DDR4 Design And Verification In Hyperlynx LINESIM/Boardsim

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April 2016



- Objective/Goal

- DDR4 vs. DDR3 from the SI/PI Perspective
- Stackup Design Consideration & SSO Effects
- Design Considerations:
 - Impedance, ODT and Manufacturing Variations

- Length Matching Requirements
- Crosstalk Effects & Timing
- Analysis Tools Comparison
- Summary

Objective/Goal

- Design & verify DDR4 interface across all operational conditions and possible manufacturing variations that meets both vendor requirements (driver and receiver) and the JEDEC standard.
- The ultimate goal in designing a DDR4 interface is that the signals meet their required eye masks and timing while crosstalk and Simultaneous Switching Output (SSO) effects are taken into consideration.

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Features/Options	DDR3	DDR4	Comments
Voltage (core, /IO)	1.5V	1.2V	Reduces memory power demand
Vref Inputs	2 – DQs & CMD/ADDR	1 -CMD/ADDR	VREFDQ now internal
Data Rate - Mb/s	800, 1066, 1333 1600, 1866, 2133	1600, 1866, 2133 2400, 2666, 3200	Migration to higher-speed I/O
tCK – DLL enabled	300MHz to 800MHz	667MHz to 1.6GHz (625MHz minimum)	Higher data rates
DQ Driver (ALT)	40Ω	48Ω	Optimized for Point-to-Point (PtP)
DQ Bus	SSTL15	POD12	Mitigate I/O noise and power
Rtt Values	120, 60, 40, 30, 20Ω	240, 120, 80, 60, 48, 40, 34Ω	Support higher data rates
ODT Control	ODT signaling required	ODT signaling not required	Ease of ODT control, allows non- ODT routing on PtP applications
VREFDQ Calibration	none	supported	Optimize internal VREFDQ
Data Bus Inversion (DBI)	none	supported	Mitigate I/O noise and power
Data Bus Write CRC	none	supported	Error detection of data traffic
C/A Parity	none	supported	Error detection of CMD/ADDR bus

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Courtesy of Micron

DDR4 Pins added

- VDDQ (2)
- VPP
- Bank Group (2)
- DBI_n
- ACT_n
- PAR
- Alert_n
- TEN

DDR3 Pins eliminated

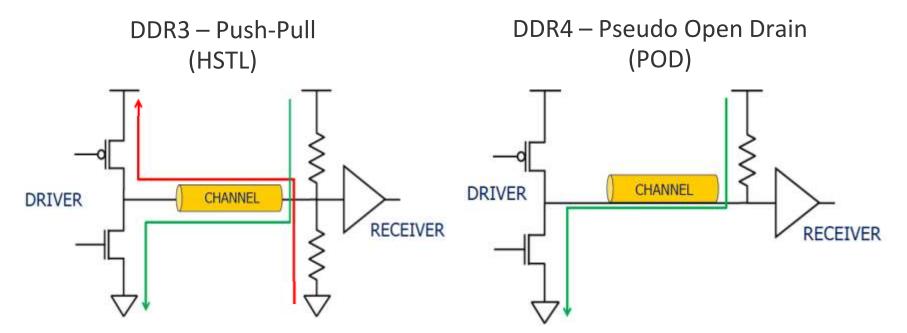
- VREFDQ
- Bank Address (1 of 3)
- VDD (1), VSS (3), VSSQ (1)

	x	8
	DDR3	DDR4
VSS	12	9
VDD	9	8
VPP	0	1
VSSQ	5	4
VDDQ	4	6
VREFCA	1	1
VREFDQ	1	0
Bank Group	0	2
Bank Address	3	2
Address	16	16
DQ	8	8
DQS/DQS#	2	2
CK/CK#	2	2
CKE	1	1
CS	1	1
ODT	1	1
ACT	0	1
RAS	1	1
CAS	1	1
WE	1	1
DM/TDQS/DBI	2	2
ZQ	1	1
Reset	1	1
TEN	0	1
PAR	0	1
Alert	0	1
Total	73	75
Nev	w for DDR4	

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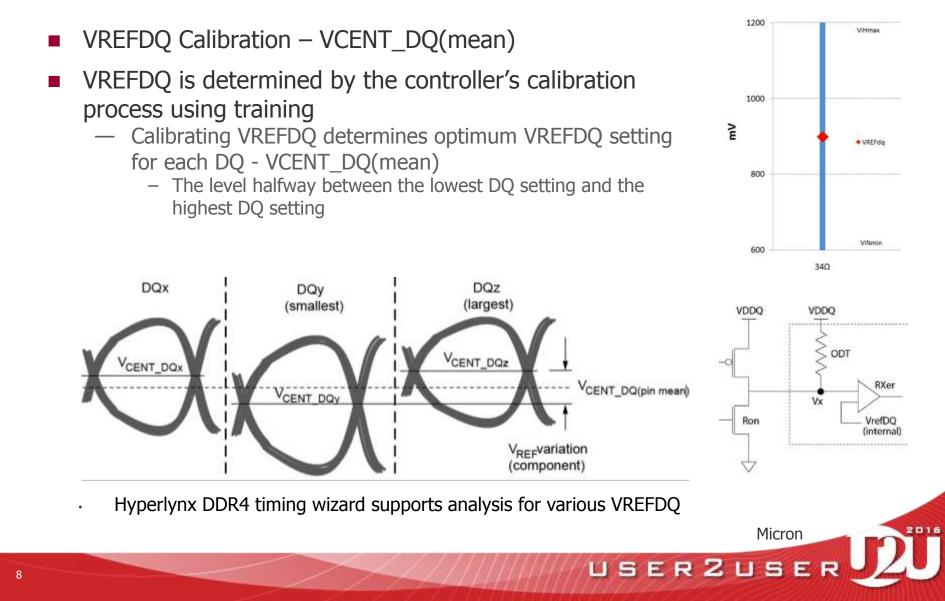
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output Driver and Termination



- POD drivers have a strong pull-down strength but a weaker pullup strength.
- Reduced overall power demand compared to using strong pullup
- Proven GDDR scheme

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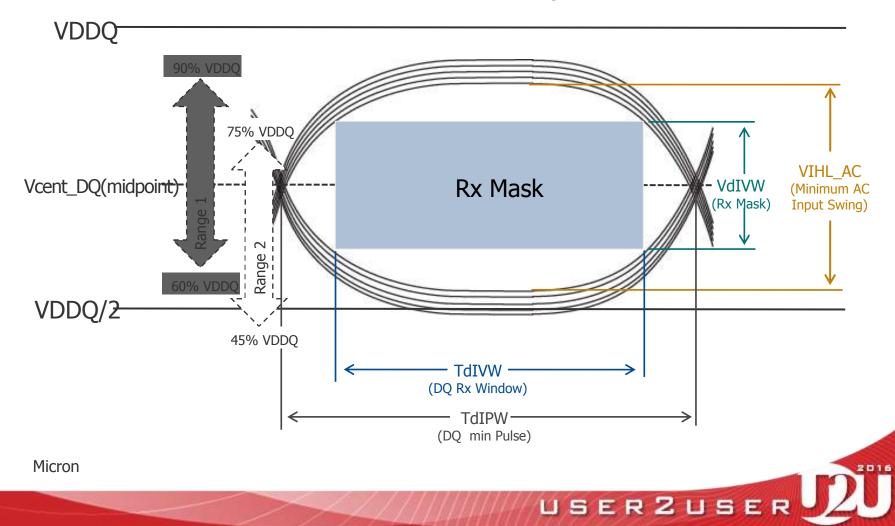


- DDR4 Rx Mask and Data-Eye
- The Data bus timing has changed from the classical setup/hold relationship to DDR4's data-eye mask
 - The controller must satisfy the data receiver mask requirements
 - Data timing specifications are applicable when referenced to calibrated VREFDQ: Vcent_DQ(midpoint)
 - The calibrated Rx mask takes the place of classical set-up and hold
- Each DRAM is individually calibrated by the controller to meet the Rx Mask requirements

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DDR4 Receiver Data Mask vs Data-Eye



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Stackup Design Considerations

- Power & Ground Planes
 Placement
- Minimize inductive path
- Data Lines Signal Group Placements
- Need to place adjacent to ground plane
- Address, Command & Control Signals Placement
- When possible place adjacent to good reference plane (i.e. ground or power)

Layer #	Recom	mended Layer Assignment
1	Signal 1	
2	GND_1	
3	Signal 2	Address CMD & CNTL
4	PWR_1	VDD =1.2V for Memory Interface
5	Signal 3	Address CMD, CNTL & CLK
6	GND_3	
7	Signal 4	DQ & DQS
8	GND_4	
9	Signal 5	DQ & DQS
10	GND_4	
11	Signal 6	Discrete signals
12	Signal 7	Discrete signals
13	GND_5	
14	Signal 8	DQ & DQS
15	GND_6	
16	Signal 9	DQ & DQS
17	GND_7	
18	Signal 10	Address CMD, CNTL & CLK
19	PWR_2	VDD =1.2V for Memory Interface
20	Signal 11	Address CMD & CNTL
21	GND_8	
22	Signal 12	

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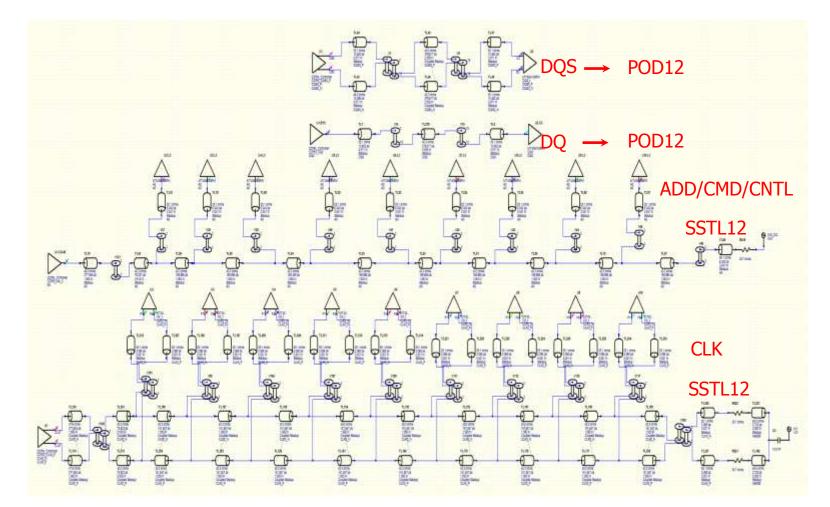
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DDR4 Signal Groups & operating Frequency

	Signal Groups	Nets	DDR4 @ 2133 MT/s
1	Clocks Group	CLK_N CLK_P	1066.5 MHz
2	Data Group	DQS_N/P[7:0] DQ[72:0] DM[7:0]/DBI[7:0]/TDQS[7:0]	1066.5 MHz
3	CTL Group with 1T Timing	CS[1:0] CKE[1:0] ODT[1:0]	533.25 MHz
4	ADD/CMD Group with 1T Timing	A[16:0] BA[1:0] BG[1:0] ACT_N PAR_N	533.25 MHz
4	ADD/CMD Group with 2T Timing	A[16:0] BA[1:0] BG[1:0] ACT_N PAR_N	266.625 MHz

Design Considerations

Impedance, ODT, & manufacturing variations

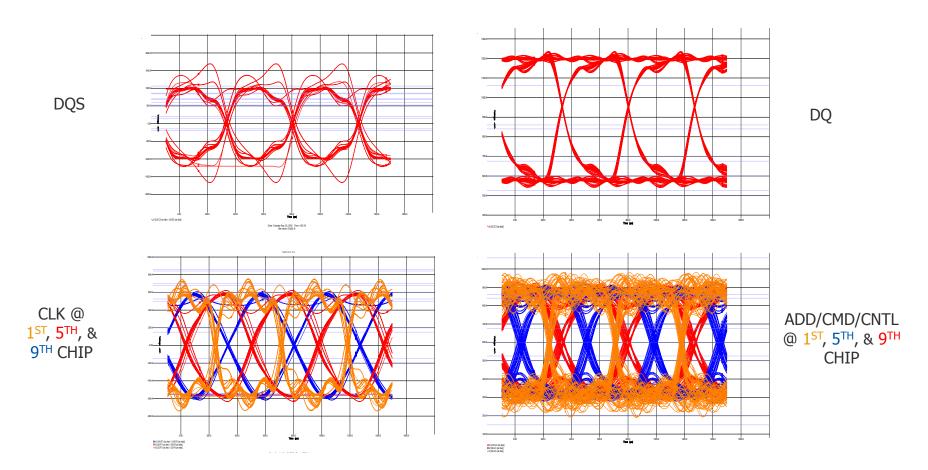


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Design Considerations

Impedance, ODT, & manufacturing variations



Optimized Data/Strobe/ADD/CNTL and Clock signals quality after all permutations. High confidence in signal quality was achieved prior to moving forward.

Typical DDR4 Signal Groups Length Matching Guidelines

	Groups	Group Matching Description	Length Matching (mils)
1	Clock Group: CLK_N & CLK_P	CLK_N to CLK_P	<u>+</u> 10
2	Data Groups: DQ[72:0]/DM[7:0]/DBI[7:0]/T DQS[7:0] & DQS[7:0]	DQ to DQ within byte lane DQ to DQS_N/P DQS_N to DQS_P	+ 50 + 50 + 10
3	CTL Group: CS[1:0] CKE[1:0] ODT[1:0]	Maximum trace segment routing to each memory chip CTL to CTL CTL signals to CLK_N/P to each memory chip	NA* <u>+</u> 20 <u>+</u> 20
4	ADD/CMD Group: A[16:0] BA[1:0] BG[1:0] ACT_N PAR_N	Maximum trace segment routing to each memory chip Maintain equal length between trace segment to each memory chip within Add/CMD to Add/CMD Add/CMD signals to CLK_N/P to each memory chip	NA* <u>+</u> 20 <u>+</u> 20 <u>+</u> 20

 All a Data lines within a byte lane must be length matched to their associated strobes within that byte lane

- To be determined through eye diagram analysis and validated through timing analysis
- *To be determined by topology

Typical DDR4 Signal Groups Crosstalk Routing Guidelines

	Signal Groups	Coupling Description	Coupling Distances (in terms of line width)
1	Clocks Group	CLK from other signals	2W
2	Data Group	DQ to DQ within same byte lane DQ to DQS within same byte lane DQ to other byte lanes DQS to other signal groups	1.5W 1.5W 1.5W 4W-5W
3	CTL Group with 1T Timing	CTL to CTL CTL to other signal groups	2.5W 4W-5W
4	ADD/CMD Group with 1T Timing	ADD/CMD to ADD/CMD ADD/CMD to other signal groups	2.5W 4W-5W

Designed for a 40 ohm system with minimum trace width of 5 mils for the ADD group and 7.9 mils for the DQ group

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To be determined through eye diagram analysis and validated through timing analysis

Don't route the entire DDR4 bus then simulate

Hyperlynx DDR4 Sample Signal Groups Timing Reports Per The length matching guidelines & crosstalk rules

Typical-Corner Case JEDEC Timing Spreadsheet from simulations

Bel Barno	PassTal	Operation	Batter Comp Battler & Pov Barro	Secalure Comp Rel Der & Pin Name	Bise Sail Doctored, [mit]	Bao Rall Overshoot Lank, Jerilj	File Ball Overstant Margin, [mk]	Ras Sal Dambost, Fundfoll	illier kal. Oversheck Tracs Polei.	Fall Ball Uniterstood, Josh7	Fail Rail Endenhoot Limb, (vit)	Fall Roll Understood Bargin, (nV)	Fall Red Universitient, (Panel all)	Fail Hall Brokenboat Traza Folini,	Sim Rad Overstood Area, [Vire]	Bito Rail Overskost Ama Liett,	Size Kall Oversteet Avec Mergin,	Rise lind Outshow Area	Rise Rall Overstool Ano Trece	Fall Rall Undershoot Anna, [V rel]	Fail Bail Unitercheck Area Clmit,	Javas Margin.	Fel: Roll Undershoot Arcs.	Felt Hall Undershoot Anna Treca
0.01	Patt	Weet and	11.1776/78	UNITAR	-	306	100	Fast	ikA.	- m	200	500.	Fee	34	1000	abod.	and in the	Field -	Anto hot	agentanti.	and .	85-4 0.1	Past.	Radian Street .
0.40 %	Pen	Albert Lord		ALC FRAFE	1	100	300	Pate	16.5	1	104	100	Pas	44	- X	11	0.1	Para	54	19	11	0.1	Pass	101
CL 80 V	Past	Athia she'l	ULITERITE.		1	358	300	Pass	18.8	1	100	300	Pas	.8.3	*	81	0.1	Past	8.0		11	18.1	Pass	516
0.40 \$	Pass	Nine start		LAUT/MPR	1	209.	100	Phis.	16.4	÷	34	100.	Pain	34		3.1	0.1	Fait	5.4		81	0.1	Pass	526
12,40.4	Past	White soft	OT OPEDIA	LEFTRE	1	104	800	Fies	HA .	1	300	800	Fest	.6.8		81	01	Pani	5/8		81	81	Paul	NV.
0.40 4	240	tillers pier!	ULTIMATE.	ULTER	1	398	300	19900	78.8	1	24	300	Pers	34.4	8	81	0.1	Para	5.0		11	18.1	Pass	NK.
0.40 8	Pass	White shart	11.1758/78	APPEND	1	208	300	Pass	10.0	1	200	300	Past	44	34	11	21	Paul	84		11	2.1	Pau	LIA.
C(40 A	Pass	Intelle sourt	11.1794076	UEFTAIN		386	300	- Paus	78.8	1	- 10	300	Fed			81	101	Face	4.0		81	004	Pase .	MA
Citt N	Per	10/84-1007	11.1798778	LEFTAR		200	300.	Fine	162	1	100	309	Pen	18.4		111	0.5	Pes	44		81	381	Pen	101.
2050.0	Pais	Filmit (sek)1.1)	12/03/01	ALL PROPERTY.	3.9	409	2011	FME	2.40	1	108	100	Fee	.58		11	0.2	Fast	2.41	.0	111	287	Pati	N/A
00807	Pass	1004 1011	11.5915	LECIMEN	11.1	422	10.7	FMA	0.043	1	. 200	100	Ees	184	8.001	.11	0.08	Fee	2 892		81.	-0.1	Ball	N/A
0081/A	Pas	Road rail(1.1)	10.03893	111.1076/001	31	419	HF3	Fms	2.488	1	339	309	Para	18.8	4	82	-0.2	Pess	2.0		81	28.9	Pm :	104.
0081.#	Peo	10Me start	11.1079.538	ALC COMPO	16.1	458	381.8	Field	2.00	1	129	309	Fea	14.6	0.001	1.1	0.198	Pero	2,000	10	0.1	(8)1	Pest	564,
30	Pass	Allow alart	\$8.78	0415	8	308	300.	TMA	76.8	1	500	300.	Para	44	8	1.5	.9.26	Paus	5.0		124	226	Pate	104
60	Page	tible shift	87.51	7013	8	208	300	Flats	15.8	1	388	300	Pass	4.8		3.25	.4.25	Pars	\$25	- 10	1.25	0.25	Pass	505
10	Care	Silver simil	88.97	3021.3	1	308	300.	Pass	165	T	38	300	Pas	34		8.25	.0.25	Part	54		8.25	0.28	Peri	505
X0	Pass	time cort	10.0	1915	3	300	300	Fast	19.8	1	38	300	Ens	38.		12	0.25	Past	58	-0	8.25	5.25	Paul	NW.
AL	Pass	White start	-24.55	1613	3.	308	100	F965	16A	1	200	300	Pes	16.4		8.25	926	Filoi	5/4.		1.55	926	Para	1216.
30	Pers	1996 and 1	38.91	M0.0		200	300	Piet	HA	1	201	200	Pet			1.21	925	Pee	84.	2.0	125	325	1944	NIA.
A0-	Pate	Nyke sart	107.01	30.03	8.	308	300	Page	768	1	.281	300	Pese	38.	18	8.21	0.25	Pani	\$25.	28	8.22	9.20	Past .	104
A0.	Pays		101.01	180		308	300	Pase	10.4		-308	100.	Pais	1.4		1.15	0.26	Feat	bin.		111	-3.26	Pasi	844
神	1999	17084.0047	10.11	VRC3		008	300.	Files	HA.	1	38	900	Pes	.84		8.21	925	Pers			121	0.25	Pair	NH.
31	Pille		11.0	71811	1	308	300	THE	194	1	200	300	Fim	3.8	1	8.20	0.25	Peri	58	18	8.20	921	Patt	505
(H)	Pass	State start	18.6	0817		308	300.	Fast	TEA.	1	201	300.	Fast	- 84		135	9.8	Paul	54		135	9.55	Pasi	NA .
M	Paul	Alloho adult	11.12	10.0	X	308	- 100	Fale	765		300	300	Pet	44	18	1.6	925	Pani	NR.		125	38	Pest	835
45	Page	Allela aler1	11.12	UALT.	A	398	300	Past	184	š	38	300	Pest	83		121	925	Page	8.0	18	121	22	Per	518
AL.	Pass	Nilds start	11.12	MILT	A.	.308	300	Phil.	164	÷	38	100	Faia	44.		121	.025	Faul	54		12	0.26	Fais	524
88	Pais	10384-3101	11.19	URLY		308	300	Files	168	1	30	300	Fasa	44	1	1.5	928	Pass	50.		18	926	Pais	NK-
21	1999	1000 1001	11.92	utur		38	307	F300	784	š	200	300	P100	38		1.0	925	Para	NA.		1.25	10	7983	105
Al .	Pass	Whe shr!	21.0	UBLT.	ð	208	300	Page	19A	š	200	300	Feet	48		122	0.28	Pest	60.	<u></u>	121	0.22	Pais	MA.
-00	Past		10.0	UBLT	÷	300	100	Pala	144	÷	-	300	Fail	44		13	28	Field	44	-		926	Pate .	No.
CN	Pen	Webs and 1	10.0	UM-OF AULGE	-	300	300	Pain Take	113	÷	30	200	Page	33	÷	12	025	Pass Pass	SX.	-	121	121	Para	tan.
200	Pass		10.0	10.01	÷	300	300	-FME -FME	16.4	÷	34	300	Fast	14	÷	12	025	Face	Sin.		10	325	Pair	Los.
656	Para		10.9	unt		200	300	Fas	184	÷	200	100	Fam	33	-	131	48	Fest	6.0		4.5	10		No.
000	Pep	White pilot1	10.10	10.07	÷	208	300	-Fast	16.5	÷	201	300	Test		G	12	0.25	Page 1	51		1.0	0.21	Pari	NA.
0.00	Past	Nine start	11.5	UEGT	÷	34	300	Pass	16.8	÷	- 10	300	Para	44		1.0	425	Paul		- <u>-</u>	120	1226	Pass	106
686	Pass	Multi-staft	12.16	18.61	-		100	Fies	19.6	÷	10	200	Pass	44		1.5	48	Past	50		136	45	Pass	5.0
0.00	Pm		11.18	ULOT	-	305	10	Pass	195	-	38	300	Pero	34		1.5	.025	Pate	6.0	1	128	0.25	Pest	544
250	Paul		11.10	UBGT	-	30	300	Thu	19.8	÷	38	300	Past	33	-	12	025	Faul	-		10	525	Paul	NK.
240	Pass	Paul and the		Int	146	400	Min .	Paint	11.0%	÷	100	10	Fant	44	100	11	0.994	Page	10.00	4	11	21	Pan	NA
200	Pass		112	ut ct	¥1	488	347	Fare	10.0	1	20	100	Pass		1.00	-11	0.199	Peri	50.406	-	11	311	Para	No.
001	Pas	Sant circl [1]		10.1	14.5	400	385.5	Para	41.00		208	100	Paul	33	0.021	11	0.00	Para	41304		41	301	Past	101.
2001	Pass	itute and		102.007	314	410	15.4	Plas	10.011	1	208	100	Fast	44	8.001	11	0.08	Fast	U ALL	1	- in	311	Fast	144
0011	Pers	FilmErunk[1.1]		MUR	112	100	165.7	Fast	41.00	1	39	200	Pess		1001	11	0.99	Pero	0.0		11	.0.1	Pass	MIN.
2018	Pers		1121	10100		400	304.5	Terr	333	1	20	100	Para	38	8 501	10	0.99	Pan	31.291		11	301	1900	NN.
0011	Pett	Rand rank(1.1)		111.22	-	400	36.	Page.	41.864	1	120	100	Fas	44	6.001	11	0.109	Pase	00016	.0	11	11	Past	NA.
bürr	Paul		21.72	10.07	WT .	419	1013	2368	98.811	1	201	100	Pass	44	1001	11	0.194	Pass	10.41		11	0.1	Paul	105
000	Pen	Real rank(1.1)		httal.	142	408	265.8	Fare	41.00	8	20	550	Pen	83	0.001	11	0.199	Pen	41.87	.8	11	.0.9	Peer	104
002	Pass	Stills about		102.003	216	405	104-4	Fhs.	32.8	1	309	399	Pasa		8.001	11	0.08	Paul	31.096		11	2011	Pasi	164
000	Pass	Final statist (12.27	116	0.6	459	386.7	Fass	41.894	1	329	320	Fasa	44	6.011	11	0.199	Pass	21905		81	0.1	Pais	NK.
048	Pen	Webs plot 1	115	102.07	316	403	300 A	F800	47361		228	10	Ppo	.44	8.001	3.1	0.109	Pero	38.467		11	383	Pes	116
				1111.00			1000-10																	

DQ to DQ within same byte lane = 1.5WDQ to DQS within same byte lane = 1.5WDQ to other byte lanes = 1.5WDQS to other signal groups = 4W-5W ADD/CMD to ADD/CMD = 2.5W CTL to CTL = 2.5W ADD/CMD/CTL to other signal groups = 4W -5W CLK from other signals = 2W

Hyperlynx DDR4 Sample Signal Groups Timing Reports for Data Byte Lanes

Received Data Signals Timing Spreadsheet and Eye Mask listed per Bit

an Manuel - R	1 4 AP															Fict View Optices	
581	P X Y	lot: 1: -0	Eye .2937 U 5165 V ive Den		K					~	>	10			19	Graph type Eye Density Bit Error Rate Show: 2 UI Eye mask Show eye mask Configure	
00001																UI and voltage scal	
0001 le-005 le-005											-1					R Auto fit to wind	wok
84005	PassEa	Operat	Driver Comp Ref Des & Pis Name	Receiver Comp Ref Des 6 Pie	Associated Strobe Net Name	Eye-A Width, TutVW_Totari,	Height	Voltage at Widest Eye Opening	Voltage,	Dubut Delay Uncertainty, (Jun)	(jes)	n Setup Time Ma with Output Oelay	argin Trace Point, (m)	Şes]	Ain Hold Time + with Outp Onlay		
Net Name	Pau	Reed 1	Ref Des & Pie Name	Comp Ref Des & Pie Rame U12.001	Strobe Met Name DOIT1_DDS8	Width, TutVW_Total, 0.0038	Height, VdfVW_Total, 150 92	Visident Eye Opensing, Vegst, IntVI 27.954	Center, Voltage, Voerdiein mi 927 212 4	Uncertainty, (jm) 4.65	(jes) 158.41	with Output Delay 151 72	Trace Point, (ml) 11 1292	(294) 161.02	With Outp Delay 155.4	R Auto fit to wind	wok
Net Name	Pain Pain	Read r Write si	Ref Dos & Pie Name US C2 US C2	Comp Ref Des & Pie Rame U12 CO1 U5 C2	Stroke Net Name DOM1_DDS8 DOM1_DDS8	Width, TelVW_Tokal, 0.0938	Height, VolfVW_Totel, 150 92 126 92	Wident Eye Opening, Voent, ImVI 27 954 53 319	Center Voltage, Voltage, 927.212 4 953.123 6	Uncertainty, (m) 4 cts 5	(jes) 158.41 158.052	with Output Delay 151 72 152 052	Trace Point, (ml) 11.1292 40.5016	(294) 181.09 185.444	with Out; Onlay 158.4 160.444	Auto fit to wind	0.50045
Net Name	Pain Pain Pain Pain	Read t Write si Mead t	Ref Dos & Pie Name US 52 US 57 US 57	Comp Ref Des & Pie Rans U12.001 U0.02 U12.003	Strobe Net Name DOM1_DOS0 DOM1_DOS0 DOM1_DOS0	Wath, TatVW_Total, 0.0938 0.0938 0.0935	Height, Vdf/vW_Totel, 150 9: 126 9: 150 9:	Wident Dye Opening, Voerst, InvVI 127 984 83 319 127 756	Center 1 Votage, Voerdisie mi 927.212 4 953.125 6 927.212 4	Uncertainty, (pn) 4.65 5. 4.65	(jrs) 155.41 156.052 156.655	with Output Onlay 151 72 152 052 153 956	Trace Point, (Ini) 11 1292 40.9016 45.118	(294) 181.09 185.444 155.706	witts Outp Desay 155 4 159 444 154 016	Auto fit to wind	0.50045
Net Rame 081_000 081_000 081_001 081_001	Pain Pain Pain Pain Pain	Read f Write si Mead f Write si	Ref Des & Pis Name US C2 US C3 US 57 US 57 US 57	Comp Ref Des 6 Pie Rens U12 C01 U9 C2 U12 C03 U12 C03 U5 B7	Strobe Net Name COR1_D250 COR1_D250 COR1_D250 COR1_D250	Width, TutVW_Tokai, 0.0938 0.0938 0.0935 0.0938	Height, Vdf/vW_Total, 150 9: 150 9: 150 9: 150 9: 138 9:	Wident Eye Opening, Voorst, ImW1 27.984 63.319 27.786 63.17	Center, 1 Votage, Voerdisie, mi 927.212 4 953.125 6 927.212 4 953.123 6	Uncertainty, (pre) 4 65 6 4 65 6	()+4) 150.41 158.052 158.055 150.835	with Output Oelay 151 72 152 052 153 956 154 835	Trace Point, (mi) 11 1292 40.9016 45 118 40.5016	975) 161.09 105.444 155.726 164.373	with Outp Oesay 155.4 150.444 154.016 158.3/3	Voltage:	0.50045
Met Rame DR1_D00 DR1_D00 DR1_D01 DR1_D01 DR1_D01	Pain Pain Pain Pain Pain Pain	Read 1 Write si Mead 1 Write si Mead 1	Ref Des & Pis Name US C2 US C3 US C3 US C3 US C3	Comp Ref Des & Pie Rans U12.001 U0.02 U12.005 U12.005 U12.005 U12.0015	Strobe Net Name 0011_0050 0011_0050 0011_0050 0011_0050 0011_0051	Width, Tut/WV, Tolari, 0.0938 0.0938 0.0938 0.0938 0.0938	Height, VotiVVV_Total, 150 9: 150 9: 150 9: 150 9:	Hideat Eye Opening, Voeri, ImVI. 127 964 63 379 27 766 63 17 64 98	Canter Votage, Votage, Votage, mi 957 212 4 953 123 6 927 212 4 953 123 6 927 212 4 953 123 6 928 197 4	Uncertainty, (pn) 4 65 5 4 65 6 4 65	(j+4) 158.41 158.052 158.685 150.825 151.611	with Output Delay 151.72 152.052 153.996 154.835 146.921	Trace Point, Brill 11 1292 40.5016 45 118 40.5016 36 7816	(ps) 161.09 105.444 155.706 164.373 104.853	with Outp Delay 155.4 153.444 154.016 158.373 169.293	Voltage:	0.50045
Net Rame	Pain Pain Pain Pain Pain Pain Pain Pain	Read r Write si Read 7 Write si Read 7 Write si	Ref Des & Pis Name US C2 US C3 US C3 US C3 US C3 US C3 US C3 US C3 US C3 US C3	Comp Ret Dets & Pie Name U12 C01 U12 C03 U12 C03 U12 C03 U12 C03 U12 C01 U12 C03 U12 C	Strobe Net Name DDR1_DDS0 DDR1_DDS0 DDR1_DDS0 DDR1_DDS0 DDR1_DDS1 DDR1_DQ81	Witth, TutVW_Total, 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508	Haight, VdfVW_Total, 150 2, 126 2, 150 3, 150 3, 150 9, 150 9, 130 9,	100 deat Eye Opening, Veerst InvVI 27 954 53 375 53 375 53 17 51 55 53 17 51 55 53 17	Center Voltage, Voentlein mi 927 212 4 953 123 6 927 212 4 953 123 6 927 212 4 953 123 6 928 197 4 949 916 6	Uncertainty, (pre) 4.55 5. 4.55 5. 4.55 5. 4.55 5. 8.	(jes) 158.41 158.052 158.688 160.895 161.611 156.348	with Output Delay 151 72 152 052 153 956 154 835 148 821 149 348	Trace Point, (70) 11 (202 40.5016 45 (18 40.5016 36 (78) 36 (78) 36 (01) 2	(prs) 161.09 105.444 155.706 164.373 164.853 103.072	with Outp Delay 155.4 150.444 154.016 158.375 169.223 167.072	Voltage:	0.50045
Met Rame	H Pain	igen Read r Write al Read r Write al Read r Write al Résul /	Ref Des & Pis Name US C2 US C3 US C3 US C3 US C3	Comp Ref Des & Pie Rans U12.001 U0.02 U12.005 U12.005 U12.005 U12.0015	Strobe Net Name 0011_0050 0011_0050 0011_0050 0011_0050 0011_0051	Widsh, TutVW, Tokel, 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508	Height, VdfVV_Total, 150 2/ 150 2/ 150 3/ 150 3/ 150 5/ 150 9/ 150 9/	Mideat Sys Opening, Veerst IntVT 27 954 83 375 27 755 83 17 81 98 83 17 81 98 81 98 81 81 81 81 81 81 81 81 81 81 81 81 81	Centair 1 Voltage, 1 927 212 4 953 123 6 927 212 4 953 123 6 928 197 4 928 197 6 928 197 6	Uncertainty, (pn) 4 65 5 4 65 6 4 65	(j+4) 158.41 158.052 158.685 150.825 151.611	with Output Delay 151.72 152.052 153.996 154.835 146.921	Trace Point, Brill 11 1292 40.5016 45 118 40.5016 36 7816	(ps) 161.09 105.444 155.706 164.373 104.853	with Outp Delay 155.4 153.444 154.016 158.373 169.293	Voltage:	low 0.50045
Met Rama DRT_D00 DRT_D00 DRT_D01 DRT_D01 DRT_D010 DRT_D010 DRT_D011 DRT_D011	ії Разія Разія Разія Разія 2 Разія 1 Разія 1 Разія 1 Разія	igen Read r Write al Read r Write al Read r Write al Résul /	Ref Des & Pis Name US C2 U12 C01 U12 C03 U12 C03 U12 C03 U5 D5 U12 C013 U5 D7 U12 C013	Comp Ref. Ders 6 Pie Barte U12 001 U12 003 U12 003 U12 0013 U12 0013 U12 0013 U12 0013	Strobe Net Name DDR1_DDS0 DDR1_DDS0 DDR1_DDS0 DDR1_DDS0 DDR1_DDS1 DDR1_DDS1	Wicesh, TuthViv_Totleri, 0.0958 0.0958 0.0958 0.0958 0.0958 0.0958 0.0958 0.0958 0.0958 0.0958 0.0958 0.0958	Height, VdfVV_Total, 150 2/ 150 2/ 150 2/ 150 2/ 150 9/ 150 9/ 150 9/ 150 9/ 150 9/ 130 9/	Wideat Eye Opening, Voert, AnVI 127 964 63 319 63 17 63 17 61 68 61 68 616 616 616 616 616 616 616 616	Centar 1 Voltage, Voltage, 19 927 212 4 953 123 6 927 212 4 953 123 6 927 212 4 953 123 6 928 197 4 949 915 6	Uncertainty, (pre) 4.53 5. 4.55 5. 4.55 5. 4.55 5. 4.55 5. 4.55 5. 4.55 5. 4.55 5. 4.55 5. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5.	()+4) 158.41 158.052 158.688 160.885 161.611 156.548 144.101	with Output Delay 151.72 152.052 153.996 154.835 148.821 148.921 149.349 139.411	Tracce Point, Dral 11.1292 40.9016 40.118 40.5018 36.7618 36.0112 34.374	(jan) 181.05 185.444 155.756 184.375 184.853 183.072 180.006	with Outs Delay 155.4 150.444 154.018 158.373 159.223 167.072 165.918	Voltage:	0.50045
Net Rame DR1_D00 DR1_D00 DR1_D01 DR1_D010 DR1_D010 DR1_D010 DR1_D010 DR1_D010 DR1_D010 DR1_D010 DR1_D010	H Pain	igen Read r Write si Read r Write si Read r Write si Read r	Ref Dex 8 Pis Name US 52 US 57 US 57	Comp Rot Des 4 Pie 102 C01 U12 C01 U12 C03 U12 C03 U12 C03 U12 C03 U12 C03 U12 C013 U6 D3 U12 C013 U6 D3 U12 C06 U13 C06 U13 C06 U13 C06	Strobe Net Name DOR1_D058 OCR1_D038 OCR1_D039 OCR1_D039 OCR1_D031 OCR1_D031 OCR1_D031 OCR1_D031 OCR1_D031 OCR1_D031	Width, TatWW, Total, 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0208 0.0208	Height, VdfVVV, Totel, 150 3, 150 5, 150 5, 150 9, 150 9,	Mideat Eye Opening, Veent, Invit 27 364 65 375 27 756 65 17 61 68 61 486 04 416 49 436 25 189 46 371	Contain 1 Votrage, Votrage, 927 212 4 953 123 6 927 212 4 953 123 6 928 187 4 949 915 6 949 915 6	Uncertainty, (res) 4.03 5.4.03 6.4.05 6.4.05 6.4.05 6.4.05 6.4.05 6.4.05 6.4.05 6.00 6.00 6.00	[2+4] 155.41 158.052 150.085 150.085 150.085 150.085 150.085 164.101 146.983 144.93 149.080 144.211	With Output Orelay 151 72 152 052 153 956 168 921 148 925 148 921 149 949 139 411 142 989 135 009 135 211	Trace Point, Brail 11 1292 40 5016 40 5016 40 5018 36 7818 36 017 36 374 34 5026 34 5026 34 5026	924) 161 09 105 444 155 706 164 373 164 883 163 072 160 006 169 283 163 369 171 77	with Cusp Decky = 156.4 1 150.444 154.016 168.373 1 168.223 1 167.472 1 168.916 1 163.283 1 168.679 1 168.77 1	Voltage:	low 0.50045
Net Rame DR1_D00 DR1_D00 DR1_D01 DR1_D01 DR1_D01 DR1_D01 DR1_D01 DR1_D01 DR1_D01 DR1_D01 DR1_D01 DR1_D01 DR1_D01 DR1_D01	H Pain	Read r Write s Plead r Write s Plead r Write s Read r Write s Read r Write s	Ref Des 8 Pis Name UB 52 UB 57 UB 87 UB 87 UB 87 UB 58 UB 50 UB 50	Comp Ret Des 6 Pie Tues 6 Pie U12 C01 U12 C03 U12 C03 U12 C03 U12 C03 U12 C013 U12 C013 U12 C013 U12 C013 U12 C013 U12 C013 U12 C00 U12 C00 U12 C01 U12 C00 U12 C01	Stroke Net Natre COR1_DOS0 COR1_DOS0 COR1_DOS0 COR1_DOS0 COR1_DOS1 COR1_DOS1 COR1_DOS1 COR1_DOS1 COR1_DOS1 COR1_DOS1	UNUED, TatVW, Toasi, 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508 0.0508	Height, Wth/W, Total. J 550 3: 126 3: 126 9: 126 9: 126 9: 126 9: 120 9: 120 9: 120 9: 120 9: 120 9: 120 9: 120 9:	Wideat Eye Opening, Veent, Invit 1 27 984 85 375 27 786 85 377 81 58 81 48 81 88 91 88 918	Contain 1 Voitage, mi S27 212 4 953 123 5 S27 212 4 953 123 5 S27 212 4 953 123 5 953 123 5 953 123 5 969 910 6 929 187 4 949 910 6 920 187 4 920 187 6 920 187 6 920 187 6 920 187 6	Uncertainty, (pn) (pn) 4 45 5 4 65 8 4 65 8 8 4 65 8 4 65 8 4 65 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	(0+4) 156.41 156.052 150.055 151.011 160.348 144.101 140.803 129.690 144.211 129.537	with Cusput Delay 151 72 152 052 153 996 154 829 148 821 149 848 138 411 142 983 136 009 128 211 134 817	Trace Point, BNIJ 11 1292 40.5015 45.118 40.5016 36.7816 36.017 36.374 34.025 34.374 34.025 34.374	974) 181 09 188 09 188 708 184 373 184 383 183 072 184 383 183 072 184 383 183 289 183 289 171 77 184 356	with Outp Device 150 444 150 444 154 010 153 373 160 203 167 072 165 910 163 910 163 878 165 878 165 878 165 877 165 860	Voltage:	low 0.50045
Net Rame DR1_D00 DR1_D00 DR1_D01 DR1_D01 DR1_D010 DR1_D010 DR1_D010 DR1_D013 DR1_D013 DR1_D013 DR1_D013 DR1_D013 DR1_D013 DR1_D013	H Pain	Read t Write al Read t Write al Read t Write al Read t Write al Read t Write al	Ref Des 8 Pis Name UII 201	Comp Ret Ren 6 Pile Ren 6 Pile Ren 6 U12 C01 U12 C03 U12 C03 U12 C03 U12 C03 U12 C04 U12 C04 U	Stroke Net Nerve DCR1_DD39 DCR1_DD39 DCR1_DD39 DCR1_DD39 DCR1_DD39 DCR1_DD39 DCR1_DD39 DCR1_DD39 DCR1_DD39 DCR1_DD31 DCR1_DD31 DCR1_DD31 DCR1_DD31 DCR1_DD31	Vitath, TatVity Tokai, 0.0508 0.0508 0.0508 0.0508 0.0608 0.0608 0.0608 0.0608 0.0608 0.0608 0.0608 0.0608 0.0608 0.0608 0.0608 0.0608	Height, With/W, Total J 150 2; 128 3; 150 5; 150 5; 150 5; 138 9; 150 9; 150 9; 150 9; 150 9; 150 3; 150 3; 150 3; 150 5;	Phote at Dye Openning, Vocent, Anvol 27 304 453 319 453 319 453 319 453 319 453 319 453 319 453 485 454 415 454 415 459 435 459 435 25, 189 463 311 20, 203 340, 344	Contain D Votage, 1 Votage, 1 Votage, 2 Votage, 1 S27,212 4 955,123 6 957,235 6 958,123 6 958,125 6 959,125 6 959,125 6 959,125 6 959,125 6 959,125 6 959,125 7 959,125 7 959,125 7	Uncertainty, (jm) (jm) 4 45 5 4 45 8 4 45 8 4 45 8 4 45 6 4 45 6 6 4 45 6 6 6 6 6 6 6 6 6 6 6 7 7 7 8 7 8 7 8 7	(p+4) 155.41 155.052 156.055 150.085 150.015 156.011 156.010 156.010 156.010 156.010 156.0000 156.0000 156.0000 156.0000 156.0000 156.0000 156.0000 156.0000 156.0000 156.0000 156.0000 156.0000 156.0000 156.0000 156.000000000000000000000000000000000000	with Output Delay 15:72 15:956 15:956 15:956 14:857 14:857 14:9348 14:9348 13:009 13:211 13:457 13:457 13:738	Trace Point, 0vil 11.1280 40.5016 45.138 40.8016 36.7816 36.7818 36.012 34.6036 34.374 34.0035 34.374 34.0035	974) 181 09 188 444 156 708 184 373 184 393 183 072 180 896 189 293 183 289 171 77 184 358 173 892	With Club Desiny 156.4 156.4 156.4 156.4 156.4 156.4 156.4 156.4 156.4 156.4 156.4 156.4 156.4 157.7 155.6 157.5 155.6 157.5	Auto fit to wind U1: Voltage: Range P Auto range Zoom:	Sow 0.50045 * 0.18574 * 1e+06 *
Net Rame DR1_D00 DR1_D00 DR1_D01 DR1_D01 DR1_D010 DR1_D010 DR1_D010 DR1_D010 DR1_D010 DR1_D010 DR1_D010 DR1_D010 DR1_D010	H Pass	Read r Write al Write al Write al Read r Write al Read r Write al Read r Write al Read r Write al Read r	Ref Dec 8 Pic Name UIS 02 UIS 03 UIS 03 UIS 03 UIS 03 UIS 03 UIS 03 UIS 03 UIS 03 UIS 04 UIS 02 UIS 04 UIS 04 UIS 04 UIS 05 UIS	Comp Ret Des 6 Pis Tueste UI 2 C01 UI 2 C01 UI 2 C03 UI 2 C03 UI 2 C03 UI 2 C03 UI 2 C03 UI 2 C04 UI 2	Strobe Net Rever DDR1_DDS8 DDR1_DDS8 DDR1_DDS8 DDR1_DDS8 DDR1_DDS1	VALD5, TdXVW_Tose, 0.0558 0.0558 0.0558 0.0558 0.0558 0.0558 0.0558 0.0558 0.0558 0.0558 0.0558 0.0558 0.0558 0.0558 0.0558 0.0558 0.0558 0.0558 0.0558	Height, With/W_Total J 155 2 126 2 126 2 126 2 126 3 126 9 126 9 126 9 126 9 126 9 126 9 126 9 126 9 126 9 126 9 126 9 126 9 126 9 126 9 126 9 128 9 128 9	Mideat Eye Openiag Vicent Int/1 127 364 153 3/15 127 755 153 17 154 168 154 168 154 168 154 168 154 168 155 189 149 435 125 189 140 371 125 303 140 344 137 852	Contain 1 Votentiget, 1 Votentiget, 1 S27 212 4 955 123 6 957 1212 4 955 123 6 955 123 6 955 123 6 955 123 6 925 197 4 949 515 6 940 515 6 940 515 6 940 515 7	Uncertainty, (pre) 4 d3 5 4 d3 8 4 d3 8 4 d3 8 8 4 d3 8 4 d3 8 6 4 d3 8 6 4 d3 8 6 9 4 d3 8 8 4 d3 8 8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	[p+k] 155.41 155.052 156.055 150.055 150.055 151.011 166.348 144.101 148.923 144.211 129.537 145.98 147.755	with Output Delay Delay 151.72 152.052 153.956 145.879 145.988 145.988 142.988 134.617 134.617 145.013	Trace Point, Bvs] 11 1292 40.5016 45 118 40.5016 36 7316 36 7316 36 0112 34 374 34 6036 34 374 34 6036 34 374 34 6036 34 374 34 6036 34 374 34 6036 35 7815	gps) 161 09 106 444 155 706 164 373 154 853 164 373 154 853 163 072 160 006 169 293 163 369 171 77 164 356 173 852 155 054	viets Cusp Devicey 155 4 155 4 156 4	Voltage:	low 0.50045
Net Reme DR1_D00 DR1_D00 DR1_D01 DR1_D01 DR1_D01 DR1_D01 DR1_D010	Н Разл Разл Разл Разл Разл Разл Разл Разл	Read r Write si Write si Write si Write si Read r Write si Read r Write si Read r Write si Read r Write si	Ref Des 8 Pis Name UB 02 U12 001 U8 07 U12 003 U12 004	Comp Ref. Des 6 Pis Turne U12 C01 U12 C03 U12 C03 U13 C04 U13 C04 U13 C04 U13 C04 U13 C04 U12 C04 U13 C04 U12	Strobe Net Rever CON1_DOSE	Vitath, TatVit, Total, 0.0958 0.0958 0.0958 0.0958 0.0968 0.0968 0.0968 0.0968 0.0968 0.0968 0.0968 0.0958 0.0958 0.0958 0.0958 0.0958	Height, With/W, Total J 150 21 150 21 150 21 150 21 150 21 150 21 150 21 150 21 150 21 150 21 150 21 150 21 150 21 150 21 150 31 150 31 150 32 150 32 150 32 150 35 158 35	Wide at Eye Openting Openting 127 384 53 375 53 375 127 785 653 177 51 586 653 178 653 178 653 178 653 375 653 375 653 375 653 375 653 375 653 375 653 375 653 375 653 375 60 265 60 273 91 465 344 93 7652 60 054	Contain 1 Voltage, 927 212 4 927 212 4 925 123 6 927 212 4 925 123 6 925 123 6 925 123 6 925 123 6 925 123 6 940 915 6 920 197 4 943 915 6 940 915 6 920 197 4 945 915 6 920 197 4 945 915 6 920 197 4 945 915 6 920 197 4	Uncertainty, (pre) 4 45 5 4 45 8 4 45 8 4 45 6 4 45 6 4 45 6 4 45 6 4 45 6 5	[0+4] 155.41 155.052 150.058 150.088 150.088 150.088 150.088 150.088 146.101 146.810 120.090 144.211 120.037 143.08 144.211 120.037 143.08 147.755 151.915	WEB: Chaptel Delay 151:72 152:052 153:986 148:921 148:921 148:921 148:921 148:923 132:411 132:623 135:029 135:029 135:021 134:617 137:98 143:913 145:913	Trace Point, 0vil Trace Point, 11 Trace 40, 5016 40, 5016 40, 5016 40, 5016 36, 7816 36, 7816 36, 7816 36, 574 34, 6036 34, 574 34, 6036 34, 374 34, 6036 34, 374 34, 6036 34, 374 34, 6036 36, 374 34, 6036 36, 374 36, 6036 36, 7318 36, 0112 36, 0112	9241 181 09 185 444 155 708 164 373 164 373 163 072 160 006 169 243 163 269 171 77 164 356 173 852 165 054 165 752	with Guy Devine 155 4 155 4 155 4 156 41 156 016 156 016 156 916 167 912 168 916 168 916 168 916 168 916 168 916 168 916 168 916 167 812 168 916 167 812 167 812 167 852	Auto fit to wind U1: Voltage: Range P Auto range Zoom:	Sow 0.50045 * 0.18574 * 1e+06 *
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Not Rame Not Rame ORT_DOD ORT_DOD ORT_DOD ORT_DOD ORT_DOT	H Pass	Read 1 Write al Write al Read 1 Write al	Ref Dec 8 Pis Name UB 52 UI 2 001 UI 2 0012	Comp Ret Des 6 Pie Turzcos U12 C03 U12 C03 U12 C03 U12 C03 U12 C04 U12	Strobe Net Net DOR1_D050 DOR1_D050 DOR1_D050 DOR1_D050 DOR1_D051	Witten, TathWitt, D.9528 Note: D.9558 D.9538 0.9558 D.9558 0.9558	Height, VithV/Total, 550 4 550 32 126 50 126 9 126 9 126 9 126 9 126 9 150 9	Wide at Dye Openities Mosral Vicara 127 364 53 319 127 766 55.17 151,58 61,486 149,435 149,435 125,171 120,203 140,344 137,882 50,054 25,054 25,054	Contains Image: Contains Voletage: Contains 4 953 / 233 4 953 / 233 6 953 / 233 6 955 / 123 6 955 / 123 6 955 / 123 6 955 / 123 6 955 / 123 6 956 / 133 6 958 / 137 4 958 / 137 4 948 916 6 920 / 137 4 940 915 6 940 915 6 940 915 6 940 915 6	Uncertainty, (pre) (pre) 4.65 5. 4.65 6. 6. 4.65 6. 6. 6. 6. 6. 6. 6. 6. 6. 6.	0+4 158.41 158.052 158.065 150.085 151.011 166.548 129.080 129.080 129.080 129.080 129.080 129.537 144.211 129.537 144.211 129.537 144.211 159.515 147.755 151.515 147.755 157.755 147.7555 147.755 147.755 147.755 147.755 147.755 147.755 147.755	with Output 0etay 151 72 152 052 153 996 146 821 146 821 146 821 146 821 146 821 146 923 146 821 146 923 146 913 147 983 148 949 148 949 149 943 149 943 140 913 140 913	Trace Point, Dvd Trace Vd 11 1292 40, 5016 48, 118 40, 5016 38, 7816 36, 7816 36, 7816 34, 374 34, 6036 34, 374 34, 6036 34, 374 34, 6036 36, 7818 36, 7818 36, 0316 34, 3774 34, 6036 36, 3774 34, 6036 36, 3774	9+4) 161 08 162 444 155 726 163 726 164 353 163 072 160 086 165 284 175 752 165 024 165 752 165 755 165 7555 165 755 165 755 165 755 165 755 165 755 165 755 165 75	Wills Gag Devian 155 4 155 4 156 41 156 10 156 203 156 203 156 203 167 072 168 373 169 373 169 77 163 873 165 873 155 404 155 404 160 750 155 404 165 467	Voltage: Voltage: Range Zoom: Move:	Sow 0.50045 [*] 0.18574 [*] 1e+06 [*]
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Not Rame Dolt _ Doo Dolt _ Doo	H Pain Pain <td>Read r Write al Read r Write si Read r Write si Read r Write al Read r Write al Write al Read r Write al Write al Wri</td> <td>Ref Des 8 Pis Name UB C2 U2 C031 U3 C5 U2 C031 U3 D3 U3 D3 U3 D4 U3 D4 U3 D5 U3 D5 U3 D6 U3 D7 U3 D6 U3 D7 U3 D6 U3 D7 U3 D7 U3 D7 U3 C7 U3 C7</td> <td>Comp Ref. Des 4 Pis Taros U12 C01 U12 C01 U12 C01 U12 C013 U12 C01</td> <td>Strobe Net Net DOR1_D020 DOR1_D020 DOR1_D020 DOR1_D020 DOR1_D020 DOR1_D021 DOR1_D021</td> <td>Witters, D. 0.9538 Tokani, D. 0.9538 D. 0.9538 D. 0.9538 D. 0.9539 D. 0.9538 D. 0.9539 D. 0.9539 D. 0.9539 D. 0.9539 D. 0.9539 D. 0.9539 D. 0.9539 D. 0.9539 D. 0.9538 D. 0.9538</td> <td>Height 4 Vistory Total 3 550 32 126 32 126 32 126 32 126 32 126 32 126 32 126 32 128 32 128 32 129 35 120 32 128 32 129 35 120 32 128 32 128 32</td> <td>Mideal Eye Openities Veart, John 1 27 504 63 315 63 315 61 465 61 465 61</td> <td>Contains Contains Contains</td> <td>Uncertainty, (yes) 4.55 6. 4.55 6. 4.55 6. 4.55 6. 4.55 6. 4.55 6. 4.55 6. 4.55 6. 4.55 6. 4.55 8. 4.55 8. 4.55 8. 4.55 8. 4.55 8. 4.55 8. 5. 4.55 8. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5.</td> <td>(0+4) 155.41 155.052 155.052 155.058 155.011 155.348 155.348 155.348 144.11 145.843 144.211 143.059 144.211 143.057 145.367 145.38 157.37 157.38 15</td> <td>with Output 0elay 151 72 152 052 153 956 148 345 148 345 148 345 148 345 148 345 148 345 148 345 148 345 148 345 148 345 138 345 134 517 134 517 134 517 145 513 145 513 140 417 141 148 142 418</td> <td>Trace Print, Drag 11 1280 40. 5016 40. 5016 40. 5016 38. 7818 40. 5017 34. 574 34. 6036 34. 374 34. 6036 34. 374 34. 6036 34. 374 34. 6036 34. 374 34. 6036 36. 7374 34. 60356 36. 374 34. 60356 36. 374 34. 60356 36. 374 36. 574 7. 78442</td> <td>9+1 151 JP 155 444 155 796 164 372 163 853 163 972 163 983 163 269 173 852 163 269 173 852 165 054 165 055 165 055 165 055 165 055 165 055 165 055 165 266 177 867 165 055 165 266 177 867 165 055 165 055 165 266 177 867 165 055 165 055 165 266 177 867 165 265 177 165 265 177 867 165 265 177 165 265 175 265</td> <td>Web Gug Deviat 155 4 155 4 155 4 155 4 155 4016 153 373 160 203 167 072 168 070 168 070 168 070 168 070 153 450 167 072 153 454 153 454 155 454 155 454 155 457 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452</td> <td>Voltage: Voltage: Range Zoom: Move:</td> <td>Sow 0.50045 [*] 0.18574 [*] 1e+06 [*]</td>	Read r Write al Read r Write si Read r Write si Read r Write al Read r Write al Write al Read r Write al Write al Wri	Ref Des 8 Pis Name UB C2 U2 C031 U3 C5 U2 C031 U3 D3 U3 D3 U3 D4 U3 D4 U3 D5 U3 D5 U3 D6 U3 D7 U3 D6 U3 D7 U3 D6 U3 D7 U3 D7 U3 D7 U3 C7	Comp Ref. Des 4 Pis Taros U12 C01 U12 C01 U12 C01 U12 C013 U12 C01	Strobe Net Net DOR1_D020 DOR1_D020 DOR1_D020 DOR1_D020 DOR1_D020 DOR1_D021 DOR1_D021	Witters, D. 0.9538 Tokani, D. 0.9538 D. 0.9538 D. 0.9538 D. 0.9539 D. 0.9538 D. 0.9539 D. 0.9539 D. 0.9539 D. 0.9539 D. 0.9539 D. 0.9539 D. 0.9539 D. 0.9539 D. 0.9538 D. 0.9538	Height 4 Vistory Total 3 550 32 126 32 126 32 126 32 126 32 126 32 126 32 126 32 128 32 128 32 129 35 120 32 128 32 129 35 120 32 128 32 128 32	Mideal Eye Openities Veart, John 1 27 504 63 315 63 315 61 465 61	Contains Contains	Uncertainty, (yes) 4.55 6. 4.55 6. 4.55 6. 4.55 6. 4.55 6. 4.55 6. 4.55 6. 4.55 6. 4.55 6. 4.55 8. 4.55 8. 4.55 8. 4.55 8. 4.55 8. 4.55 8. 5. 4.55 8. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5.	(0+4) 155.41 155.052 155.052 155.058 155.011 155.348 155.348 155.348 144.11 145.843 144.211 143.059 144.211 143.057 145.367 145.38 157.37 157.38 15	with Output 0elay 151 72 152 052 153 956 148 345 148 345 148 345 148 345 148 345 148 345 148 345 148 345 148 345 148 345 138 345 134 517 134 517 134 517 145 513 145 513 140 417 141 148 142 418	Trace Print, Drag 11 1280 40. 5016 40. 5016 40. 5016 38. 7818 40. 5017 34. 574 34. 6036 34. 374 34. 6036 34. 374 34. 6036 34. 374 34. 6036 34. 374 34. 6036 36. 7374 34. 60356 36. 374 34. 60356 36. 374 34. 60356 36. 374 36. 574 7. 78442	9+1 151 JP 155 444 155 796 164 372 163 853 163 972 163 983 163 269 173 852 163 269 173 852 165 054 165 055 165 055 165 055 165 055 165 055 165 055 165 266 177 867 165 055 165 266 177 867 165 055 165 055 165 266 177 867 165 055 165 055 165 266 177 867 165 265 177 165 265 177 867 165 265 177 165 265 175 265	Web Gug Deviat 155 4 155 4 155 4 155 4 155 4016 153 373 160 203 167 072 168 070 168 070 168 070 168 070 153 450 167 072 153 454 153 454 155 454 155 454 155 457 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452 155 452	Voltage: Voltage: Range Zoom: Move:	Sow 0.50045 [*] 0.18574 [*] 1e+06 [*]
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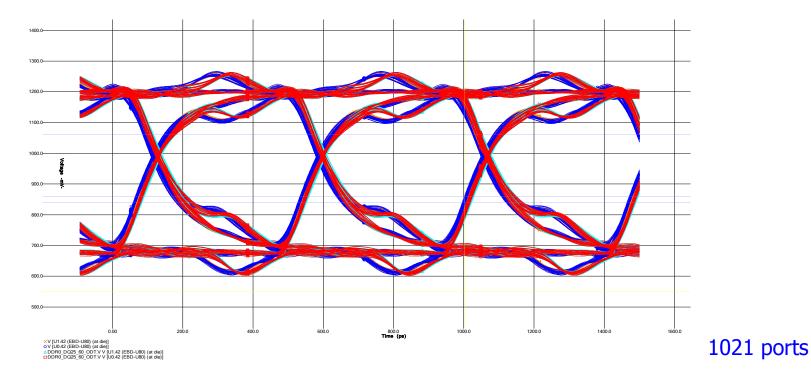
The timing wizard allows you to assess your signal quality across many possible variation (i.e. design and manufacturing variations) with multiple timing reports

- Objective/Goal
- DDR4 vs. DDR3 from the SI/PI Perspective
- Stackup Design Consideration & SSO Effects
- Design Considerations:
 - Impedance, ODT and Manufacturing Variations

- Length Matching Requirements
- Crosstalk Effects & Timing
- Analysis Tools Comparison
- Summary

Analysis Tools Comparison (Data Signal)

Hyperlynx Boardsim results vs 21/2 D field solver s-parameter extracted results overlaid



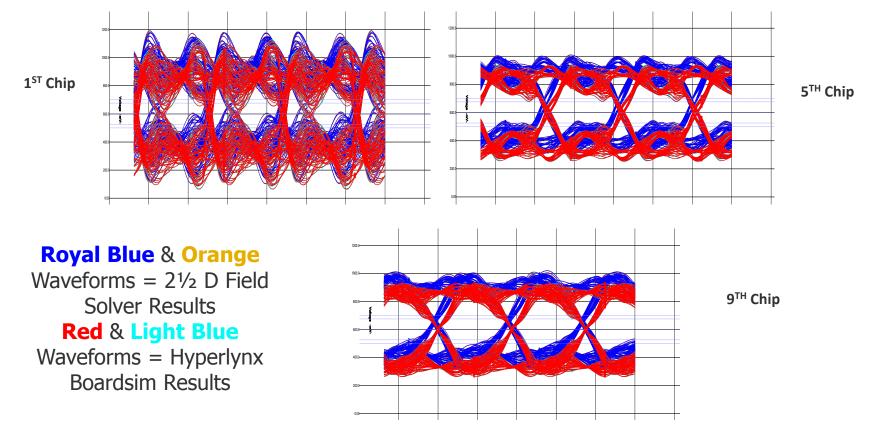
Royal Blue & **Orange** Waveforms = 2 ¹/₂-D Field Solver Results **Red** & **Light Blue** Waveforms = Hyperlynx Boardsim Results

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High confidence can be extrapolated from the Hyperlynx Boardsim simulations when the signals are ground referenced.

Analysis Tools Comparison (ADD Signal)

Hyperlynx Boardsim results vs 21/2 D field solver s-parameter extracted results overlaid



Again reasonably high confidence can be extrapolated from the Hyperlynx Boardsim simulations when the signals are power referenced.

- Objective/Goal
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 - Impedance, ODT and Manufacturing Variations

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- Length Matching Requirements
- Crosstalk Effects & Timing
- Analysis Tools Comparison

— Summary

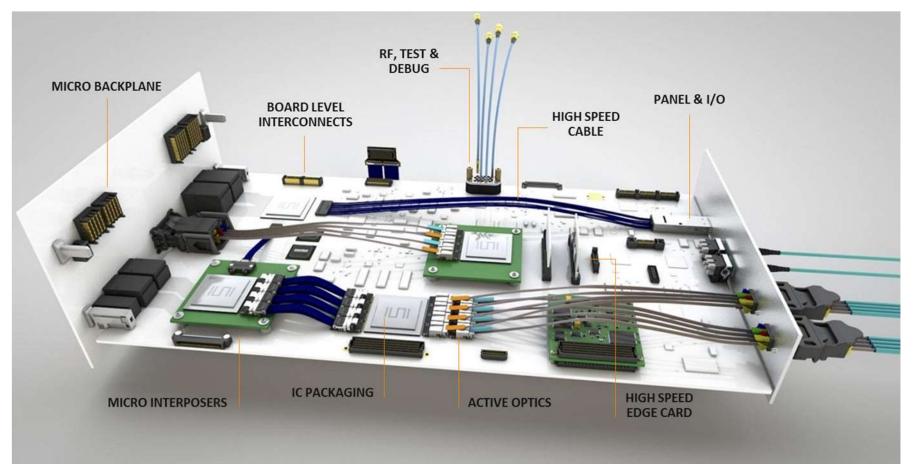
Summary

- We have discussed the differences between DDR3 and DDR4 from SI/PI perfective to help us assess what is need to evaluate DDR4 interface
- We have discussed and shown the necessary steps required for achieving a successful DDR4 interface across all operating conditions and timing requirements and standards.
- We have shown some very insightful tool correlation on a routed board between Hyperlynx BoardSim and a 2¹/₂ D field solver.
- Original paper from Rula Bakleh, SI/PI Consultant at Teraspeed Consulting



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