

ERL Proposals for KR and C2C

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For IEEE 802.3ck Ad-Hoc

Supporters

- Phil Sun, Credo
- Adee Ran, Intel

Outlines

- Background
- TX ERL sensitivity analysis
 - R_d, z_p, Z_c, C_p, C_b
- Summary & proposals

One page summary

- In TP0v of D1p3, it requires device/package model based on COM parameters to derive ERL reference value
 - However, device/package model was defined from COM calculation point-of-view, not ERL
 - ERL is sensitive to some parameters, reference ERL by COM parameters is NOT the case of minimum ERL within valid COM parameters
- Provide supporting materials for Comment #202, #203
- Analysis
 - Sweeping some parameters to check the minimum ERL values & derive dERL accordingly
 - z_p, C_p, C_b, Z_c, R_d
- Results
 - By considering z_p, Z_c, R_d valid ranges, dERL = -3 dB is proposed

TX ERL reference values – sensitivity analysis

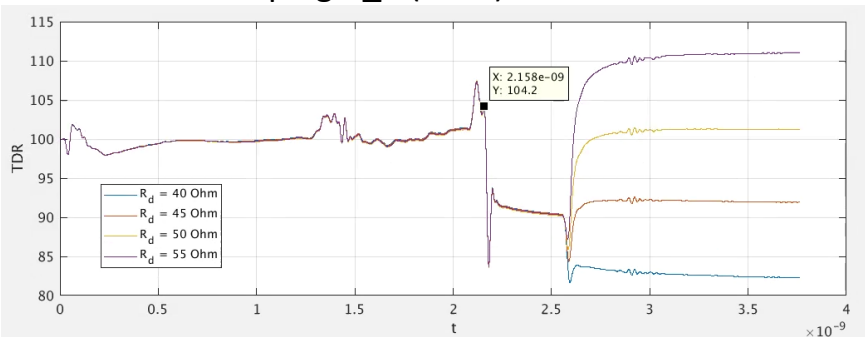
- One measured TP0 to TP0v test fixture
 - IL = 2.12 dB @ 26.56 GHz
- Sweep device/package parameters to check ERL sensitivity & find min ERL in the valid range
 - Valid range show in right-hand-sided table
- COM spread sheet
 - In appendix

Parameters	Value in D1p3	Valid range	Note
R_d (Ohm)	50	45 ~ 55	50 +/- 10%
z_p (mm)	31	12 ~ 31	
Z_c (Ohm)	87.5	80 ~ 95	87.5 +/- 10%
C_p (fF)	87	<= 87	
C_b (fF)	30	<= 30	

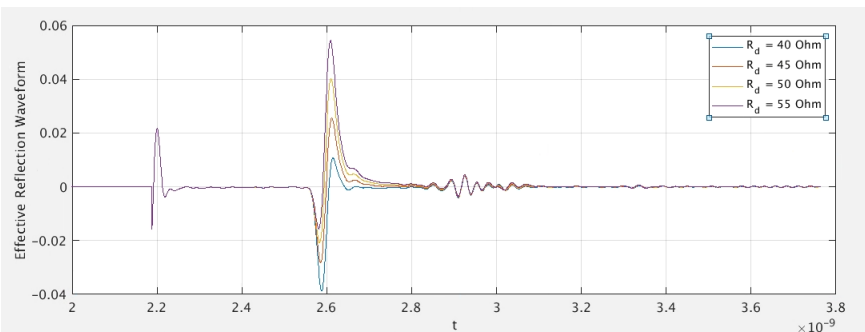
- R_d = single-ended termination resistance
- z_p = transmission line length
- Z_c = transmission line characteristics impedance
- C_p = single-ended package capacitance at package-to-board interface
- C_b = single-ended device bump capacitance

TX TDR and ERW with Sweeping R_d

- TDR with sweeping R_d (Ohm)



- Effective reflection waveform (ERW) with sweeping R_d (Ohm) – $N_{bx} = 21$



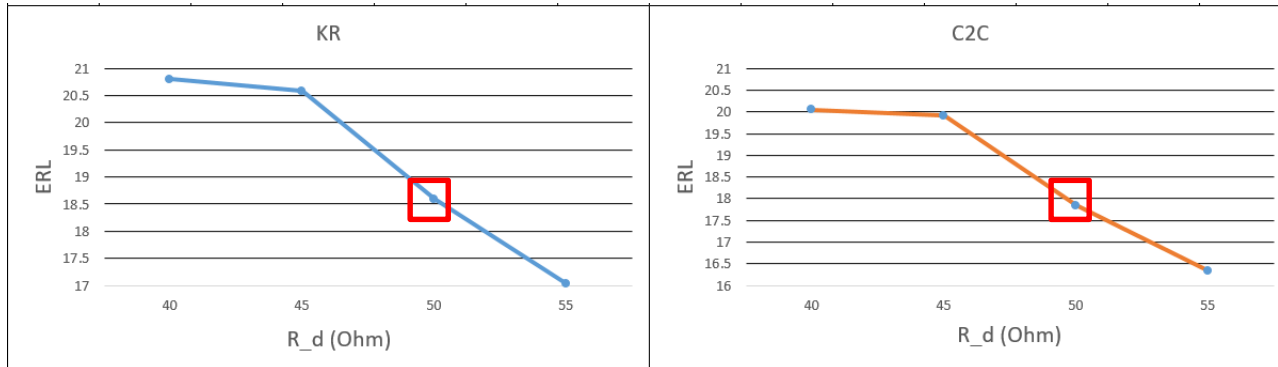
- Observing from TDR & ERW
 - It's obvious that $R_d = 50$ Ohm is not the case with minimum ERL
 - $R_d = 55$ Ohm is
- ERL parameter, T_{fx} , is derived from TDR
 - at the starting time of the boundary when impedance going down from around 100 Ohm (at the TPO) to 85 Ohm (due to C_p)

TX ERL with Sweeping R_d

- ERL ($z_p = 31$ mm, $C_p = 87$ fF, $C_b = 30$ fF)

	Reference			
R_d (Ohm)	40	45	50	55
Tfx (ns)	2.158			
KR ($N_{bx} = 21$)	20.80	20.59	18.60	17.04
C2C ($N_{bx} = 6$)	20.05	19.91	17.84	16.34

- +/- 10% manufacturing variation of R_d and Z_c shall be considered
- Reference ERL is sensitive to R_d
 - dERL shall be -1.50 ~ -1.56 dB
- Q: What's the COM values of R_d = 50 vs. 55 Ohm?
 - Shown in next slide



COM Analysis of 8 KR baseline Channels – Sweeping R_d

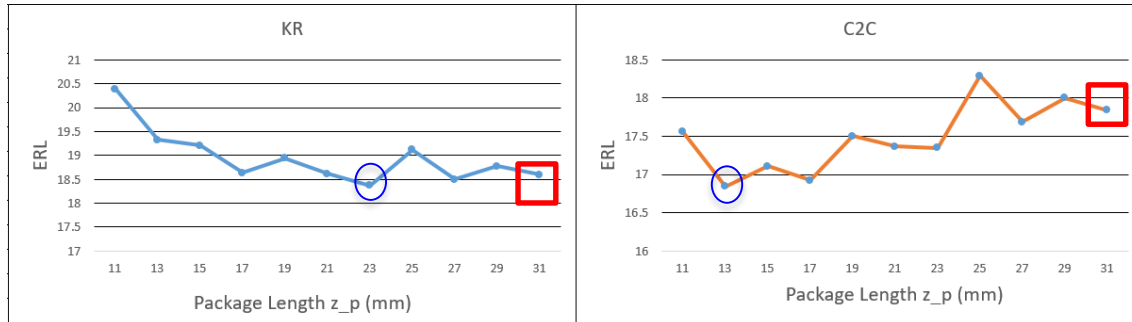
- 8 KR baseline channels
 - List in slide 6 of [heck_3ck_01_0519.pdf](#)
 - COM excel sheet in appendix
- Observations
 - COM is not sensitive to R_d +/- 10%
 - < 0.2 dB for critical channels with COM ≈ 3.0 dB
 - Could be included in 3 dB COM margin
- Proposal
 - No touch to COM parameters, such as R_d, Z_c
 - COM variation due to R_d +/- 10% & Z_c +/- 10% could be covered by 3 dB margin
 - ERL variation due to R_d & Z_c variation could be covered by negative dERL spec

Channel	Rd = 50 (Ohm)	Rd = 55 (Ohm)	dCOM (dB)
Cable_BKP_28dB_0p575m_more_isi	2.85	2.78	-0.07
Cable_BKP_16dB_0p575m_more_isi	5.75	5.29	-0.46
CaBP_BGAVia_Opt2_28dB	4.69	4.55	-0.14
Std_BP_12inch_Meg7	4.08	4.10	0.02
DPO_IL_12dB	6.55	6.18	-0.37
OAch4	2.88	2.75	-0.13
CAch3_b2	3.90	3.72	-0.18
Bch2_b7p5_7	2.84	2.67	-0.17

TX ERL with Sweeping z_p

- ERL ($C_p = 87$ fF, $C_b = 30$ fF, $R_d = 50$ Ohm)

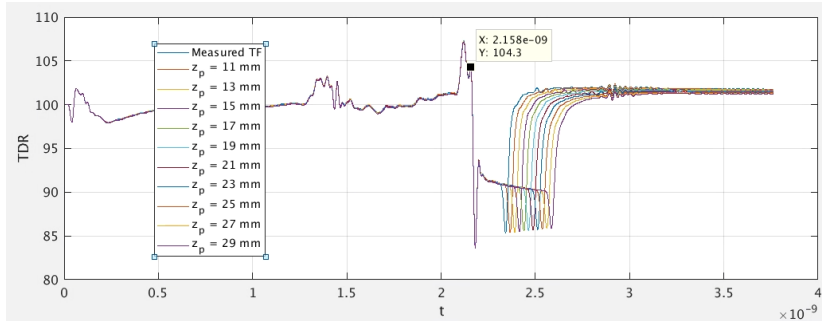
	Reference										
Pkg length (mm)	11	13	15	17	19	21	23	25	27	29	31
Rd (Ohm)	50										
Tfx (ns)	2.158										
KR ($N_{bx} = 21$)	20.39	19.33	19.21	18.63	18.94	18.61	18.37	19.12	18.50	18.77	18.60
C2C ($N_{bx} = 6$)	17.56	16.84	17.11	16.92	17.50	17.37	17.35	18.29	17.69	18.00	17.84



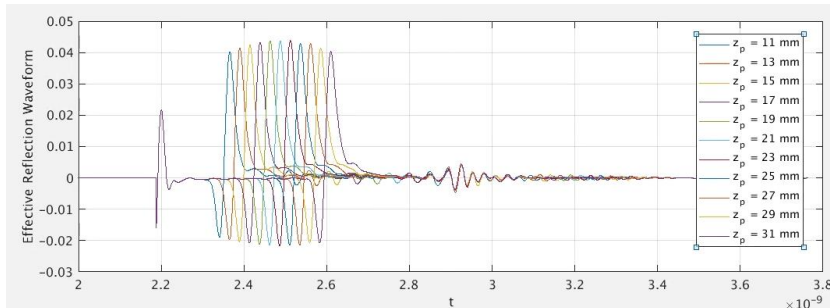
- Maximum package length doesn't mean minimum ERL
 - Let's observe ERW in next slide
- Allocate dERL to cover reference ERL variation due to package length variation
 - KR: -0.23 dB, C2C: -1.00 dB

TX TDR and ERW with Sweeping z_p

- TDR with sweeping z_p (mm)



- Effective reflection waveform (ERW) with sweeping z_p (mm) – $N_{bx} = 21$



- Observing from ERW
 - The major reflection contributes from re-reflection due to 'C_p' & 'C_b', while the location depends on z_p
 - The ERL fluctuation observed by sweeping z_p is due to 'Time gating weighting function, $Grr(t)$ ' to generate Effective reflection waveform

TX ERL with Sweeping Z_c , C_p , C_b

- Sweeping Z_c – similar as R_d case
 - $Z_c = 80$ Ohm has the minimum ERL, which requires $-0.48 \sim -0.54$ dERL to cover its variation
- Sweeping C_p , C_b
 - It's obviously that larger C_p & C_b cause smaller ERL
 - If we shall $C_p = 87$ fF & $C_b = 30$ fF is the maximum capacitance we can accept, we don't need to allocate dERL for these two parameters
- Detailed information of sweeping Z_c , C_p , C_b can be found in the appendix

ERL Sensitivity Analysis – Summary of KR

- By considering ERL variation due to z_p , Z_c , & R_d ,
 - dERL shall be at least = $(-0.23) + (-0.48) + (-1.56) = -2.27$
- Sweeping z_p with $Z_c = 80$ & $R_d = 55$
 - dERL is -2.27
- Proposal
 - dERL = -3 dB

KR case ($N_{bx} = 21$)	Min calculated ERL by sweeping parameters				
	D1p3	z_p	Z_c	R_d	$z_p, Z_c=80, R_d=55$
Parameter settings					
z_p (mm)	31	23	31	31	27
C_p (fF)	87	87	87	87	87
C_b (fF)	30	30	30	30	30
Z_c (Ohm)	87.5	87.5	80	87.5	80
R_d (Ohm)	50	50	50	55	55
ERL (dB)	18.60	18.37	18.12	17.04	16.33
dERL (dB)		-0.23	-0.48	-1.56	-2.27

ERL Sensitivity Analysis – Summary of C2C

- By considering ERL variation due to z_p , Z_c , & R_d ,
 - dERL shall be at least = $(-1.00) + (-0.54) + (-1.50) = -3.04$
- Sweeping z_p with $Z_c = 80$ & $R_d = 55$
 - dERL is -2.66
- Proposal
 - dERL = -3 dB

C2C case ($N_{bx} = 6$)	Min calculated ERL by sweeping parameters				
	D1p3	z_p	Z_c	R_d	$z_p, Z_c=80, R_d=55$
Parameter settings					
z_p (mm)	31	13	31	31	13
C_p (fF)	87	87	87	87	87
C_b (fF)	30	30	30	30	30
Z_c (Ohm)	87.5	87.5	80	87.5	80
R_d (Ohm)	50	50	50	55	55
ERL (dB)	17.84	16.84	17.30	16.34	15.18
dERL (dB)		-1.00	-0.54	-1.50	-2.66

Proposals

- Propose dERL = -3 dB in Table 163-5
- Propose dERL = -3 dB in Table 120F-1

Thank You

COM spread sheet – IEEE KR for ERL

- ERL22 for TX ERL
- ERL11 for RX ERL

Table 93A-1 parameters				I/O control			Table 93A-3 parameters		
Parameter	Setting	Units	Information				Parameter	Setting	Units
f_b	53.125	Gbd		DIAGNOSTICS	1	logical	package_tl_gamma0_a1_a2	[0 0.0009909 0.0002772]	
f_min	0.05	GHz		DISPLAY_WINDOW	1	logical	package_tl_tau	0.006141	ns/mm
Delta_f	0.01	GHz		RESULT_DIR	.\results\100GEL_KR_(date)\	logical	package_Z_c	[87.5 87.5 : 92.5 92.5]	Ohm
C_d	[1.2e-4 1.2e-4]	nF	[TX RX]	SAVE_FIGURES	0	logical	Table 92 - 12 parameters		
L_s	[0.12, 0.12]	nH	[TX RX]	Port Order	[3 4 1 2]		Parameter	Setting	
C_b	[0.3e-4 0.3e-4]	nF	[TX RX]	RUNTAG	KR_eval_		board_tl_gamma0_a1_a2	[0 3.8206e-04 9.5909e-05]	
z_p_select	[1 2]		[test cases to run]	COM_CONTRIBUTION	0	logical	board_tl_tau	5.790E-03	ns/mm
z_p (TX)	[31 31; 1.8 1.8]	mm	[test cases]	Operational			board_z_c	100	Ohm
z_p (NEXT)	[0 0; 0 0]	mm	[test cases]	COM Pass threshold	3	dB	z_bp (TX)	110.3	mm
z_p (FEXT)	[0 0; 0 0]	mm	[test cases]	ERL Pass threshold	8	dB	z_bp (NEXT)	110.3	mm
z_p (RX)	[29 29; 1.8 1.8]	mm	[test cases]	DER_O	0.0001		z_bp (FEXT)	110.3	mm
C_p	[0.87e-4 0.87e-4]	nF	[TX RX]	T_r	0.0075	ns	z_bp (RX)	110.3	mm
R_o	50	Ohm		FORCE_TR	1	logical	C_0	[0.23e-4]	nF
R_d	[50 50]	Ohm	[TX RX]	Local Search	2		C_1	[0.19e-4]	nF
A_v	0.413	V		BREAD_CRUMBS	1	logical	Include PCB	0	logical
A_fe	0.413	V		SAVE_CONFIG2MAT	1	logical	Floating Tap Control		
A_ne	0.608	V		TDR and ERL options			N_bg	3	0 1 2 or 3 groups
L	4			TDR	1	logical	N_bf	3	taps per group
M	32			ERL	1	logical	N_f	40	UI span for floating taps
filter and Eq				ERL_ONLY	1	logical	bm_max	0.05	max DFE value for floating taps
f_r	0.75	*fb		TR_TDR	0.01	ns	B_float_RSS_MAX	0.02	rss tail tap limit
c(0)	0.54		min	N	200		N_tail_start	25	(UI) start of tail taps limit
c(-1)	[-0.34;0.02;0]		[min;step;max]	beta_x	0		ICN parameters		
c(-2)	[0.0;0.02;0.12]		[min;step;max]	rho_x	0.618		f_v	0.594	*Fb
c(-3)	[-0.06;0.02;0]		[min;step;max]	fixture delay time	[2.40e-9 2.14e-9]	port1 port2	f_f	0.594	*Fb
c(1)	[-0.2;0.05;0]		[min;step;max]	TDR_W_TXPKG	1		f_n	0.594	*Fb
N_b	12	UI		N_bx	21	UI	f_2	40,000	GHz
b_max(1)	0.85			Tukey_Window	1	logical	A_ft	0.600	V
b_max(2..N_b)	[0.3 0.2*ones(1,10)]			Noise, jitter			A_nt	0.600	V
b_min(1)	0.3			sigma_RJ	0.01	UI	Receiver testing		
b_min(2..N_b)	[0.05 -0.03*ones(1,10)]			A_DD	0.02	UI	RX_CALIBRATION	0	logical
g_DC	[-20;1;0]	dB	[min;step;max]	eta_0	8.20E-09	V^2/GHz	Sigma BBN step	5.00E-03	v
f_z	21.25	GHz		SNR_TX	33	dB			
f_p1	21.25	GHz		R_LIM	0.95				
f_p2	53.125	GHz							
g_DC_HP	[-6;1;0]		[min;step;max]						
f_HP_PZ	0.6640625	GHz							

COM spread sheet – IEEE C2C for ERL

- ERL22 for TX ERL
- ERL11 for RX ERL

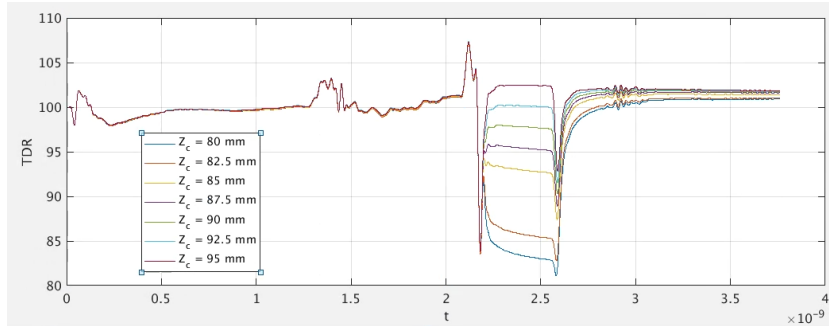
Table 93A-1 parameters				I/O control			Table 93A-3 parameters		
Parameter	Setting	Units	Information				Parameter	Setting	Units
f_b	53.125	GBd		DIAGNOSTICS	1	logical	package_tl_gamma0_a1_a2	[0 0.0009909 0.0002772]	
f_min	0.05	GHz		DISPLAY_WINDOW	1	logical	package_tl_tau	0.006141	ns/mm
Delta_f	0.01	GHz		CSV_REPORT	1	logical	package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm
C_d	[1.2e-4 1.2e-4]	nF	[TX RX]	RESULT_DIR	\\results\100GEL_KR_(date)\		Table 92 - 12 parameters		
L_s	[0.12, 0.12]	nH	[TX RX]	SAVE_FIGURES	0	logical	Parameter	Setting	Units
C_b	[0.3e-4 0.3e-4]	nF	[TX RX]	Port Order	[3 4 1 2]		board_tl_gamma0_a1_a2	[0 3.8206e-04 9.5909e-05]	
z_p select	[1 2]		[test cases to run]	RUNTAG	KR_eval_		board_tl_tau	5.790E-03	ns/mm
z_p (TX)	[31 31; 1.8 1.8]	mm	[test cases]	COM_CONTRIBUTION	0	logical	board_tl_z_c	100	Ohm
z_p (NEXT)	[0 0; 0 0]	mm	[test cases]	Operational			z_bp (TX)	110.3	mm
z_p (FEXT)	[0 0; 0 0]	mm	[test cases]	COM Pass threshold	3	dB	z_bp (NEXT)	110.3	mm
z_p (RX)	[29 29; 1.8 1.8]	mm	[test cases]	ERL Pass threshold	8	dB	z_bp (FEXT)	110.3	mm
C_p	[0.87e-4 0.87e-4]	nF	[TX RX]	DER_D	1.00E-05		z_bp (RX)	110.3	mm
R_o	50	Ohm		T_r	0.0075	ns	C_o	[0.29e-4]	nF
R_d	[50 50]	Ohm	[TX RX]	FORCE_TR	1	logical	C_1	[0.19e-4]	nF
A_v	0.413	V		Local Search	2		Include PCB	0	logical
A_fe	0.413	V		BREAD_CRUMBS	1	logical	Floating Tap Control		
A_ne	0.608	V		SAVE_CONFIG2MAT	1	logical	N_bg	0	0 1 2 or 3 groups
L	4			TDR and ERL options			N_bf	3	taps per group
M	32			TDR	1	logical	N_f	40	UI span for floating taps
filter and Eq				ERL	1	logical	bmaxg	0.05	max DFE value for floating taps
f_r	0.75	*fb		ERL_ONLY	1	logical	B_float_RSS_MAX	0.02	rss tail tap limit
c(0)	0.54	min		TR_TDR	0.01	ns	N_tail_start	25	(UI) start of tail taps limit
c(-1)	[-0.28;0.02;0]	[min;step;max]		N	200		ICN parameters		
c(-2)	[0.0;0.2;0.1]	[min;step;max]		beta_x	0		f_v	0.594	*Fb
c(-3)	[-0.04;0.02;0]	[min;step;max]		rho_x	0.618		f_f	0.594	*Fb
c(1)	[-0.1;0.05;0]	[min;step;max]		fixture delay time	[2.40e-9 2.14e-9]		f_a	0.594	*Fb
N_b	6	UI		TDR_IW_TXPKG	1		f_2	40.000	GHz
b_max(1)	0.65			N_bx	6	UI	A_ft	0.600	V
b_max(2_N_b)	[0.15 0.1*ones(1,4)]			Tukey_Window	1	logical	A_nt	0.600	V
b_min(1)	0.3			Noise, jitter			Receiver testing		
b_min(2_N_b)	[0.05 -0.04*ones(1,4)]			sigma_RJ	0.01	UI	RX_CALIBRATION	0	logical
g_DC	[-20;1;0]	dB	[min;step;max]	A_DD	0.02	UI	Sigma BBN step	5.00E-03	V
f_z	21.25	GHz		eta_o	2.00E-08	V^2/GHz			
f_p1	21.25	GHz		SNR_TX	33	dB			
f_p2	53.125	GHz		R_LM	0.95				
g_DC_HP	[-4;1;0]		[min;step;max]						
f_HP_P2	0.6640625	GHz							

COM spread sheet – IEEE KR for COM

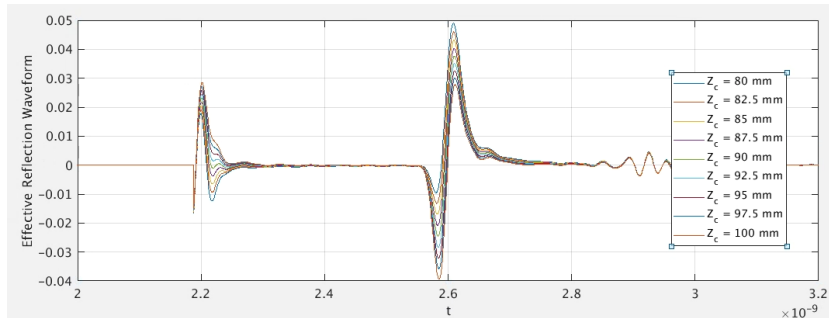
Table 93A-1 parameters				I/O control			Table 93A-3 parameters				
Parameter	Setting	Units	Information				Parameter	Setting	Units		
f_b	53.125	GBd		DIAGNOSTICS	1	logical	package_tl_gamma0_a1_s	[0.0.0009909.0.0002772]			
f_min	0.05	GHz		DISPLAY_WINDOW	0	logical	package_tl_tau	0.006141	ns/mm		
Delta_f	0.01	GHz		CSV_REPORT	1	logical	package_Z_c	[87.5.87.5 ; 92.5.92.5]	Ohm		
C_d	[1.2e-4.1.2e-4]	nF	[TX RX]	RESULT_DIR	\results\100GEL_KR_(date)\						
L_s	[0.12, 0.12]	nH	[TX RX]	SAVE_FIGURES	0	logical					
C_b	[0.3e-4.0.3e-4]	nF	[TX RX]	Port Order	[1 3 2 4]						
z_p select	[1 2]		[test cases to run]	RUNTAG	KR_eval_						
z_p (TX)	[12.31,1.8.1.8]	mm	[test cases]	COM_CONTRIBUTION	0	logical	Table 92-12 parameters				
z_p (NEXT)	[12.29,1.8.1.8]	mm	[test cases]	Operational			Parameter	Setting			
z_p (FEXT)	[12.31,1.8.1.8]	mm	[test cases]	COM Pass threshold	3	dB	board_tl_gamma0_a1_a2	[0.3.8206e-04.9.5909e-05]			
z_p (RX)	[12.29,1.8.1.8]	mm	[test cases]	ERL Pass threshold	8	dB	board_tl_tau	5.790E-03	ns/mm		
C_p	[0.87e-4.0.87e-4]	nF	[TX RX]	DER_0	0.0001		board_Z_c	100	Ohm		
R_0	50	Ohm		T_r	0.0075	ns	z_bp (TX)	110.3	mm		
R_d	[50.50]	Ohm	[TX RX]	FORCE_TR	1	logical	z_bp (NEXT)	110.3	mm		
A_v	0.413	V		Local Search	2		z_bp (FEXT)	110.3	mm		
A_fe	0.413	V		BREAD_CRUMBS	1	logical	z_bp (RX)	110.3	mm		
A_ne	0.608	V		SAVE_CONFIG2MAT	1	logical	C_0	[0.29e-4]	nF		
L	4						C_1	[0.19e-4]	nF		
M	32			TDR and ERL options			Include PCB			0	logical
filter and Eq				TDR	1	logical	Floating Tap Control				
f_r	0.75	*fb		ERL	1	logical	N_bg	3	0.1.2 or 3 groups		
c(0)	0.54		min	ERL_ONLY	0	logical	N_bf	3	taps per group		
c(-1)	[-0.34.0.02.0]		[min.step.max]	TR_TDR	0.01	ns	N_f	40	UI span for floating taps		
c(-2)	[0.0.02.0.12]		[min.step.max]	N	3500		bmaxg	0.05	max DFE value for floating taps		
c(-3)	[-0.06.0.02. 0]		[min.step.max]	beta_x	0		B_float_RSS_MAX	0.02	rss tail tap limit		
c(1)	[-0.2.0.05.0]		[min.step.max]	rho_x	0.618		N_tail_start	25	(UI) start of tail taps limit		
N_b	12	UI		fixture delay time	[0.0.]	port1 port2)	ICN parameters				
b_max(1)	0.85			TDR_W_TXPKG	0		f_v	0.594	*Fb		
b_max(2..N_b)	[0.3.0.2*ones(1,10)]			N_bx	21	UI	f_f	0.594	*Fb		
b_min(1)	0.3			Tukey_Window	1	logical	f_n	0.594	*Fb		
b_min(2..N_b)	[0.05-0.03*ones(1,10)]			Noise, jitter			f_2	40.000	GHz		
g_DC	[-20.1.0]	dB	[min.step.max]	sigma_RJ	0.01	UI	A_ft	0.600	V		
f_z	21.25	GHz		A_DD	0.02	UI	A_nt	0.600	V		
f_p1	21.25	GHz		eta_0	8.20E-09	V^2/GHz					
f_p2	53.125	GHz		SNR_TX	33	dB	Receiver testing				
g_DC_HP	[-6.1.0]		[min.step.max]	R_LM	0.95		RX_CALIBRATION	0	logical		
f_HP_P2	0.6640625	GHz					Sigma BBN step	5.00E-03	V		

TX TDR and ERW with Sweeping Z_c

- TDR with sweeping Z_c (Ohm)



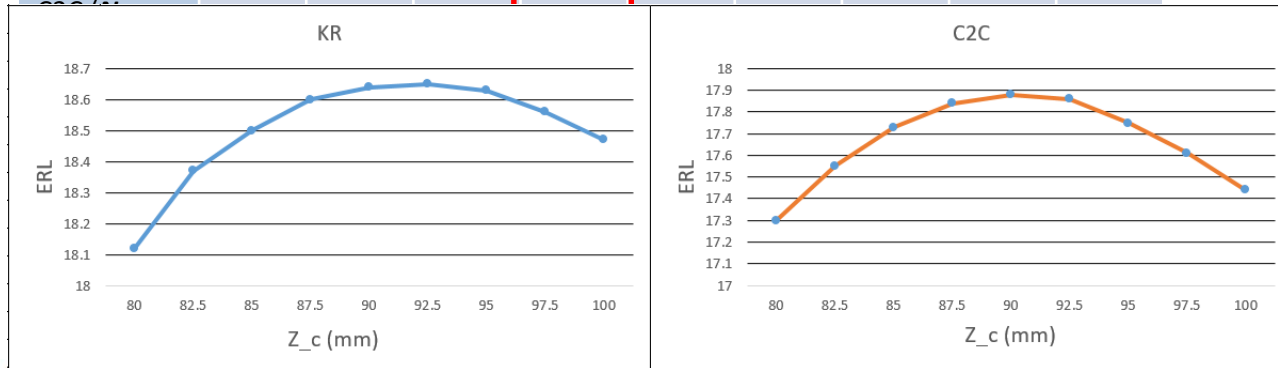
- Effective reflection waveform (ERW) with sweeping Z_c (Ohm) – $N_{bx} = 21$



TX ERL with Sweeping Z_c

- ERL ($z_p = 31$ mm, $C_p = 87$ fF, $C_b = 30$ fF)

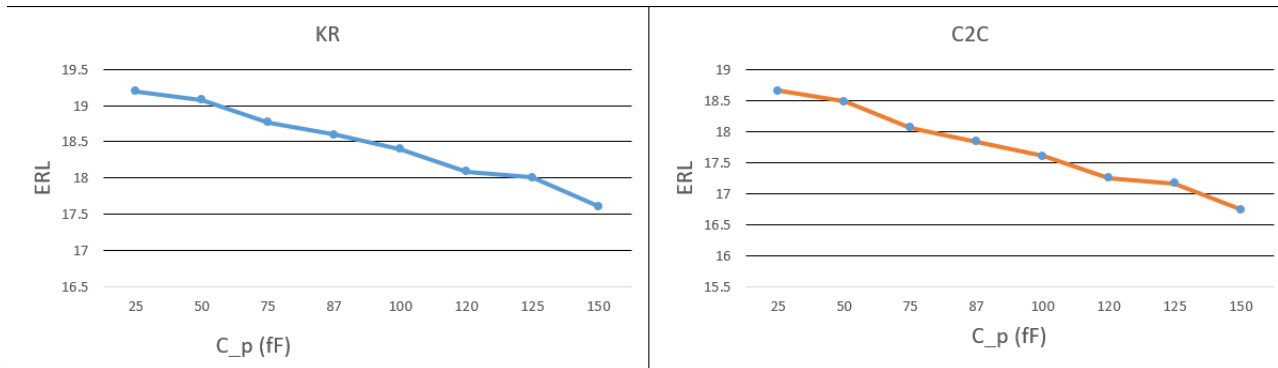
	Reference									
Z_c (mm)	80	82.5	85	87.5	90	92.5	95	97.5	100	
R_d (Ohm)	50									
T_{fx} (ns)	2.158									
KR ($N_{bx} = 21$)	18.12	18.37	18.50	18.60	18.64	18.65	18.63	18.56	18.47	



TX ERL with Sweeping C_p

- ERL ($z_p = 31$ mm, $C_b = 30$ fF)

	Reference						
C_p (fF)	25	50	75	87	100	125	150
R_d (Ohm)	50						
Tfx (ns)	2.158						
KR ($N_{bx} = 21$)	19.20	19.08	18.77	18.60	18.40	18.01	17.61
C2C ($N_{bx} = 6$)	18.66	18.48	18.06	17.84	17.60	17.16	16.74



TX ERL with Sweeping C_b

- ERL ($z_p = 31$ mm, $C_p = 87$ fF)

	Reference						
C_b (fF)	25	30	50	75	100	125	150
R_d (Ohm)	50						
Tfx (ns)	2.37						
KR ($N_{bx} = 21$)	18.84	18.60	17.64	16.57	15.63	14.82	14.10
C2C ($N_{bx} = 6$)	18.08	17.84	16.91	15.87	14.96	14.17	13.47

