



Transmitter De-emphasis for PCI Express[®] 2.0 Low-Swing Mode

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Acknowledgements / Disclaimer

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Implementation of the suggestions and methods illustrated in this presentation may or may not be in compliance with the PCIe 2.0 Base Spec.

Background

- Mobile platforms have traditionally utilized PCIe® low swing mode for transmitter (Tx) power savings on graphics interfaces
 - ✓ Mobile platforms are very “*mW conscious*”!
 - ✓ Power consumption can add up → 32 Tx within a x16 link
 - ✓ Typical implementation: $\sim 1/2$ Voltage swing (Vswing) = $\sim 1/2$ Tx Pwr

EXAMPLE	Nominal Tx Vswing	Tx Current Consumption	Tx Power Consumed (w/ 1V Supply)	Tx Total System Power Savings (w/ x16 Link)
Standard or Full Swing Mode	1.0 Vpp	20mA	20mW	NA
Low Swing Mode	0.5 Vpp	10mA	10mW	320mW

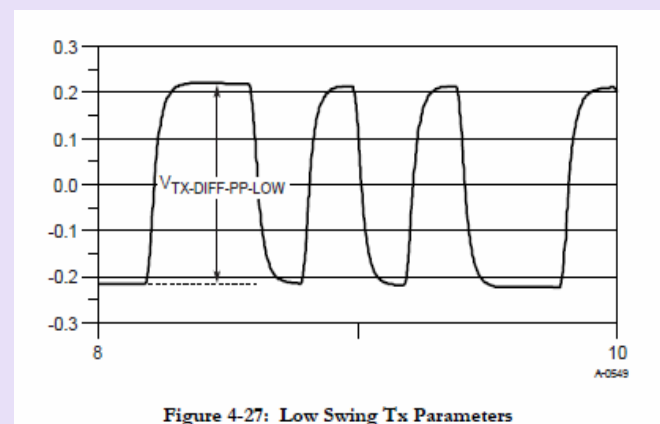
Presentation Nomenclature:

Low Swing Mode = Low Power Mode = Half Swing Mode

Background

- **The good news:** low swing mode is now explicitly defined in the PCIe 2.0 Base Specification!
 - ✓ Mobile Graphics Low-Power Addendum 1.0 has been “absorbed” by the PCIe 2.0 Base Spec
 - ✓ Low swing mode can now be optionally implemented for either 2.5GT/s or 5.0GT/s
 - The method for enabling/selecting low swing mode is not defined in the spec

		2.5GT/s	5.0GT/s	
$V_{TX-DIFF-PP-LOW}$	Low power differential p-p Tx voltage swing	0.4 (min) 1.2 (max)	0.4 (min) 1.2 (max)	V



Background

- **An observation:** while a variable Vswing range is provided, the PCIe 2.0 Base Spec does not include the use of TX de-emphasis for low swing mode
 - ✓ Prior to PCIe 2.0, low swing implementations @ 2.5GT/s never used and/or required de-emphasis

4.3.3.2. Low and Full Swing Transmitter Output Levels

Both the 2.5 GT/s and 5.0 GT/s PCI Express specifications define two voltage swing levels: full swing and low swing. Full swing signaling implements de-emphasis, while low swing does not.

-from PCIe 2.0 Base Spec (highlight added)

- **The question:** Is de-emphasis needed for low swing mode *operating at 5 GT/s* ?
 - ✓ It may be, especially for mobile graphics (Gfx) topologies

Presentation Nomenclature:

De-emphasis = Equalization = EQ

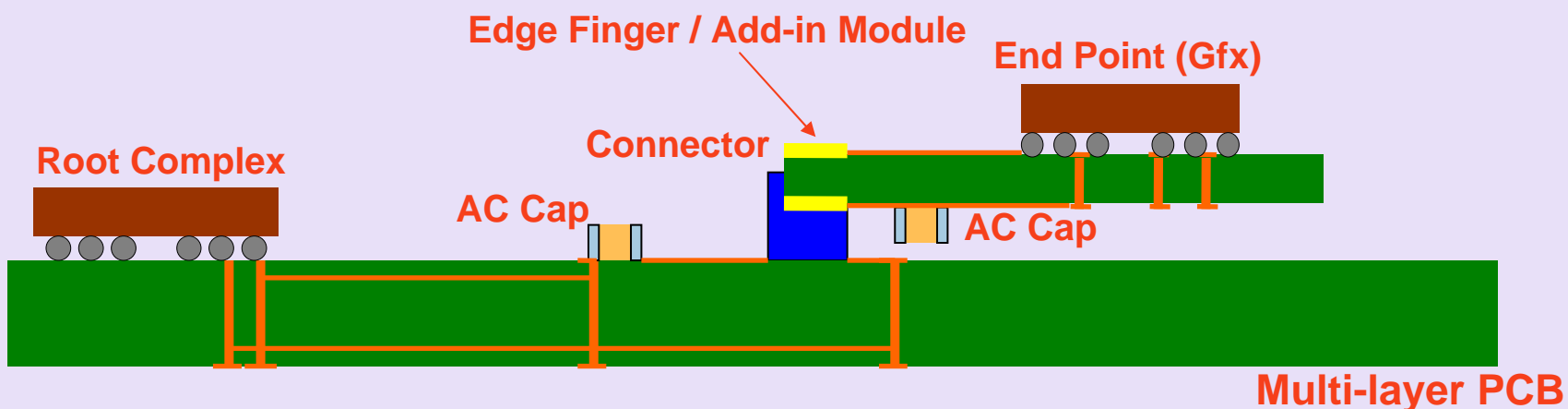
Motivation

- Analysis of 5 GT/s mobile graphics interfaces shows advantages of Tx de-emphasis for low swing mode

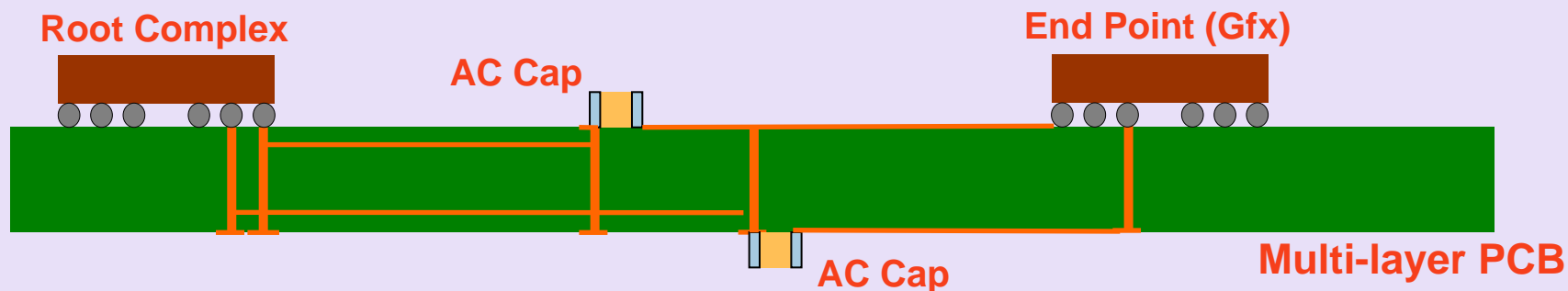


- While mobile interfaces can be much shorter than other PCIe channels, relatively lossy and/or longer channel lengths are sometimes required
 - ✓ Allows for maximum topology support and interoperability:
 - Several Gfx topologies need to support longer trace lengths (>3")
 - Connector based add-in card topologies must also be supported

Mobile PCI Express Graphics Topologies



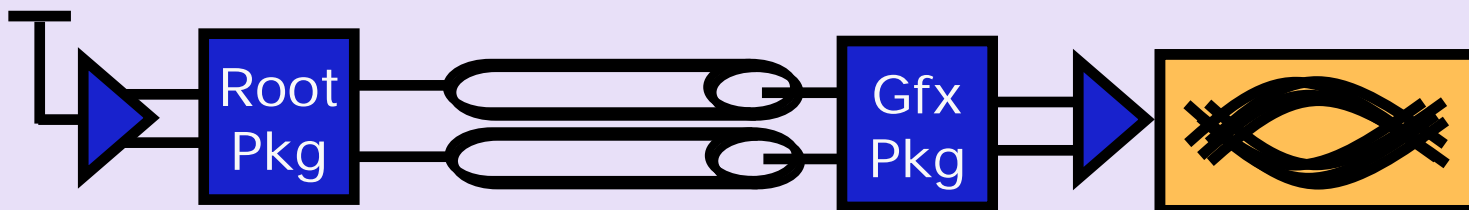
Connector Based Topology: Max lengths on motherboard of 3-6" plus add-in card



Device Down Topology: Max lengths of 3-10"

Low Swing with De-emphasis Motivation

- Why not just increase V_{swing} vs. use de-emphasis?
 - ✓ After all, the low swing spec allows for Voltage swings ranging from 0.4 – 1.2V...
 - Voltage swing adjustments alone don't necessarily solve problem!
 - Equalization (de-emphasis) also needed since eye width can become more of a limiter than eye height!
- Introducing de-emphasis can help reduce need to greatly increase V_{swing} or use full swing mode
 - ✓ Large V_{swing} takes away from Pwr benefits of low swing
 - ✓ Impact to power of de-emphasis will depend on Tx design



Implementation Overview

Standard Swing= Current Spec

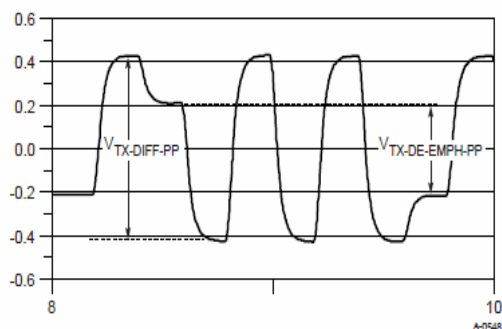


Figure 4-26: Full Swing Signaling Voltage Parameters Showing -6 dB De-emphasis

Standard Swing
(800mVpp MIN, w/de-emphasis)

Low Swing= Current Spec Implementation

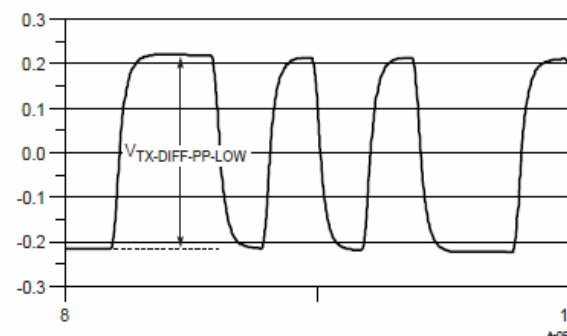
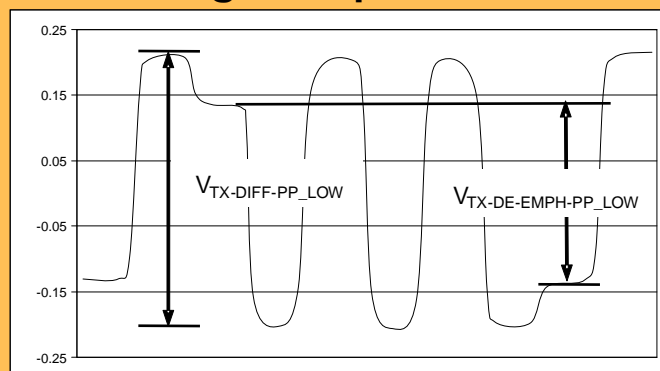


Figure 4-27: Low Swing Tx Parameters

Low Swing
(400mVpp MIN, NO de-emphasis)

Low Swing= Proposed @ 5GT/s



Low Swing
(400mVpp* MIN, w/de-emphasis)

*For 5GT/s Only:

- 400mVpp min would only apply to transition bits
(de-emphasis levels may fall below 400mV)
- Vswing tuning may still be required to meet pin or topology eye targets (e.g. Vswing above 400mVpp)

Implementation Proposal

- All 5GT/s components that use low-swing should support a targeted, optional de-emphasis level:
 - ✓ ~3.5dB (+/- 1dB) and/or 0dB @ pin
 - Similar to Standard Swing, but larger tolerance for flexibility at low swing
 - ✓ Support seen as a necessity for most PCIe graphics topologies in mobile platforms (Root Complex + End Point devices)
- Rx specs don't change regardless of low swing implementation
- Some Tx Vswing tuning may be needed to meet eye targets
 - ✓ Example: Vswing above 400mVpp at Tx pad due to package losses
 - ✓ Example: Longer PCB trace lengths may require larger Vswing
- Standard Swing Tx OK if low swing w/ de-emphasis not supported

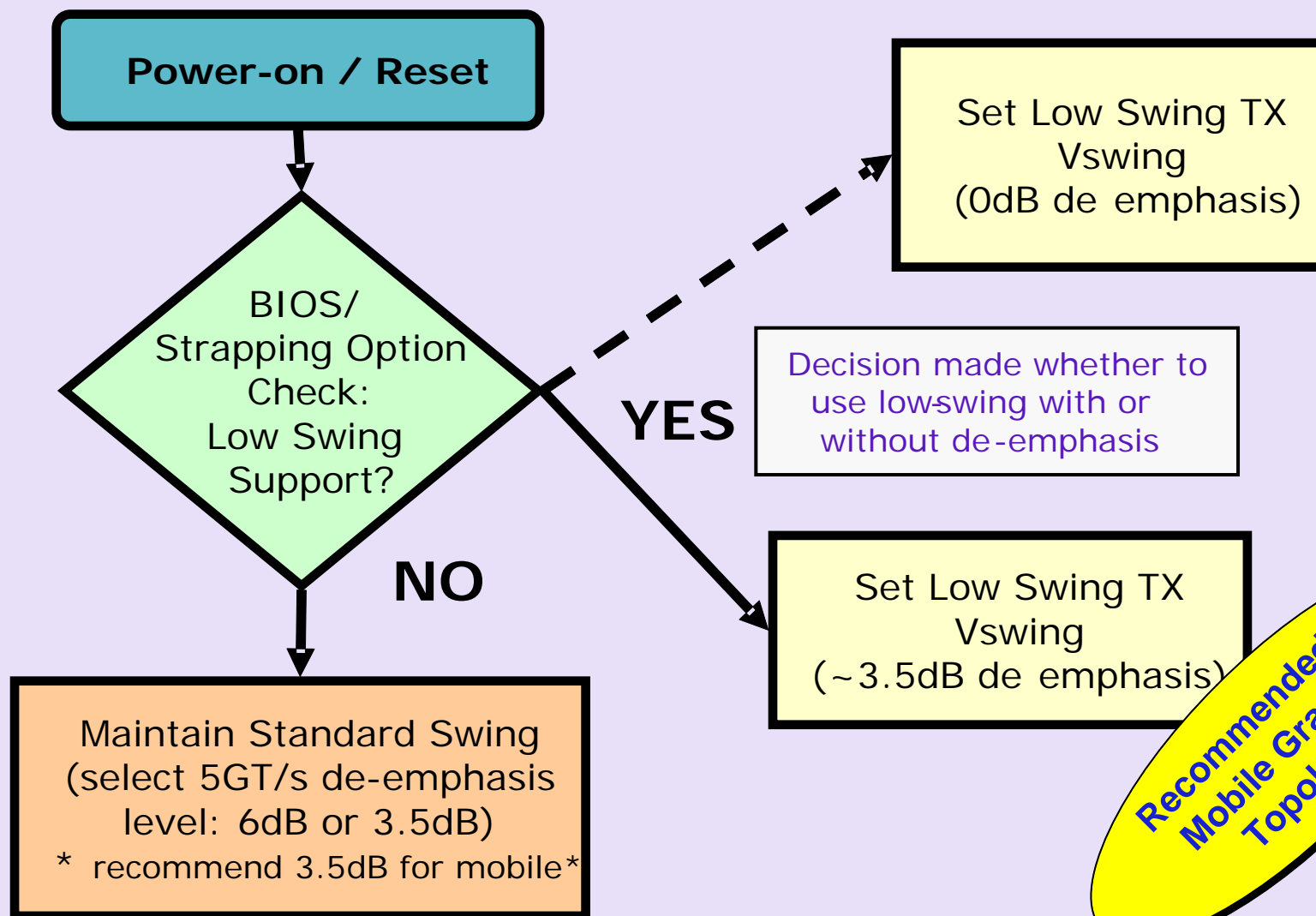
Note: The authors intend to propose a change to the PCIe 2.0 Base Spec to clarify that this optional method of implementation is allowed.

Implementation Enabling

- Enabling of low swing mode and/or de-emphasis remains implementation specific
 - ✓ Done without changes to current spec protocol, training, or compliance testing
 - ✓ Example Implementations:
 - Root Complex: After reset, BIOS enables low swing mode with de-emphasis before detect of PCIe devices is performed
 - End Point Device: Hardware strapping option is used to enable low swing mode and/or low swing de-emphasis level
- System designer must select appropriate de-emphasis enabled low swing devices
 - ✓ Must ensure both devices on both ends of link support low swing with de-emphasis for maximum interoperability



Low Swing/De-emphasis Enable Flow

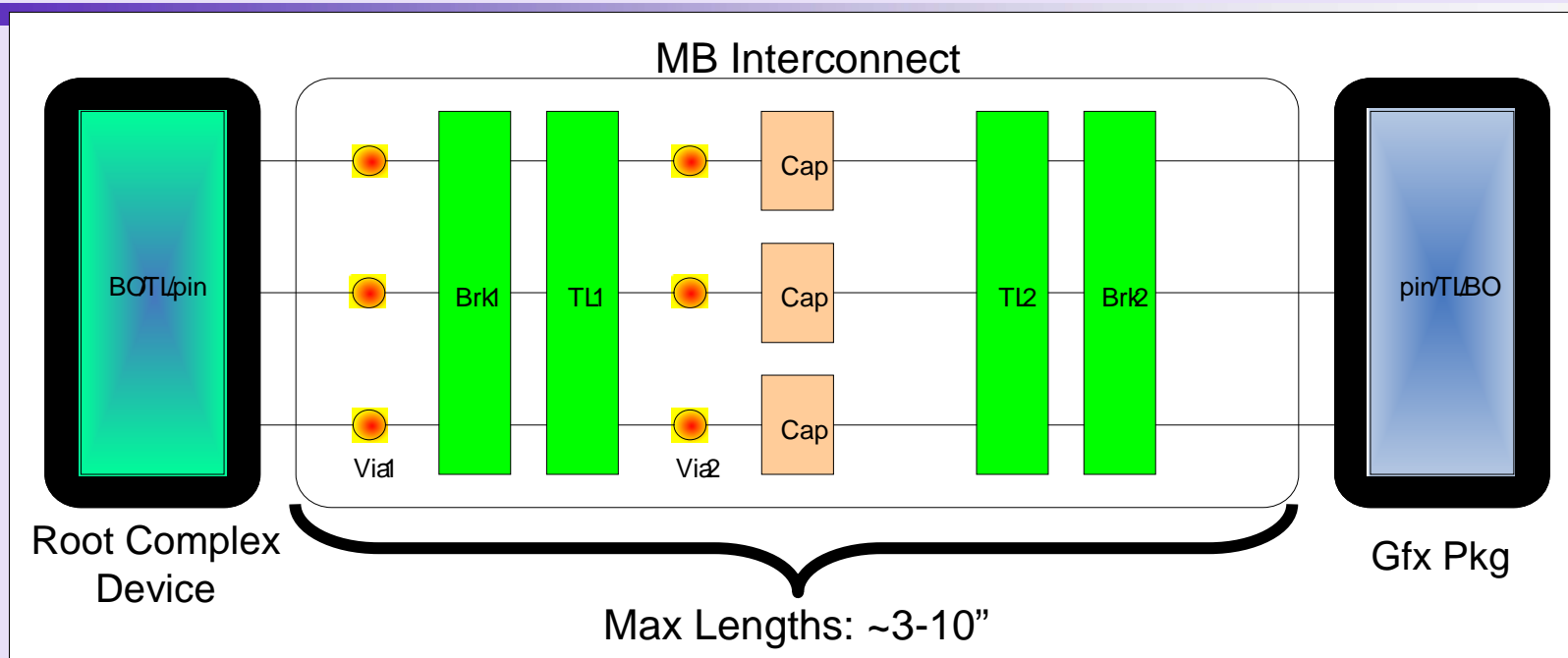


Decision made whether to use lowswing with or without de-emphasis

Set Low Swing TX Vswing (~3.5dB de emphasis)

Recommended for Mobile Graphics Topologies

Mobile Simulation Case Study (Device Down Topology)

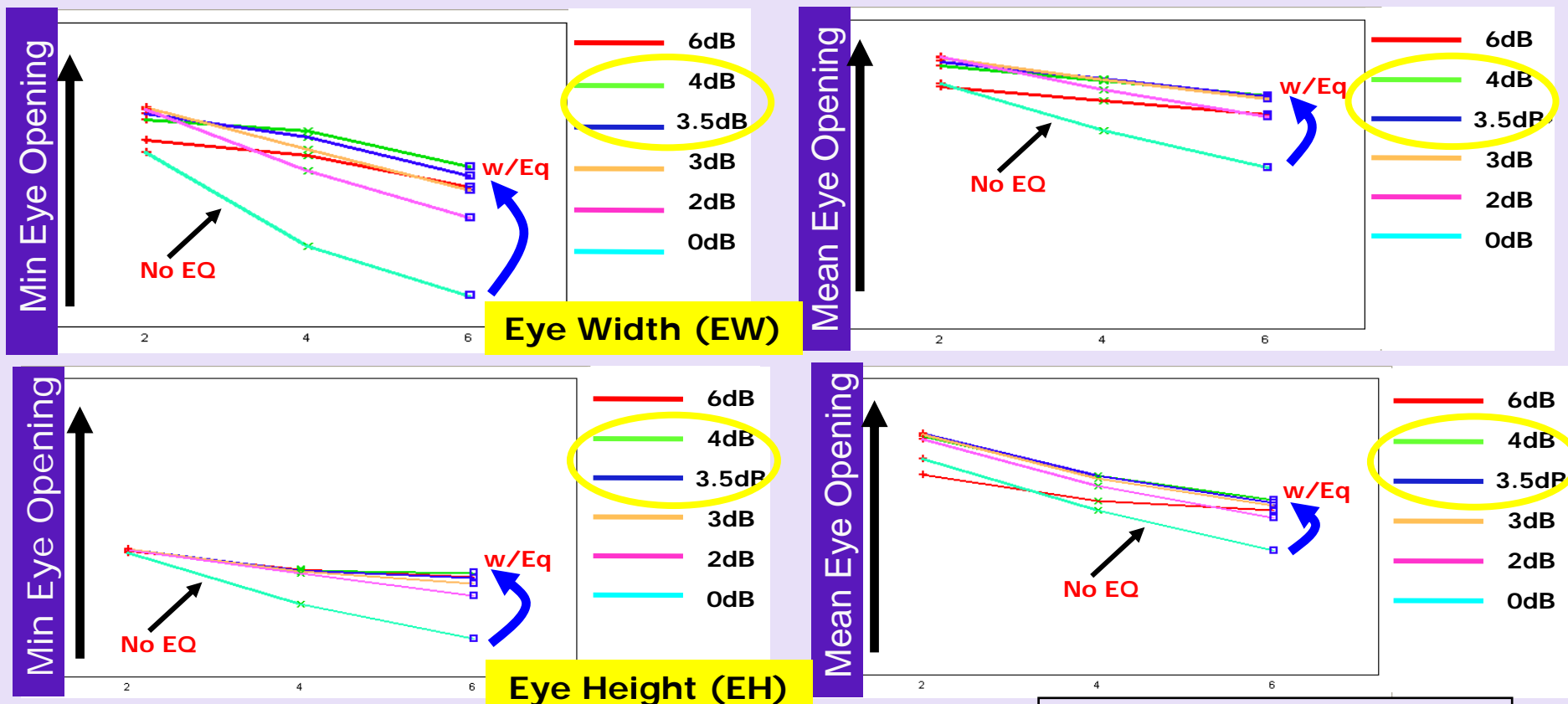


Topology	Root Complex Pkg	Via1	Brk1	TL1	Via2	TL2	Brk2	Gfx Pkg
Root2Gfx	Non-Interleaved / uS	Lyr1-3	sL	sL	Lyr3-1	uS	uS	Non-Interleaved / uS
Gfx2Root	Non-Interleaved / uS	Lyr1-3	sL	sL	Lyr3-1	uS	uS	Non-Interleaved / uS

NOTE: This topology should NOT be considered worst case; offered only as an example of a typical implementation; connector based topologies may produce worst case results

What de-emphasis level is best?

- Swept de-emphasis of 5 GT/s low swing mode from 0 to 6dB
 - ✓ ~3.5dB @ pin found to be “best fit” → improves margins!
 - For device down topologies, 6dB found to over equalize in some cases
 - For connector based topologies, separately found that adding any EQ helps!

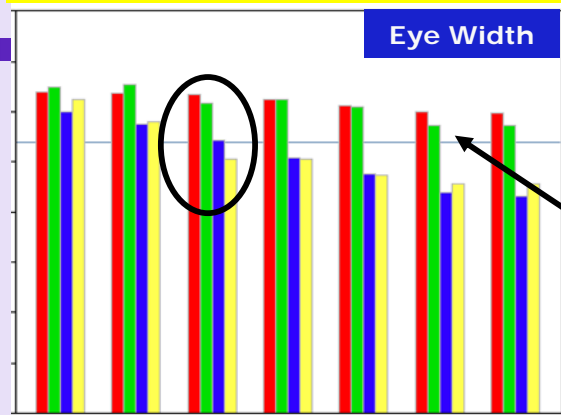


Simulation Snapshot: Benefits of Tx De-emphasis

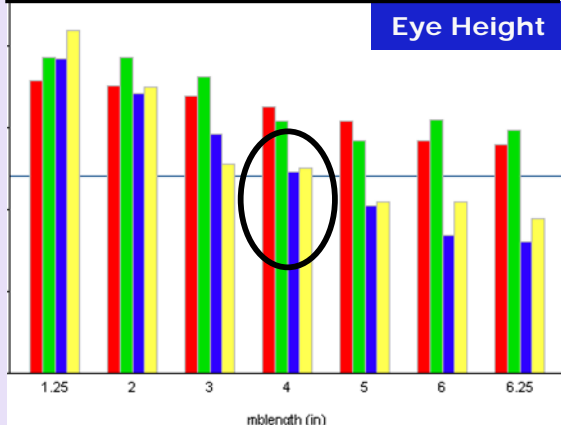
- Analyzed four TX low swing settings @ 5GT/s
 1. 400mVpp TX swing w/ NO de-emphasis
 2. 400mVpp TX swing w/3.5dB de-emphasis
 3. 550mVpp TX swing w/ NO de-emphasis
 4. 550mVpp TX swing w/3.5dB de-emphasis
- Notes:
 - ✓ *As expected, Eye Width (EW) found to be more of a limiter than Eye Height (EH)*

Results- 400mVpp

Root Complex Driving

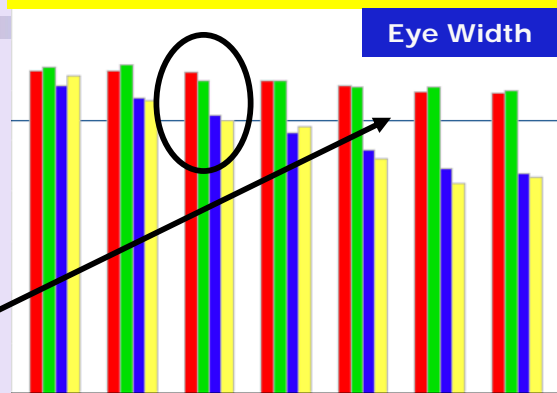


MB PCB Length

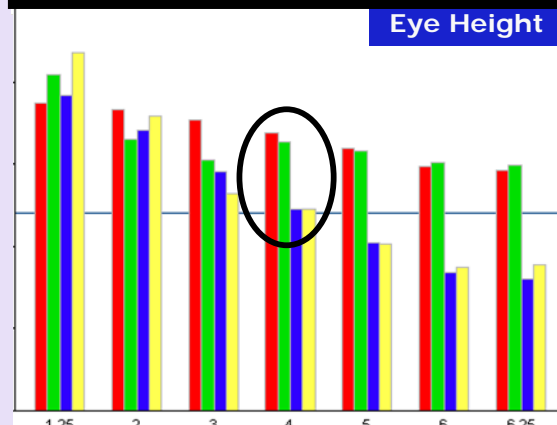


MB PCB Length

Graphics Driving



MB PCB Length



MB PCB Length

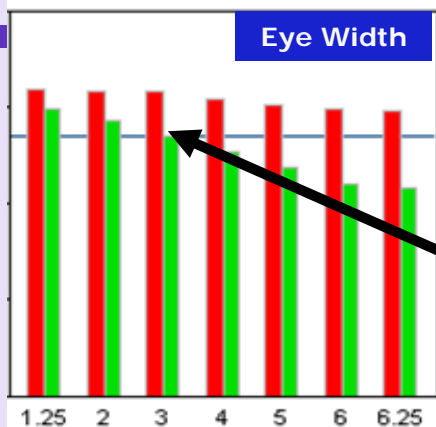
Target

Data Source: Intel Corporation

- w/out Tx de-emphasis: <3" for EW, <4" for EH
- w/Tx de-emphasis of 3.5dB: > 6" with margin for both EW,EH!

Results- 550mVpp

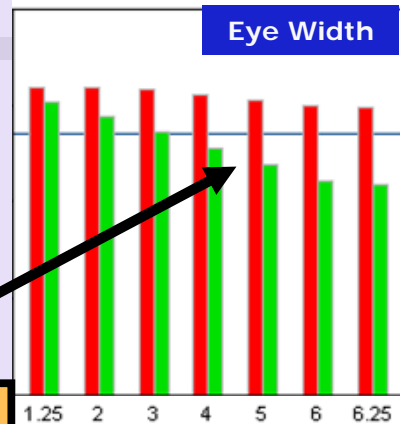
Root Complex Driving



MB PCB Length

Y
 Eye_Wt: ~3.5dB
 Eye_Wt: 0dB

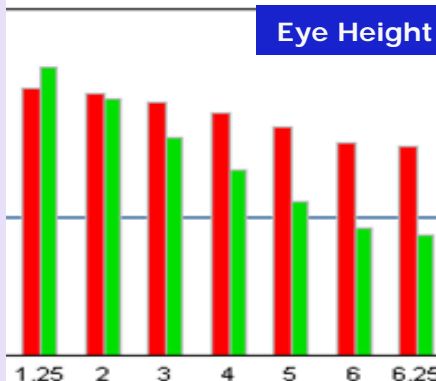
Graphics Driving



MB PCB Length

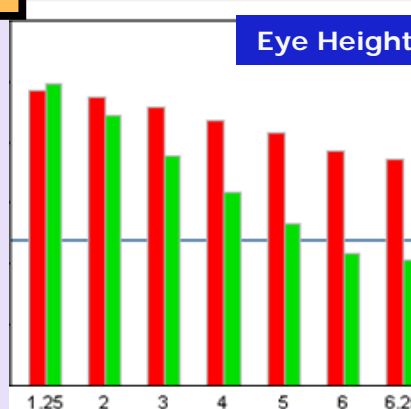
Y
 Eye_Wt: ~3.5dB
 Eye_Wt: 0dB

w/out EQ (green bar),
 Eye Width target fails
 above 3" of PCB routing!



MB PCB Length

Y
 Eye_Ht: ~3.5dB
 Eye_Ht: 0dB



MB PCB Length

Y
 Eye_Ht: ~3.5dB
 Eye_Ht: 0dB

With increased Vswing *and* TX de-emphasis, all routing lengths meet & exceed targets for both Eye Width & Eye Height!

Simulation Conclusions

- Adding almost any level of de-emphasis to low swing mode at 5 GT/s improves eye margins for most channels!
- ~3.5dB de-emphasis appears to be a good “sweet spot” for 5 GT/s low swing signals
 - ✓ Follows standard swing de-emphasis target
- Low swing with de-emphasis allows for a greater range of topologies and flexible routing lengths to be supported
 - ✓ Without de-emphasis, only channels < 3” may pass at 5 GT/s



Summary

- Low swing mode provides power savings for mobile graphics topologies
- When low swing mode is used at 5GT/s, TX de-emphasis will greatly increase solution space for mobile graphics
 - ✓ Voltage swing adjustments alone aren't enough
- Tx low swing w/ de-emphasis is not currently dictated by the base spec, but is optionally implemented
 - ✓ Low swing 5GT/s de-emphasis target = ~3.5dB (+/- 1dB) and/or 0dB
 - ✓ Standard Swing Tx OK if low swing w/ de-emphasis not supported
 - ✓ Rx specs don't change regardless of low swing implementation
- Low swing with de-emphasis is implementation specific
 - ✓ Up to each device to decide how to enable: BIOS/Driver/Strapping, etc.
 - ✓ Done without changes to current spec protocol or training

Thank you for attending the
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