



PCIe Simulation

Using WEBENCH Interface Designer

Fast and accurate Multi-Gbps Simulations

December 2016

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WEBENCH® Interface Designer

Quickly optimize signal integrity in high-speed designs



Start!

Select!

Sim!

WEBENCH® Interface Designer

Tx:

Mid Channel:

Rx:

Max Data Rate: Gbps

Device Mode:

Start Design



WEBENCH Optimizer

Lowest BOM Cost | Smallest Footprint | EQ Score

Footprint (mm²): 16 | BOM Cost (\$/k): 7.45 | EQ Score: 0.78

Basic Input Selections

Rating: All | Protocol: ALL | Device Function: All

Max Data Rate: 10.312 Gbps | VSupply: All

Advanced Filter

- Server & Storage
- Telecom & Datacom
- Wireless Infrastructure
- Display, Video and Imaging
- Optical
- Other Interface

Results Summary

Footprint (mm²): 5.58 - 225.00

BOM Cost (\$/k): 1.05 - 52.43

Data Rate (Gbps): 11.30 - 52.50

Supply Voltage (V): 1.8 - 5

PowerPerChannel (mW): 0.00 - 288.75

Configure | History | Log | Link Optimizer

Channel 1

Specify Channel 1 properties

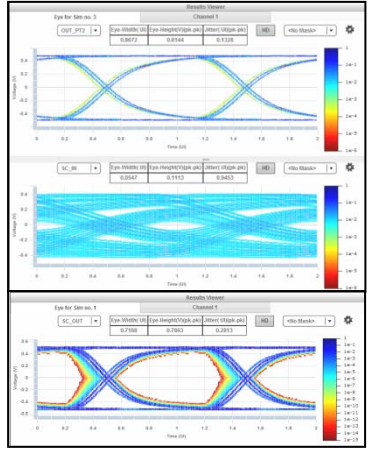
Channel Length: 1 inches

Insertion Loss at Nyquist: 6 dB @ 5.1562 GHz

Reflection: Low

Calculate Channel

Part Name	Quantity	Unit	Alt Part	Manufacturer	Series	Package	Notes
241100111	1	mm	241100111	TI	Series 1	100-pin	100-pin
241100112	1	mm	241100112	TI	Series 1	100-pin	100-pin
241100113	1	mm	241100113	TI	Series 1	100-pin	100-pin
241100114	1	mm	241100114	TI	Series 1	100-pin	100-pin
241100115	1	mm	241100115	TI	Series 1	100-pin	100-pin

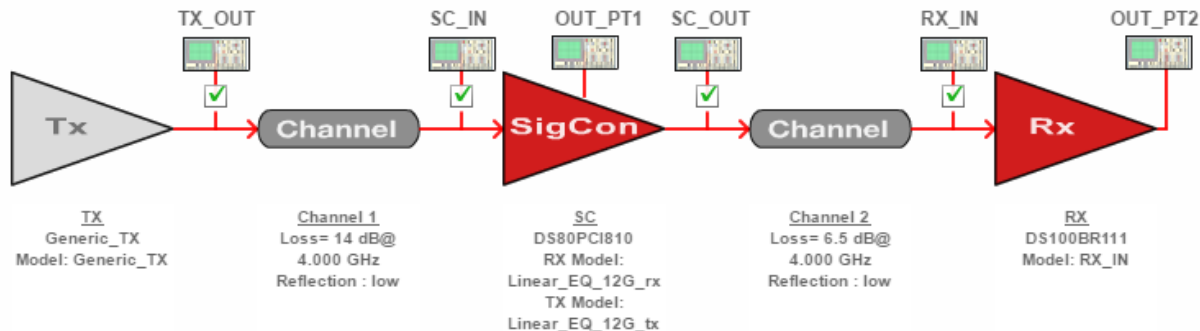


www.ti.com/interfacedesigner

Configure the Simulation Components

- **Transmit**

- Utilize Tx FIR
- Emulate PCIe settings



- **Channel**

- Set “Insertion Loss at Nyquist” to define channel attenuation

- **Alternate Method for Channel**

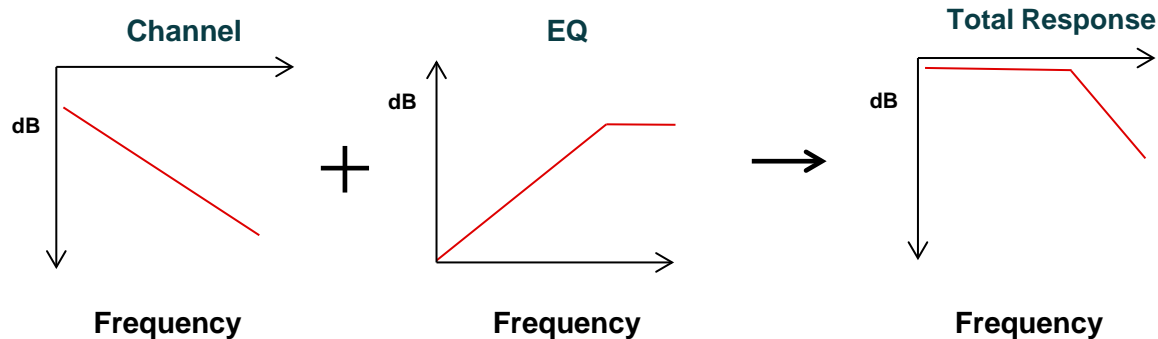
- Import your own S4P file to use in the simulation

- **Receiver**

- Utilize TI CTLE to emulate PCIe Rx

Equalizer Theory

Continuous Time
Linear Equalization
(CTLE)



Common Terminology: Nyquist Frequency (GHz) = $\frac{1}{2}$ Data Rate (Gbps)

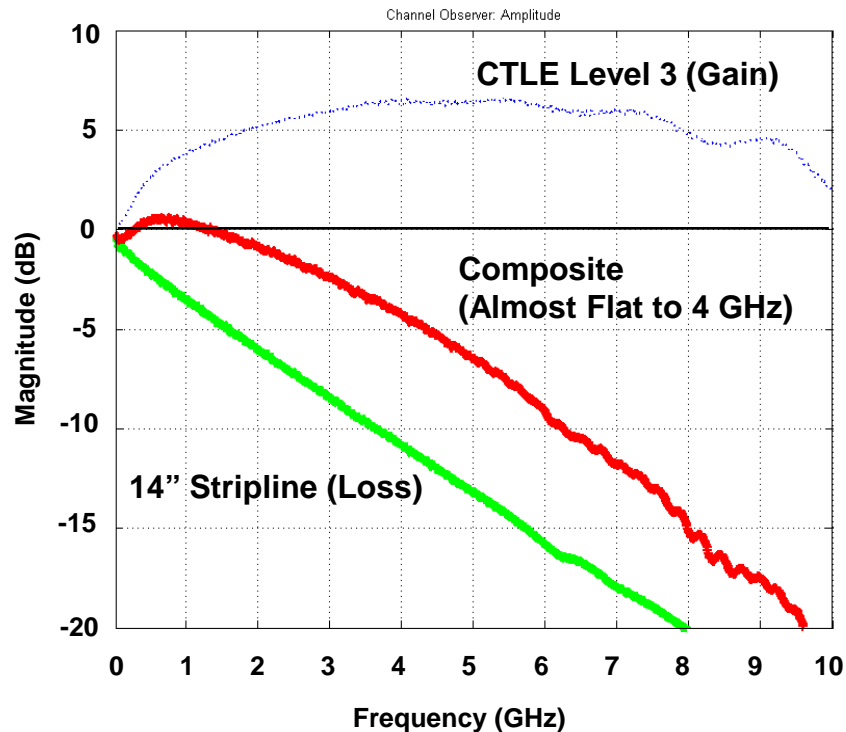
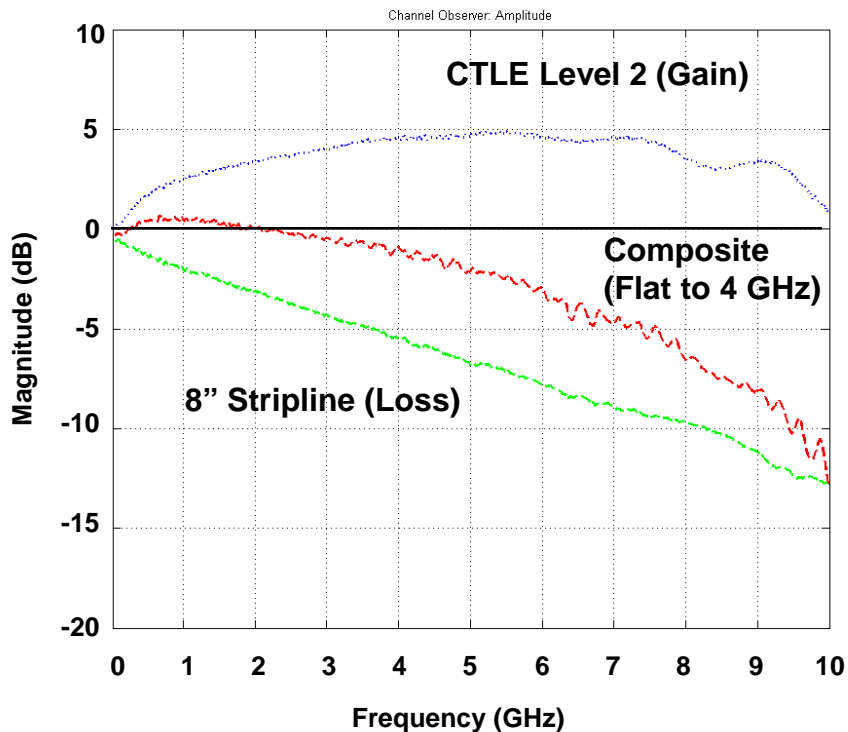
Equalizer goals:

- ✓ Remove loss variations over frequency (ISI, Dj). Similar amplitude for higher-frequency signals and lower-frequency signals or make the loss **equal** over frequencies, hence “equalizer”
- ✓ Work with link training algorithms by remaining a linear function.

PCIe Linear Equalization Example

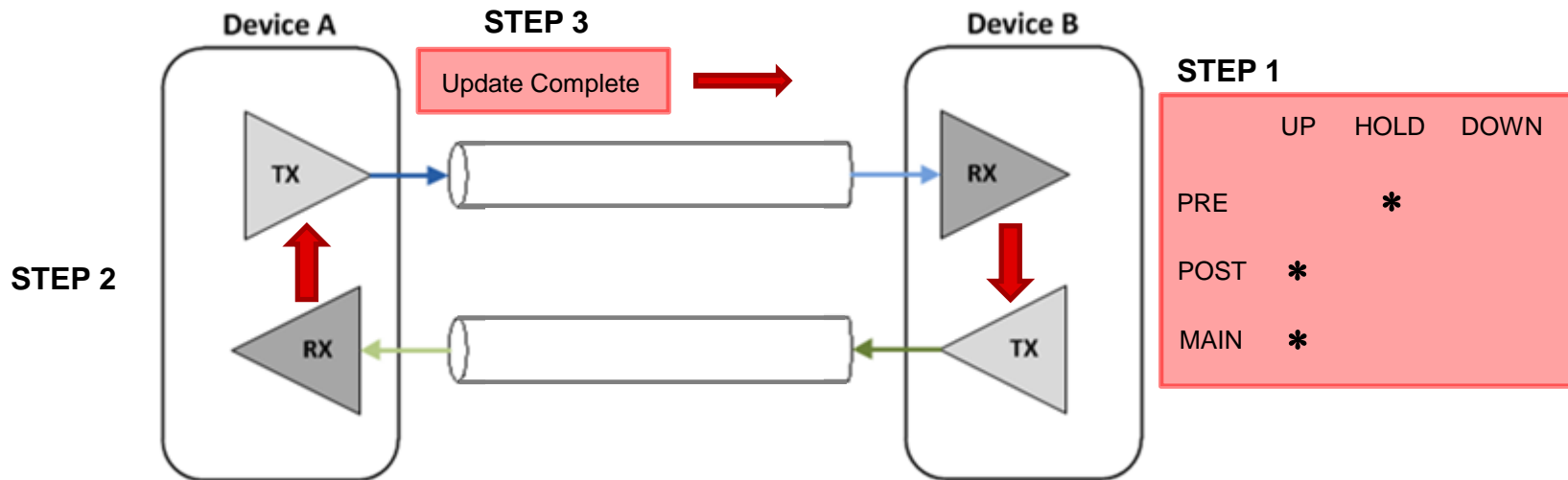
- Using Linear Equalization to compensate for channel losses and pass analog waveform information
 - Linear Equalization
 - Equalization (Link or Backchannel) Training
 - WEBENCH configuration
 - Simulation Results

Linear Equalization Theory



Link Equalization Training

- Many popular serial interfaces use this type of handshake
 - PCIe (8 Gbps), 10G-KR (10 Gbps), SAS (12 Gbps)
 - Uses Rx EQ to tune the attached Tx FIR coefficients



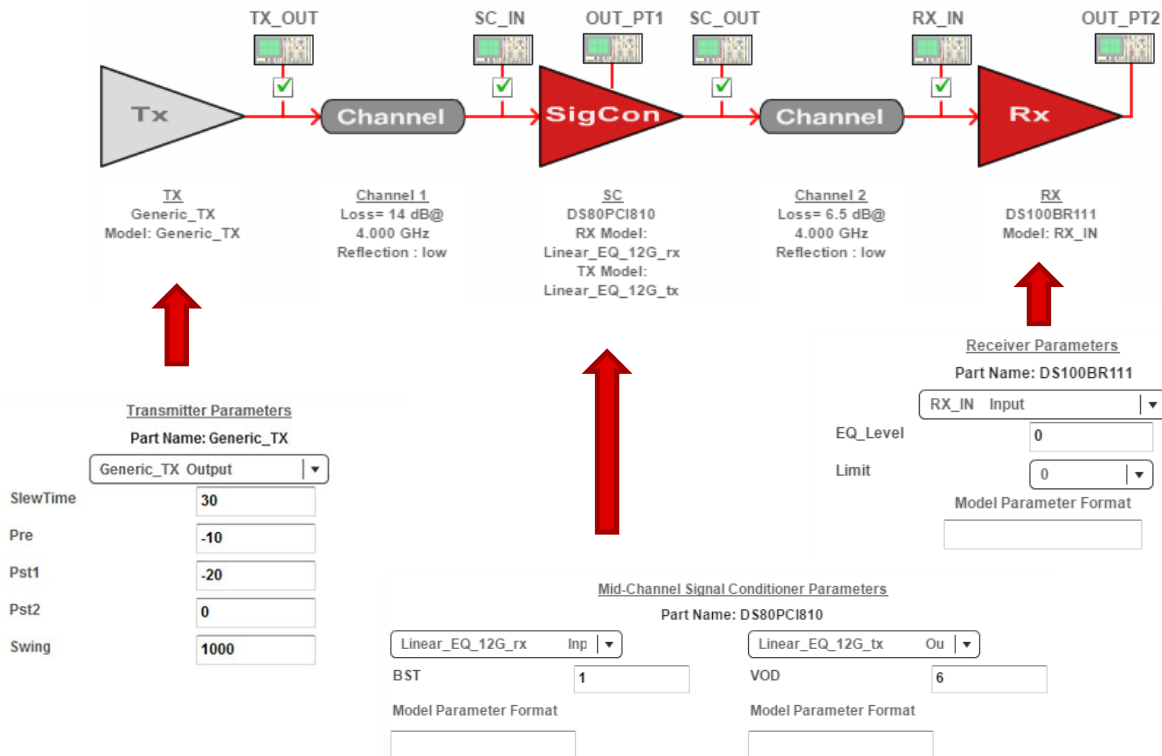
PCIe - Transmit Equalization

PCI Express Transmit Preset Ratios

		PCIe Standard		WEBENCH Generic_TX Settings		
Preset Number		Pre-cursor (dB)	De-emphasis (dB)	Pre (%)	Pst1 (%)	Swing (mV)
Gen 1	P4	0.0	0.0	0.0	0.0	1000
	P1	0.0	-3.5	0.0	-16.6	1000
	P0	0.0	-6.0	0.0	-25.0	1000
Gen 3	P9	3.5	0.0	-16.6	0.0	1000
	P8	3.5	-3.5	-12.5	-12.5	1000
	P7	3.5	-6.0	-10.0	-20.0	1000
	P5	1.9	0.0	-10.0	0.0	1000
	P6	2.5	0.0	-12.5	0.0	1000
	P3	0.0	-2.5	0.0	-12.5	1000
	P2	0.0	-4.4	0.0	-20.0	1000
	P10	0.0	-9.5	0.0	-33.0	1000

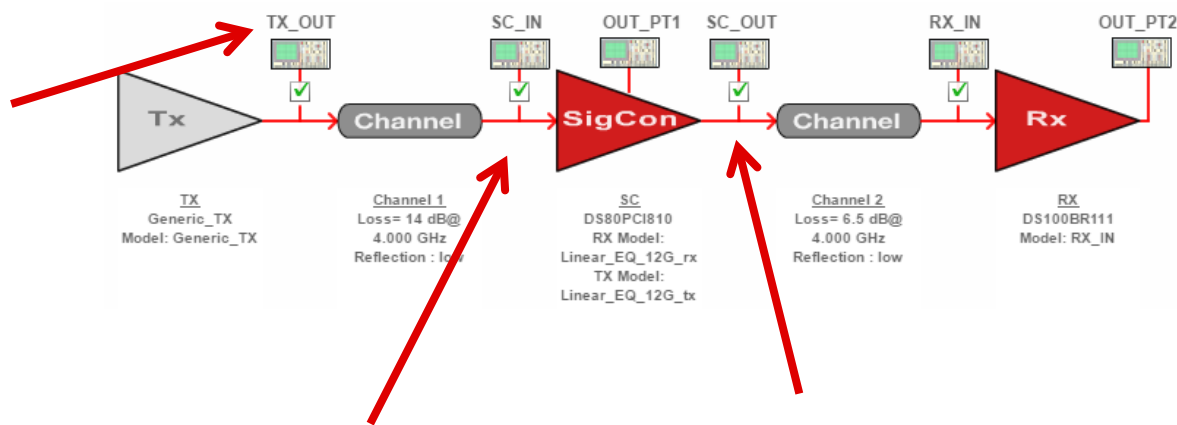
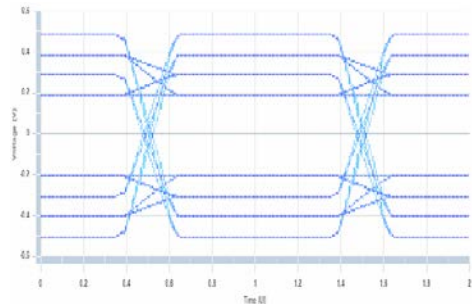
Simulation Setup with DS80PCI810

- **Configure Channel 1**
 - 14 dB loss
 - CPU Package + Trace
- **Configure Channel 2**
 - 6.5 dB loss
- **Models**
 - Tx set to Preset 7
 - SigCon set as shown
 - Rx set to 6 dB gain



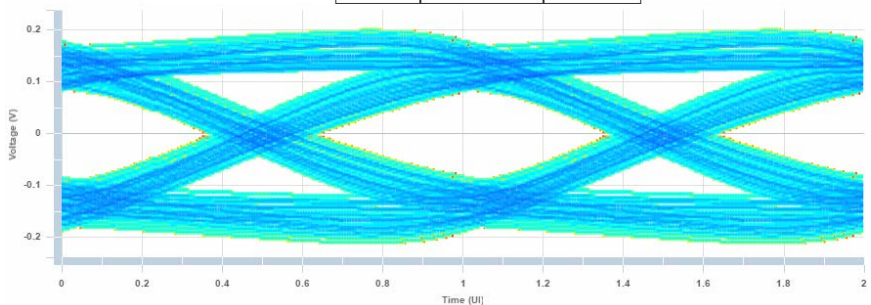
Simulation Results

TX_OUT



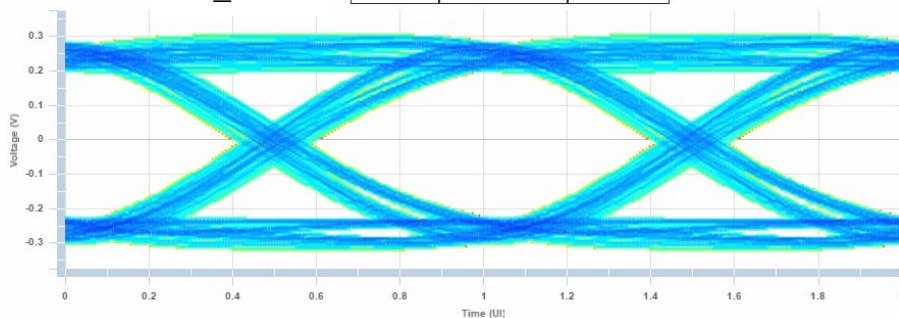
SC_IN

Eye-Width (UI)	Eye-Height (V)(pk-pk)	Jitter (UI)(pk-pk)
0.6250	0.1675	0.3750



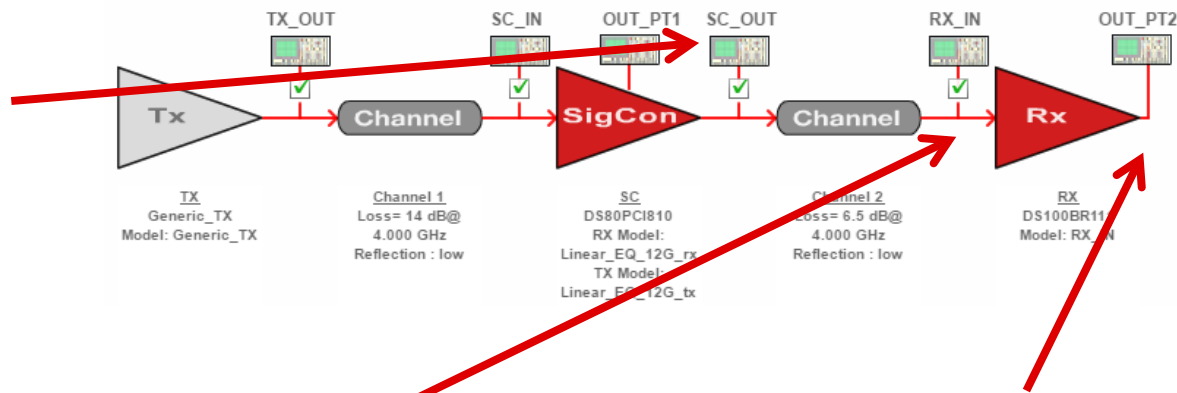
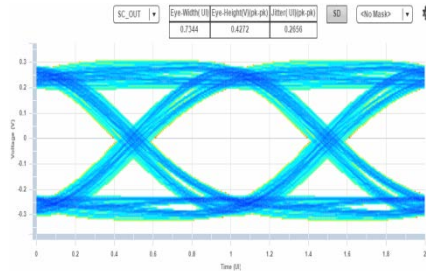
SC_OUT

Eye-Width (UI)	Eye-Height (V)(pk-pk)	Jitter (UI)(pk-pk)
0.7344	0.4272	0.2656

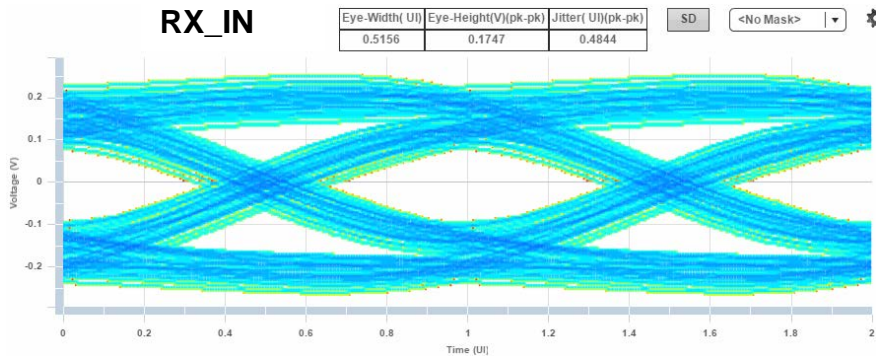


Simulation Results

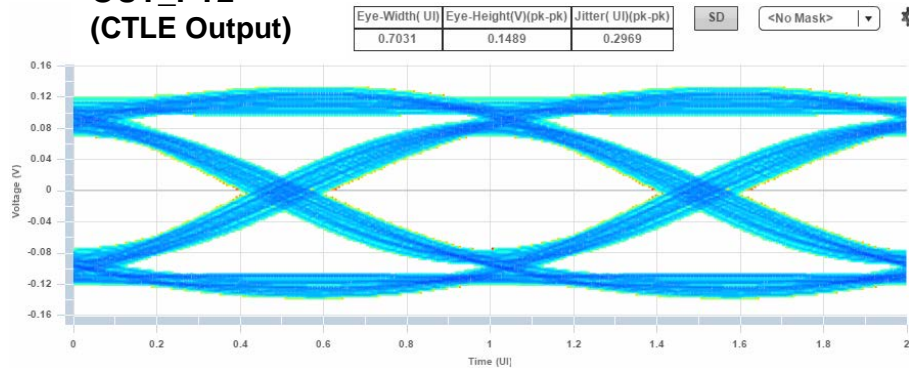
SC_OUT



RX_IN

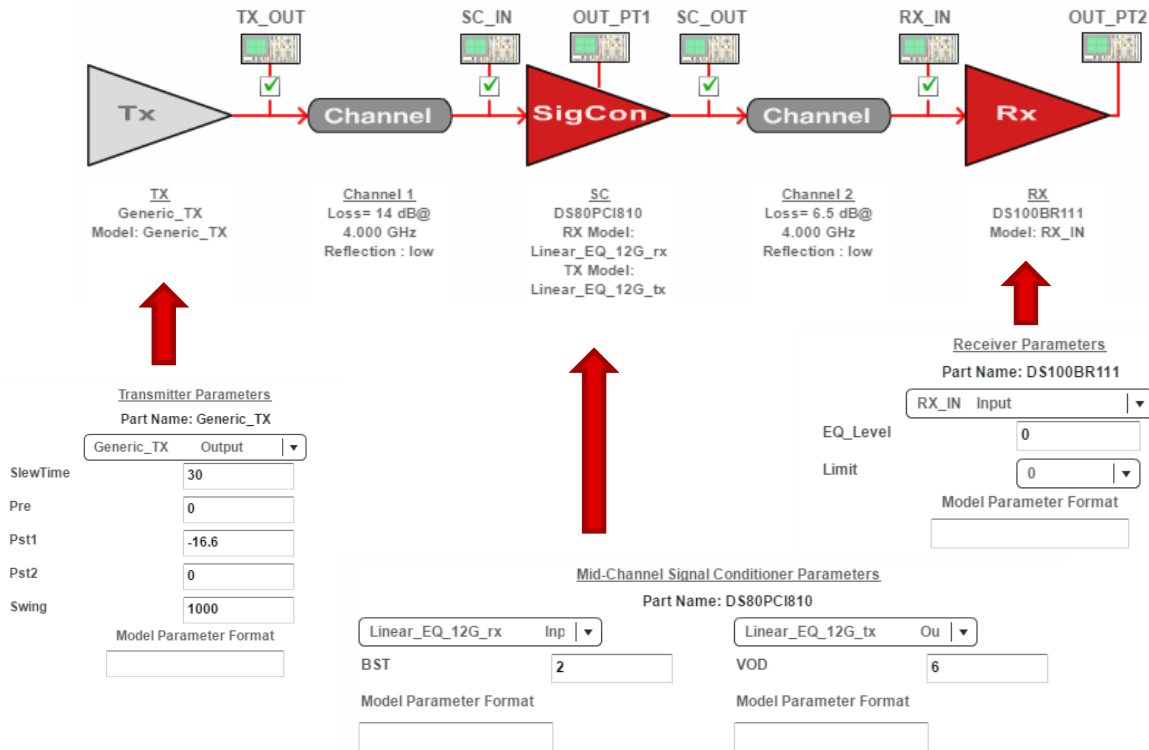


OUT_PT2
(CTLE Output)



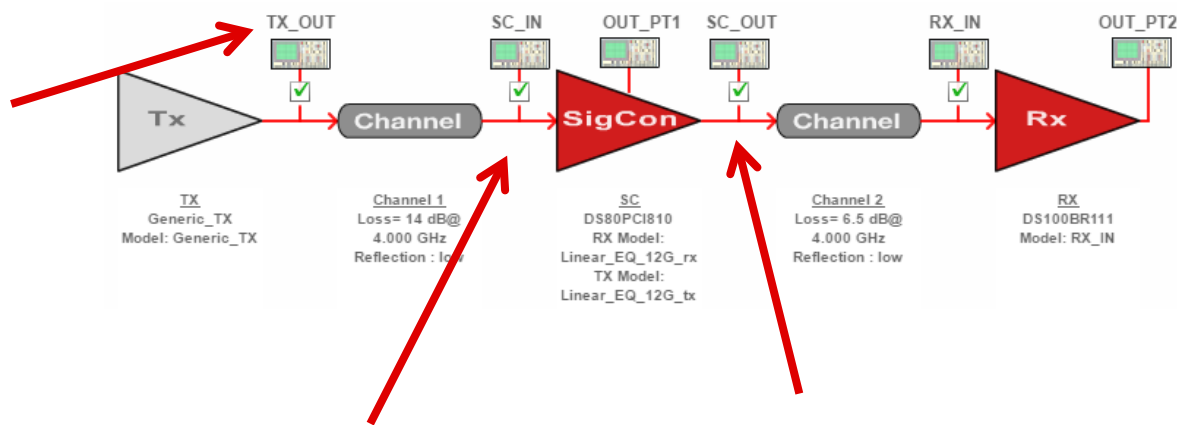
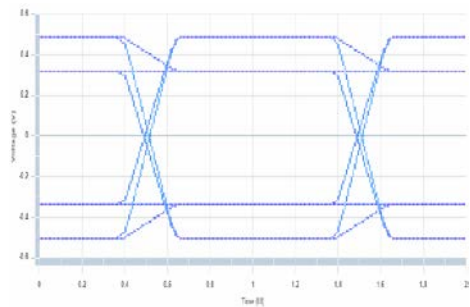
Simulation Setup with DS80PCI810

- **Configure Channel 1**
 - 14 dB loss
 - CPU Package + Trace
- **Configure Channel 2**
 - 6.5 dB loss
- **Models**
 - Tx set to Preset 1
 - SigCon set as shown
 - Rx set to 6 dB gain



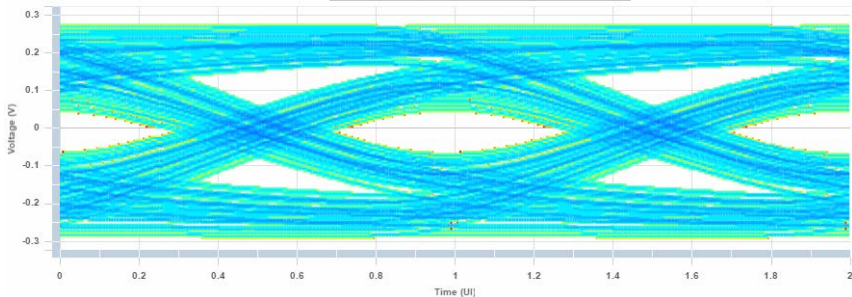
Simulation Results

TX_OUT

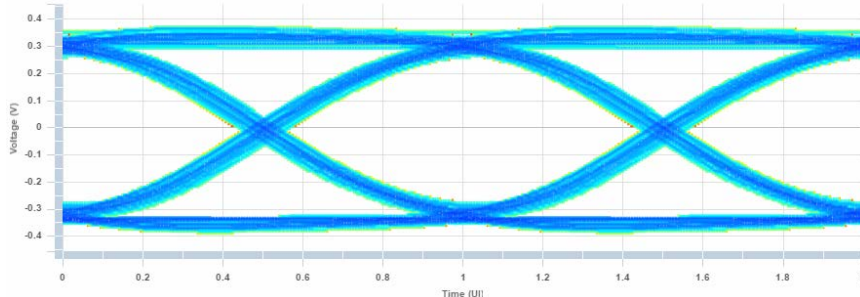


SC_IN

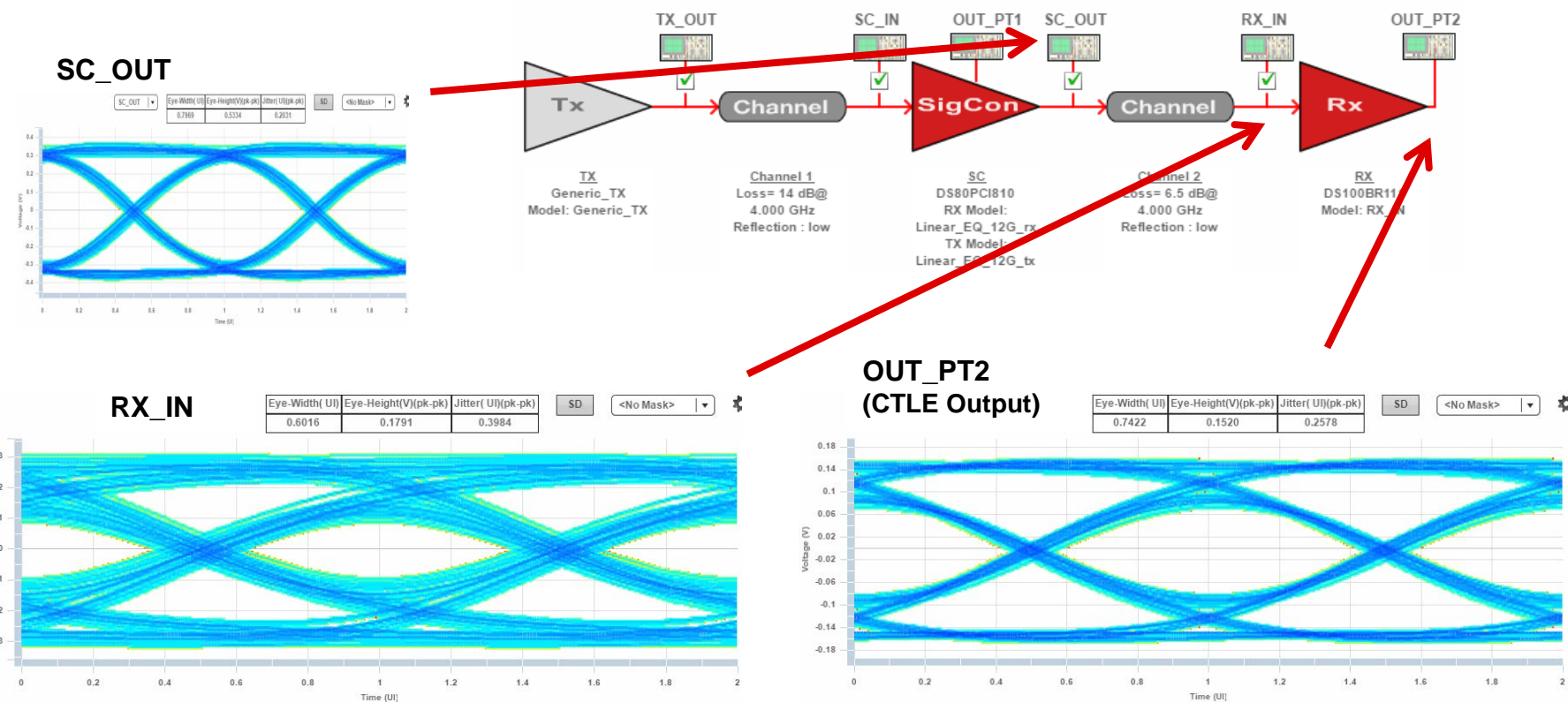
Eye-Width(U)	Eye-Height(V)(pk-pk)	Jitter(U)(pk-pk)
0.3828	0.1160	0.6172



Eye-Width(U)	Eye-Height(V)(pk-pk)	Jitter(U)(pk-pk)
0.7969	0.5334	0.2031



Simulation Results

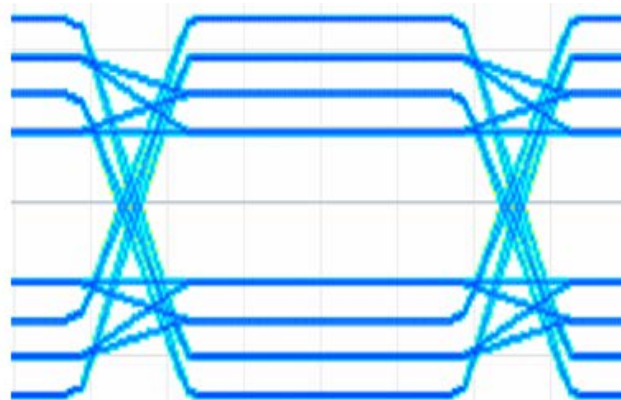
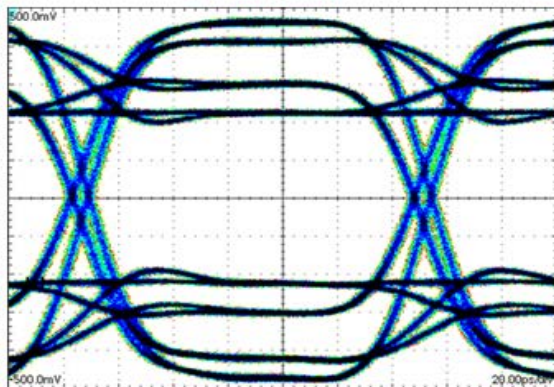


Extra Information

PCIe Simulation - Lab Correlation

PCIe Preset 7: Lab vs. WEBENCH Simulation

- Repurposed 25G TI Retimer IP as Tx generator to run at 8 Gbps



Transmitter Parameters
Part Name: Generic_TX

Generic_TX Output

SlewTime: 30

Pre: -10

Pst1: -20

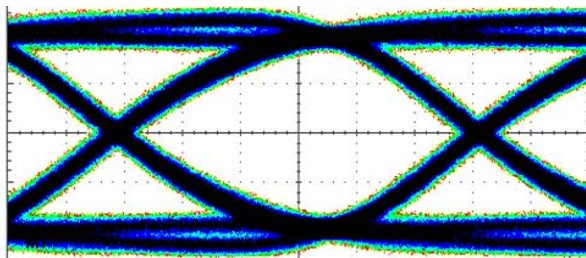
Pst2: 0

Swing: 1000

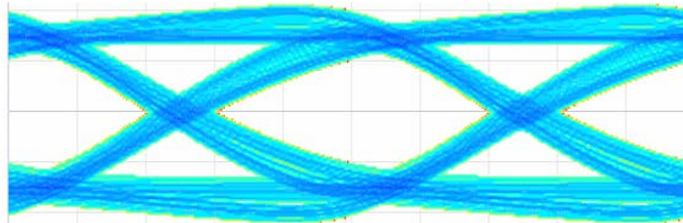
	PCIe Standard		WEBENCH Generic_TX Settings		
Preset Number	Pre-cursor (dB)	De-emphasis (dB)	Pre (%)	Pst1 (%)	Swing (mV)
P7	3.5	-6.0	-10.0	-20.0	1000

PCIe Preset 7: Driving 14" of Trace

Lab Measurement



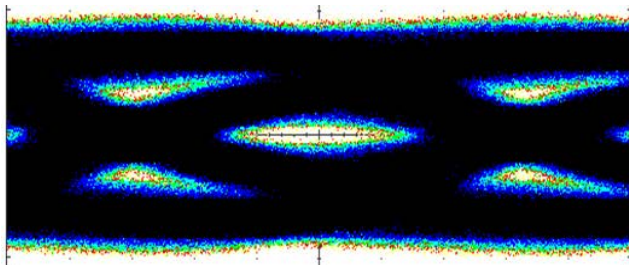
WEBENCH Simulation



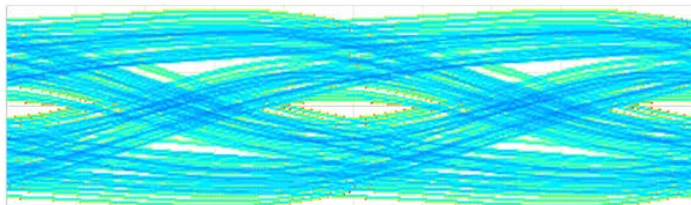
- Test Channel: PCIe Breakout + Short Calibration Channel
- Nominal Attenuation: -12 dB @ 4 GHz

PCle Preset 7: Driving 24" of Trace

Lab Measurement



WEBENCH Simulation



- Test Channel: PCIe Breakout + Long Calibration Channel
- Nominal Attenuation: -20 dB @ 4 GHz
- The open eye at 14" has collapsed due to the increased channel loss.

Simulation Window with DS80PCI810

- **Configure input channel**

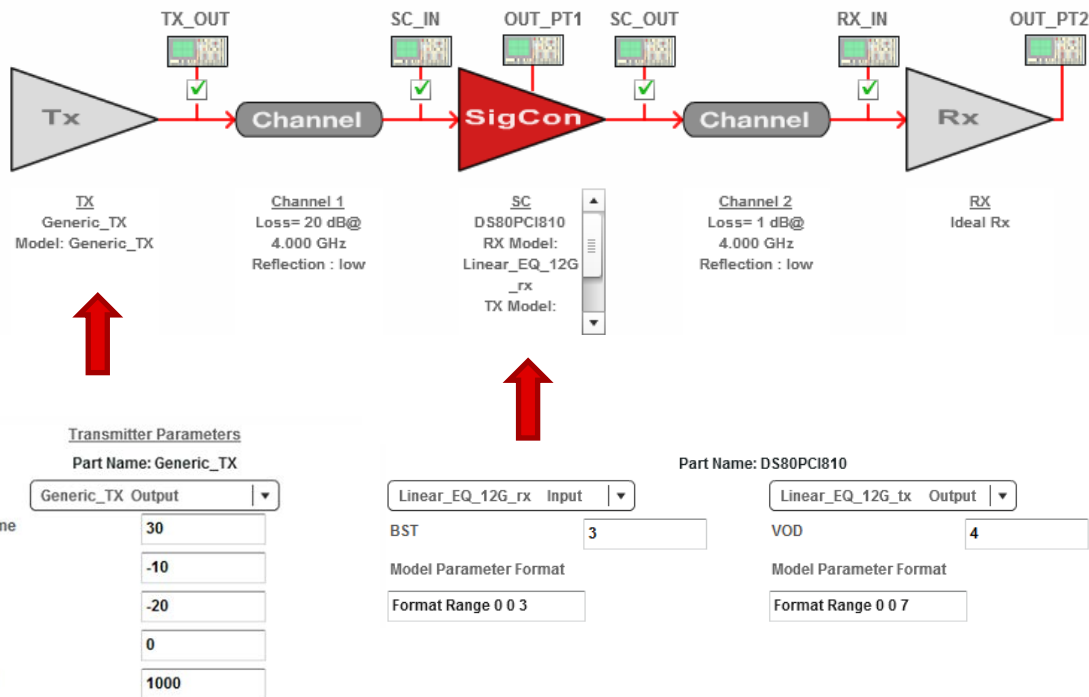
- 20 dB loss
- Hit “Apply”

- **Configure output channel**

- 1 dB loss
- Hit “Apply”

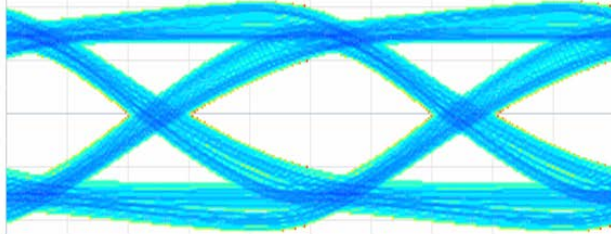
- **Device configuration**

- Set BST to 3
- Set VOD to 4
- Hit “Apply”

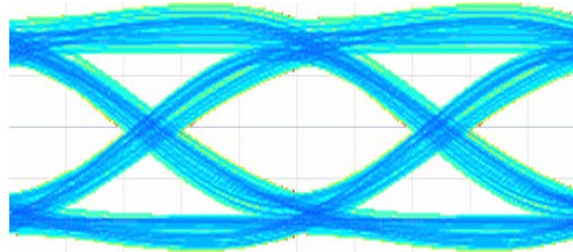


Effect of adding DS80PCI810 Linear Equalization

Simulation -12 dB
Without PCI810



Simulation -20 dB
With PCI810

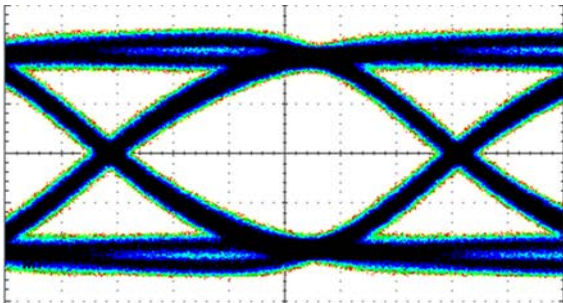


8 dB Reach Extension!!!

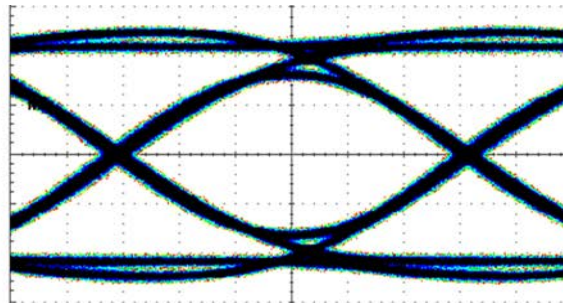
- DS80PCI810 Settings:
 - EQ = 11'b (Model Level 3 of 4)
 - VOD = 011'b (Model Level 4 of 8)
- Equalized waveform retains analog characteristics
 - **Required for equalization link training algorithms**

Effect of adding DS80PCI810 Linear Equalization

Lab Measurement 14"
Without PCI810



Lab Measurement 24"
With PCI810



- DS80PCI810 Settings:
 - EQ = 11'b (Model Level 3 of 4)
 - VOD = 011'b (Model Level 4 of 8)
 - VOD_DB = 000'b (Model Level 1 – minimum)

10" Reach Extension!!!