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Optimizing Waveform fidelity in SERDES & Other high-speed digital application

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Agenda

- DDIC market trend
- Types of pre-emphasis
  - Analog and Digital
- Digital pre-emphasis in a nutshell
  - Definition of pre-emphasis
- Pre-emphasis setting in Cohu high-speed digital instrument
  - Waveform collection method
  - How pre-emphasis influence waveshape
- Pre-emphasis use model concept

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Current Display Driver IC Market Trend

Speed

VESA eDP 1.5
2021

VESA eDP 1.4a
2015

mipi C-PHY
2014

mipi D-PHY
2003

LVDS
199x

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What is Pre-emphasis?

Types of pre-emphasis

Analog (Audio)

Digital (SERDES)

Reason for pre-emphasis

Signal degradation happens because of long transmission line and jitter

Analog signal (Audio)

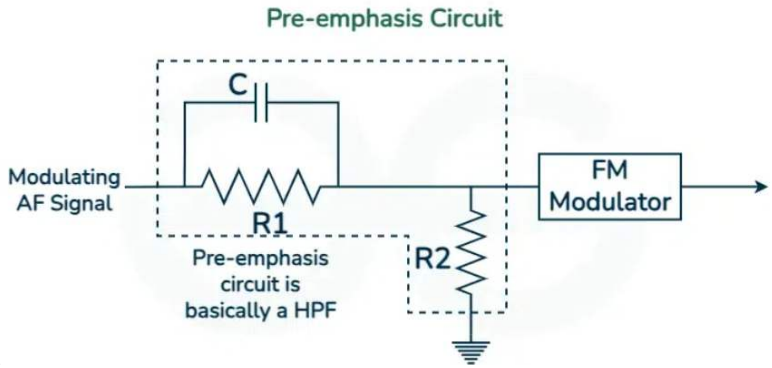
In general, signals with higher modulation frequencies have lower SNR, pre-emphasis helps amplify high frequency signal components such that they will have magnitude higher than noise components. This led to improvement in the Signals to Noise Ratio

Digital signal (SERDES)

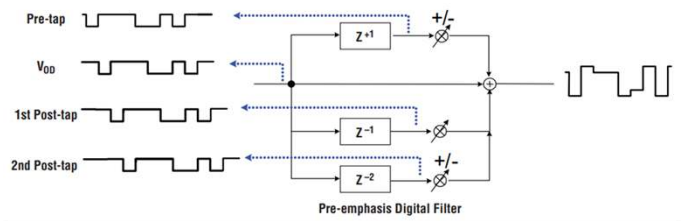
Pre-emphasis boots the high-frequency energy on every transition in the data stream by combining different delays, weights, and polarity to optimize channel loss through finite impulse response (FIR) filter.

Pre-emphasis circuits

Analog Audio Pre-emphasis



Digital SERDES Pre-emphasis



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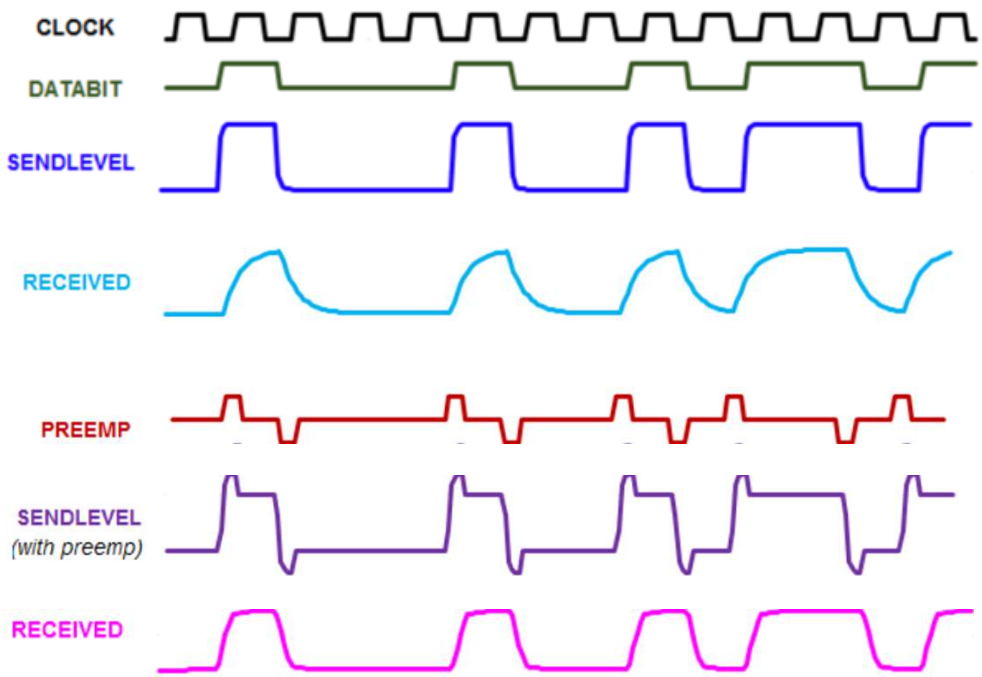
Digital signal pre-emphasis in a nutshell



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Definition of Pre-emphasis for digital signal (SERDES)

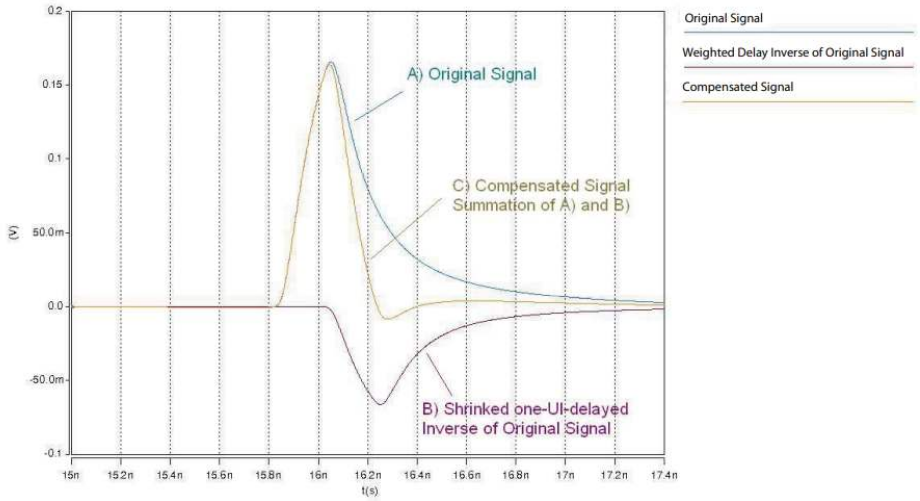
High-speed digital signal

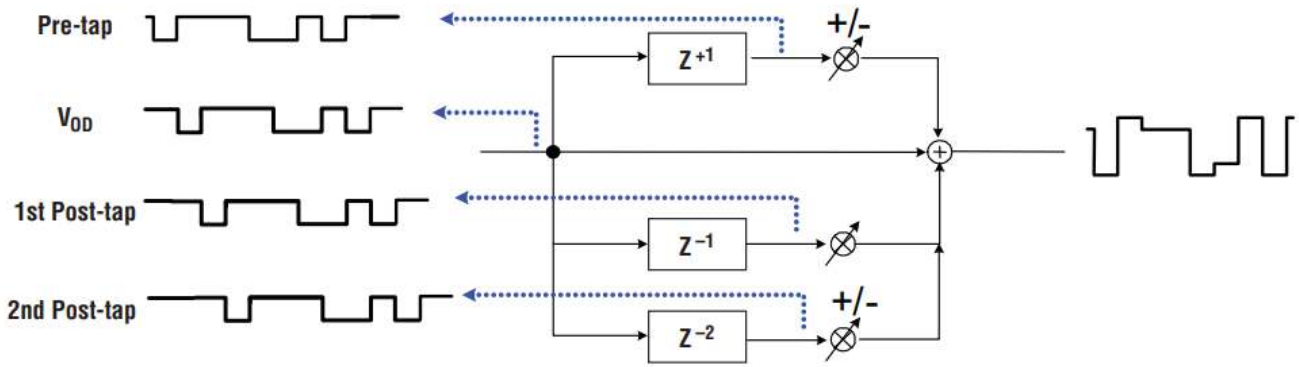
- As high-speed digital signal traveling through a PCB, skin effect and dielectric losses will degrade and attenuate the high-frequency content of the signal

Pre-emphasis

- The objective of pre-emphasis is to apply delay and inversion to the original signal and sum it back with proper weight to compensate the inter-symbol-interference (ISI) from the nearby data symbol

Pre-emphasis Digital Filter





Pre-emphasis Digital Filter

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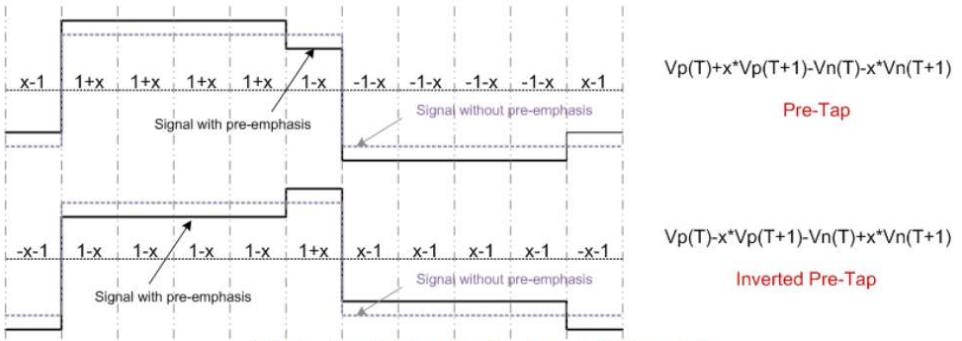
Pre-emphasis

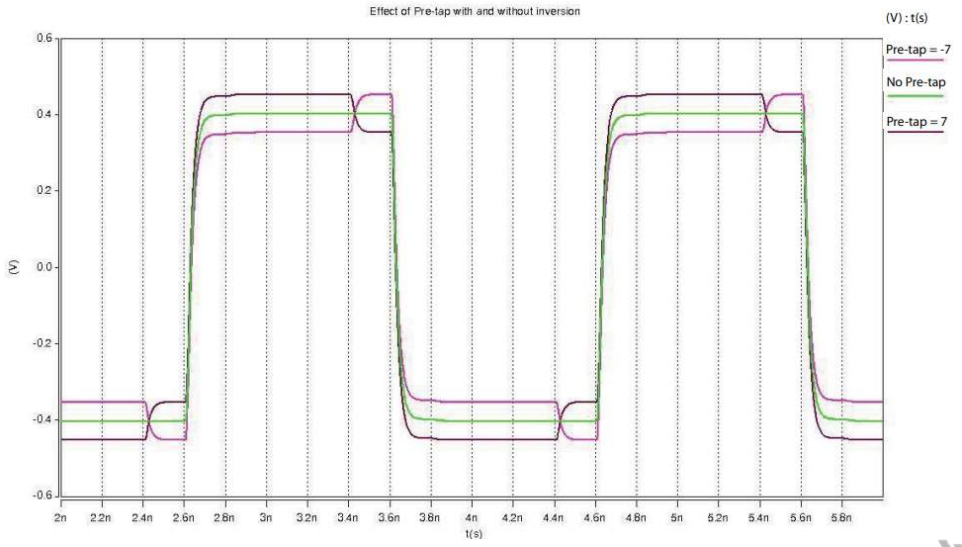
Pre-1

- 32 voltage steps total (value range from -1 to +1)
- Each voltage step represent a 10mV common mode differential or 5mV common mode single ended
- Pulse active for 1 native clock resolution before
  - For instance. 1.25Gbps, UI = 800ps
  - Native rate is 8 x 1.25Gbps = 10Gbps (100ps)
  - Pre-emphasis is valid for one native rate period

Pre-1



a) Ideal pre-tap effect (assuming V_{OD}=1 and x is the tap weight)



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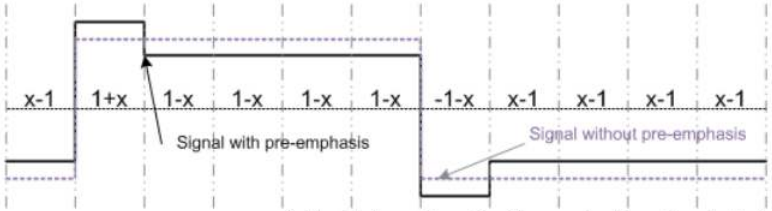
Pre-emphasis

Post-1

- 32 voltage steps total (value range from -1 to 0)
- Each voltage step represent a 10mV common mode differential or 5mV common mode single ended
- Pulse active for 1 native clock resolution after
  - For instance. 1.25Gbps, UI = 800ps
  - Native rate is 8 x 1.25Gbps = 10Gbps (100ps)
  - Pre-emphasis is valid for one native rate period

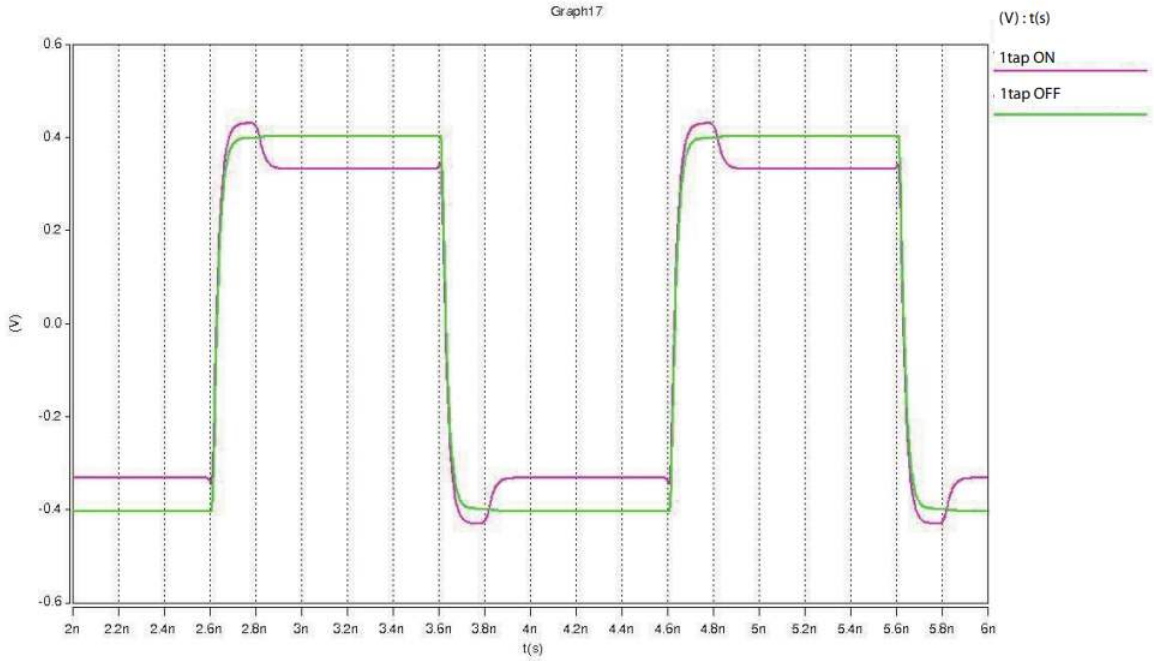
Post-1



Vp(T)-x*Vp(T-1)-Vn(T)+x*Vn(T-1)

1st Post-Tap

a) Ideal 1st post-tap effect (assuming V_{OD}=1 and x is the tap weight)



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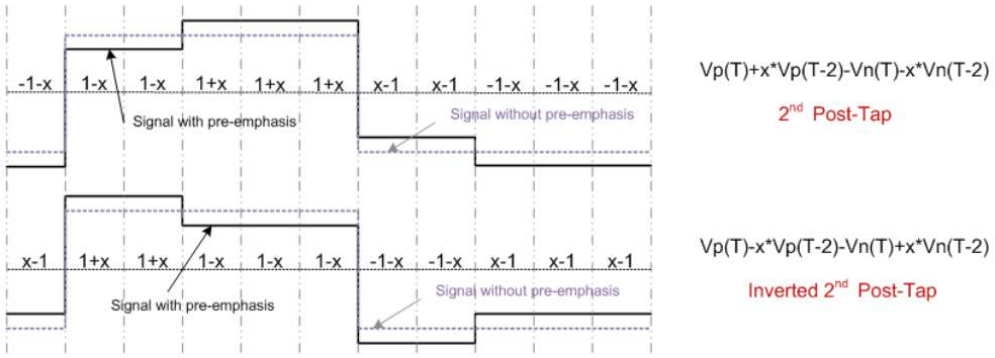
Pre-emphasis

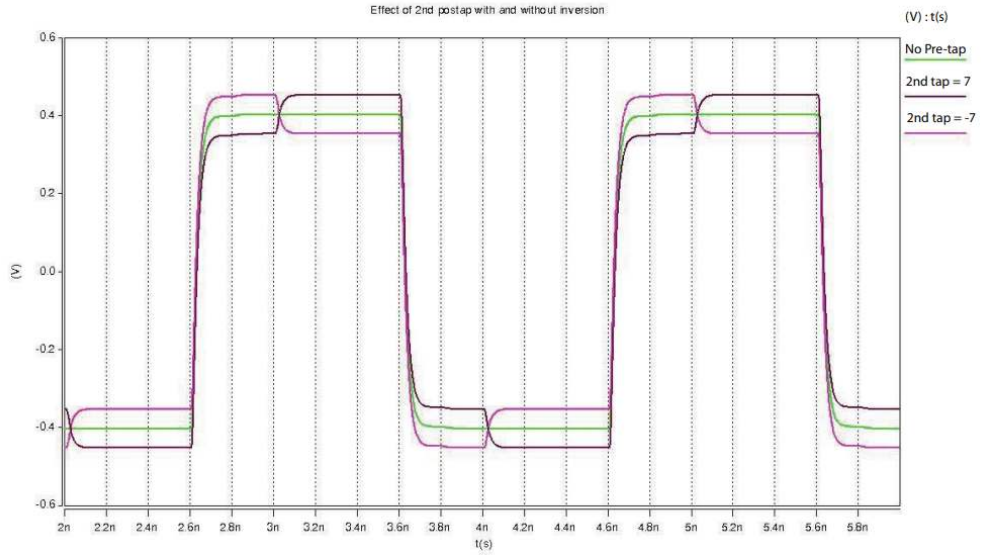
Post-2

- 32 voltage steps total (value range from -1 to +1)
- Each voltage step represent a 10mV common mode differential or 5mV common mode single ended
- Pulse active for 2 native clock resolution after
  - For instance. 1.25Gbps, UI = 800ps
  - Native rate is 8 x 1.25Gbps = 10Gbps (100ps)
  - Pre-emphasis is valid for one native rate period

Post-2



a) Ideal 2nd post-tap effect (assuming V_{OD}=1 and x is the tap weight)



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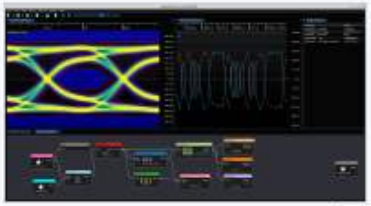
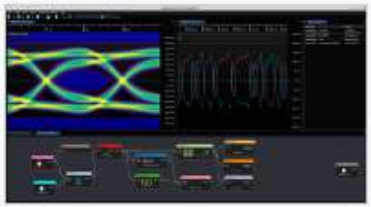
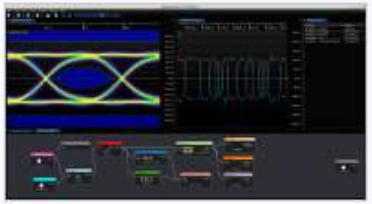
Pre-emphasis setting

	Baseline	Excessive pre cursor	Optimized	Excessive post cursor
	 Baseline signal with no emphasis. Transition bits are clearly weaker than non-transition bits and the signal is touching the mask (fail).	 Excessive pre-cursor emphasis. The eye is more closed than the baseline, indicating minimal pre-cursor ISI was present and the emphasis is doing more harm than good.	 Well-tuned post-cursor emphasis. The eye is open and transition and non-transition bits are well matched in amplitude, indicating a correct level of equalization. The signal is passing the mask test.	Excessive post-cursor emphasis. The eye is starting to close and transition bits have significant overshoot, indicating excessive equalization. The "double banding" artifact visible in the eye indicates the presence of significant ISI[5]:2 caused by the excessive emphasis.
Width	Worst	Better	Best	Better
Height	Good	Bad	Best	Bad
Jitter	Worst	Better	Best	Better

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Direct Connection

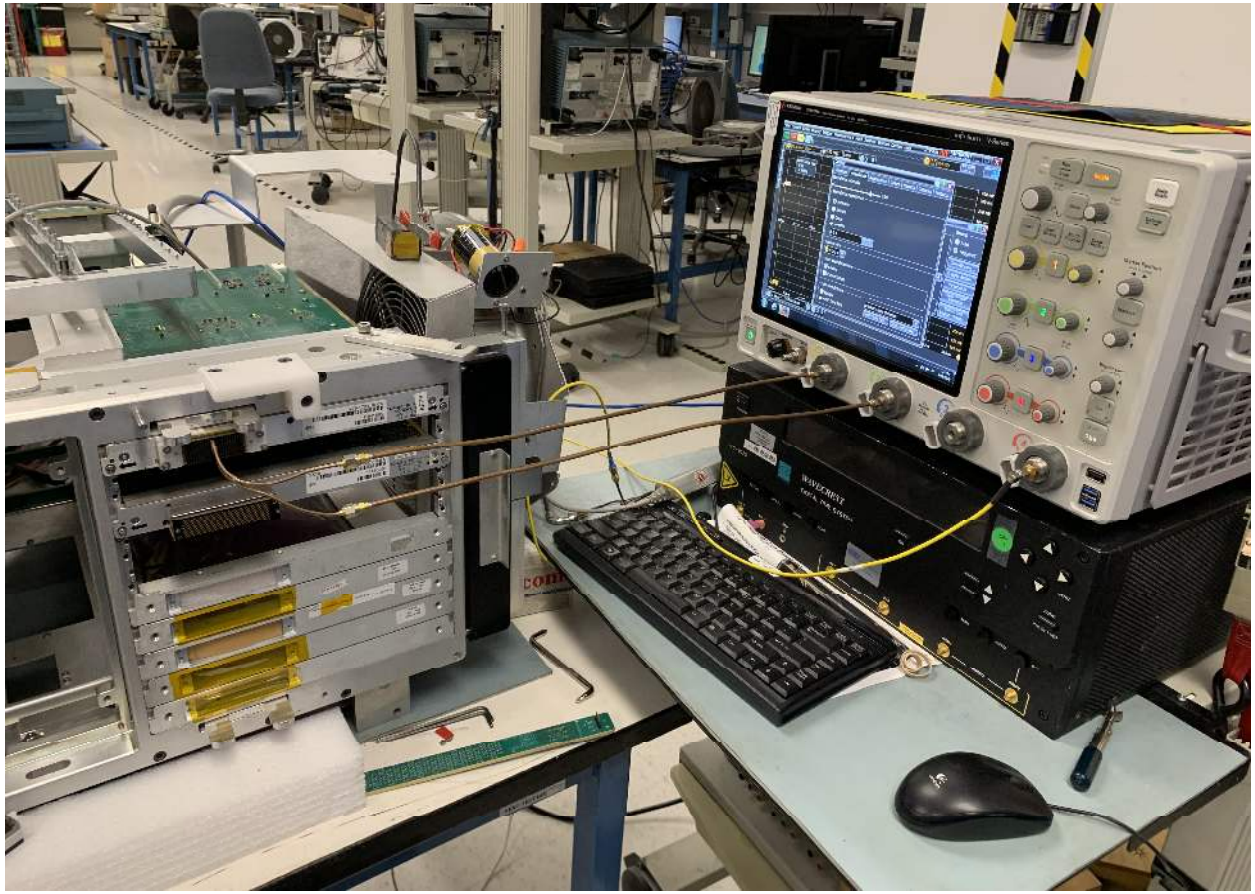
Equipment used

1. HSI2x high-speed digital instrument
2. Semi-rigid coax cable with bandwidth of 30GHz
3. High bandwidth oscilloscope

Connection

1. Direct connection into instrument connector
2. Connector has a 25GHz bandwidth

Eye Diagram collection method



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HBR2 CP2520 at 8Gbps

- **Direct connection with no pre-emphasis**

- **Direct Connection with pre-emphasis**

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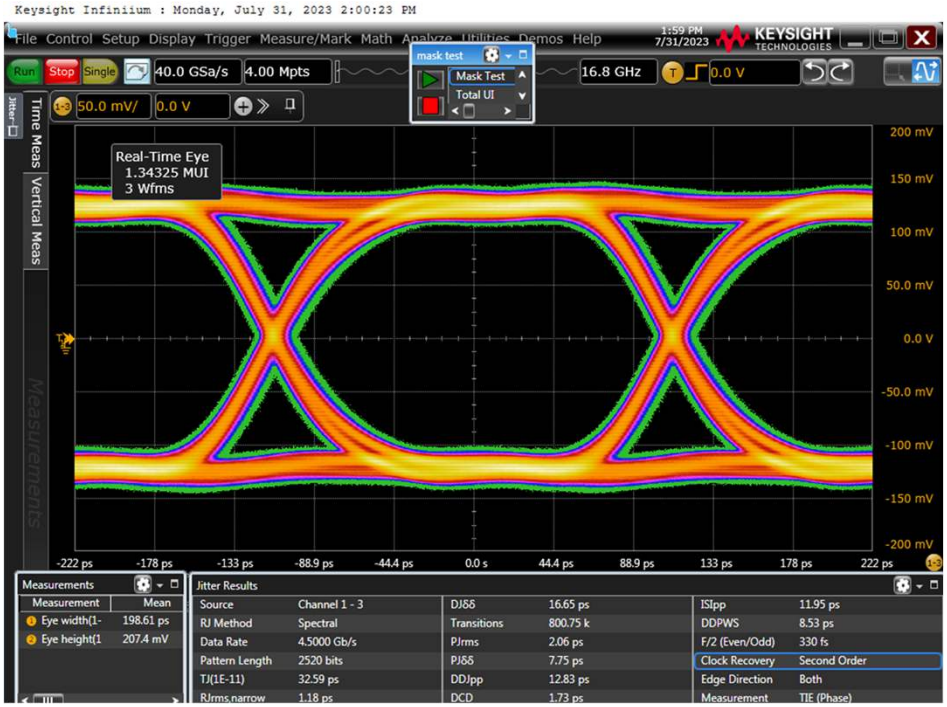
HBR2 CP2520 at 4Gbps

- Direct connection with no pre-emphasis

- Direct Connection with pre-emphasis



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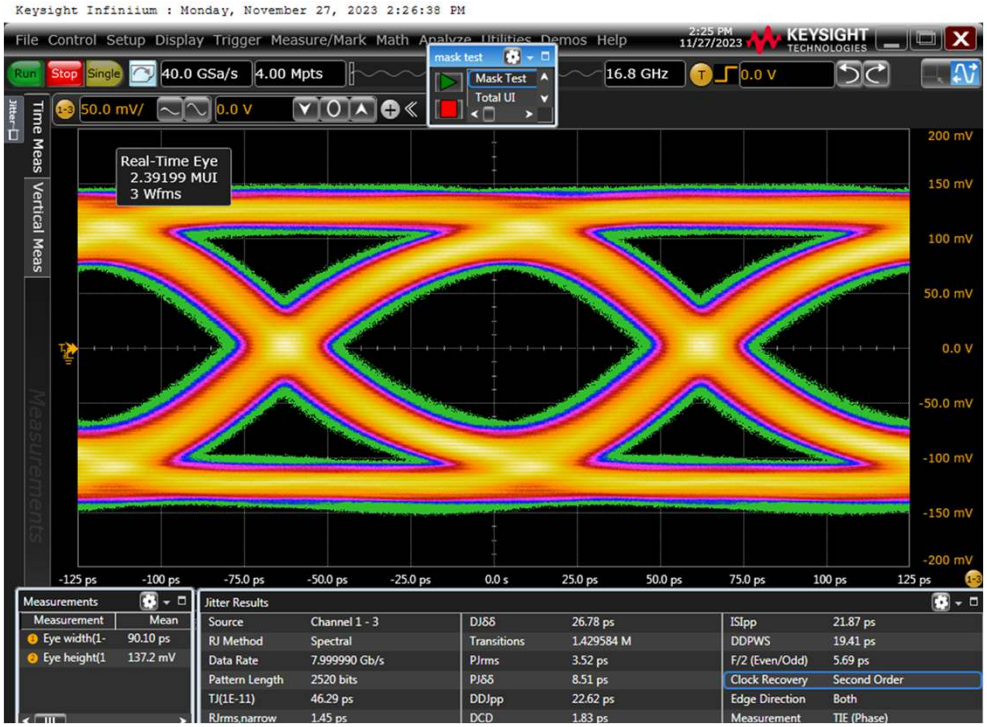
HBR2 CP2520 at 8Gbps with optimized pre-emphasis

- Eye Diagram on load board



- Eye Diagram on instrument connector

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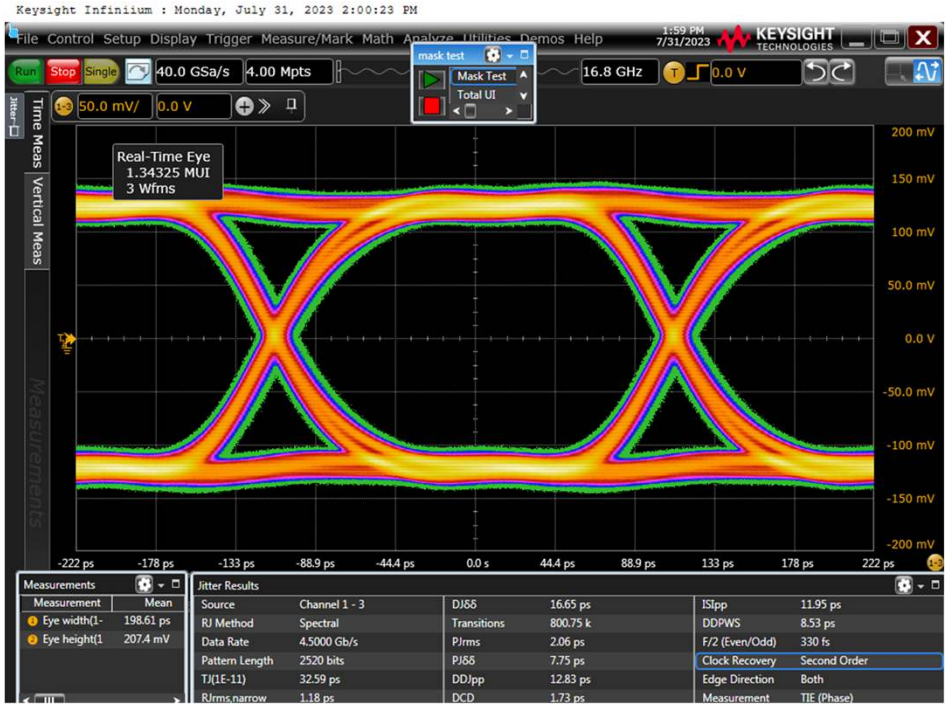
HBR2 CP2520 at 4Gbps with optimized pre-emphasis

❑ Eye Diagram on Load Board

❑ Eye Diagram on Instrument Connector



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How pre-emphasis influence waveshape (Pre-1=Max)

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How pre-emphasis influence waveshape (Pre-1=Mid)

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How pre-emphasis influence waveshape (Pre-1=Min)

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How pre-emphasis influence waveshape (Post-1=Max)

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How pre-emphasis influence waveshape (Post-1=Mid)

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How pre-emphasis influence waveshape (Post-1=Min)

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How pre-emphasis influence waveshape (Post-2=Max)

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How pre-emphasis influence waveshape (Post-2=Mid)

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How pre-emphasis influence waveshape (Post-2=Min)

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Too many settings

Pre-emphasis setting challenges

- **There are 3 knobs for pre-emphasis setting**
  - Pre-1
  - Post-1
  - Post-2
- **Each knobs has 32 settings**
  - A combination of 32K settings with 3 knobs
  - To determine the optimum setting will be time consuming and challenging without oscilloscope
- **Pre-emphasis use model concept**
  - Automate the pre-emphasis setting through engineering characterization
  - API with selection of mid, minimum and maximum pre-emphasis setting

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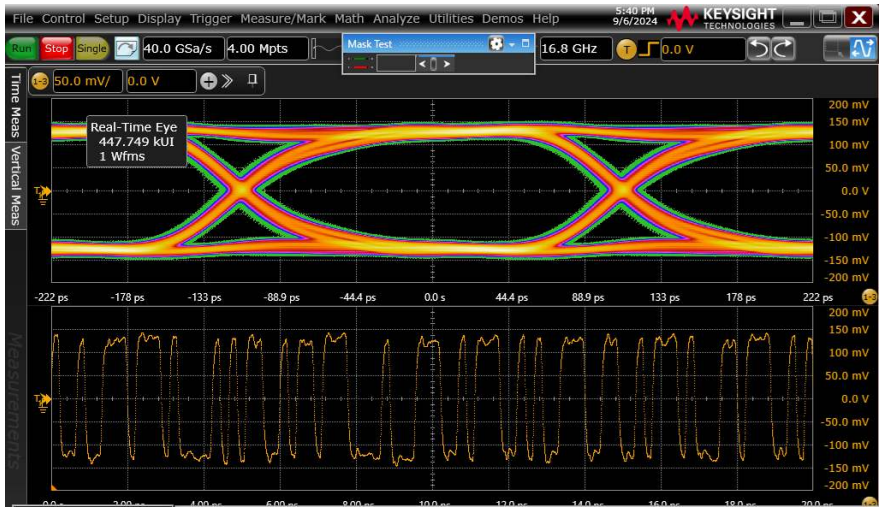
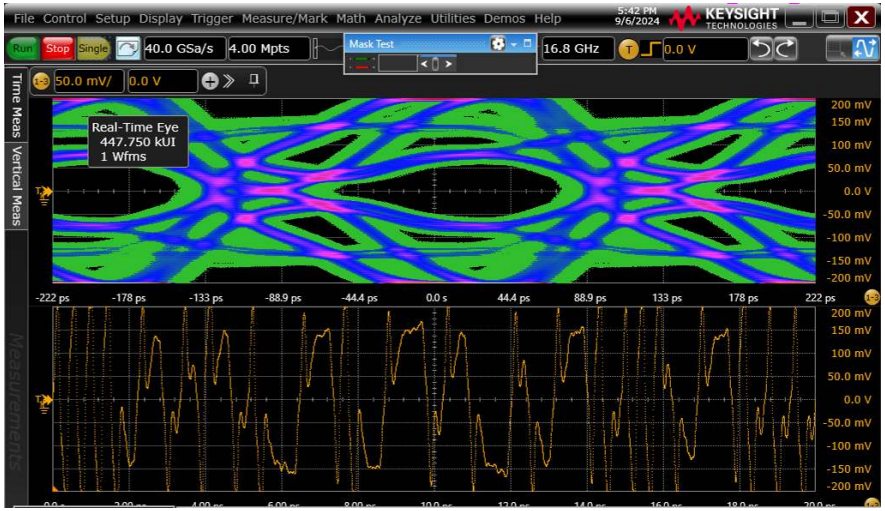
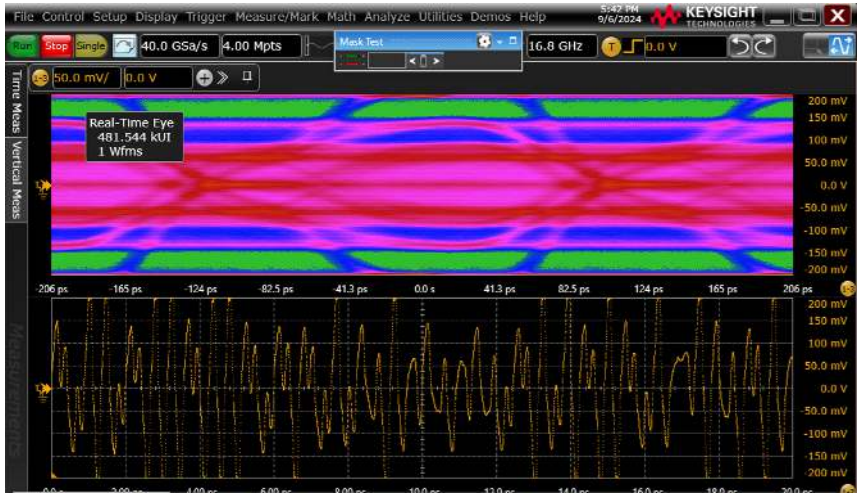
4Gbps PRBS7 Pre-emphasis setting (Mid, Max, Min)



Mid



Min



Max

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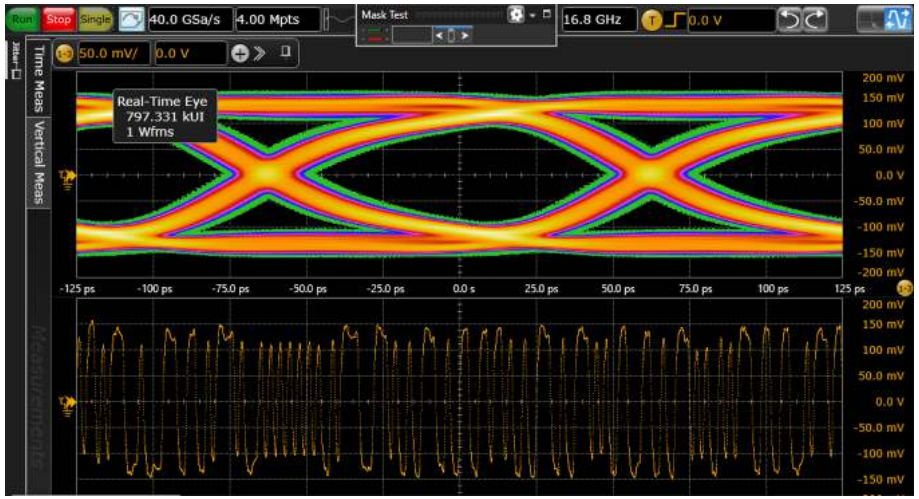
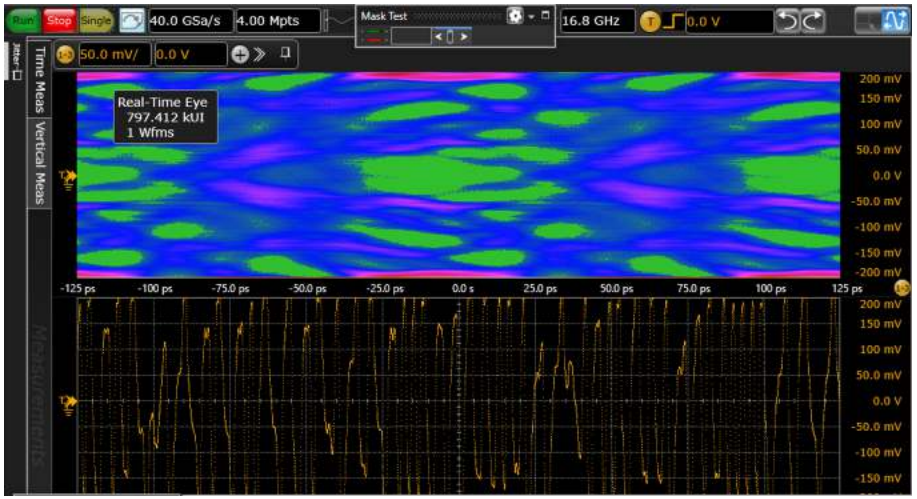
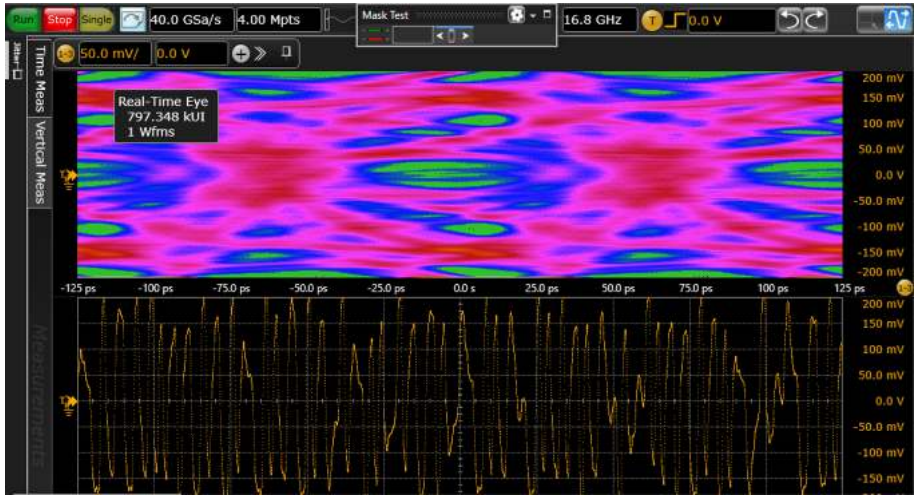
8Gbps PRBS7 Pre-emphasis setting(Mid, Max, Min)



Mid



Min



Max

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