Limits for AC Common Mode Voltage for C2M

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Overview

- **Contribution in support of following C2M common mode noise comments on 802.3ck D3.2**
  - Comment R2-8 TP1a common mode output limits
  - Comment R2-9 TP4 common mode output limits
  - Comment R2-21 TP4 common mode output limits
  - Comment R2-22 host input common mode limits
  - Comment R2-18 common mode test method
  - Comment R2-20 common mode test method.

Background Material

- **In the 25G AUI 802.3bm defined TP1a AC VCM to 17.5 mV RMS**
  - TP1a limit for CL 120E is also 17.5 mV RMS
  - CL120G initially also specified 17.5 mV RMS at TP1a but later increased to 25 mV RMS
  - The peak-peak common mode voltage is ~5x to 6x larger
- **CR/KR clauses have had 30 mV of AC common mode voltage**
  - If one scales the CR/KR 1200 mV output amplitude with C2M 750 mV the AC RMS voltage should not have been increased >18.75 mV
- **During 802.3ck D3.1 and D3.2 we transitioned from RMS common mode to peak-peak**
  - CR TP2 AC common modes with 1200 mV driver has
    - Vcmpp-LF=30 mV
    - Vcmpp-HF=80 mV
  - CR TP1a AC common modes with 750 mV driver has
    - Vcmpp-LF=32 mV
    - Vcmpp-HF=80 mV
  - Output AC common mode is proportional to signal amplitude if one scaled CR AC common mode at TP1a the total AC common mode ≤68.75 mV p-p!

Some Thought and Observations on New AC Common Mode Method

- **Generally, the new AC common mode method is an improvement over simpler single RMS measurement**
  - A very common form of AC common mode is drive P/N current mismatch which result in broadband synchronous common mode
  - Generally, the low frequency/DC-DC common modes are asynchronous may require to equivalent time scope (ETS) to use free trigger
  - What is the optimum LF and HF bands for common mode measurements
    - From conversion perspective and cable attenuation it is preferable to push the corner of LF/HF from current 100 MHz to few GHz
    - But when LF band pushed to 1 GHz then some of the synchronous broad band common modes gets in the band and on ETS synchronous vs non-synchronous may require different triggering
    - The current 100 MHz LF band should not be increased, and if reduced need to make sure on die DC-DC convertors noise are captured in the band
  - AC common amplification is possible on lower loss reflective channels, but with increasing SDD21 attenuation generally AC common will attenuate as fast and sometime faster for channel with higher SCC21 attenuation.

Comparing CL-162 and CL-120G

- Considering CR 1200 mV vs 120G 750 mV TP1a needs to be adjusted down!

Table 162–11—Summary of transmitter specifications at TP2

Parameter	Subclause reference	Value	Units
Signaling rate, each lane (range)	162.9.4.1	53.125 ± 50 ppm[a]	GBd
Differential pk-pk voltage with Tx disabled (max)[b]	93.8.1.3	30	mV
DC common-mode voltage (max)[b]	93.8.1.3	1.9	V
AC common-mode peak-to-peak voltage (max) Low frequency, $V_{CMPP-LF}$ High frequency, $V_{CMPP-HF}$	162.9.4.4	 30 80	 mV mV
Differential pk-pk voltage, v_{di} (max)[b]	93.8.1.3	1200	mV

Table 120G–1—Host output characteristics at TP1a

Parameter	Reference	Value	Units
Signaling rate, each lane (range)		53.125 ± 50 ppm[a]	GBd
DC common-mode output voltage (max)	120G.5.1	2.8	V
DC common-mode output voltage (min)	120G.5.1	–0.3	V
Single-ended output voltage (max)	120G.5.1	3.3	V
Single-ended output voltage (min)	120G.5.1	–0.4	V
Peak-to-peak AC common-mode voltage (max) Low-frequency, $V_{CMPP-LF}$ High-frequency, $V_{CMPP-HF}$	120G.5.1	 32 80	mV
Differential peak-to-peak output voltage (max) Transmitter disabled Transmitter enabled	120G.5.1	 35 750	mV

CL-120G TP1a vs TP4

- **Modules have much lower DC-DC convertor noise considering TIA photo-current sensitivity**
  - Not clear why Vcmp-LF is 60 mV
  - By comparisons 1200 mV CR TP2 has total of 110 mV of Vcm but even the half amplitude short mode with just 600 mV the TP4 Vcm is 140 mV
  - Vcm at TP4 needs to be lower to allow room for some amplifications in the channel.

Table 120G–1—Host output characteristics at TP1a

Parameter	Reference	Value	Units
Signaling rate, each lane (range)		53.125 ± 50 ppm[a]	GBd
DC common-mode output voltage (max)	120G.5.1	2.8	V
DC common-mode output voltage (min)	120G.5.1	–0.3	V
Single-ended output voltage (max)	120G.5.1	3.3	V
Single-ended output voltage (min)	120G.5.1	–0.4	V
Peak-to-peak AC common-mode voltage (max) Low-frequency, $V_{CMPP\text{-}LF}$ High-frequency, $V_{CMPP\text{-}HF}$	120G.5.1	 32 80	mV
Differential peak-to-peak output voltage (max) Transmitter disabled Transmitter enabled	120G.5.1	 35 750	mV

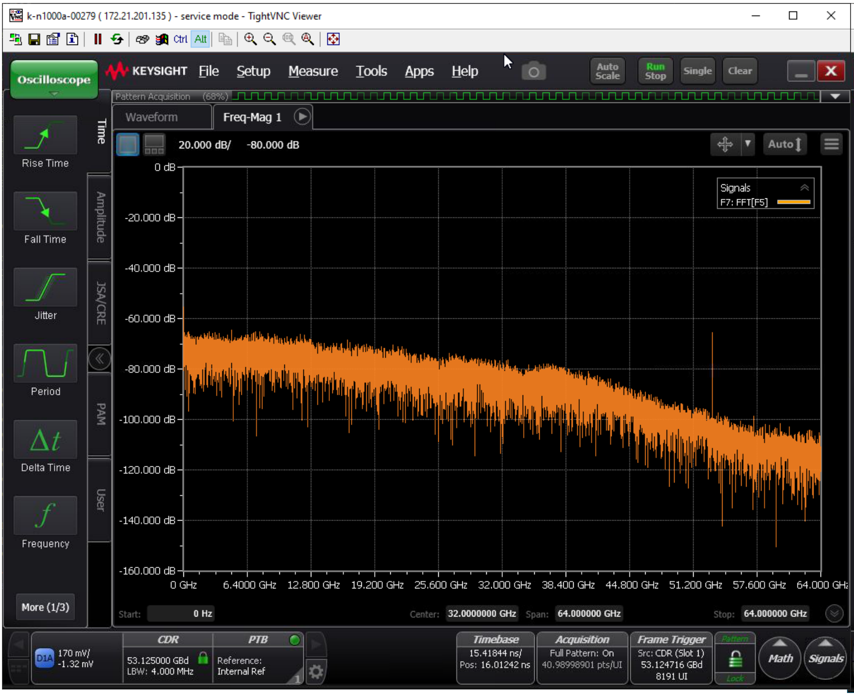
Table 120G–3—Module output characteristics at TP4

Parameter	Reference	Value	Units
Signaling rate, each lane (nominal)		53.125[a]	GBd
Peak-to-peak AC common-mode voltage (max) Low-frequency, $V_{CMPP\text{-}LF}$ High-frequency, $V_{CMPP\text{-}HF}$	120G.5.1	 60 80	mV
Differential peak-to-peak output voltage (max) Short mode Long mode	120G.5.1	 600 845	 mV mV

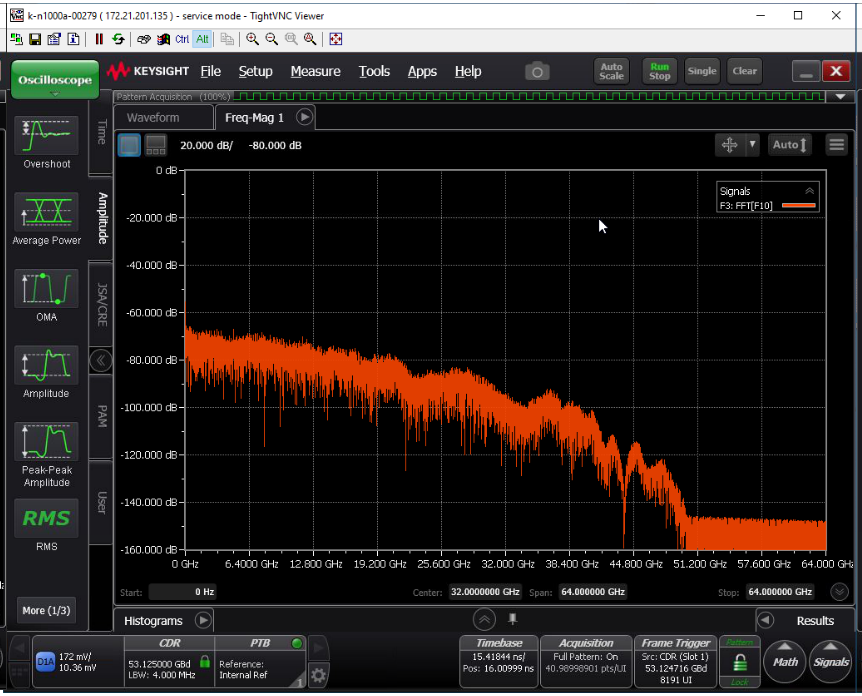
FFT Response of the Common Mode Noise

- **FFT response is for 2” and 9” Lim channels the common mode response generally follows differential response**
  - C2M channels [lim_3ck_adhoc_01_073119]
  - Measured on equivalent time scope without any filters.

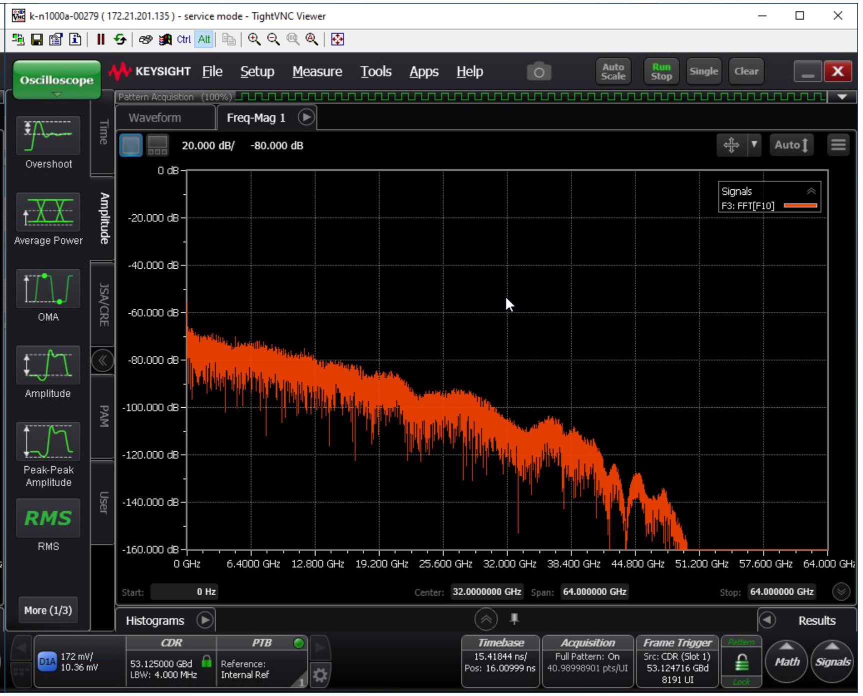
SerDes Output



After Lim 2 Inch Channel



Lim 9 Inch Channel



Summary of Common Mode Results for Several Channels

- **For common mode excitation based on P/N current imbalance all the channel investigated attenuates the high frequency broadband > 100 MHz common mode**
  - These experiments had negligible LF common mode.

Channel	Vcm RMS (mV)	Vcm p-p (mV)	Diff. Signal p-p (mV)	Ratio Vcm/Signals p-p (dB)
SerDes Output	13	87	850	-19.8
Lim 2" Channel lim_3ck_adhoc_01_073119	8.3	56	697	-21.9
Lim 9" Channel lim_3ck_adhoc_01_073119	5.8	37	541	-23.3
OSFP MTF matoglu_3ck_adhoc_01_030420	8.8	52	678	-22.3
QSFP-DD 2m (lane 3) palkert_3ck_02a_1119	3.3	23	430	-25.4
QSFP-DD 2m (lane 4) palkert_3ck_02a_1119	4	28	433	-23.8

BER Impact of Common Mode at TP1a

- **Common mode generated using imbalance in the P/N driver currents which generates broadband synchronous common mode**
  - In this measurement there was negligible LF common mode
  - Average BER would be somewhat better than reported below if portion of Vcm was asynchronous LF common mode
  - 80 mV HF common mode has a real impact on BER and with additional 30 mV LF asynchronous the BER impact will be somewhere between 80 mV and 110 mV reported below.

Vendor A C2M RX		Vendor B C2M RX	
VCMN (mVpp)	BER (PRBS31)	VCMN (mVpp)	BER (PRBS31)
43.5	0	69	4E-10
54	0	78	2E-09
68	0	83	2E-08
80	0	95	5E-07
105	3E-9	110	2E-06
133	1E-6	132	2E-05

TP1a and TP4 AC Common Mode Proposal

- **At TP1a**
  - Keep current 30 mV LF Vcm
  - Keep Current 80 mV HF Vcm
  - Total max LF+HF Vcm ≤ 80 mV total
- **At TP4**
  - Reduce LF Vcm to 25 mV
  - Reduce HF Vcm to 75 mV
  - Total max LF+HF Vcm ≤ 75 mV total.

Summary

- **Common mode was generated on a SerDes test board where the primary common generation was by current imbalance between P/N drivers**
  - The SerDes test board practically speaking had no LF common mode ~4 mV
  - If the common mode was larger >~ 5 mV then physical 100 MHz LP and 100 MHz HP filters would have been required with equivalent time scopes
- **AC common mode per draft D3.2 with is an improvement overall compared to legacy single RMS measurement**
  - Separating low frequency common mode typically asynchronous where high frequency common mode is synchronous allow use of equivalent time scope
  - The 100 MHz LF captures all DC-DC convertors
  - 100 MHz LF band is low enough not to capture synchronous broadband common modes
- **AC common mode levels in D3.2 draft for KR and CR given 1200 mV drivers are reasonable**
  - Just need to adjust AC common mode levels for C2M at TP1a and TP4 considering much smaller differential signal swing!