PAM SMF Transmitter Testing

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Next Generation 100G Optics Study Group
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Overview

- Background
- Experimental Setup and Previous Measured Results
- Principal of Bandwidth Improvement
- Signal Processing for PAM-8 to Reduce Rise / Fall Time
- Future Work

Background

- heaton_01_0312_ng100goptx presented the concept for digital linearization of a DAC to compensate for non-linearity in the electrical-to-optical conversion

- lewis_01_0512_ng100goptx presented measured results showing 8 GBaud PAM-8 (24 Gbit/s) eye diagrams generated using an electroabsorption modulator and a 64 Gsample/s 8-Bit DAC

- schell_01_0712_optx presented measured results showing up to 28 GBaud PAM-4 (56 Gbit/s) and PAM-8 (84 Gbit/s) eye diagrams generated using an electroabsorption modulator and a 3-Bit DAC

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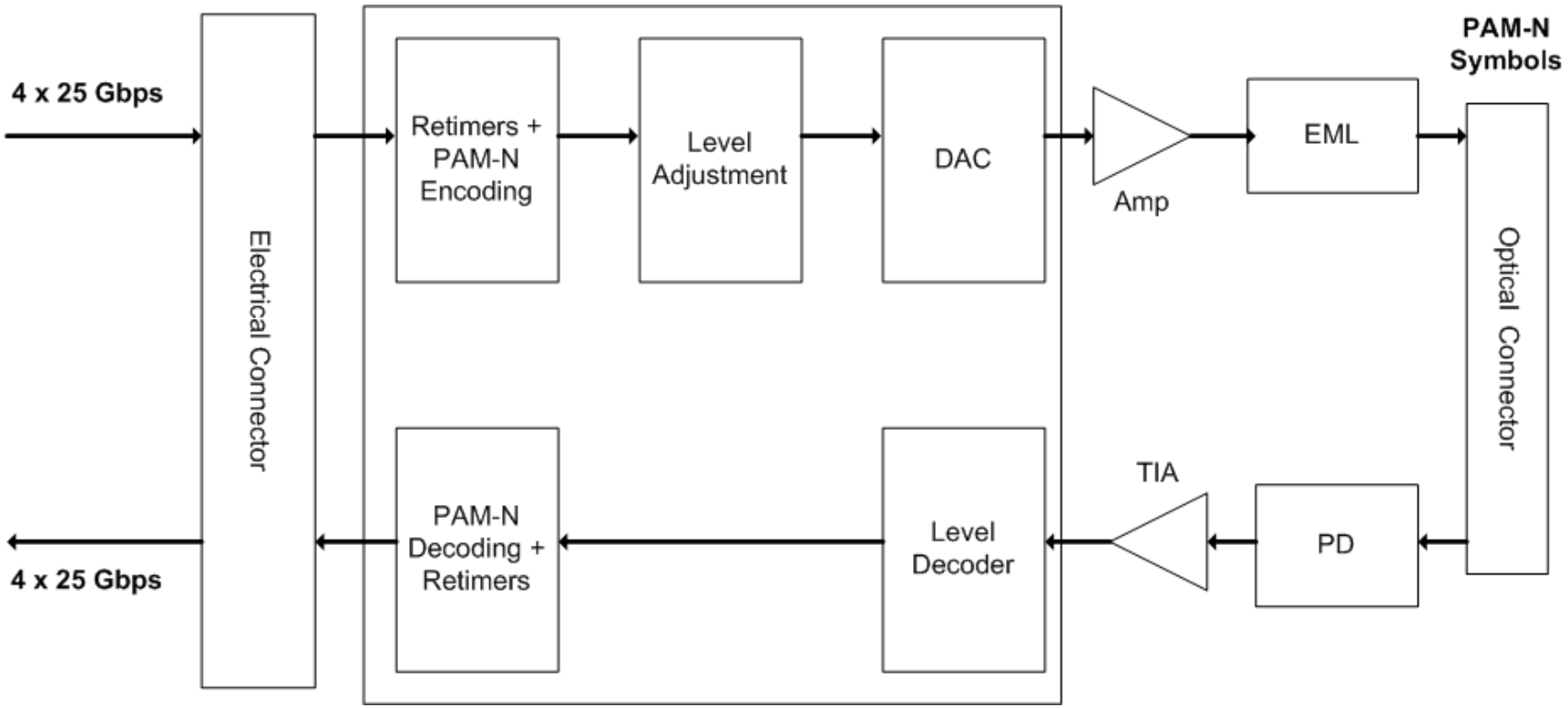
100G SMF PMD with PAM



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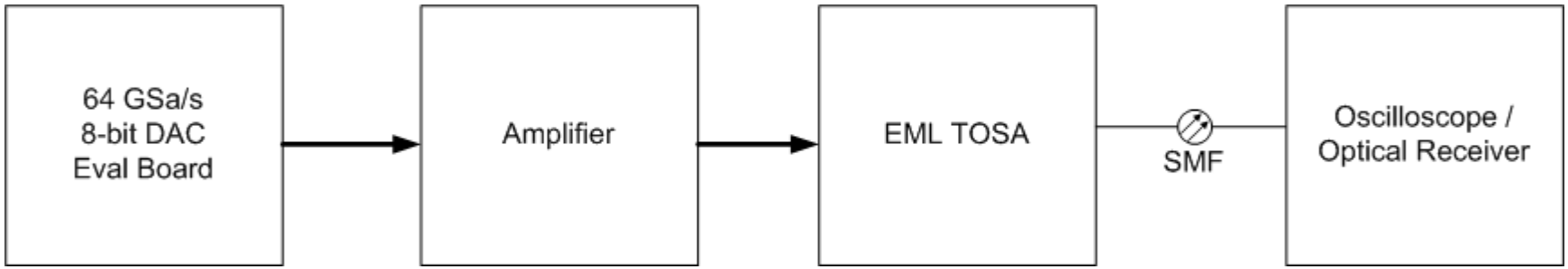
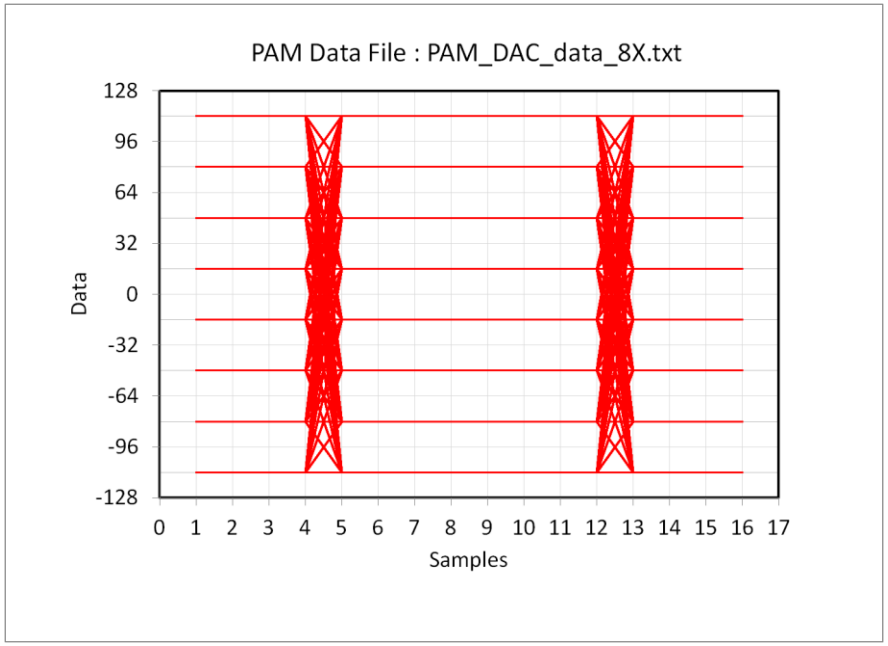
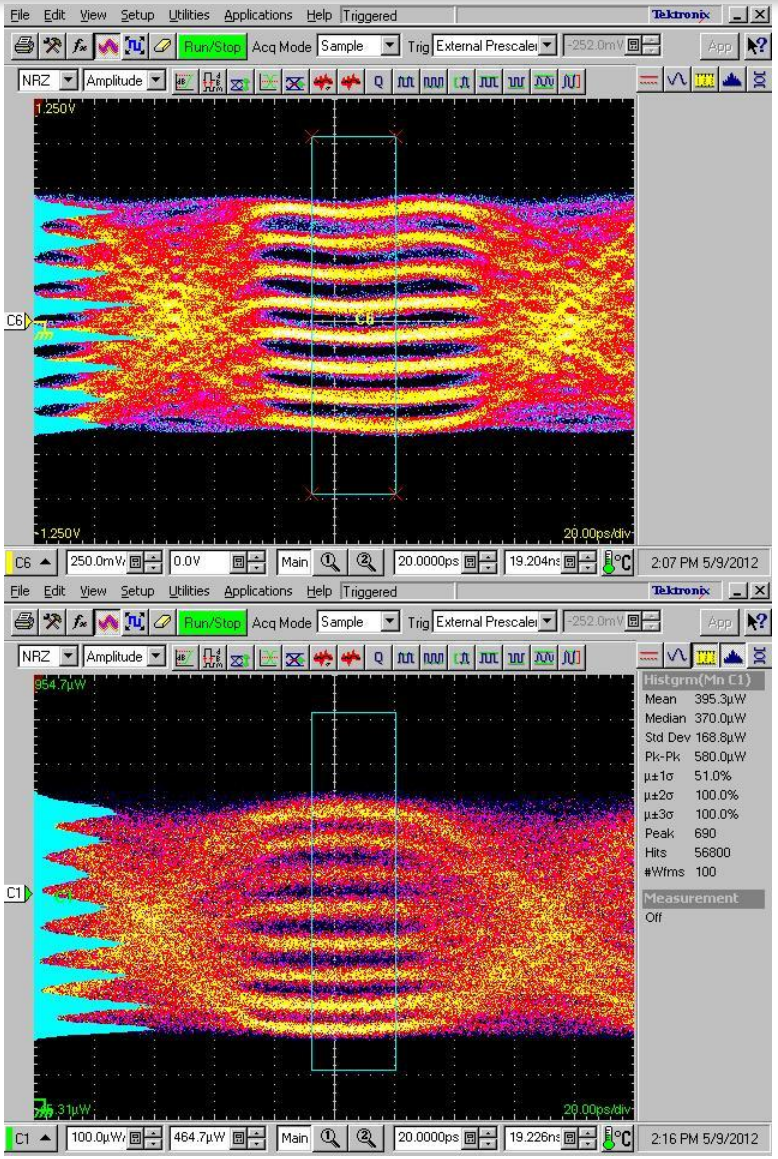
Experimental Setup



- DAC evaluation board from Fujitsu
- SMF is a short patch cord connecting the TOSA directly to the optical port of the oscilloscope

Electrical and Optical Eyes for Reference Data Set





Can we reduce the rise time by applying a correction from the DAC ?

Need to emphasize the high frequency components

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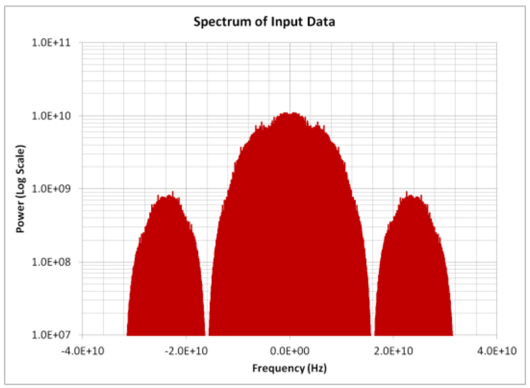
PAM DAC – Theory of RF Roll-Off Compensation

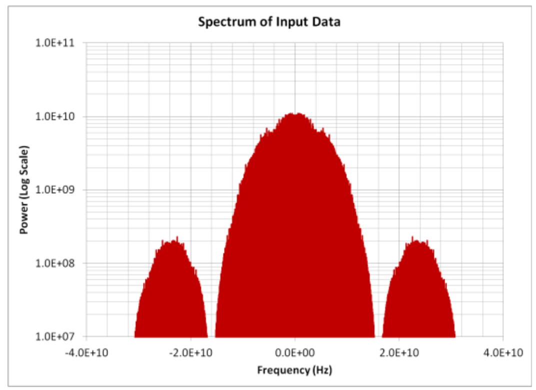
$$A(f)^2 = B(f) \times B^{-1}(f)$$

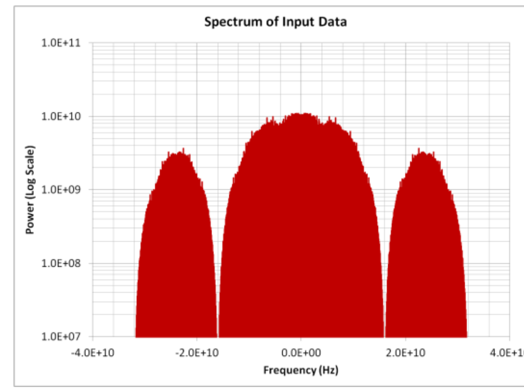
Ideal Spectrum

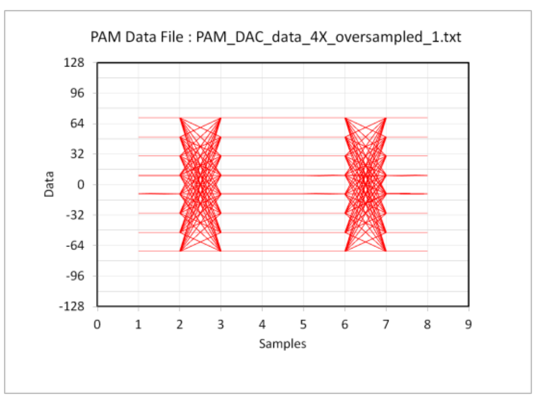
Measured Spectrum

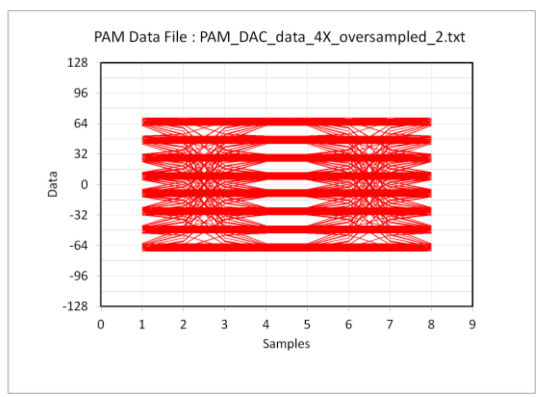
Inverse of Measured Spectrum

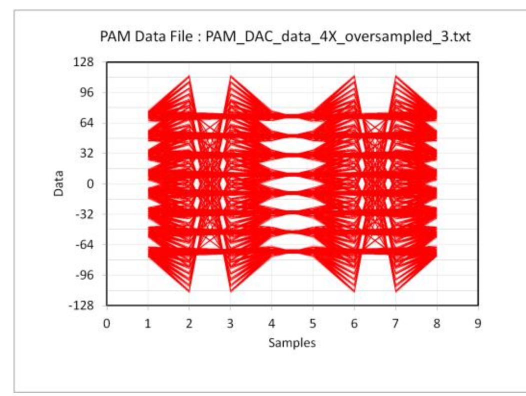












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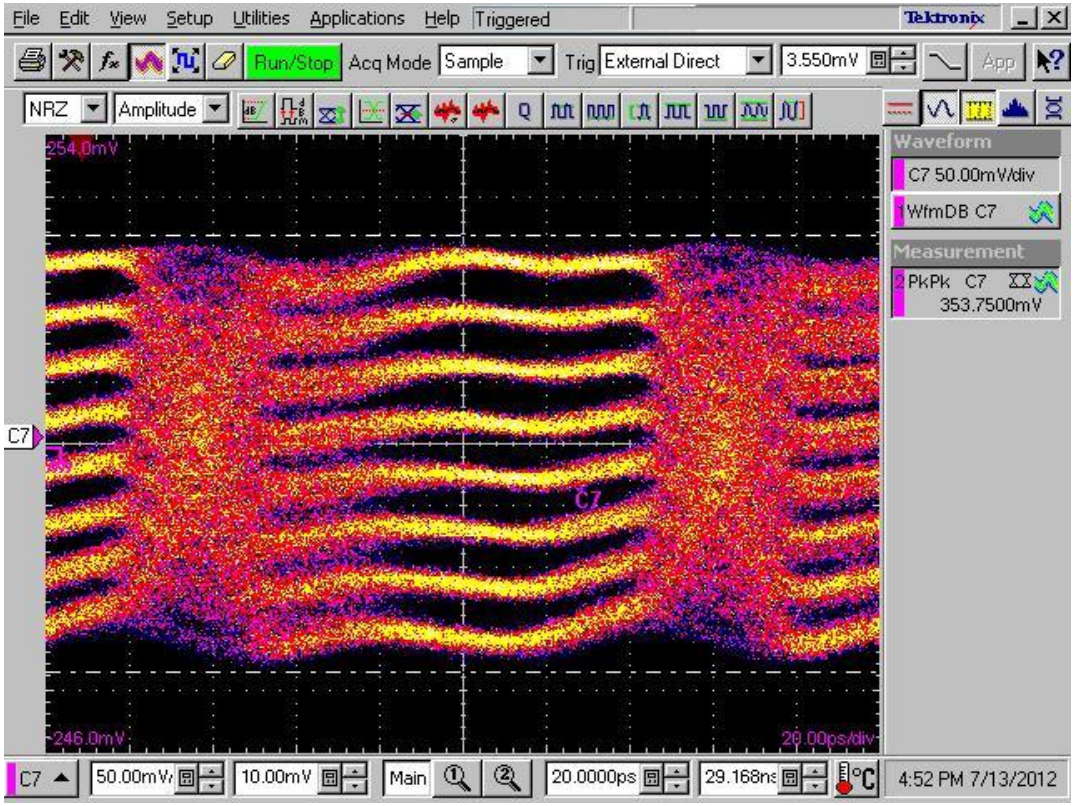
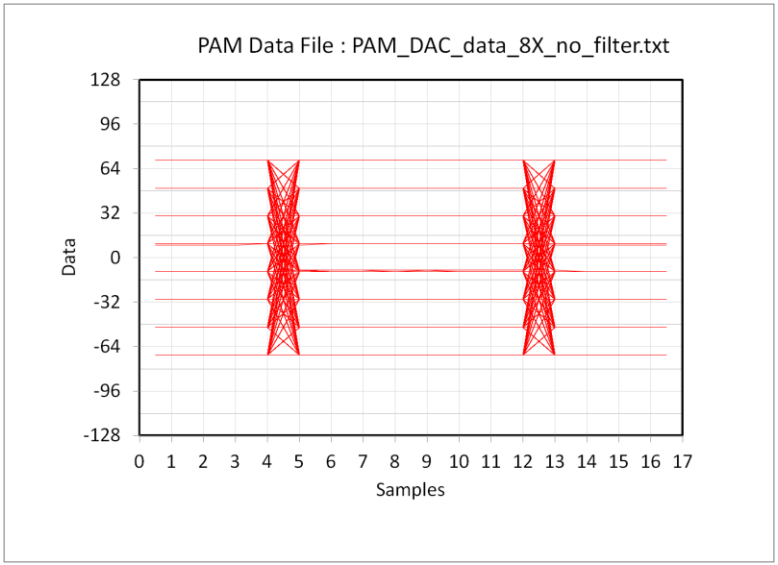
Original Data - Electrical





Estimated 10% to 90% rise time = 26.8 ps and fall time = 20.3 ps [mean = 23.55 ps]

Estimated 20% to 80% rise time = 18.2 ps and fall time = 12.4 ps [mean = 15.30 ps]

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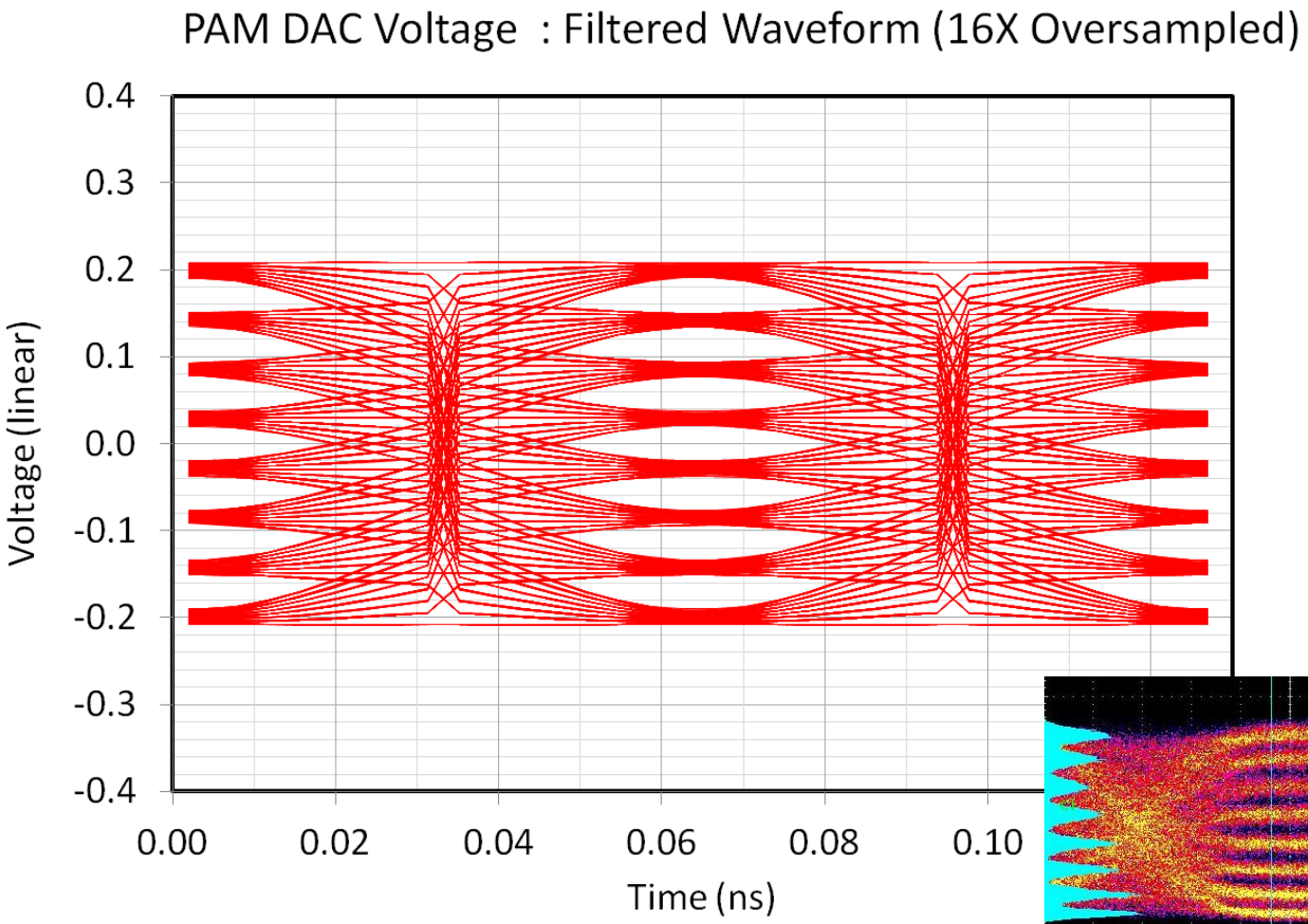
PAM DAC Data – Eye Diagram to be Corrected



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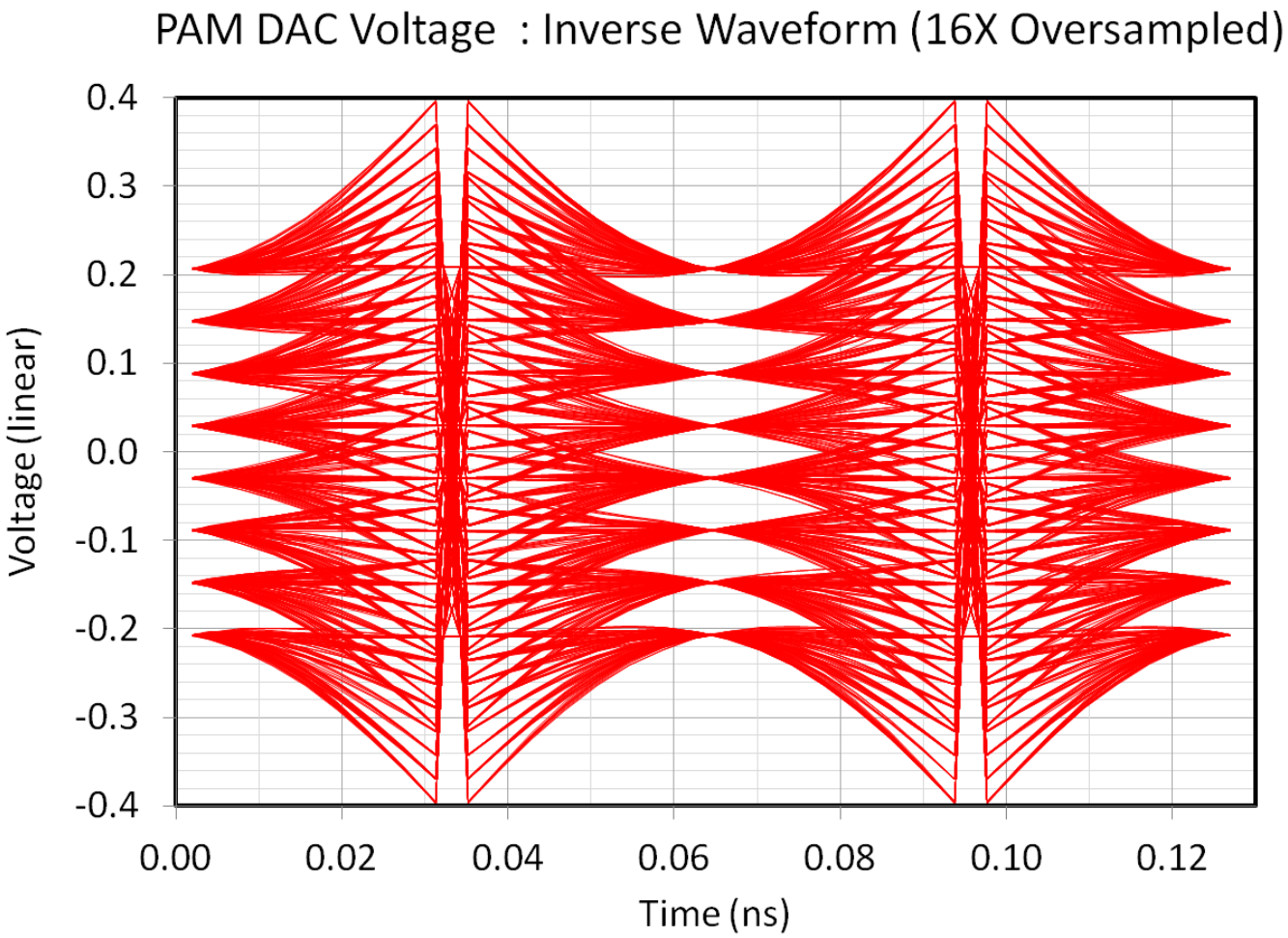
PAM DAC Data – Ideal Compensating Waveform



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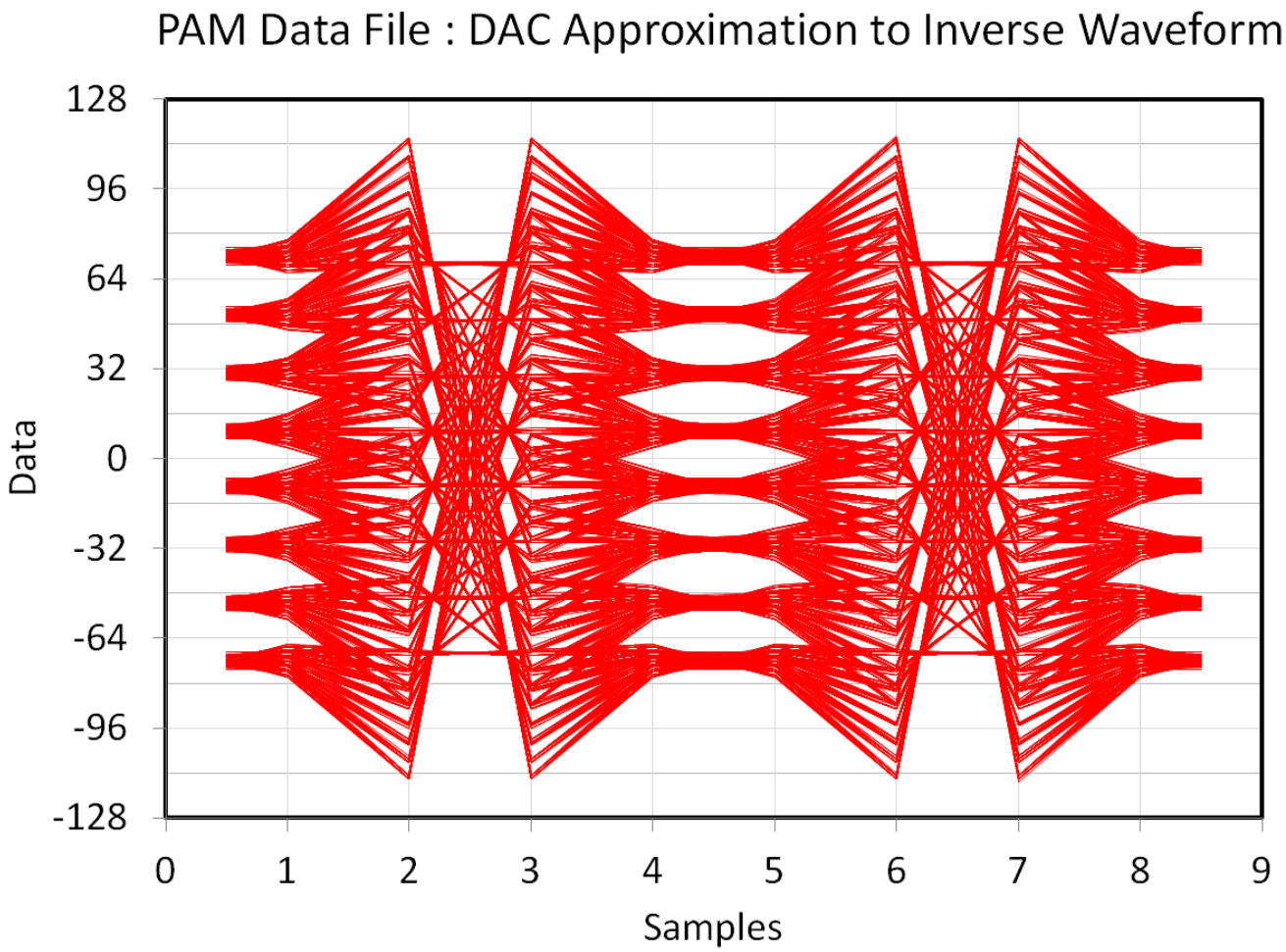
PAM DAC Data – Digital Data With DAC Limitations



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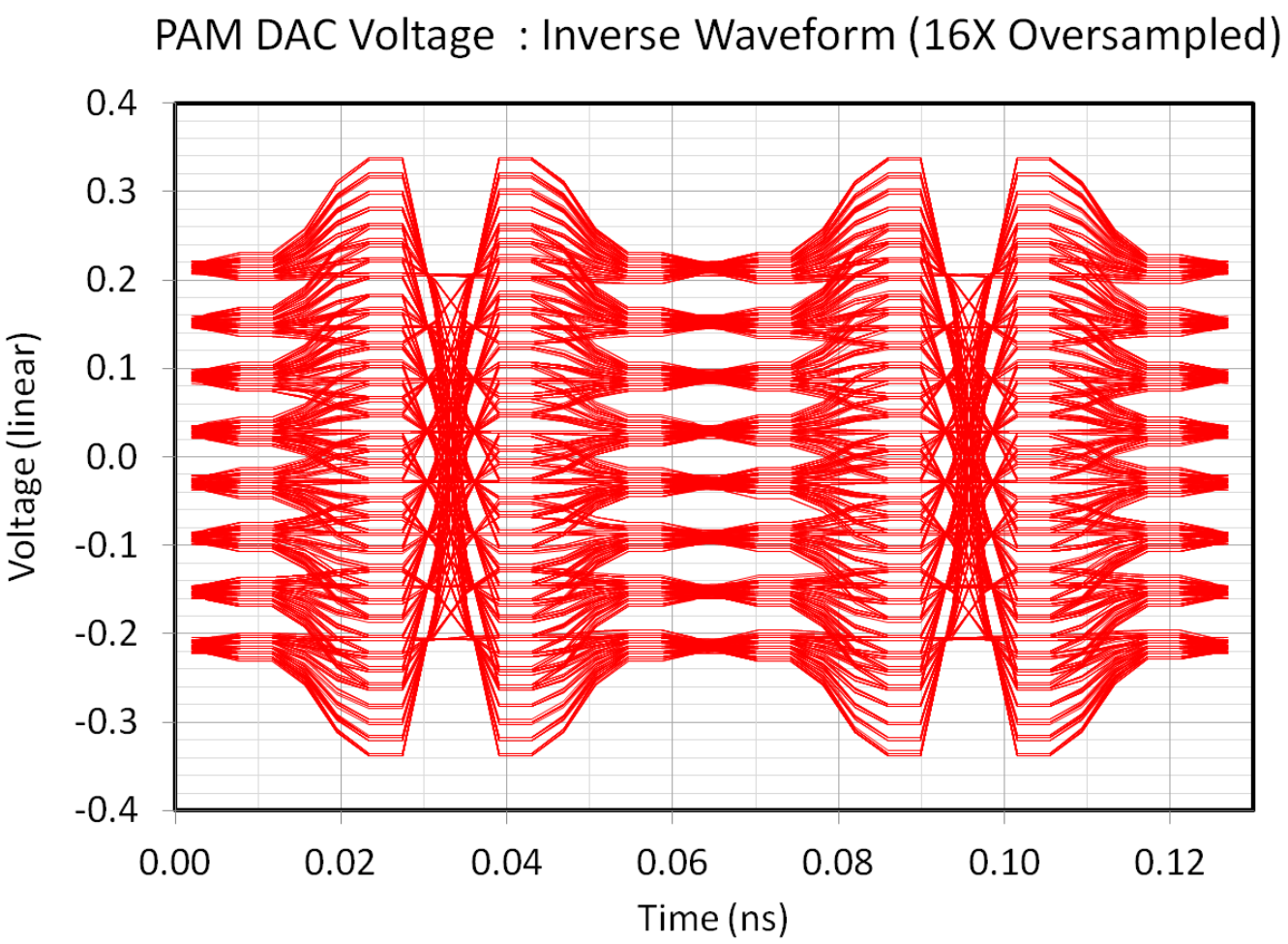
PAM DAC Data – Voltage Compensating Waveform



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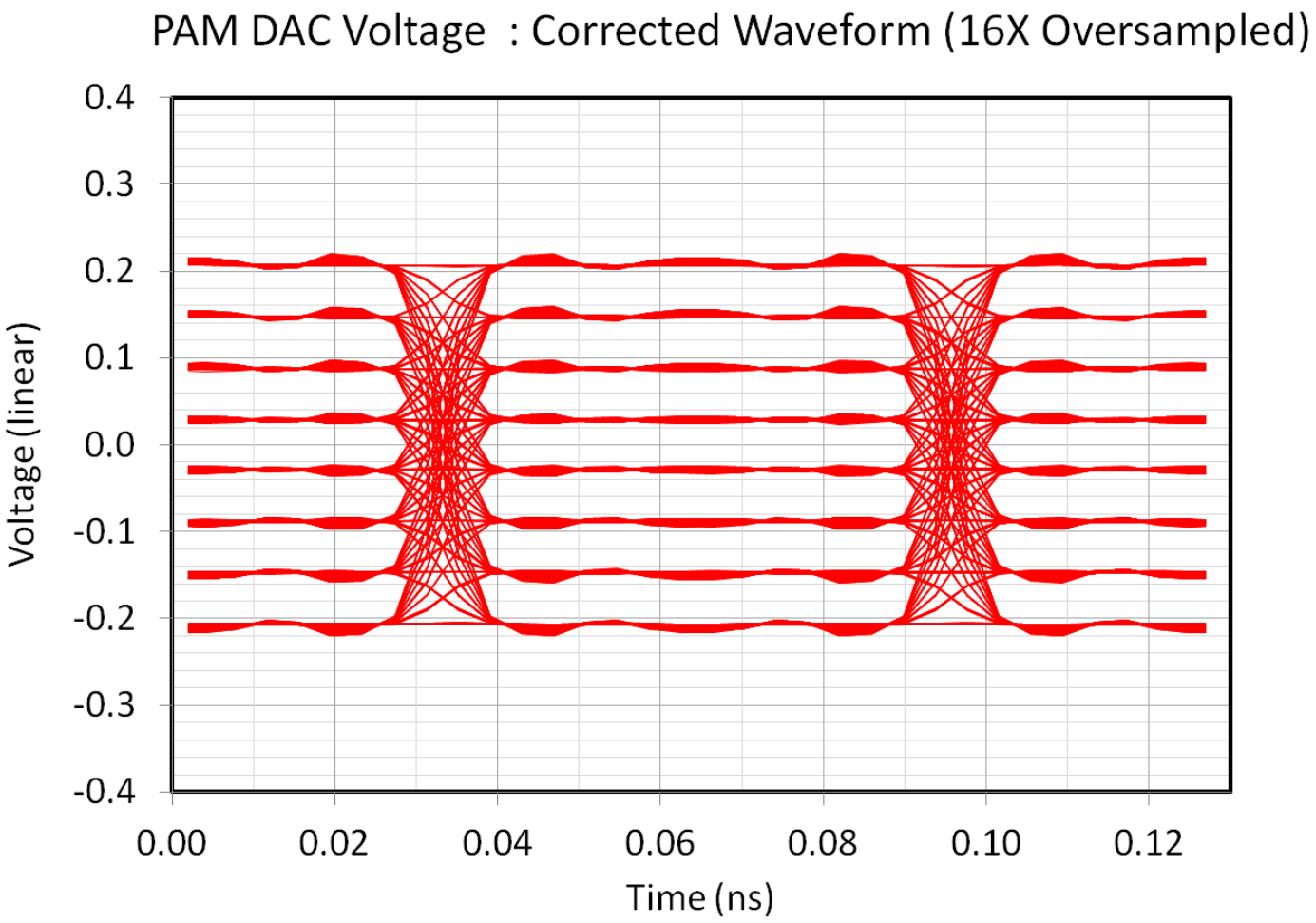
PAM DAC Data – Voltage Compensated Signal



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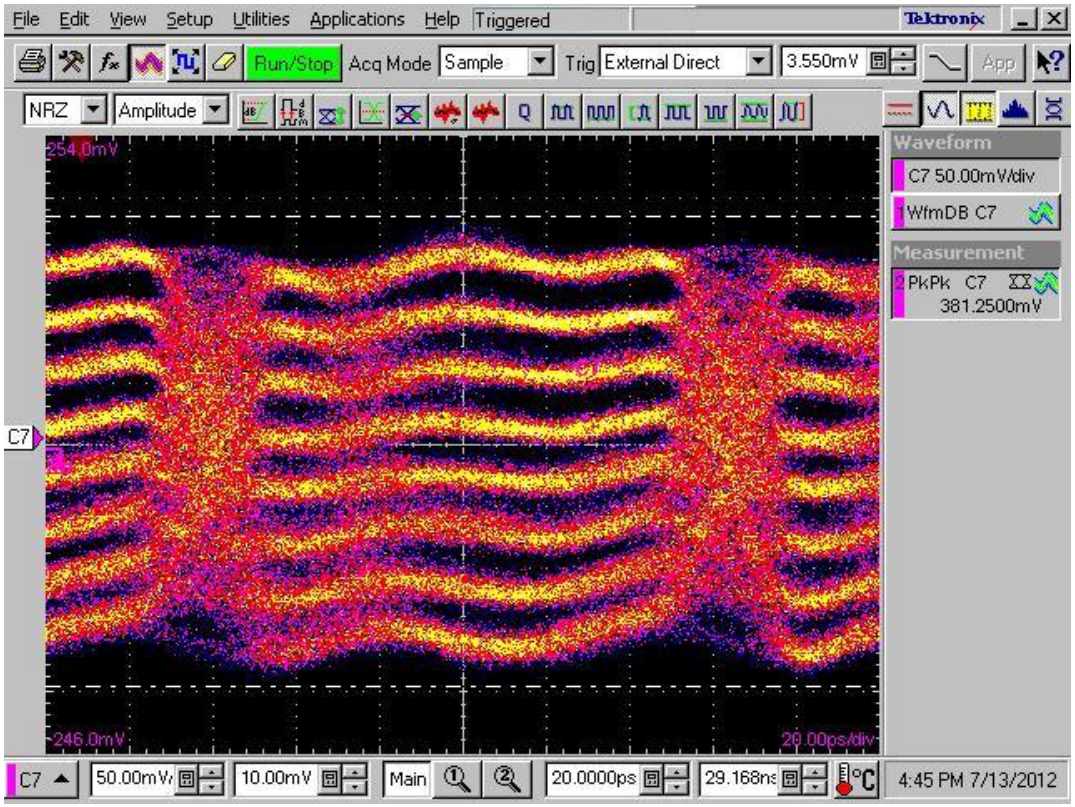
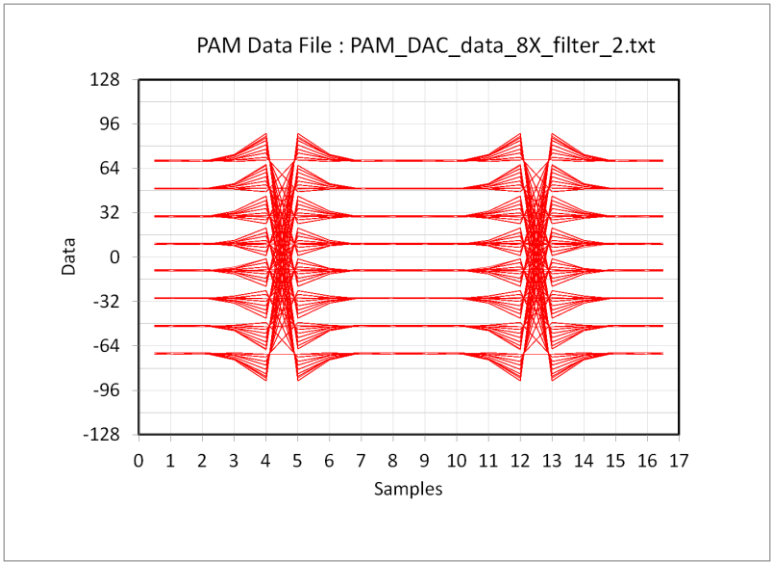
Pre-Emphasised Data (1) - Electrical





Estimated 10% to 90% rise time = 19.7 ps and fall time = 18.3 ps [mean = 19.00 ps]

Estimated 20% to 80% rise time = 12.3 ps and fall time = 12.6 ps [mean = 12.45 ps]

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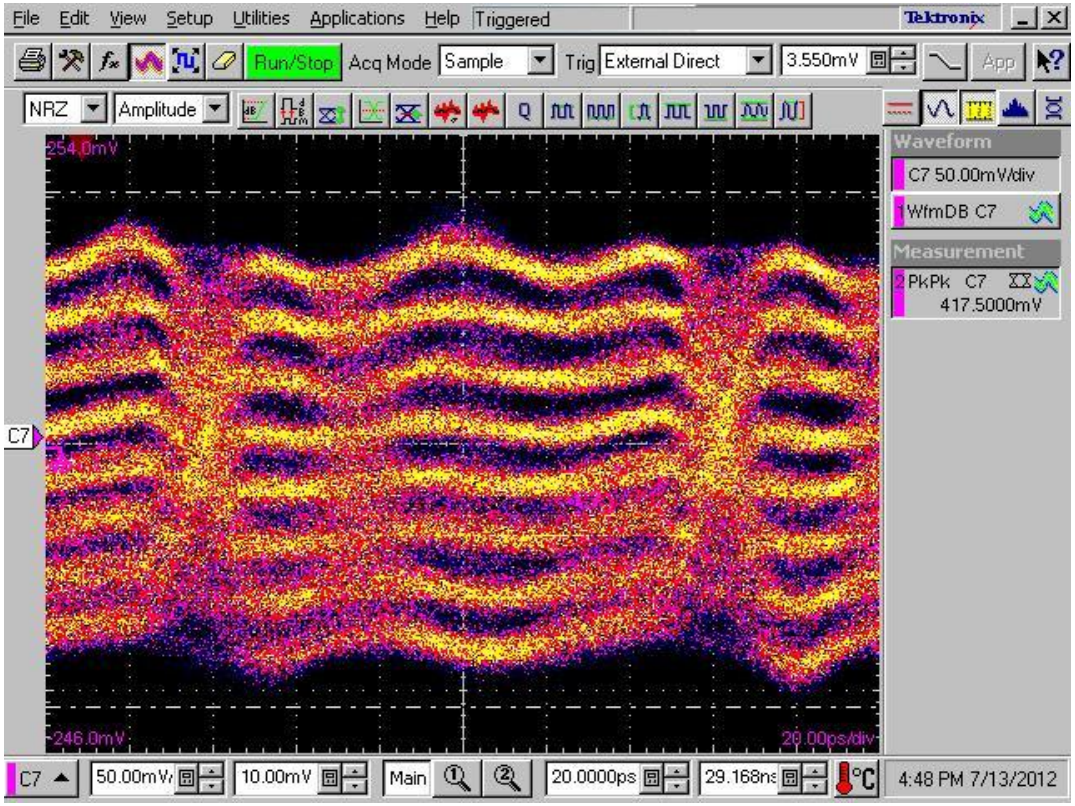
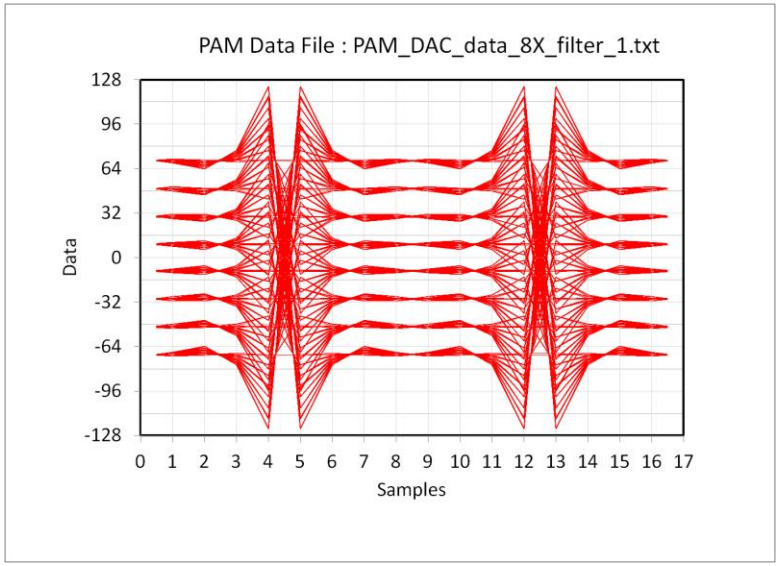
Pre-Emphasised Data (2) - Electrical





Estimated 10% to 90% rise time = 19.8 ps and fall time = 12.6 ps [mean = 16.20 ps]

Estimated 20% to 80% rise time = 12.7 ps and fall time = 8.4 ps [mean = 10.55 ps]

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Rise and Fall Time Comparison Table

	20% to 80%	10% to 90%
Un-compensated Data Set	15.30 ps	23.55 ps
Compensated Data Set 1	12.45 ps	19.00 ps
Compensated Data Set 2	10.55 ps	16.20 ps

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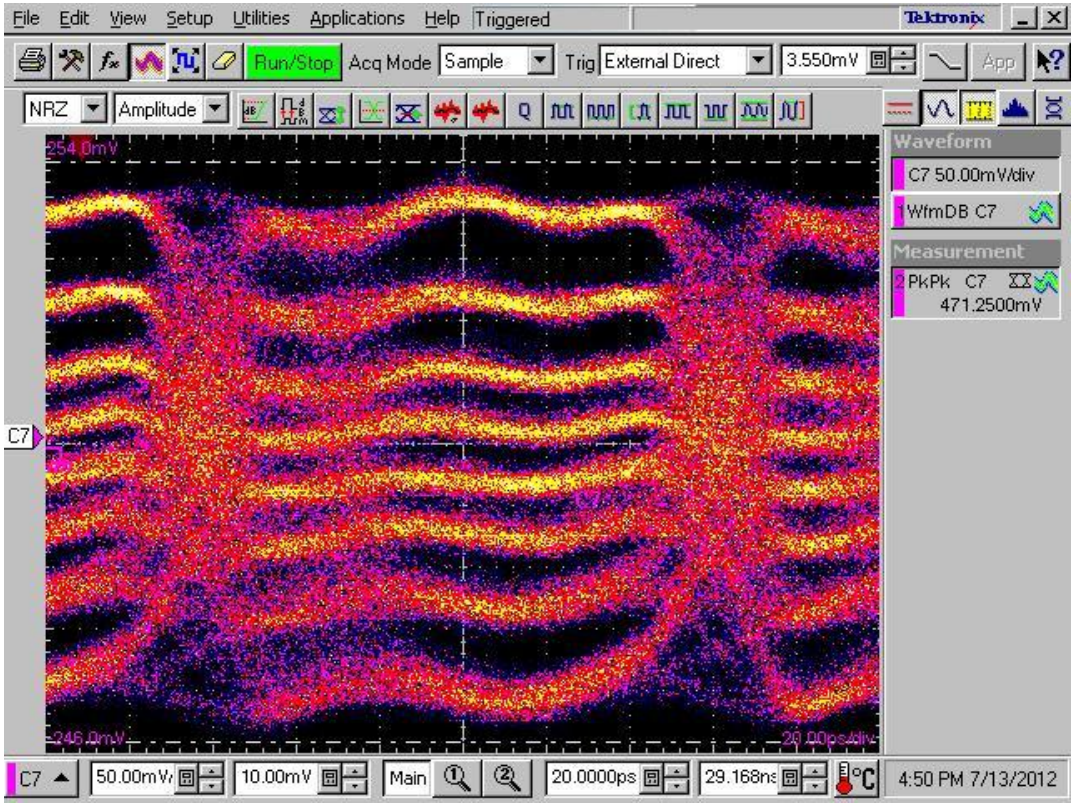
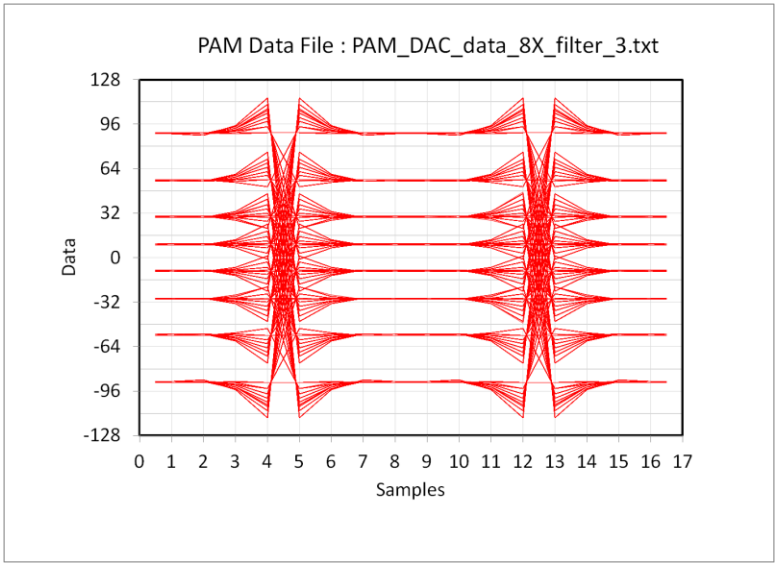
Pre-Emphasised and Level Adjusted Data - Electrical





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Summary

- Theory of spectral shaping to compensate for frequency roll-off to increase the data rate of a PAM-8 Optical Transmitter
  - Can compensate for the amplitude of the frequency response of the modulator as well as linear and (small) non-linear phase
  - Can compensate for the overall frequency response of the link
    - As long as the combined link roll-off is not too high around the third harmonic frequency of the bit pattern
- The theory is applied to 8 Gbaud PAM-8 (24 Gbit/s) and 16 Gbaud PAM-8 (48 Gbit/s)
- Measured results are shown for 8 GBaud PAM-8 electrical eyes where the average rise / fall time was reduced by 31%
- Future work
  - Demonstrate optical data rate improvement experimentally
  - Demonstrate nonlinearity compensation

Additional Slides – For Answers to Questions

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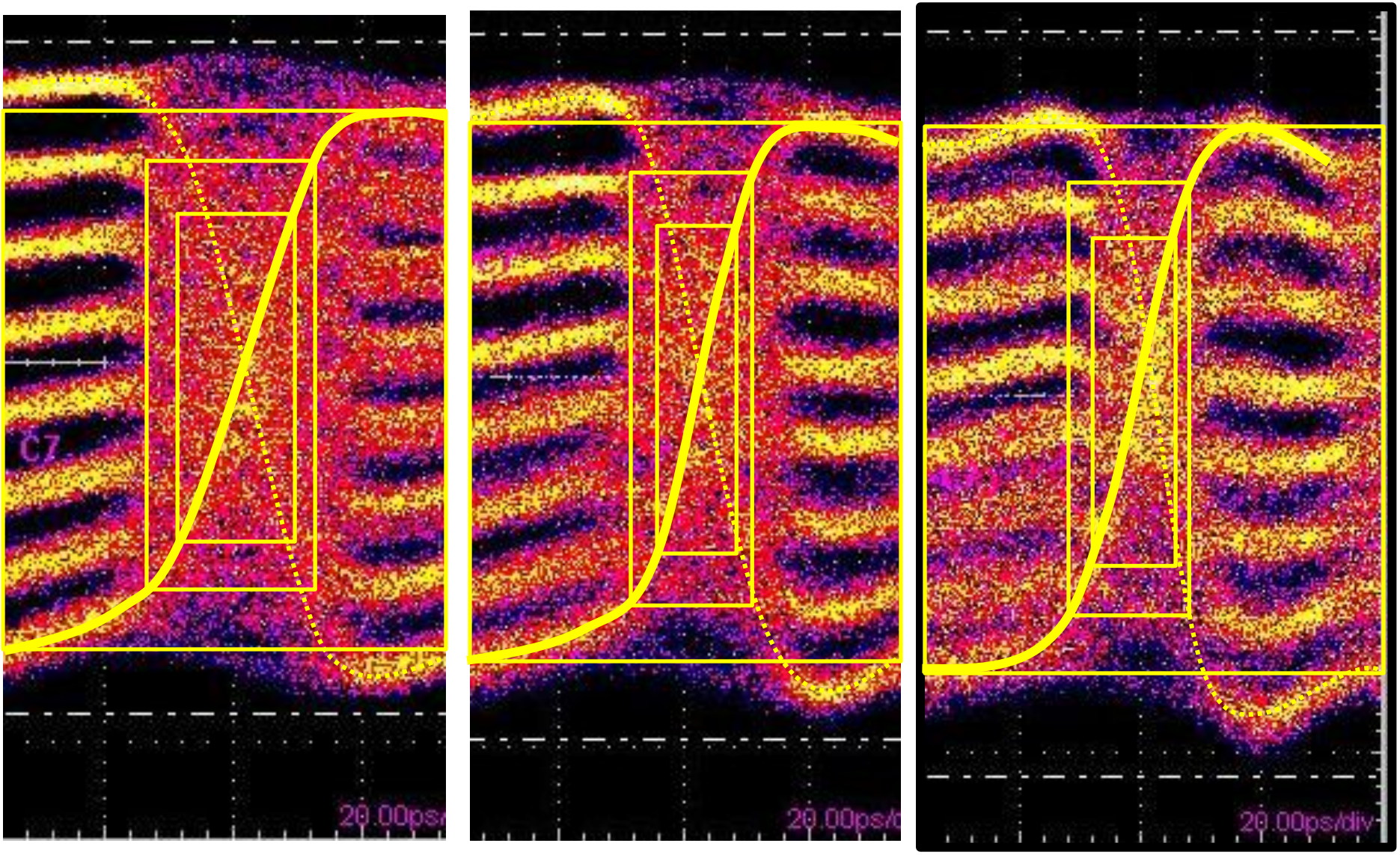
Electrical Eye Rise Time Measurements



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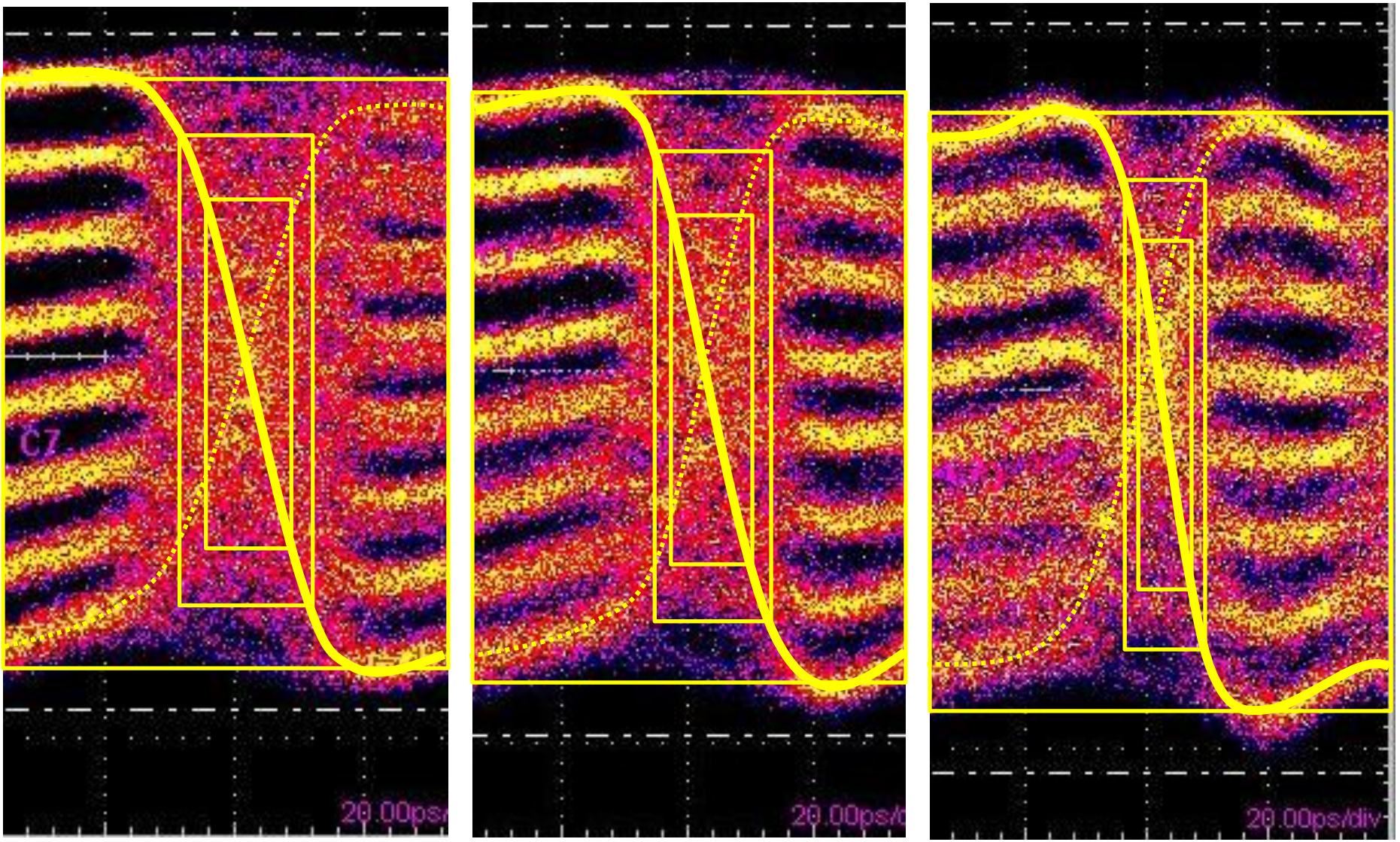
Electrical Eye Fall Time Measurements



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