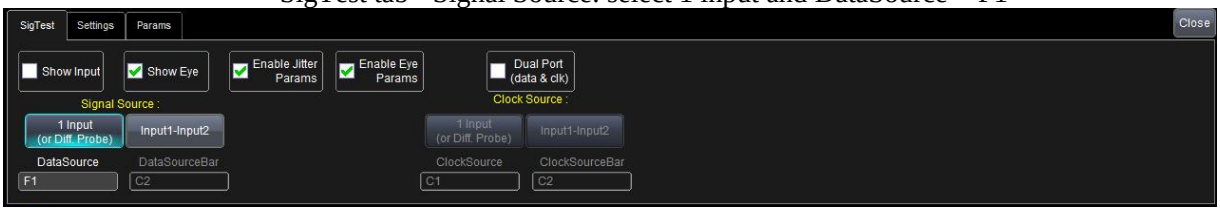


Figure 4

- Settings tab
  - Standard: select USB3.0 Compliance
  - Bitrate: 5Ghz
  - Jitter Filter order: Second Order
  - Corner Freq: 50khz (in order to measure low frequency Sj)
  - Damping: 707.11e-3
  - CTLE box: check
  - The rest of the selections should be default and shown in Figure 5

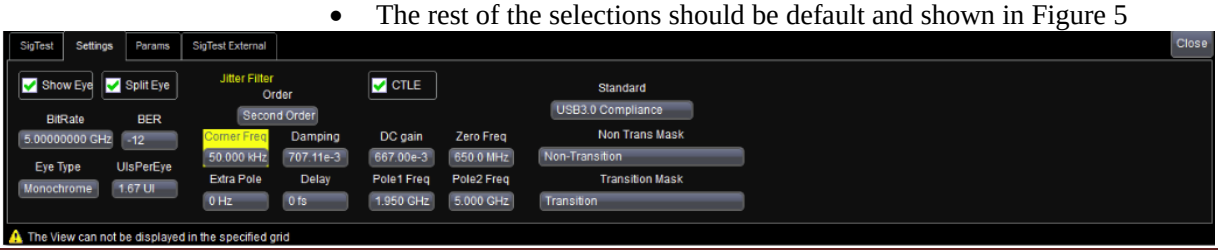


Figure 5

- Params tab:
  - Enable Jitter Params box: Check
  - Rj(rms) In: 0fs
  - MaxPP Jitter box: Check
  - Rj(rms) box: Check
  - The rest of the selections should be default and shown in Figure 6:

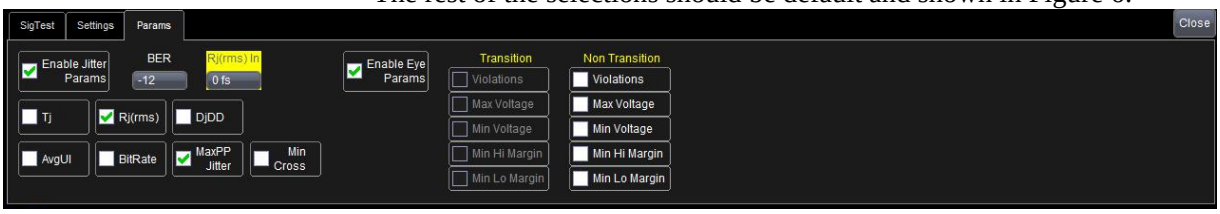


Figure 6

- On Oscilloscope controls, press clear sweeps and single capture (8M Samples at 40GS/s)
- Record the Rj(rms) value measured in SigTest Jitter

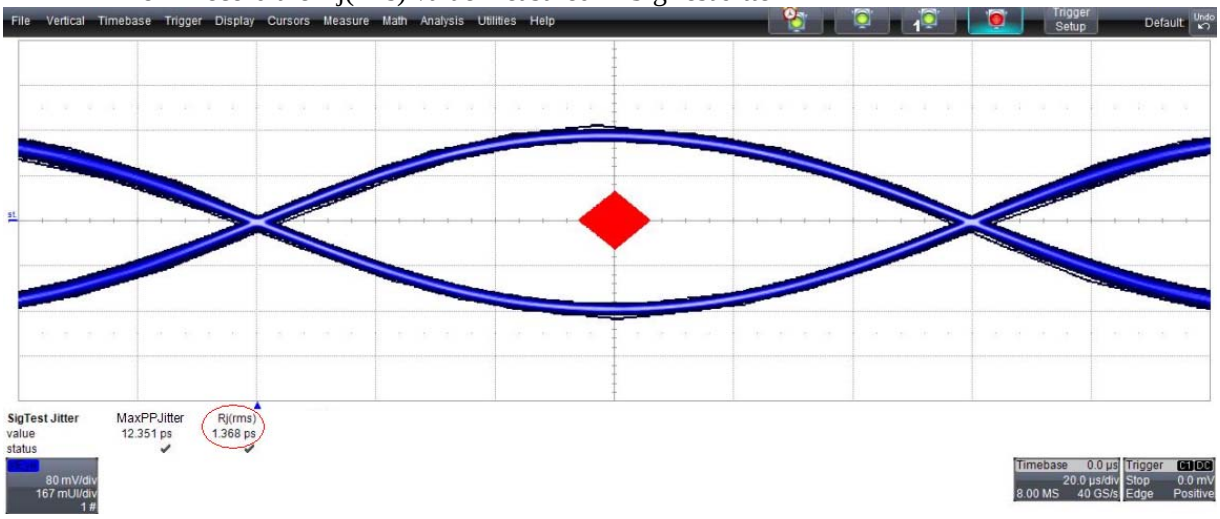


Figure 7

- Go back to the PeRT3 GUI
  - Adjust the PeRT3 HFRJ until Rj(rms) measurement in SigTest Jitter reads 2.42ps ±10% RMS
  - The final HFRJ value of PeRT3 will be recorded and fixed for all future tests.

- Back to the Sigtest
  - In Params tab: input the final measured Rj(rms) value in Rj(rms) In box as shown in Figure 9.
  - This Rj value will be used for all future measurements.

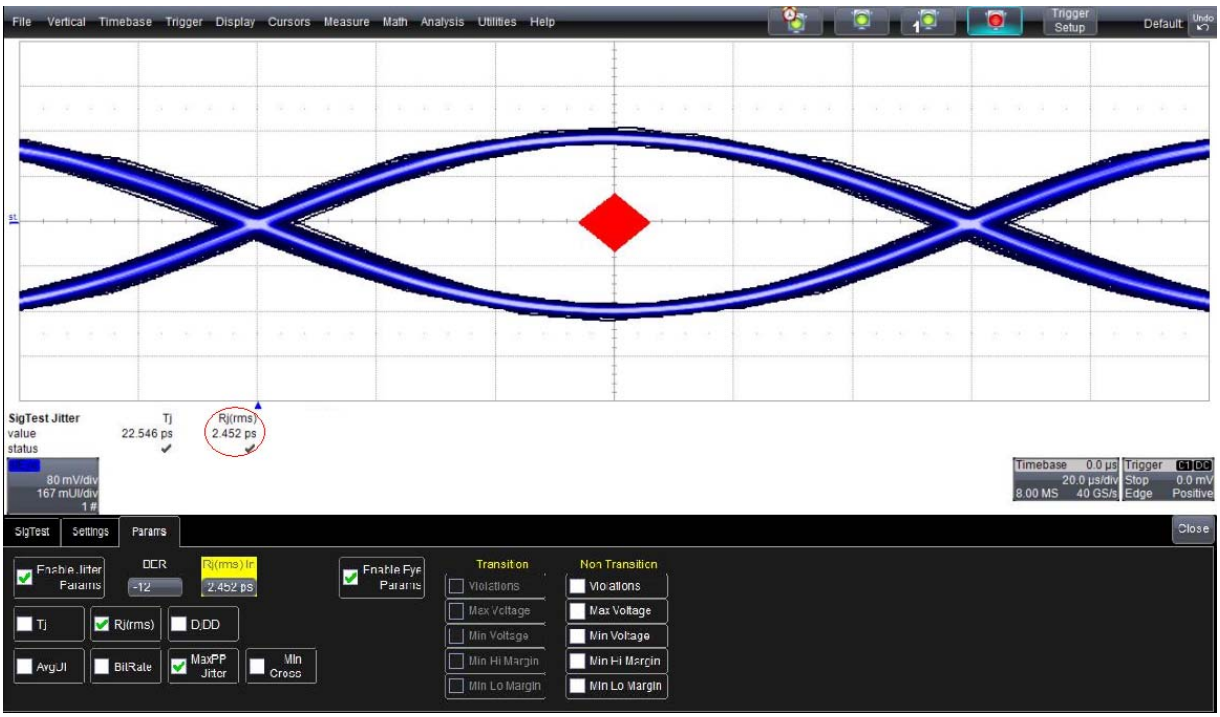


Figure 9

Sinusoidal Jitter Calibration:

(Detailed oscilloscope panel setup is described in Appendix C)

- On the PeRT3 GUI:
  - Keep all setting from RJ calibration
  - Change output pattern to CP0

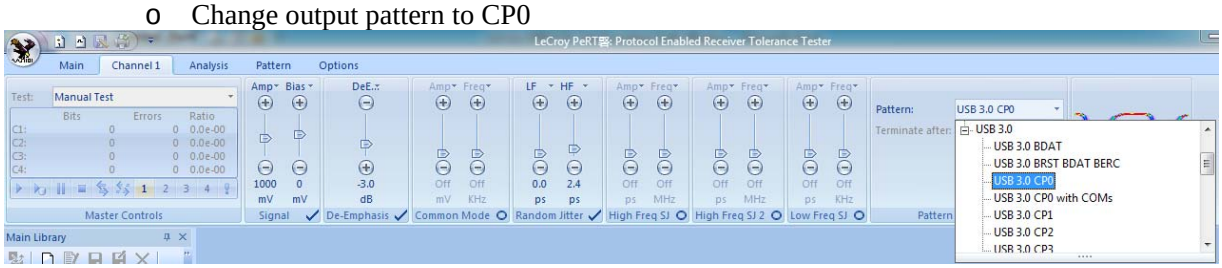


Figure 10

- On the LeCroy Scope SigTest:
  - Maintain all setting from RJ calibration
  - Clear sweeps and take single trigger of 8MS capture
  - Record the **Max P-P Jitter** value (ex, **Max P-P Jitter** = 46.017ps)

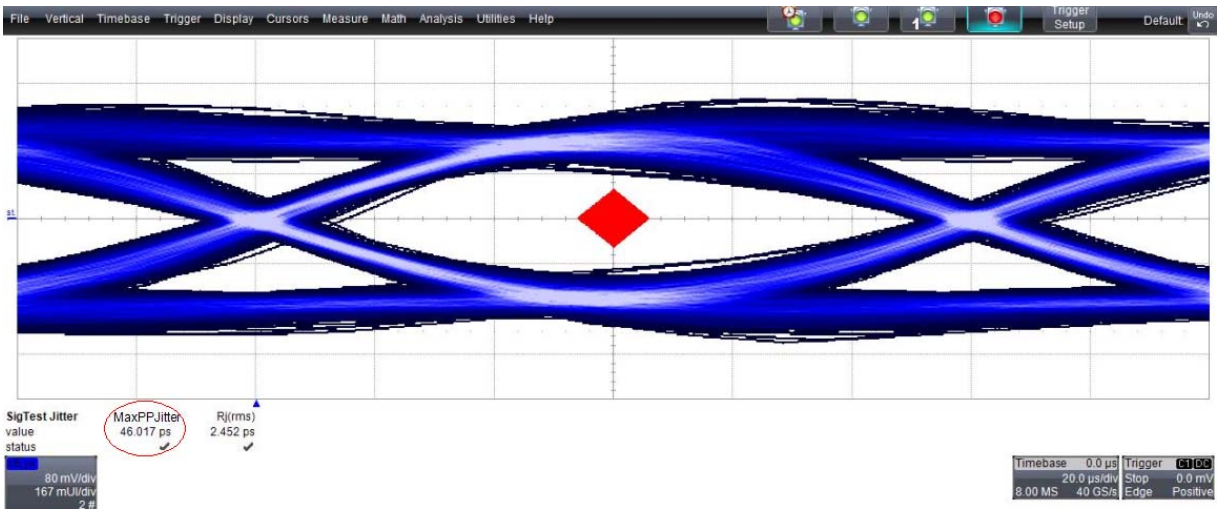


Figure 11

- Back to the PeRT3
  - Enable HFSJ to 20Mhz, 40ps

Figure 12

- Back to SigTest:
  - Clear sweep and capture single trigger of 8MS capture
  - Record the new **Max P-P Jitter** value (ex, **Max P-P Jitter** = 87.761ps)

    NOTE: now the difference in **Max P-P Jitter** before and after adding HFSJ is 41.744ps(=87.761- 46.017), this satisfies the spec requirements. The difference in **Max P-P Jitter** is beyond the spec requirement, we need to adjust the HFSJ in PeRT3 until **Max P-P Jitter** difference is within 40ps ± 5%
  - The newly calibrated jitter amplitue value is for SJ=20Mhz
  - Now repeat the **Sinusoidal Jitter Calibration** procedure for SJ = 50Mhz, 33Mhz, 10Mhz, 4.9Mhz, 2Mhz, 1Mhz, and 0.5Mhz

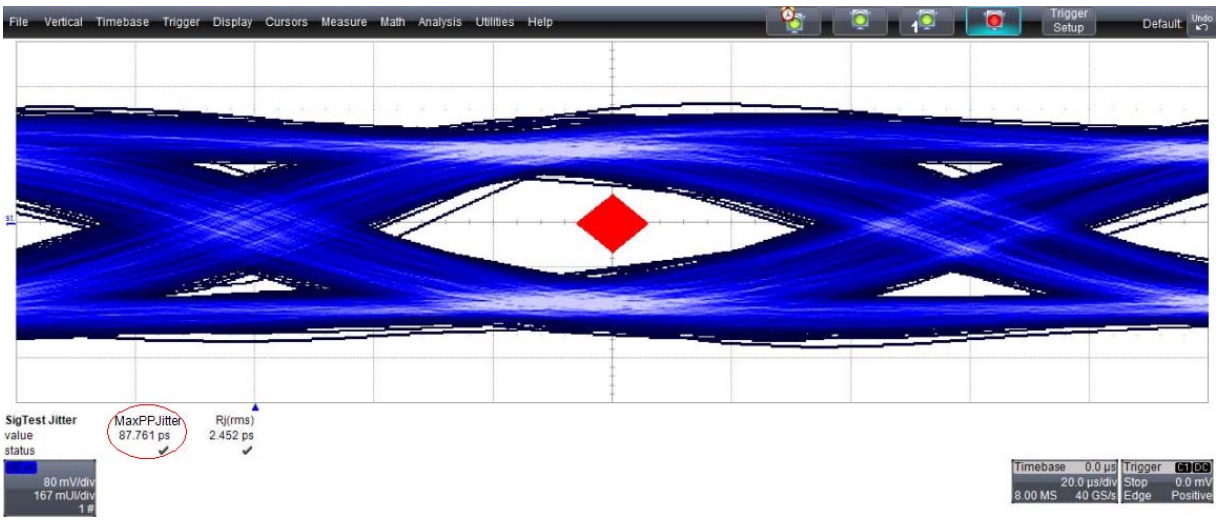


Figure 13

Eye Height Calibration:

- On the PeRT3:
  - Turn SSC: ON
  - Click on apply settings
- In LeCroy Scope SigTest:
  - Enable JTF by setting Jitter Filter Corner Frequency:
    - Corner Freq = 4.859Mhz

Figure 14

- Clear sweeps and take single trigger of 8MS capture
- Enable **Min Hi Margin** and **Min Lo Margin** measurements as described in Figure 15.
- Take the different between absolute value of Min Hi Margin and Min Lo Margin
  Example:
  Min Hi Margin = 22.5mV
  Min Lo Margin = -22.9mV
  Your eye height = abs(22.5) + abs(22.9) = 45.4mV
  This means that the eye opening is 45.4mV over the default margin of 100mV which is equivalent to 145.4mV eye opening.

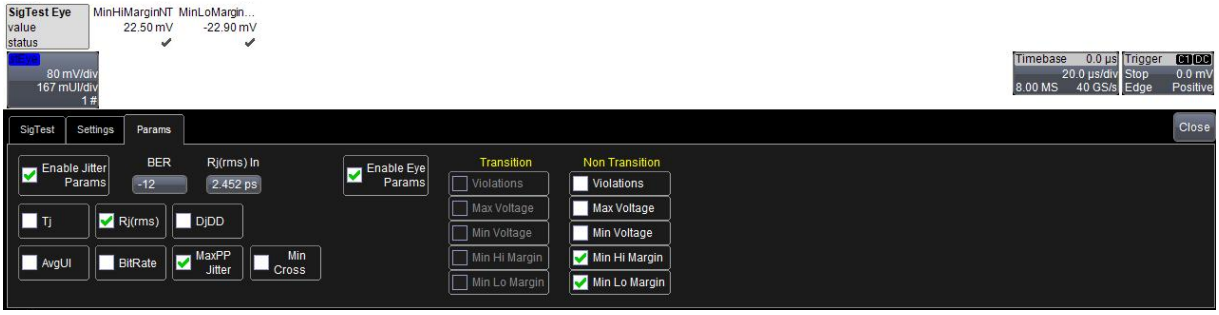


Figure 15

- On the PeRT3:
  - Adjust PeRT3 amplitude until eye height meets the 145mV for Device Channel and 180mV for Host Channel requirements

    NOTE: 145mV/180mV eye height requirement which is s recently added modification to the USB electrical spec. This required the presence of the Compliance channel and 3M cable. Otherwise eye will be too open!

Total Jitter Verification:

- With the calibrated RJ, SJ, Eye Height, Take the **Max P-P Jitter** measurement on SigTest. (ex, **Max P-P Jitter** = 87.761ps)
- Make sure the **Max P-P Jitter** measured is within 85ps < x < 100ps

NOTE:
Table 2 provides a sample calibration result. Please use this calibrated results as a reference for Rx Jitter Source calibration.

The following table can be used for calibration exorcise:

	Conditions	Measured Value	Calibrated Value on PeRT3
Source:	RJ - 2.42 (+-10%)	2.452ps	2.2ps
Test Pattern	CP1		
Scope Settings (CTLE)	On		
Scope Settings (JTF)	Off		
PeRT3 setting (SSC)	Off		

	Conditions		TJ before SJ is on	TJ after SJ is on	Measured TJ difference	Calibrated SJ at Frequency
Source:	SJ (+-5%)	SJ = 50Mhz 40ps	46.017	87.337	41.330	47ps
Source:	SJ (+-5%)	SJ = 33Mhz 40ps	46.017	87.125	41.408	47ps
Test Pattern	CP0	SJ = 20Mhz 40ps	46.017	87.761	41.744	47ps
Scope Settings (CTLE)	On	SJ = 10Mhz 40ps	46.017	87.543	41.562	47ps
Scope Settings (JTF)	Off	SJ = 4.9Mhz 40ps	46.017	86.556	40.539	47ps
PeRT3 setting (SSC)	Off	SJ = 2Mhz 100ps	46.017	146.02	100.003	110ps
		SJ = 1Mhz 200ps	46.017	245.86	199.843	210ps
		SJ = 500khz 400ps	46.017			

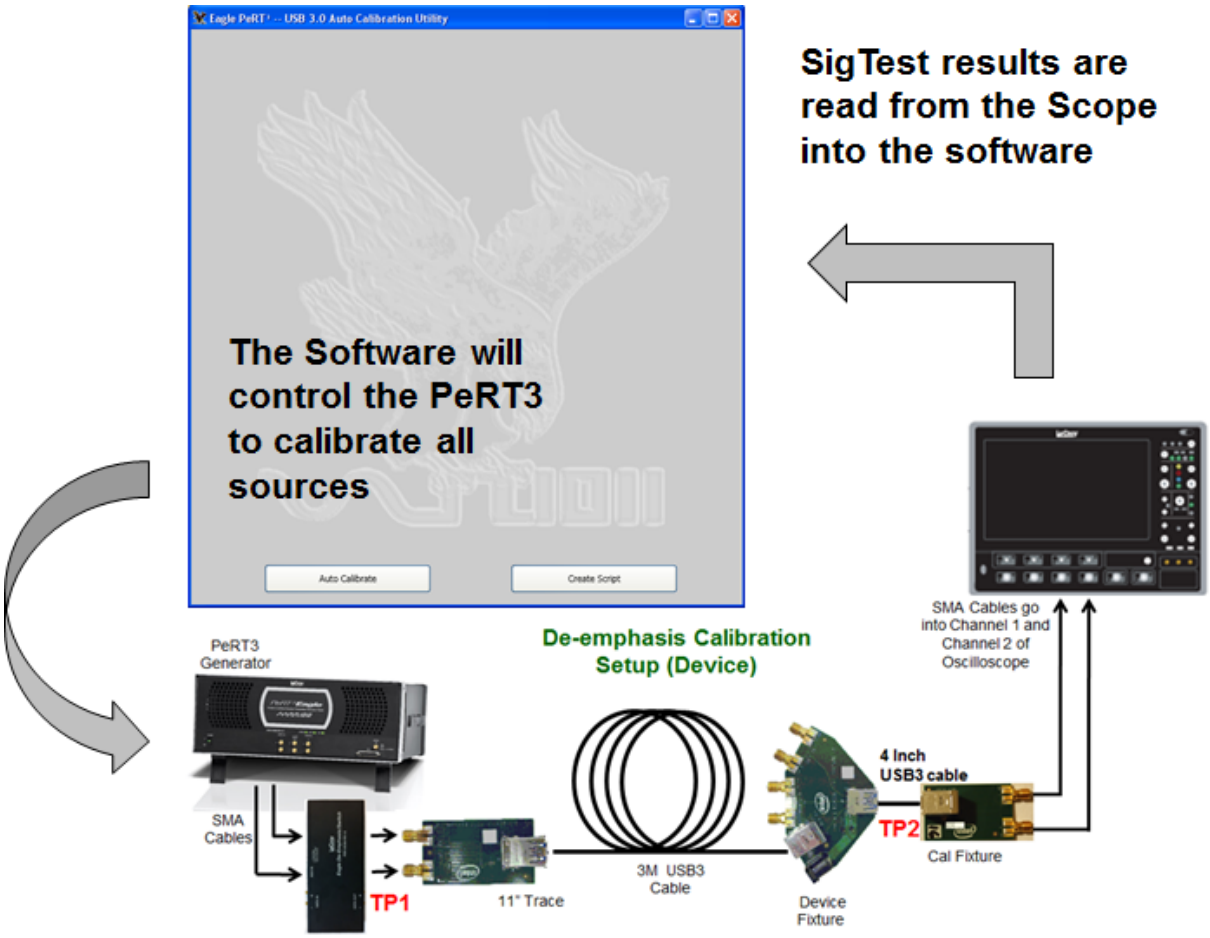
	Conditions	Measured Value	Calibrated Value on PeRT3
Source:	Eye Height = 145mV/180mV (+-10%)	145mV	640mV
Test Pattern	CP0		
Scope Settings (CTLE)	On		
Scope Settings (JTF)	On		
PeRT3 setting (SSC)	On		

	Conditions
Source:	TJ (20Mhz SJ)
Test Pattern	CP0
Scope Settings (CTLE)	On
Scope Settings (JTF)	On
PeRT3 setting (SSC)	On

87.761ps

Table 2

Automated Signal Source Calibration Software:



NOTE: On Device Test Fixture 2, only use the upper port, the lower port is not connected!

- Configure the setup as shown in Figure XX
- Confirm that the PeRT3 software is closed
- Press on Auto-calibrate
- After the calibration process is complete, press on Create Script and save the script for Compliance testing.

Step 2: DUT loopback Initialization

(Detailed initialization sequence is described in Appendix D)

- Connect the test equipment as illustrated in Figure 16 for Device testing

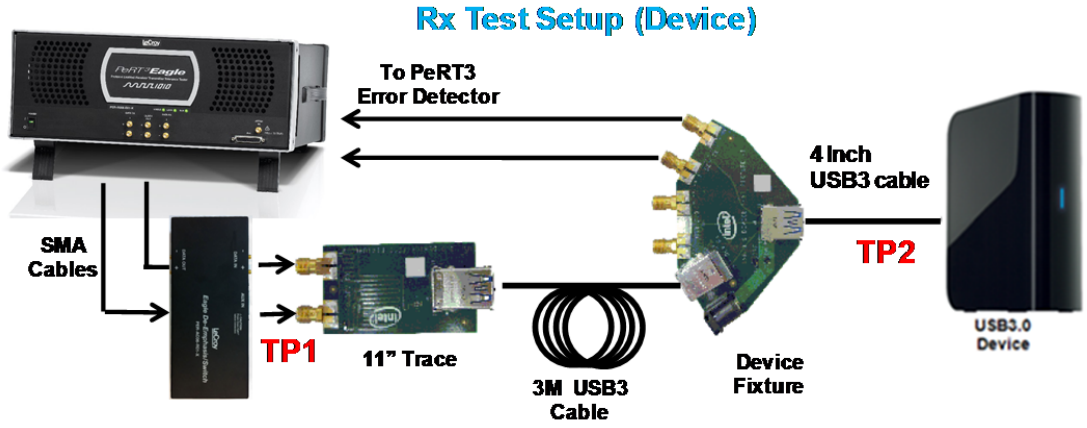


Figure 16

NOTE: On Device Test Fixture 2, only use the upper port, the lower port is not connected!

- Connect the test equipment as illustrated in Figure 17 for Host testing

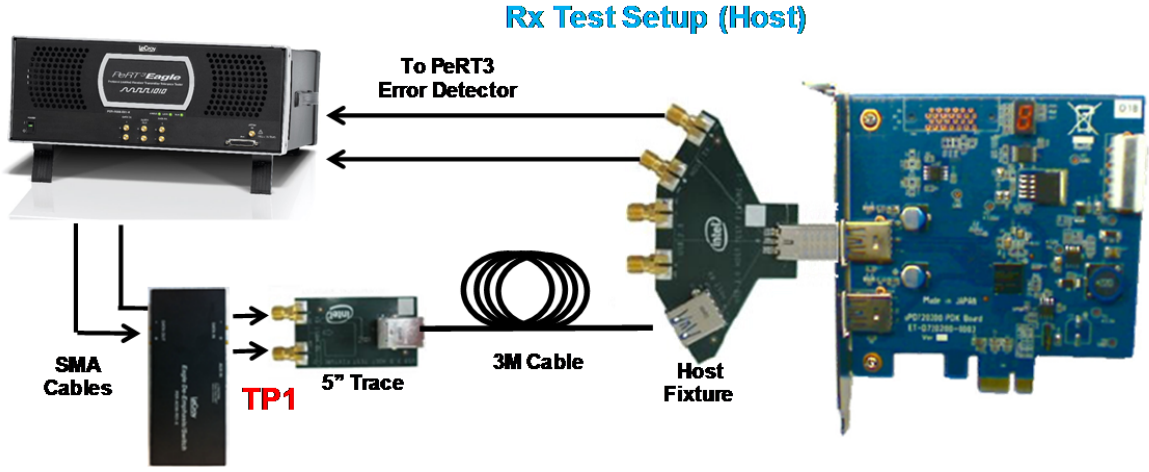


Figure 17

NOTE: On Device Test Fixture 2, only use the upper port, the lower port is not connected!

- Power off the PeRT3 and close the PeRT3 software and power off the DUT
- Power on the PeRT3 hardware and wait for 30secs until the Green/Red LED lights on PeRT3 are off
- Open the PeRT3 software and the software will automatically detect the hardware. Wait until the software completes synchronization (30sec to 1minute)
- In the Main tab, select **USB3.0** under protocol, Select **SSC** to be on
- Press Apply and wait for the logic to be loaded
- Under DUT Initialization, select the proper direction (**Device or Host**)
- Select **Loopback** for Initialize, **Default** for Sequence, **Bit Errors** for Count

Figure 18

If using De-emphasis box:

- Go into Channel 1 setup and set the following parameters;
  - Enable each field by clicking on the small circle on right bottom side.
  - Signal amplitude = 1000mV
  - De-emphasis = 3.0dB
  - HFRJ (on the right side) = 2.4
  - HFSJ 1: freq = 20Mhz, Amp = 45ps (you can type in the values by clicking on the numbers field)

If using Pre-emphasis solution:

- Go into Channel 1 setup and set the following parameters;
  - Enable each field by clicking on the small circle on right bottom side.
  - Signal amplitude = 700mV
  - Pre-emphasis: Amp=4, Dur=9
  - HFRJ (on the right side) = 2.4
  - HFSJ 1: freq = 20Mhz, Amp = 45ps (you can type in the values by clicking on the numbers field)

- Check the DUT and make sure the DUT is in powered off (by confirming the 5V power support to Device Fixture is not connected)
- Go in the Main Tab, then press Connect and observe DUT status (status should show “waiting for DUT”)
- Power up the DUT (by connecting the Device Fixture)
- At this point, if the DUT Status is “signal locked” and the status light of channel 1 is green, then proceed to next step

- Otherwise DUT have failed Rx Compliance, refer to appendix D for DUT loopback initialization sequence and troubleshooting

Step 3: Tolerance Testing

LFPS Testing (TBD)

Jitter Tolerance Sweep

If you have performed Rx calibration using USBAutoCal software, then follow the next steps, otherwise proceed to "If you calibrated the Rx jitter sources manually, follow the procedure below":

- In the PeRT3 GUI, import the calibrated test script
- Right click on the test script and select **Run Test**
- The compliance test will run automatically and open the test results

If you calibrated the Rx jitter sources manually, follow the procedure below. Otherwise proceed to Observe Results:

- In the PeRT3 GUI, go to test scripts and open "USB Compliance"
- Inside the test script, apply the calibrated Signal Amplitude, Pre-emphasis, Rj and Sj values
- Run the opened test script by right click on the test script and select Run Test

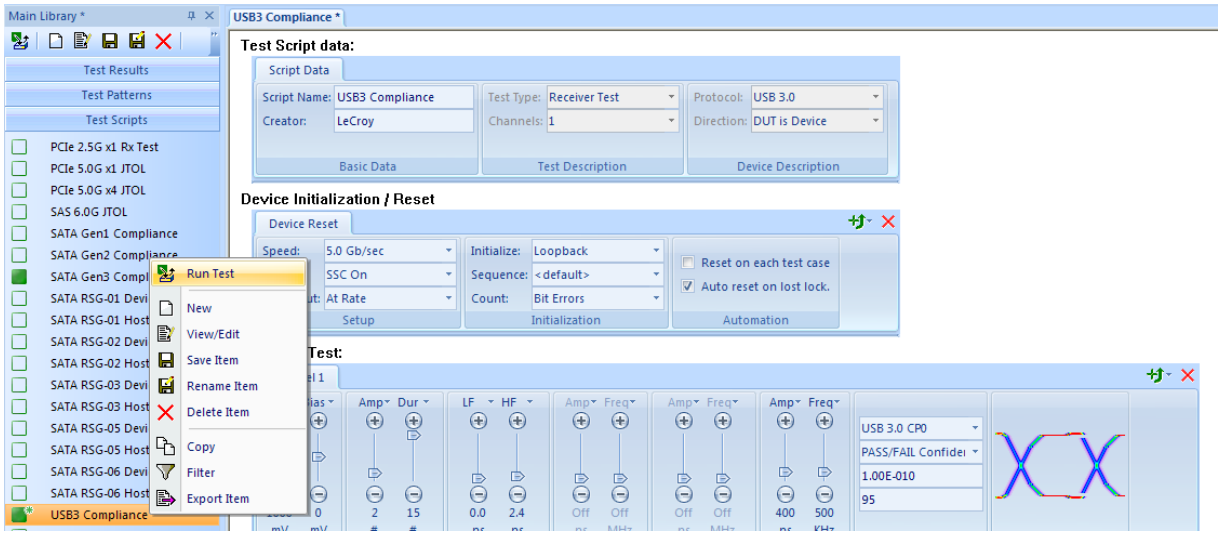


Figure 19

- Test result will load automatically
- In the PeRT3 GUI, go to Analysis Tab and Select Scatter chart view:

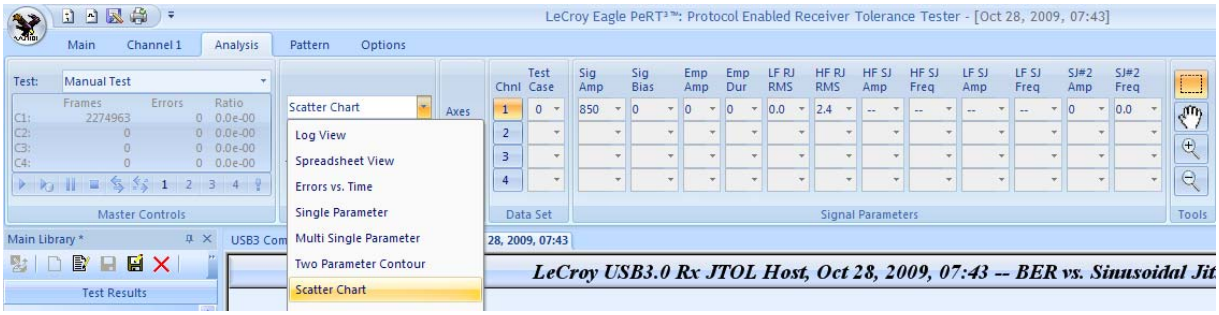


Figure 20

Observe Results:

- Right click on the test result and select “Spreadsheet View” for Graph Type
- If the column under Errors read all Zeros, this DUT has passed the Electrical Compliance Rx test

Note:
Is some cases, the DUT might loss lock when Jitter source change from 1Mhz to 500khz point, and the 500khz point will fail. It is acceptable to restart the test with 500khz enabled prior to loopback initialization and continue the test of 500khz point for compliance testing.

Index A – Resource Requirements

The resource requirements include two instruments with accessories.

	Units	
LeCroy SDA 813Zi-A (with PeRT3 and QualiPHY Software – QPHY USB3) - Matched SMA-SMA cables (3 pairs)	1	
PeRT3 – 1 Channel	1	
De-emphasis Box)	1	
USB3.0 Test fixture set from USB-IF (Sold by USB-IF) a. Host Test Fixture b. Device Test Fixture c. Host 5inch ref Channel d. Device 11inch ref Channel e. Device Cal Fixture f. 3M USB3.0 cable g. 4inch USB3.0 cable h. 4inch USB3.0 micro-B cable i. Vbus Power supply	1 set	     

Table 3

Appendix B – Test Setups

Pre-emphasis calibration (no channel in between PeRT3 and Scope):

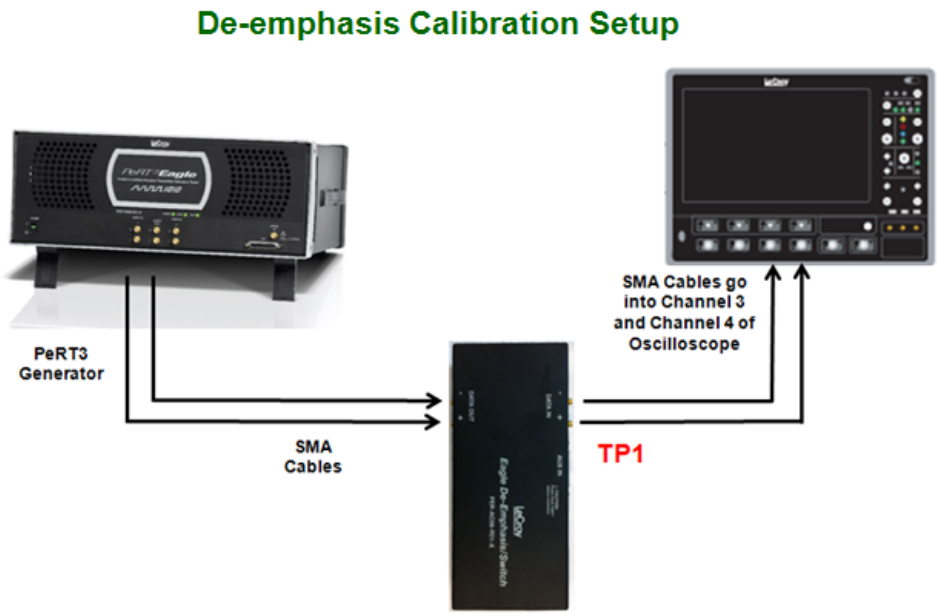


Figure 22

Rj/Sj/EyeHeight calibration (reference channel and cable is applied):

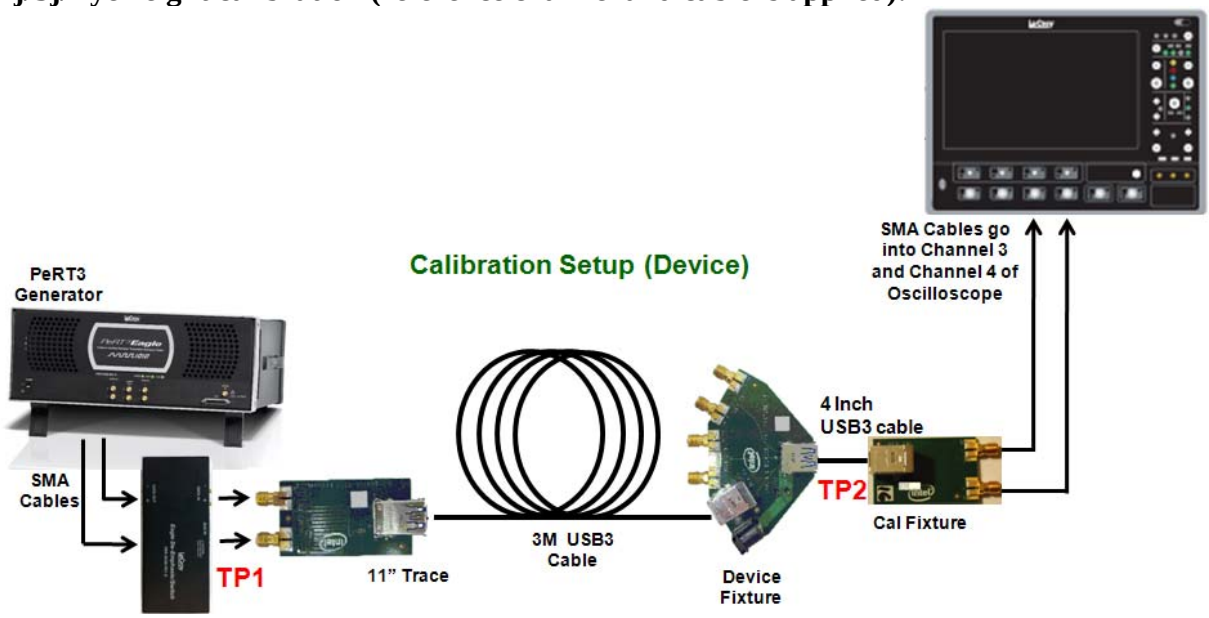


Figure 23

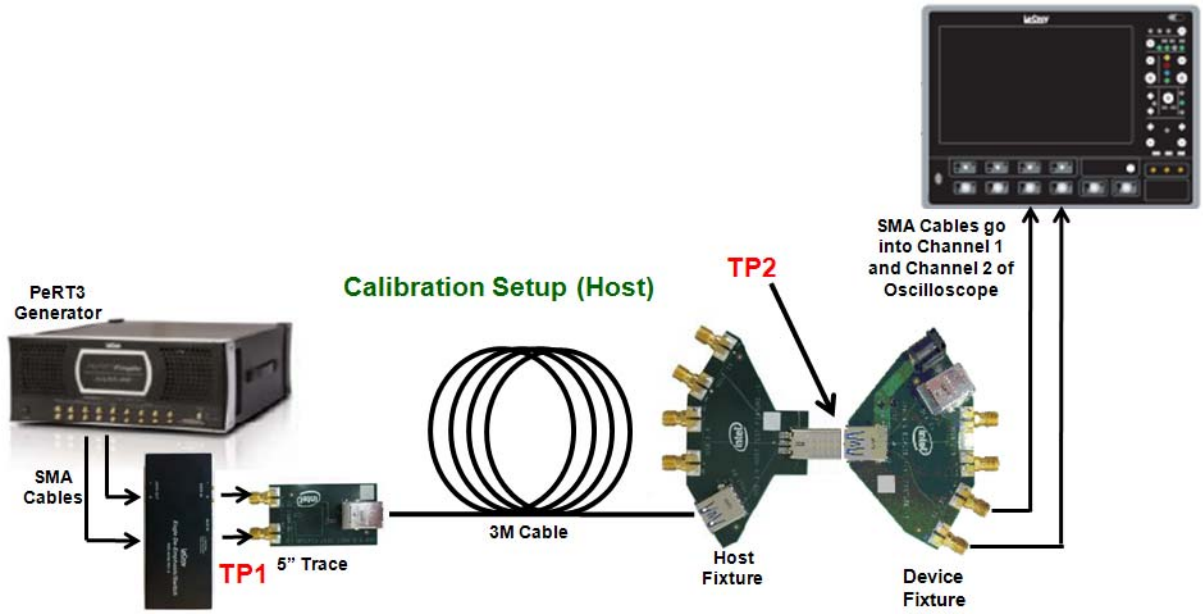


Figure 24

Rx test setup:

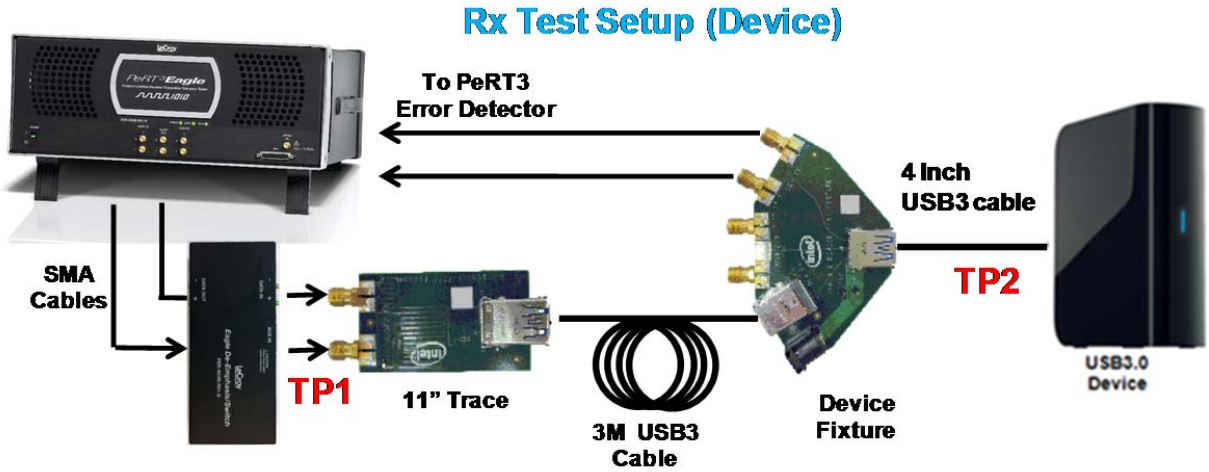


Figure 25

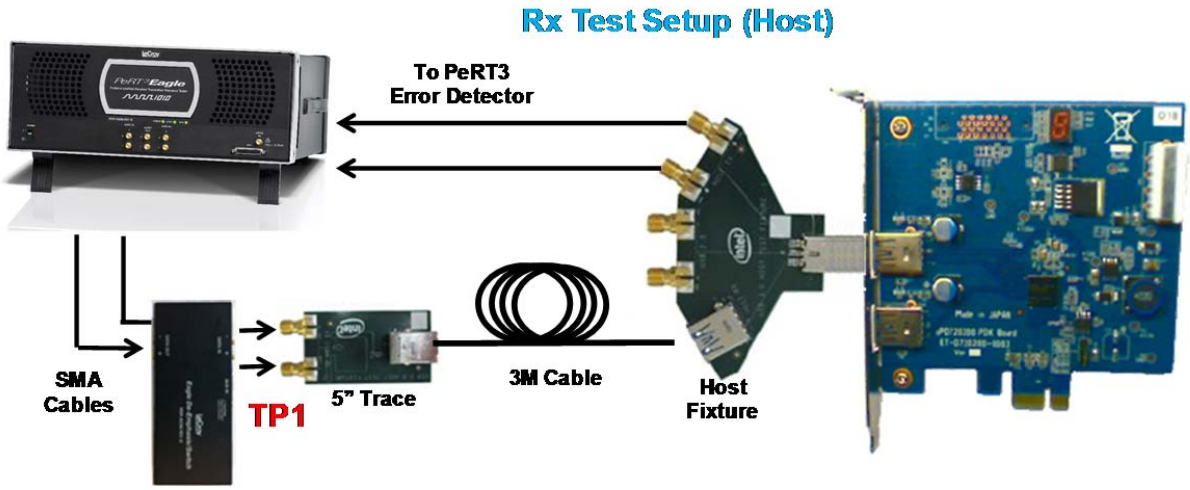

Rx Test Setup (Host)
To PeRT3
Error Detector
SMA
Cables
TP1
5" Trace
3M Cable
Host
Fixture

Figure 26

Appendix C – Oscilloscope Panel Setup
TBD

Appendix D – DUT Loopback Initialization Sequence/Troubleshooting
TBD

Appendix E – PeRT^3 Accuracy
TBD