CAUI-4 C2C Transmitter and Receiver Compliance

IEEE 802.3 bm

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Transmitter FFE Requirements

- CAUI-4 C2C transmitter only require modest amount of post and pre
  - Full KR4 transmit FFE is overkill when there is no back channel
- Result previously shown the CAUI-4 C2C links with TX FFE+ CTLE is rather insensitive to the transmit FFE setting
  - Transmit pre-cursor is nice too have but often may not even get optimized to the best level
- Updated de-emphasis definition is based on KR CL 72 and is consistent with CL83A
- Assuming C2C channel loss is <=15 dB CTLE=12 dB then a moderate amount transmit de-emphasis is sufficient
  - Post=C(1)=[1:2.0] with 4 to 8 setting is sufficient
  - Pre=C(-1)=[1:1.5] with 3 to 4 setting is sufficient
    - The eye amplitude gain due to pre-cursor after CTLE is only ~10%

10G-KR Transmitter Compliance (Comment 77, 79, 78, 81, 82, 114,

- A compliance method based on 10G-KR (CL72) but some of constrain eliminated or relaxed is sufficient for CAUI-4 applications
  - $R_{pst}=v_1/v_2$ = C(1) post cursor = 2.0
  - $R_{pre}=v_3/v_2$ = C(-1) post cursor =1.5
  - VMA= (v_2-v_5) = 120 mV at maximum (C1) and C(-1)
  - Δv_2/VMA, Δv_5/VMA is the VMA ripple <10%
  - (v_1+v_4)/v_1, (v_2+v_5)/v_2, and (v_3+v_6)/v_3 <5%

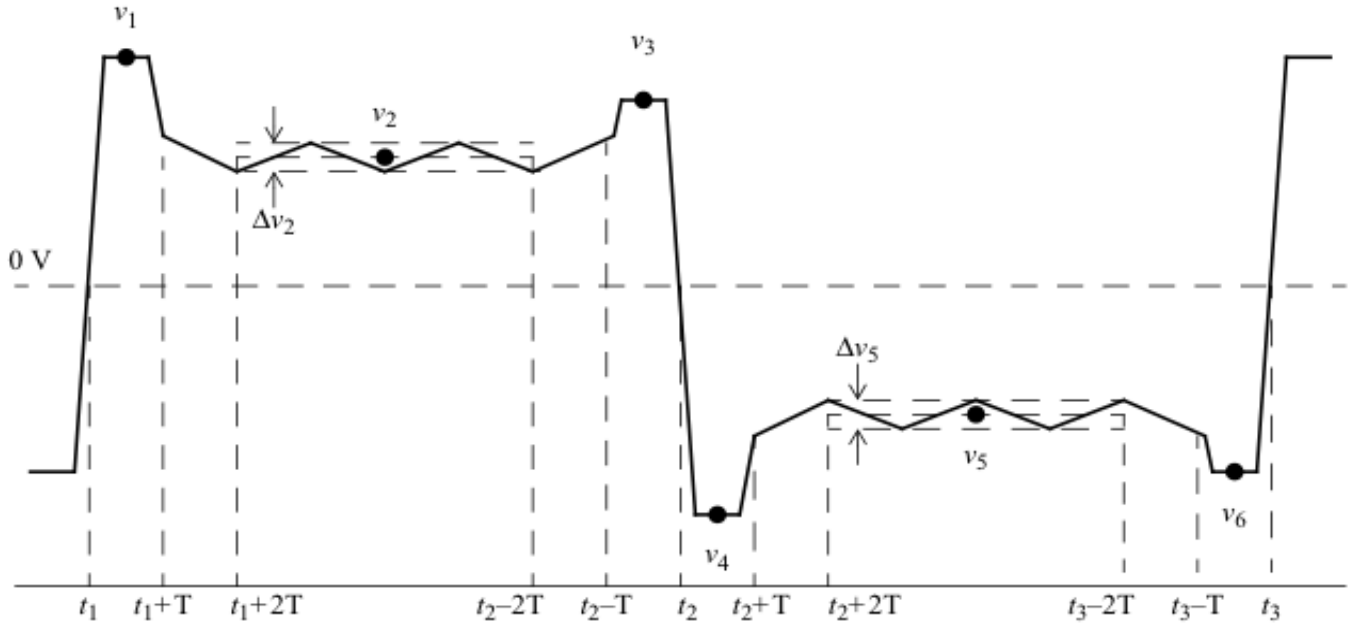
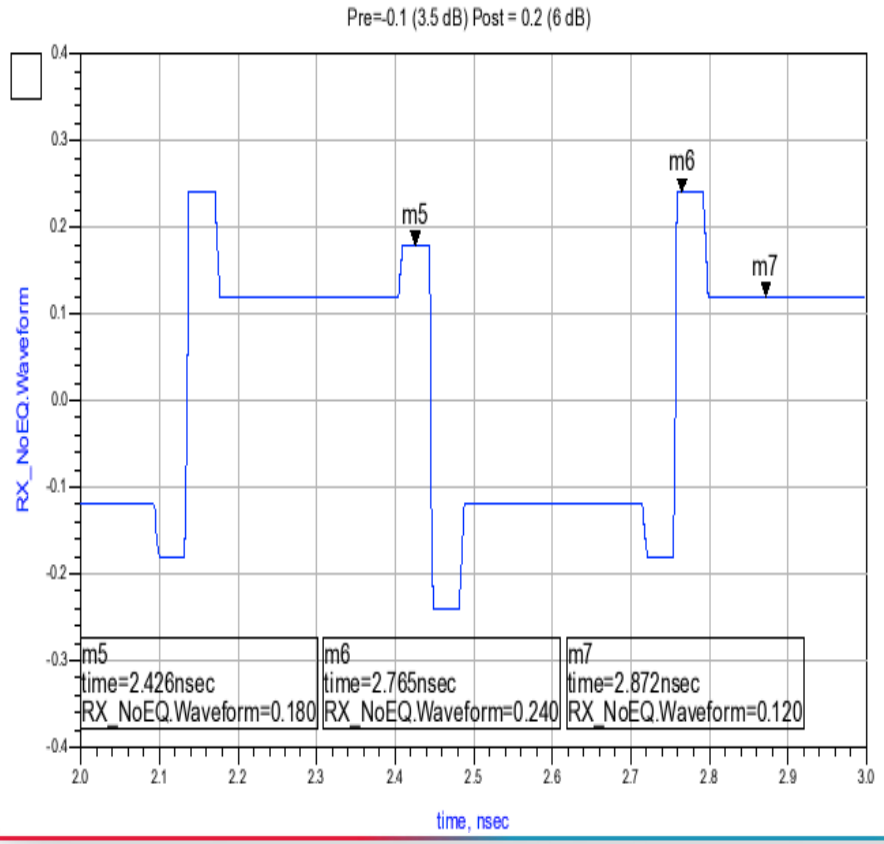
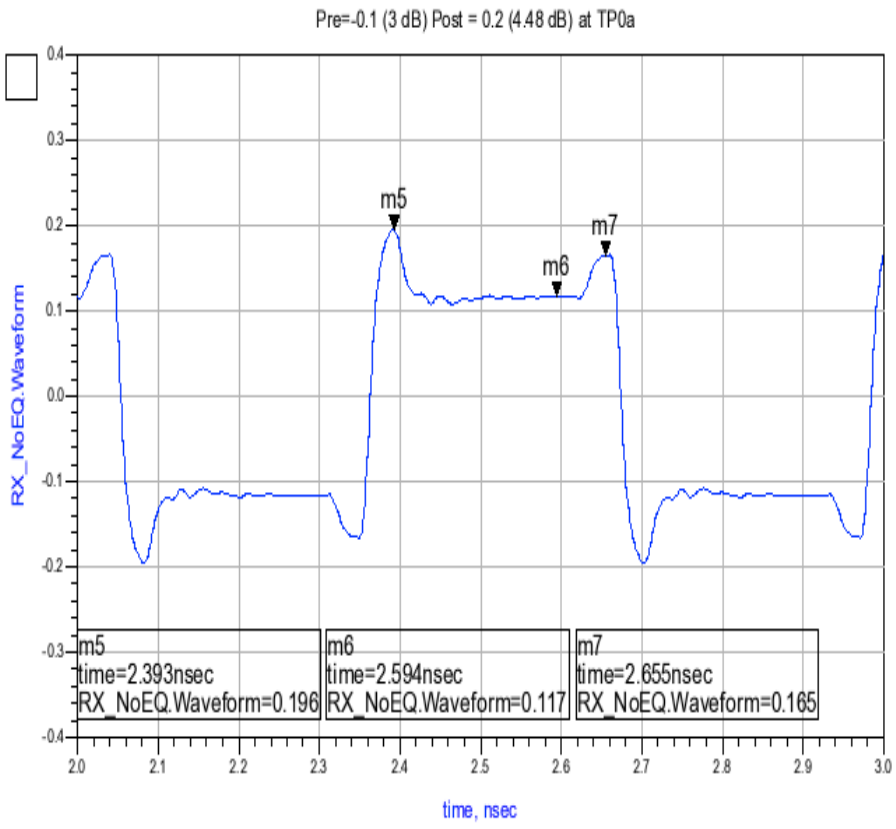


Figure 72–12—Transmitter output waveform

Example Transmitter Waveform (Comment 79)

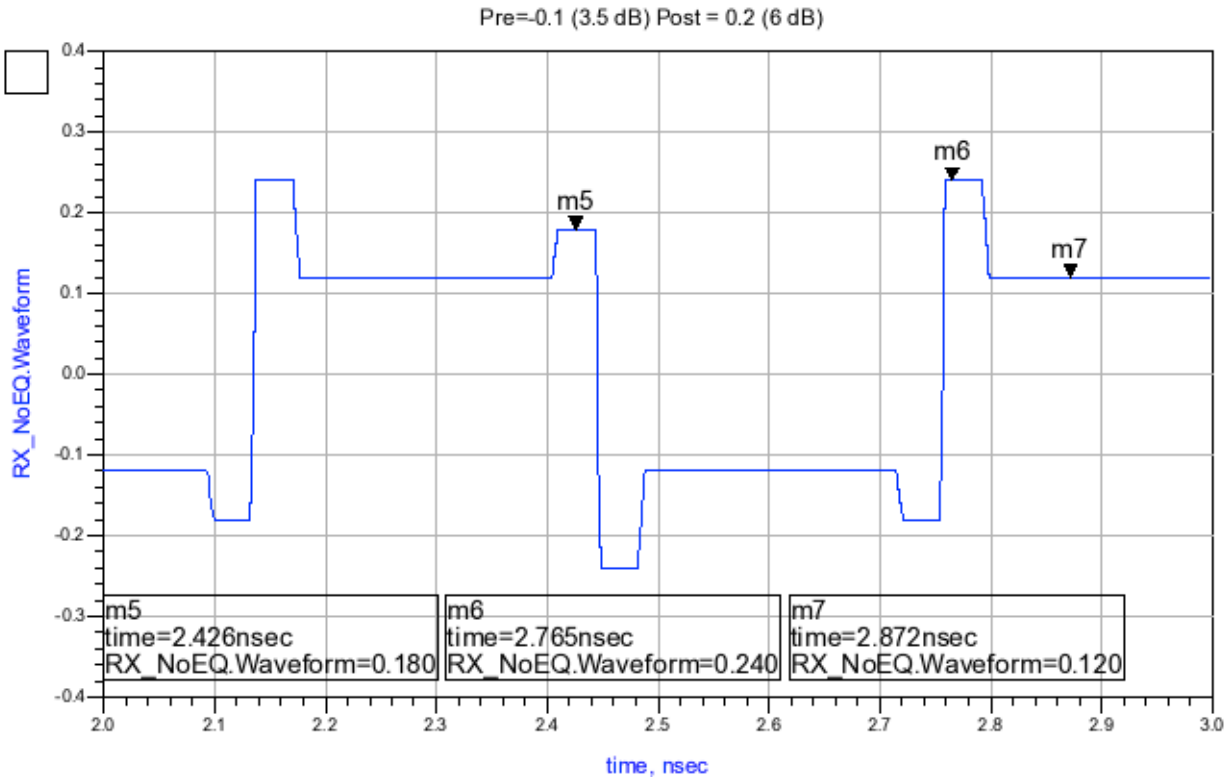
- Example TX output at device output and TP0a
  - KR approach which is consistent with CL83A and accounts for de-emphasis loss due to package/test PCB
  - The de-emphasis need to be guaranteed at TP0a in this example larger pre and post would need to meet C(1)=2 and C(-1)=1.5





Transmitter Waveform (Comment 79)

- Per KR CL72 transmitter FFE definition
  - With post cursor C(1)=2.0 (6 dB) and pre cursor C(-1)=1.5 (3.5 dB)
  - With previous results showing 600 mV fast transmitter and close 15 dB channel the min VMA would then be 120 mV

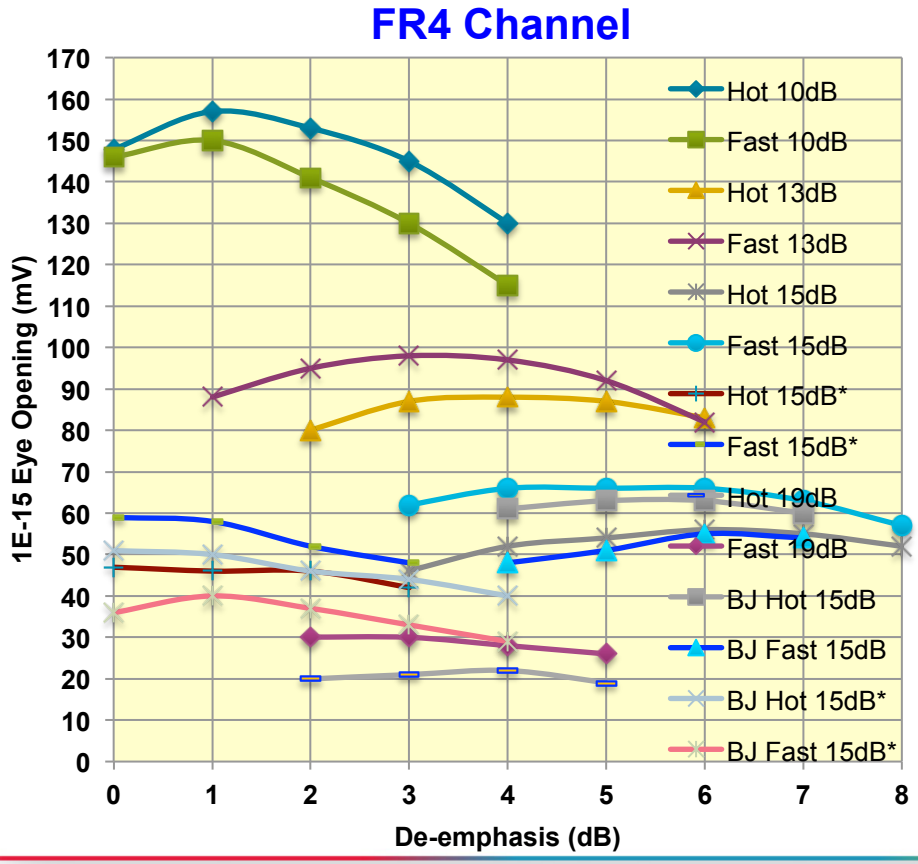


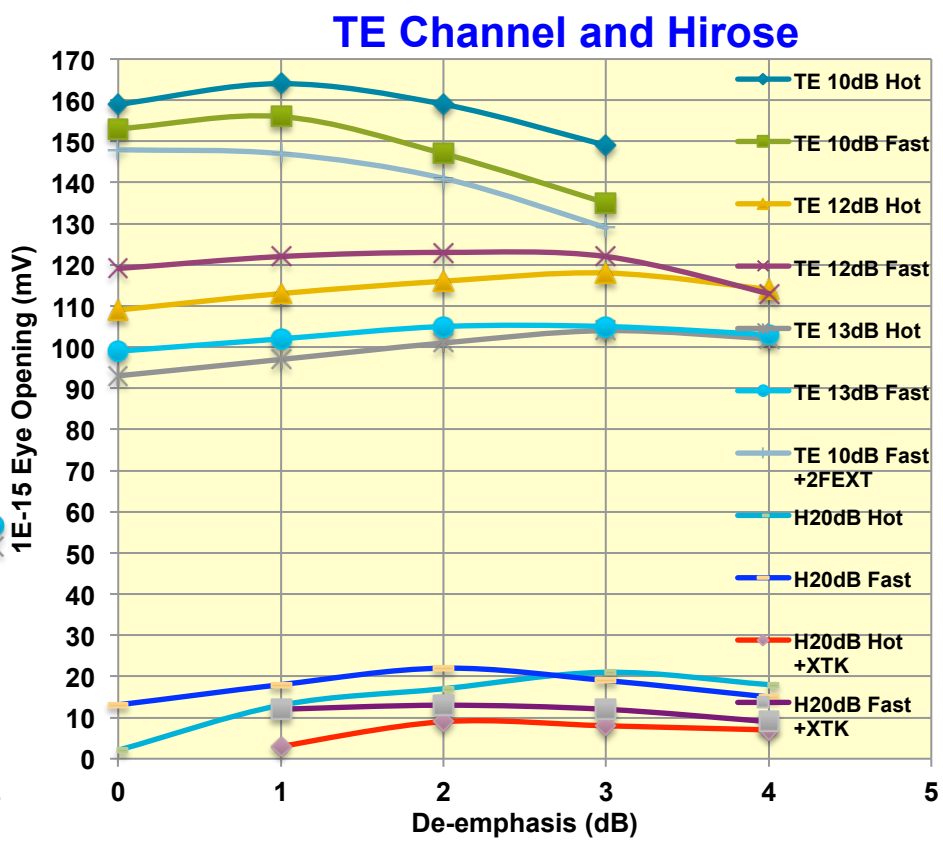
Transmitter FFE Test Procedure

- Transmitter equalization pre-cursor and post cursor is measured at TP0a. The test pattern for the transmitter output waveform is the square wave test pattern with (8 ones, 8 zeros) of 83.5.10. The scope is set to waveform lock and waveform averaging is set to 32. The waveform is observed through a fourth-order Bessel-Thomson response with a bandwidth of 40 GHz.
- Post cursor is defined as ratio of
- C(-1)=v1/v2
- Post cursor is defined as ratio of
- C(1)=v3/v2
- The post cursor C(1) measured at TP0a shall be adjustable from 1 to 2.0 in 0.25 steps with variation of +/-0.125
- The pre cursor C(-1) measured at TP0a shall be adjustable from 1 to 1.5 in 0.25 steps with variation of +/-0.125

Summary of Eye Opening

- Fast driver performs better for higher loss channel
  - For full simulation details see http://www.ieee802.org/3/bm/public/mar13/ghiasi_01_0313_optx.pdf
  - Optimizing TX FFE pre-cursor improves results below by ~10%
  - Hot driver uses 800 mV, fast driver uses 600 mV, BJ uses BJ D2.1 package module instead of large in house BGA
  - All results are with 9 dB CTLE with exception of result with * based on 14 dB CTLE



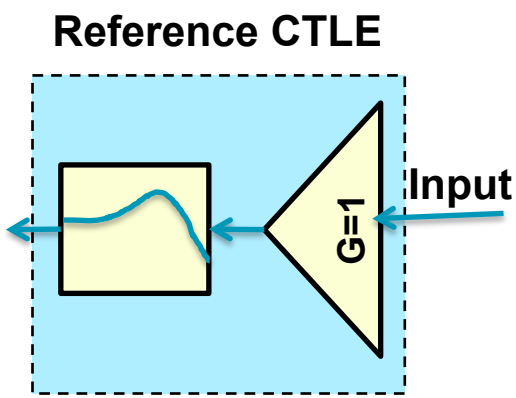


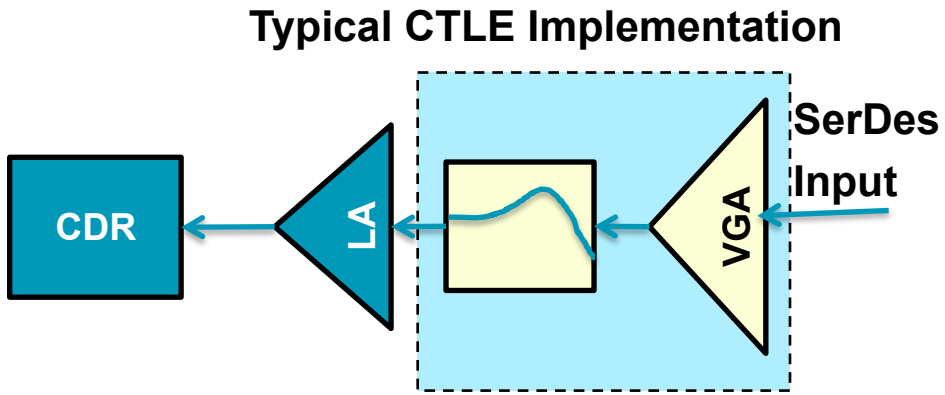
OIF 28G VSR/CAUI-4 Chip to Module CTLE Definition

- Based on most common implementation of CTLE with single pole with 2 zeros

$$Gain = G\frac{P1 \bullet P2}{Z}\frac{(Z - j*\omega)}{(P1 - j*\omega)(P2 - j*\omega)}$$

  - For reference comparison the CTLE should have no AC gain
  - Actual implementation will have VGA as well as limiting AMP with AC gain
  - Scopes software CTLE implementation is based on the reference CTLE for TP5 compliance

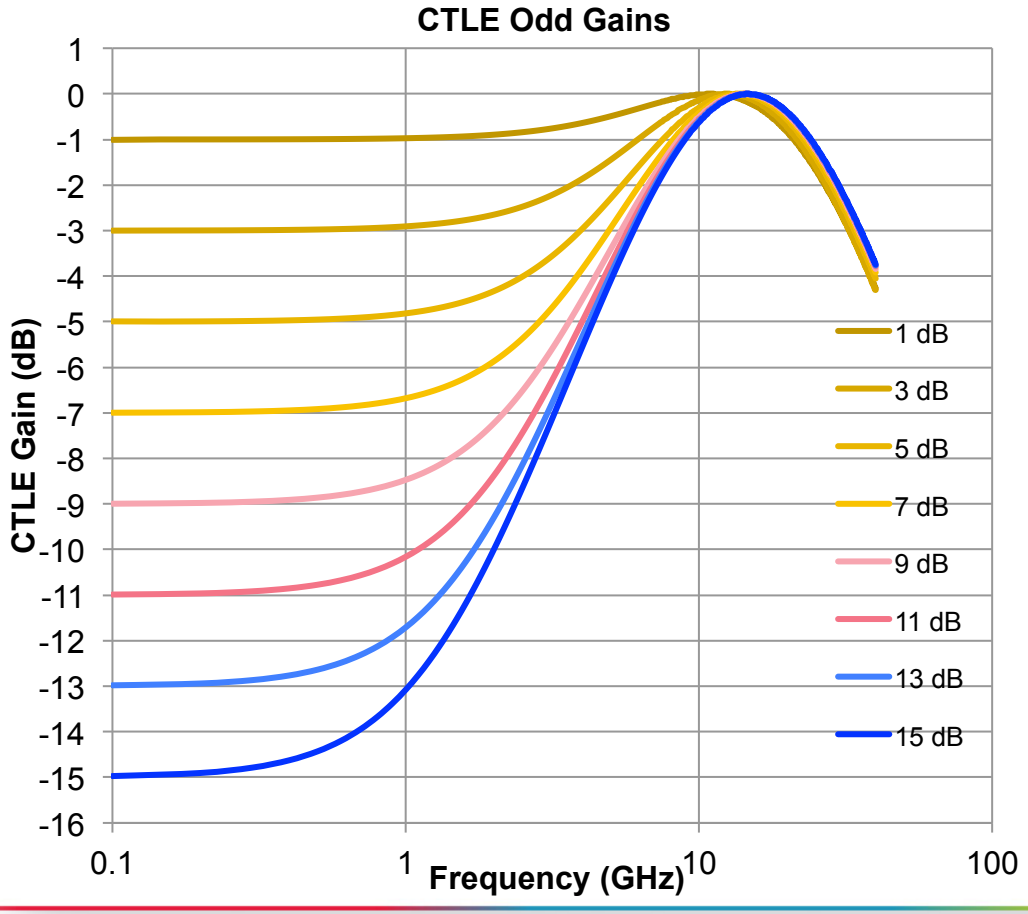




Expanded CTLE Filters (comment 85, 87)

- OIF 28G-VSR and CAUI-4 chip to module were expanded from 9 dB to 15 dB
  - To make sure filter response is always passive G and Z were slightly adjusted and the new coefficient for G and Z have more significant digits
  - With the new filter coefficient the peak gain is in the 0 to -0.005 dB range

http://www.ieee802.org/3/bm/public/tools/index.html



Gain (dB)	G (Linear)	Z (GHz)	P1 (GHz)	P2 (GHz)
1	0.89125	8.3640e9	1.86e10	1.41e10
2	0.79433	7.0990e9	1.86e10	1.41e10
3	0.70795	5.6760e9	1.56e10	1.41e10
4	0.63096	4.9601e9	1.56e10	1.41e10
5	0.56234	4.3580e9	1.56e10	1.41e10
6	0.50119	3.8440e9	1.56e10	1.41e10
7	0.44668	3.3990e9	1.56e10	1.41e10
8	0.39811	3.0120e9	1.56e10	1.41e10
9	0.35481	2.6720e9	1.56e10	1.41e10
10	0.31623	2.3728e9	1.56e10	1.41e10
11	0.28184	2.1090e9	1.56e10	1.41e10
12	0.25119	1.8755e9	1.56e10	1.41e10
13	0.22387	1.6690e9	1.56e10	1.41e10
14	0.19953	1.4853e9	1.56e10	1.41e10
15	0.17783	1.3225e9	1.56e10	1.41e10

TP5 Compliance for CAUI4 C2C

- TP5 compliance on actual physical hardware should be exactly as described in CL83E with software CTLE and scope
  - Measure Eye height, eye width, and VEC
- To verify the channel compliance the signal at TP5 must be compliant
  - Channel compliance at TP5 is a deviation from 802.3BJ COM where every channel is penalized by the worst case receiver package loss
  - COM may not be ready for CAUI4 C2C in Sept 2013 if we plan to go to working group ballot
  - Commercial tool can also perform the channel compliance at TP5
  - Signal compliance at channel output is exactly as defined above
- At this point in time it is key to define TP5 compliance requirement with fact commercial tool can verify it now, COM can be added back during the working group.

TP5 Receiver Table Parameters (Comment 83, 86)

Parameters	Test Value	Units
Signaling rate per lane (range)	25.78125 ± 100 ppm	PPM
Unit interval (UI) nominal	38.787879	ps
DC common-mode output voltage (max)	1.5	V
DC common-mode output voltage (min)	-0.3	V
Common-mode AC output voltage (max, RMS)	17.5	mV
Differential peak-to-peak output voltage (max) Transmitter disabled Transmitter enabled	 35 1000	mV
Minimum eye height with nominal FFE and optimum CTLE at 1E-15	45	mV (p-p)
Minimum eye width with the above FFE and CTLE	0.46	UI
Vertical Eye Closure	12	dB
Differential output return loss (min)	Equation (83E–2)	dB
Common to differential mode conversion (min)	Equation (83E–3)	dB
Differential termination mismatch (max)	10	%
Transition time (min, 20% to 80%)	10	ps

Table 83D-3 Receiver Interference Tolerance Parameters (Comment 84)

Parameters	Test Value	Units
Signaling rate per lane (range)	25.78125 ± 100 ppm	PPM
Unit interval (UI) nominal	38.787879	ps
Applied Broadband noise	Adjust to meet eye height and eye width	
Applied peak-to-peak random jitter	Adjust to meet eye height and eye width	
Maximum eye height with optimum CTLE at 1E-15	50	mV (p-p)
Maximum eye width with the above CTLE at 1E-15	0.48	UI
Target Vertical Eye Closure	12	dB
Target Channel Insertion Loss at 12.89 GHz	15	dB

Summary

- CAUI-4 C2C has been investigated extensively
  - 20 dB channel does not look feasible with CTLE
  - Assuming transmit mask is met then 15 dB CTLE is feasible
  - If 20 dB is absolutely required then implementation will be DFE based and MTTPFA has to be managed
- Methodology presented here is based on proven KR CL72, CAUI-10 CL83A, and CAUI-4 CL83E
  - The combination of transmitter eye mask already in the draft with transmitter pre/post cursors guarantees compliant transmitter
  - The combination of host output parameters at TP5 and interference tolerance at TP5a completes the receiver specifications
  - It is not clear if we can get the COM ready by the interim meeting in York, if not then commercial tool could be used for channel design and verification where COM may get added during working group ballot.

Thank You !