106Gbps C2C COM Investigation (I)

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li_3ck_02_0719
For IEEE 802.3ck

September, 2019

Intel

802.3ck C2C Assumptions and Investigations

Observations

- 802.3ck C2C is similar to LR where end-to-end link performance is evaluated.
- 802.3ck C2C differs from LR where C2C link is shorter and simpler, e.g. up to 1 connector
- 3 sets of C2C channels were contributed and studied:
  - 100G C2C-S Channel Estimate: http://www.ieee802.org/3/ck/public/19_07/lim_3ck_04_0719.pdf [1]
  - Examples of C2C Channels With Impairments 10dB 16dB 18dB 20dB Test Cases: http://www.ieee802.org/3/ck/public/adhoc/july10_19/rabinovich_3ck_adhoc_01a_071019.pdf [2]
  - Channel Models for 100 Gb/s, 200Gb/s, 400 Gb/s C2C AUI: http://www.ieee802.org/3/ck/public/19_05/gore_3ck_01a_0519.pdf [3]

Investigation in this study

- Investigate C2C reference TX and RX architectures
- Investigate 2 die termination resistance

106Gbps C2C COM Reference RX Scheme

- Use current trending LR reference RX as a starting point with DER_0 = 1e-5
- TX
  - T_r=6.16ps, A_DD = 0.02UI, sigma_RJ = 0.01UI
  - TX EQ
    - 2 or 3 pre-taps + 1 post-tap
  - RLM = 0.95, SNR_{TX}=33dB
- RX
  - RX input referred noise (eta_0): 8.2e-9 V^2/GHz
  - Equalization
    - CTLE
      - f_z = f_p1 = 21.25GHz
      - f_p2 = 53.125 GHz
      - f_HP_PZ: 0.664 GHz
- RX *(cont.)*
  - DFE Configuration
    - 4~12 fixed post-taps
    - DFE tap coef.: Fixed Taps: Tap 1 ≤ 0.85, others ≤ 0.2
- Package/TX/RX Capacitance and Termination
  - Length: [13/7, 31/13, 13/11, 31/29]mm (TX/RX) T-line + 1.8mm PTH
    - T-line/PTH parameters: a1=0.0009909, a2= 0.0002772, tau=6.14e-3 ns/mm, $Zc_{T\text{-}line}$=87.5Ω, Zc_{PTH}=92.5Ω
  - Rd: 45 or 50 Ohms

802.3ck C2C COM Configuration

Table 93A-1 parameters			
Parameter	**Setting**	**Units**	**Information**
f_b	53.125	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[1.2e-4 1.2e-4]	nF	[TX RX]
L_s	[0.12, 0.12]	nH	[TX RX]
C_b	[0.3e-4 0.3e-4]	nF	[TX RX]
z_p select	[1, 2, 3, 4]		[test cases to run]
z_p (TX)	[13 31 13 31; 1.8 1.8 1.8 1.8]	mm	[test cases]
z_p (NEXT)	[7 13 11 12; 1.8 1.8 1,8 1,8]	mm	[test cases]
z_p (FEXT)	[13 31 13 31; 1.8 1.8 1.8 1.8]	mm	[test cases]
z_p (RX)	[7 13 11 29; 1.8 1.8 1.8 1.8]	mm	[test cases]
C_p	[0.87e-4 0.87e-4]	nF	[TX RX]
R_0	50	Ohm	
R_d	[50 50]	Ohm	[TX RX]
A_v	0.413	V	vp/vf=.694
A_fe	0.413	V	vp/vf=.694
A_ne	0.608	V	
L	4		
M	32		
filter and Eq			
f_r	0.75	*fb	
c(0)	0.54		min
c(-1)	[-0.34:0.02:0]		[min:step:max]
c(-2)	[0:0.02:0.12]		[min:step:max]
c(-3)	[-0.06:0.02: 0]		[min:step:max]
c(1)	[-0.2:0.05:0]		[min:step:max]
N_b	4	UI	
b_max(1)	0.85		
b_max(2..N_b)	0.2		
g_DC	[-20:1:0]	dB	[min:step:max]
f_z	21.25	GHz	
f_p1	21.25	GHz	
f_p2	53.125	GHz	
g_DC_HP	[-6:1:0]		[min:step:max]
f_HP_PZ	0.6640625	GHz	

I/O control		
DIAGNOSTICS	0	logical
DISPLAY_WINDOW	0	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\100GEL_KR_{date}\	
SAVE_FIGURES	1	logical
Port Order	[1 3 2 4]	
RUNTAG	KR_eval_	
COM_CONTRIBUTION	0	logical
Operational		
COM Pass threshold	3	dB
ERL Pass threshold	10	dB
DER_0	1.00E-05	
T_r	6.16E-03	ns
FORCE_TR	1	logical
Include PCB	0	logical
TDR and ERL options		
TDR	0	logical
ERL	0	logical
ERL_ONLY	0	logical
TR_TDR	0.01	ns
N	3000	
beta_x	2.53E+09	
rho_x	**0.25**	
fixture delay time	0	s
TDR_W_TXPKG	0	
N_bx	24	UI
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
Noise, jitter		
sigma_RJ	0.01	UI
A_DD	0.02	UI
eta_0	8.20E-09	V^2/GHz
SNR_TX	33	dB
R_LM	0.95	

Table 93A–3 parameters		
Parameter	**Setting**	**Units**
package_tl_gamma0_a1_a2	[0 0.0009909 0.0002772]	
package_tl_tau	6.141E-03	ns/mm
package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm

Table 92–12 parameters 5.2dB at 26.56GHz		
Parameter	**Setting**	
board_tl_gamma0_a1_a2	*[0 0.000599 0.0001022]*	1.286 dB/in or 0.0506 dB/mm at 100 ohms
board_tl_tau	*6.200E-03*	ns/mm
board_Z_c	90	Ohm
z_bp (TX)	*102.7*	mm
z_bp (NEXT)	*102.7*	mm
z_bp (FEXT)	*102.7*	mm
z_bp (RX)	*102.7*	mm

Floating Tap Control		
N_bg	**0**	**0 1 2 or 3 groups**
N_bf	*3*	taps per group
N_f	40	UI span for floating taps
bmaxg	0.2	max DFE value for floating taps

COM v2.7 is used in this study.

802.3ck C2C Channels*

CH#	Description	Reference Document	IL (dB) at 26.56GHz
1	Channel1\Asic_Mezz_Retimer_L10_Thru.s4p	lim_3ck_04_0719.pdf	16.56
2	Channel2\Asic_Mezz_Retimer_L23_Thru.s4p		16.88
3	Channel3\Asic_Mezz_Deep_Retimer_L10_Thru.s4p		17.37
4	Channel4\Asic_Mezz_Deep_Retimer_L23_Thru.s4p		17.77
5	Impaired_C2C_20dB_P1_to_P2\Impaired_C2C_20dB_P1_to_P2_thru_ExtPEC.s4p**	rabinovich_3ck_adhoc_01a_071019.pdf	19.52
6	gore_3ck_02_0519_PCB\C2C_PCB_SYSVIA_20dB_thru.s4p	gore_3ck_01a_0519.pd	20.08
7	gore_3ck_02_0519_Cabled\C2C_CA_CONN_SYSVIA_20dB_thru.s4p		19.86

Notes:

- **: All channel data are from IEEE 802.3ck Task Force Tools & Channels page: http://www.ieee802.org/3/ck/public/tools/index.html*
- ***: 4 FEXT configuration is used in this study*

COM Analysis Results

w/ Rd = 50 ohms, DFE Tap Length 4 to12, and w/o TX Pre-Tap 3

Rd = [50, 50] ohms, no TX Pre-Tap 3, Package Length = [13, 7]mm (TX/RX)						Rd = [50, 50] ohms, no TX Pre-Tap 3, Package Length = [31, 13]mm (TX/RX)						Rd = [50, 50] ohms, no TX Pre-Tap 3, Package Length = [13, 11]mm (TX/RX)						Rd = [50, 50] ohms, no TX Pre-Tap 3, Package Length = [31, 29]mm (TX/RX)					
Ch id	4	6	8	10	12	Ch id	4	6	8	10	12	Ch id	4	6	8	10	12	Ch id	4	6	8	10	12
1	2.72	3.53	4.43	5.34	6.27	1	3.19	3.44	3.76	4.59	5.21	1	4.07	4.3	4.96	5.08	6.3	1	4.69	4.78	4.96	5.04	5.22
2	2.78	3.45	4.18	5.43	6.57	2	3.27	3.54	3.75	4.8	5.7	2	4.69	4.96	5.43	5.44	6.6	2	5.18	5.16	5.29	5.4	5.55
3	2.44	3.34	4.06	5.03	5.75	3	2.89	3.21	3.47	4.31	4.68	3	3.54	3.7	4.51	4.6	5.59	3	4.14	4.32	4.45	4.64	4.78
4	2.73	3.44	4.07	5.23	6.13	4	3.09	3.41	3.58	4.56	5.1	4	4.34	4.62	5.08	5.05	6.04	4	4.66	4.72	4.73	4.94	5.05
5	3.06	3.9	4.43	5.43	6.01	5	3.27	3.32	3.62	4.63	4.94	5	4.19	4.29	5.17	5.31	5.95	5	4.55	4.57	4.75	4.94	4.99
6	3.09	4.19	4.58	5.6	6.49	6	4.08	4.36	4.47	5.19	5.75	6	4.73	5.18	5.58	5.58	6.43	6	4.94	5.21	5.26	5.38	5.48
7	3.31	4.05	4.29	5.35	5.99	7	3.81	3.89	3.96	4.79	5.42	7	4.96	5.04	5.3	5.34	5.99	7	4.76	4.79	4.9	5.04	5.16

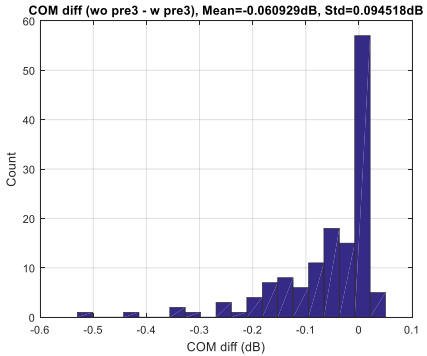
- Observations
  - Short package lengths (e.g. 7, 13mm) limits COM performance when DFE tap length ≤ 6
  - 4-tap DFE failed 3dB COM with [13/7, 31/13]mm (TX/RX) packages
  - Need 6-tap DFE to pass 3dB COM for the test channels

COM Analysis Results

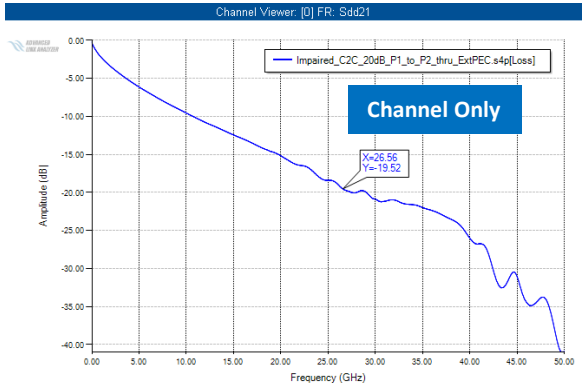
w/ Rd = 50 ohms, DFE Tap Length 4 to12, and w/ TX Pre-Tap 3

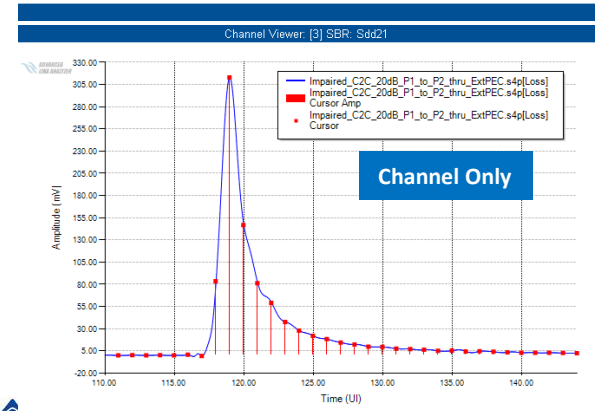
Rd = [50, 50] ohms, Package Length = [13, 7]mm (TX/RX)						Rd = [50, 50] ohms, Package Length = [31, 13]mm (TX/RX)						Rd = [50, 50] ohms, Package Length = [13, 11]mm (TX/RX)						Rd = [50, 50] ohms, Package Length = [31, 29]mm (TX/RX)					
Ch id	4	6	8	10	12	Ch id	4	6	8	10	12	Ch id	4	6	8	10	12	Ch id	4	6	8	10	12
1	2.72	3.53	4.43	5.4	6.32	1	3.19	3.41	3.76	4.73	5.35	1	4.14	4.39	4.91	5.11	6.31	1	4.73	4.84	4.94	5.02	5.26
2	2.78	3.45	4.18	5.57	6.73	2	3.27	3.54	3.75	4.94	5.92	2	4.79	5.08	5.43	5.44	6.67	2	5.18	5.27	5.35	5.43	5.61
3	2.44	3.34	4.06	5.03	5.75	3	2.89	3.21	3.47	4.35	4.84	3	3.54	3.73	4.51	4.57	5.59	3	4.18	4.34	4.5	4.64	4.75
4	2.73	3.44	4.07	5.23	6.13	4	3.09	3.41	3.58	4.61	5.35	4	4.34	4.62	5.08	5.05	6.04	4	4.67	4.73	4.76	4.91	5.05
5	3.06	3.9	4.43	5.68	6.36	5	3.27	3.32	3.65	5.07	5.47	5	4.52	4.61	5.35	5.48	6.2	5	4.64	4.64	4.79	5.07	5.18
6	3.09	4.19	4.58	5.65	6.54	6	4.1	4.36	4.51	5.4	5.93	6	4.94	5.34	5.61	5.66	6.56	6	5.01	5.26	5.26	5.43	5.6
7	3.31	4.05	4.29	5.5	6.13	7	3.82	3.89	3.96	4.97	5.61	7	5.04	5.13	5.32	5.38	6.09	7	4.84	4.87	4.91	5.05	5.27

- Observations
  - TX pre-tap 3 improves COM by ~0.06dB (mean, std.=0.09dB)
    - Test Channels 5 and 6 seen >0.2dB COM improvement with pre-tap 3 and 13/11mm TX/RX packages

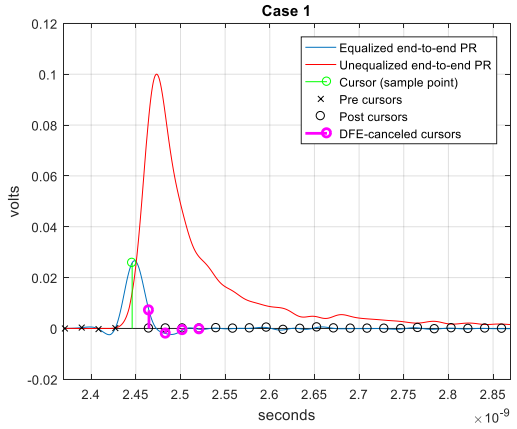


CH5: Impaired_C2C_20dB_P1_to_P2_thru_ExtPEC.s4p with 13/11 TX/RX Packages



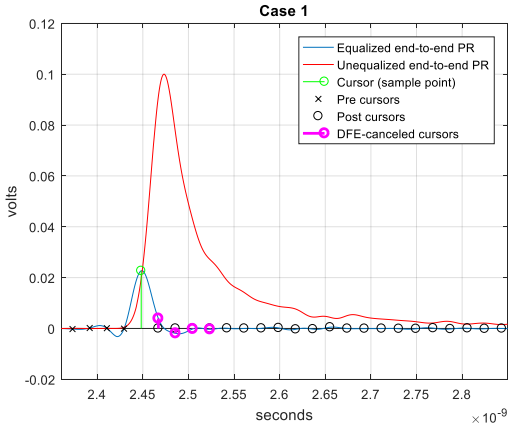


w/ 13/11mm TX/RX Packages w/o TX pre3



COM = 4.19dB
TX FIR=[0.0400 -0.2000 0.7600 0]
CTLE=[-15, -3]dB
DFE=[0.2758 -0.0782 -0.0254 -0.0127]

w/ 13/11mm TX/RX Packages w/ TX pre3



COM = 4.52dB
TX FIR=[-0.0200 0.0800 -0.2400 0.6600 0]
CTLE=[-15, -3]dB
DFE=[0.1726 -0.0843 -0.0081 -0.0148]

TX pre-tap 3 improves COM by ~0.33dB

COM Analysis Results

w/ Rd = 45 ohms, DFE Tap Length 4 to12, and w/o TX Pre-Tap 3

Rd = [45, 45] ohms, no TX Pre-Tap 3, Package Length = [13, 7]mm (TX/RX)						Rd = [45, 45] ohms, no TX Pre-Tap 3, Package Length = [31, 13]mm (TX/RX)						Rd = [45, 45] ohms, no TX Pre-Tap 3, Package Length = [13, 11]mm (TX/RX)						Rd = [45, 45] ohms, no TX Pre-Tap 3, Package Length = [31, 29]mm (TX/RX)					
Ch id	4	6	8	10	12	Ch id	4	6	8	10	12	Ch id	4	6	8	10	12	Ch id	4	6	8	10	12
1	3.26	4.13	4.86	5.66	6.39	1	3.44	3.74	4.05	4.85	5.29	1	4.25	4.5	5.34	5.53	6.42	1	4.79	4.9	5.07	5.18	5.42
2	3.36	4.12	4.73	5.9	6.78	2	3.68	3.94	4.17	5.2	5.78	2	4.82	5.1	5.81	5.86	6.7	2	5.3	5.37	5.42	5.55	5.75
3	2.95	3.81	4.43	5.27	5.74	3	3.1	3.43	3.73	4.57	4.82	3	3.66	4	4.9	4.97	5.6	3	4.17	4.39	4.54	4.73	4.87
4	3.19	3.98	4.46	5.58	6.12	4	3.43	3.73	3.84	4.85	5.24	4	4.54	4.84	5.53	5.54	6.11	4	4.76	4.84	4.9	5.08	5.24
5	3.45	4.21	4.58	5.51	5.87	5	3.44	3.53	3.86	4.75	4.82	5	4.17	4.39	5.34	5.45	5.93	5	4.66	4.67	4.76	5.02	5.1
6	3.54	4.64	4.94	5.88	6.57	6	4.25	4.55	4.63	5.38	5.76	6	4.9	5.35	5.88	5.92	6.48	6	4.85	5.13	5.22	5.4	5.61
7	3.84	4.47	4.61	5.6	6.06	7	4.04	4.08	4.19	4.99	5.4	7	5.1	5.18	5.6	5.63	6.02	8	4.78	4.81	4.84	5.07	5.24

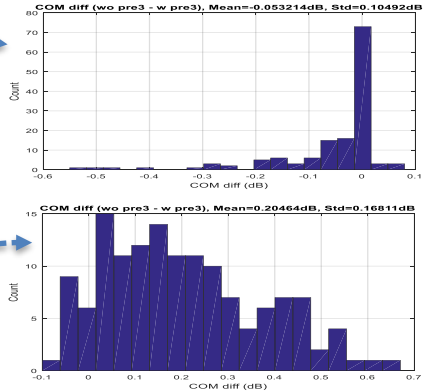
- Observations
  - Short package length (e.g. 7, 13mm) limits COM performance when DFE tap length ≤ 6
  - 4-tap DFE failed 3dB COM threshold with 13/7mm (TX/RX) packages and marginal with 31/13mm packages

COM Analysis Results

w/ Rd = 45 ohms, DFE Tap Length 4 to12, and w/ TX Pre-Tap 3

Rd = [45, 45] ohms, Package Length = [13, 7]mm (TX/RX)						Rd = [45, 45] ohms, Package Length = [31, 13]mm (TX/RX)						Rd = [45, 45] ohms, Package Length = [13, 11]mm (TX/RX)						Rd = [45, 45] ohms, Package Length = [31, 29]mm (TX/RX)					
Ch id	4	6	8	10	12	Ch id	4	6	8	10	12	Ch id	4	6	8	10	12	Ch id	4	6	8	10	12
1	3.26	4.13	4.86	5.66	6.31	1	3.44	3.74	4.05	5.01	5.43	1	4.25	4.52	5.34	5.53	6.42	1	4.85	4.96	5.07	5.18	5.34
2	3.36	4.12	4.73	5.89	6.78	2	3.68	3.94	4.17	5.38	6.06	2	4.82	5.27	5.81	5.86	6.75	2	5.38	5.43	5.45	5.56	5.75
3	2.95	3.81	4.43	5.27	5.72	3	3.1	3.43	3.73	4.54	4.81	3	3.66	4	4.9	5.02	5.67	3	4.21	4.41	4.57	4.76	4.91
4	3.19	3.98	4.46	5.58	6.17	4	3.43	3.73	3.84	4.9	5.3	4	4.54	4.82	5.53	5.54	6.13	4	4.76	4.87	4.9	5.08	5.27
5	3.45	4.21	4.58	5.78	6.38	5	3.49	3.58	3.86	5.22	5.37	5	4.58	4.66	5.53	5.7	6.25	5	4.66	4.61	4.84	5.04	5.13
6	3.54	4.64	4.94	5.88	6.63	6	4.29	4.55	4.63	5.55	5.95	6	5.1	5.5	5.88	5.97	6.54	6	5.02	5.27	5.3	5.43	5.65
7	3.84	4.47	4.61	5.7	6.21	7	4.04	4.08	4.19	5.18	5.66	7	5.19	5.27	5.6	5.66	6.14	8	4.78	4.81	4.9	5.07	5.24

- Observations
  - TX pre-tap 3 improves COM by ~0.05dB (mean, std.=0.11dB)
    - Test Channels 5 and 6 seen >0.2dB COM improvement with pre-tap 3 and 13/11mm TX/RX packages
  - Compared to Rd=50, Rd=45 improves COM by ~0.2dB (mean, std. = 0.17dB)



Summary and Conclusions

- With the C2C test channels, we found reference TX/RX with the following configuration can pass 3dB COM threshold
  - LR transmitter (3 pre-taps and 1 post-tap)
  - LR-like receiver with LR CTLE and 6-tap DFE
  - Rd = 50 ohms (TX and RX)
- Rd = 45 ohms improves COM performance, but still needs 6 DFE taps
  - Improve COM especially with short TX/RX packages
  - RX with 4-tap DFE still failed or was marginal for 3dB COM with short packages (13/7mm and 31/13mm)
- TX pre-tap 3 improves COM
  - COM improvement varies from 0 to 0.4dB which depend on channels and packages
- Recommendations
  - Baseline TX with 3 pre-taps and 1 post-tap
  - Baseline RX with LR CTLE, 6-tap DFE with Rd = 50 ohms

Summary and Conclusions *(cont.)*

- Next Steps
  - Short package lengths and combinations
    - Does C2C has short or extra short package length requirements (e.g. retimer/CDR)?
  - Need more C2C channels

Thank You !