Channel Operating Margin (COM) for CDAUI-8 chip-to-chip interfaces

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Introduction

- Table 120D-7 is incomplete (comment #53)
- This presentation contains a proposal to complete the table

Overview of proposed changes

- Define TBD device package and termination parameters
  - Begin with R_d = 40 Ω, C_d = 280 fF, C_p = 110 fF
  - In addition, change transmission line Z_c (Table 93A–3) to 90 Ω
- Change $b_{max}(1)$ from 1 to 0.5
  - Larger values appear to be unnecessary
- 2-stage receiver equalizer (replaces Equation 93A–22)

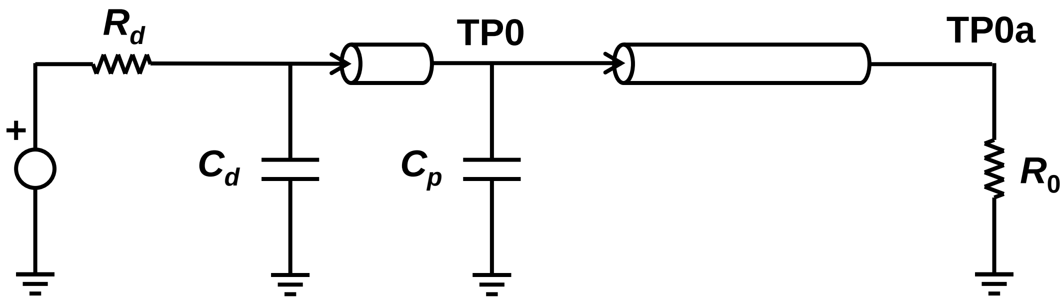
$$H_{ctf}(f) = \left[\frac{10^{g_{DC}/20} + j\,f/f_z}{1 + j\,f/f_{p1}}\right]\left[\frac{10^{g_{DC2}/20} + j\,f/f_{z2}}{1 + j\,f/f_{p2}}\right]$$

  - $f_z = f_{p1} = f_b / 2.5$, $g_{DC} = -15$ to 0 in 1 dB steps
  - $f_{z2} = f_{p2} = f_b / 40$, $g_{DC2} = -4$ to 0 in 1 dB steps

Overview of proposed changes, continued

- Cut η_0 in half (to approximately −155 dBm/Hz)
- Change R_{LM} from 0.92 to 0.95
- Increase N_b from 5 to 10 (to mitigate package reflection)

Transmitter differential peak voltage calibration



- Set A_v and A_{fe} to achieve minimum steady voltage v_f
  - 0.4 V per Table 120D−1
- Set A_{ne} to achieve maximum steady-state voltage
  - 0.6 V per Table 120D−1
- TP0 to TP0a test fixture is 38 mm of host transmission line
  - Refer to Table 92−12
- Use D_p = 2 and N_p = D_p+1+N_b to calculate linear fit pulse

Proposal

Parameter	Symbol	Baseline	Proposal	Units
Signaling rate	f_b	26.5625	26.5625	GBd
Device package model Single-ended device capacitance Transmission line length, test 1 Transmission line length, test 2 Single-ended package capacitance Transmission line characteristic impedance *	 C_p z_p z_p C_p Z_c	 TBD 12 30 TBD 78.2	 280 12 30 110 90	 nF mm mm nF Ω
Single-ended reference resistance	R_0	50	50	Ω
Single-ended termination resistance	R_d	TBD	40	Ω
Receiver 3 dB bandwidth	f_r	0.75 x f_b	0.75 x f_b	GHz
Transmitter equalizer, minimum cursor coefficient	$c(0)$	0.6	0.6	—
Transmitter equalizer, pre-cursor coefficient Minimum value Maximum value Step size	$c(-1)$	 −0.15 0 0.05	 −0.15 0 0.05	 — — —
Transmitter equalizer, post-cursor coefficient Minimum value Maximum value Step size	$c(1)$	 −0.25 0 0.05	 −0.25 0 0.05	 — — —

* This parameter is defined in Table 93A-3.

Proposal, continued

Parameter	Symbol	Baseline	Proposal	Units
Continuous time filter, DC gain	g_{DC}			
Minimum value		−15	−15	dB
Maximum value		0	0	dB
Step size		1	1	dB
Continuous time filter, DC gain 2	g_{DC2}			
Minimum value		n/a	−4	dB
Maximum value		n/a	0	dB
Step size		n/a	1	dB
Continuous time filter, zero frequencies	f_z	f_b / 4	f_b / 2.5	GHz
	f_{z2}	n/a	f_b / 40	GHz
Continuous time filter, pole frequencies	f_{p1}	f_b / 4	f_b / 2.5	GHz
	f_{p2}	f_b	f_b / 40	GHz
Transmitter differential peak output voltage				
Victim	A_v	0.4	0.38*	V
Far-end aggressor	A_{fe}	0.4	0.38*	V
Near-end aggressor	A_{ne}	0.6	0.55*	V

* Calibrated to yield v_f = 0.4 (for victim and far-end aggressors) or v_f = 0.6 (for near-end aggressors).

Proposal, continued

Parameter	Symbol	Baseline	Proposal	Units
Number of signal levels	L	4	4	—
Level separation mismatch ratio	R_{LM}	0.92	0.95	—
Transmitter signal-to-noise ratio	SNR_{TX}	31	31	dB
Number of samples per unit interval	M	32	32	—
Decision feedback equalizer (DFE) length	N_b	5	10	UI
Normalized DFE coefficient magnitude limit $n = 1$ $n = 2$ to N_b	$b_{max}(n)$	 1 0.2	 0.5 0.2	 — —
Random jitter, RMS	σ_{RJ}	0.01	0.01	UI
Dual-Dirac jitter, peak	A_{DD}	0.02	0.02	UI
One-sided noise spectral density	η_0	5.2E−8	2.6E−8	V^2/GHz
Target detector error ratio	DER_0	1E-6	1E-6	—
Channel operating margin, min.	COM	2	2	dB

Summary of results

Test case	1	2	3	4	5	6	7	8	9	10
IL at 13.28 GHz, dB	19.6	14.7	6.9	19.5	17.4	11	9.2	18.6	19.1	17.4
Baseline + 30 mm package	0.47	0.88	0.98	0.38	0.09	1.08	0.89	1.45	−0.25	0.87
+ change $b_{max}(1)$ to 0.5	0.28	0.88	0.99	0.19	0.04	1.08	0.89	1.34	−0.29	0.92
+ add 2-stage receiver equalizer	0.62	1.24	1.54	0.44	0.36	1.63	1.53	1.90	0	1.13
+ reduce η_0 by 3 dB	1.03	1.41	1.59	0.80	0.60	1.72	1.59	2.35	0.28	1.41
+ change R_{LM} to 0.95	1.31	1.69	1.87	1.08	0.88	2	1.87	2.62	0.56	1.69
+ change N_b to 10	2.55	3.3	3.33	2.35	1.83	3.23	3.14	4.19	1.3	2.47

- Test cases 1 through 7 are from mellitz_3bs_01_0714.pdf
- Test case 8 is from shanbhag_02_0914.pdf
- Test cases 9 and 10 are from mellitz_3bs_01_0315.pdf

Addendum to results

Test case	1	2	3	4	5	6	7	8	9	10
IL at 13.28 GHz, dB	19.6	14.7	6.9	19.5	17.4	11	9.2	18.6	19.1	17.4
This proposal with N_b set to 5	**1.31**	**1.69**	**1.87**	**1.08**	**0.88**	**2**	**1.87**	**2.62**	**0.56**	**1.69**
Change R_d to 47 Ω, C_d to 200 fF, C_p to 100 fF, a_2 to 4 x 1.455E−4 ns/mm, Z_c to 78.2 Ω, z_p to 18 mm	1.36	1.9	2.55	1.29	1.36	2.51	2.40	3.19	0.06	2.24
This proposal with N_b set to 10	**2.55**	**3.3**	**3.33**	**2.35**	**1.83**	**3.23**	**3.14**	**4.19**	**1.3**	**2.47**
Change R_d to 47 Ω, C_d to 200 fF, C_p to 100 fF, a_2 to 4 x 1.455E−4 ns/mm, Z_c to 78.2 Ω, z_p to 18 mm	2.85	3.41	3.42	2.61	2.17	3.49	3.26	4.55	1.74	2.99

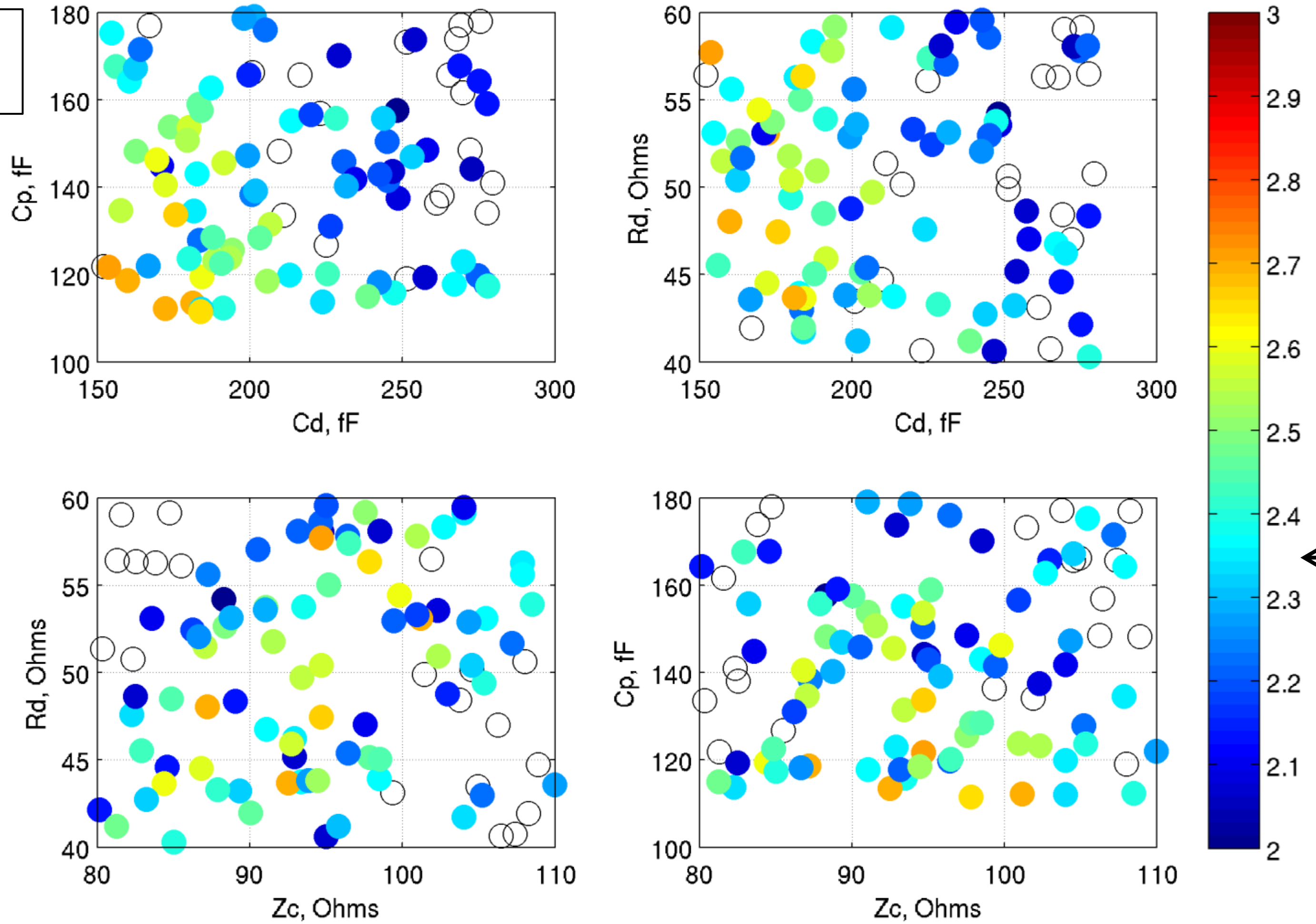
NOTE: a_2 is a parameter of the package transmission line model (see Table 93A-3).

- Substitute device package and termination parameters proposed by Mellitz
  - z_p set to 7 mm for near-end aggressors

- [A_v, A_{fe}, A_{ne}] values recalibrated to [0.42, 0.42, 0.6] V

Device package and termination parameters

Channel #4
z_p = 30 mm



Proposal COM (2.35 dB)

- 100 trials with uniformly distributed R_d, C_d, C_p, and Z_c values
- Many combinations result in COM similar to or better than proposal

Summary and conclusions

- COM greater than 2 dB for a number of interesting channels using proposed values
- Other combinations of device package and termination parameters yield same or better results
  - Not necessary to reduce package transmission line length