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DDR5 Registering Clock Driver Definition (DDR5RCD03)

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DDR5 REGISTERING CLOCK DRIVER DEFINITION (DDR5RCD03)**Contents**

	Page
1 Scope	1
2 Mechanical Outline	2
2.1 Pinout.....	3
2.2 Terminal Functions.....	4
3 Device Standard.....	6
3.1 Description	6
3.2 Logic Diagram Positive Logic.....	7
3.3 Register Operation.....	8
3.3.1 Chip Select Operation.....	8
3.3.2 ODT Operation.....	8
3.3.3 QCA Bus Operation	9
3.3.4 QCS Operation	10
3.3.5 Output Inversion and Mirroring	10
3.3.6 ZQ Calibration.....	10
3.3.7 Latency Equalization Support	11
3.3.8 Per-group Output Delay Control	11
3.3.9 Per-bit QCA Output Delay Control.....	12
3.3.10 Power Down Operation	12
3.3.11 VHost Mode	12
3.3.12 Transparent Mode.....	13
3.3.13 CA Validation Pass-Through Mode	13
3.3.14 DRAM Interface and Data Buffer Interface Training Support	14
3.4 Command Address Bus	14
3.4.1 Double Data Rate DCA	15
3.4.2 Single Data Rate DCA.....	18
3.4.3 SDR to DDR Transition	19
3.5 Parity.....	19
3.5.1 Single UI DRAM Commands with Parity Enabled.....	20
3.5.2 2UI DRAM Commands with Parity Enabled.....	21
3.5.3 ALERT_n Assertion.....	24
3.6 DCA Decision Feedback Equalization.....	25
3.6.1 DFE Tap Configurations	26
3.6.2 DFE Gain and Tap Range.....	26
3.6.3 DCA DFE Tap Measurement	27
3.7 Continuous Time Linear Equalization (CTLE).....	29
3.7.1 Background.....	29
3.7.2 CTLE Transfer Function	29
3.8 RX Loopback.....	33
3.8.1 Loopback Mode.....	33
3.8.2 Loopback Ports.....	33
3.8.3 Pin Assignment for Loopback, Timing Diagrams, and Timing Parameters	34

Contents (cont'd)

3.8.4	Internal Loopback Mode Entry	37
3.9	DLBD and DLBS Fine Vref Control and Input Delay Control.....	38
3.10	Device Initialization	38
3.11	Reset Initialization with Stable Power	40
4	Power Down operation.....	43
4.1	Power Savings Modes	43
4.1.1	PDE Power Down Mode	43
4.1.2	PDE Power Down Mode with ODT Control.....	44
4.2	Self Refresh Modes	46
4.2.1	Self Refresh Mode with Clock Stop Entry	46
4.2.2	Exit from Self Refresh Mode with Clock Stop	47
4.2.3	Self Refresh Mode without Clock Stop Entry	47
4.2.4	Self Refresh Mode without Clock Stop Exit	47
5	Training Modes.....	53
5.1	CS Training Modes.....	53
5.1.1	DCS Training Mode (DCSTM) - Host Interface.....	53
5.1.2	QCS Training Mode (QCSTM) - DRAM Interface	55
5.2	CA Training Modes.....	56
5.2.1	DCA Training Mode (DCATM) - Host Interface	56
5.2.2	Enhanced DCATM.....	58
5.2.3	QCA Training - DRAM Interface	59
5.2.4	CA Pass-through Mode	59
5.2.5	BCS and BCOM Training - Data Buffer Interface.....	60
5.2.6	BCOM Pass-Through Mode.....	60
5.3	DFE Training Mode (DFETM)	62
5.3.1	DFE Training Pattern Comparison and Feedback Features	64
5.3.2	DFE Parameter Sweep Acceleration	66
5.3.3	Method to Update RW In-band during Training.....	68
5.4	Dual Frequency Support.....	70
5.4.1	Initial Frequency Setting	71
5.4.2	Input Clock Frequency Change	71
6	Data Buffer Control Bus.....	72
6.1	Control Bus Signals.....	72
6.1.1	Control Bus Signal Termination.....	72
6.2	Control Bus Timing.....	73
6.3	Control Bus Commands	74
6.3.1	Data Buffer Control Bus Command Truth Table.....	74
6.3.2	Command Sequences.....	74
6.4	Command Sequence Descriptions.....	74
6.4.1	WR/RD Burst Length Processing.....	76
6.4.2	MRR Burst Length Processing.....	77
6.4.3	MRW Commands.....	78
6.4.4	MRR Commands	79
6.4.5	WR Commands	83
6.4.6	RD Commands	84

Contents (cont'd)

6.4.7	PDE Commands	86
6.4.8	MPC Command	86
6.4.9	NOP / Power Down Exit	87
7	SidebandBus Interface	88
7.1	SidebandBus Requirements during Initialization of RCD	88
7.2	Feature Summary	88
7.3	Operating Ranges	89
7.4	External Pins	89
7.4.1	Serial Clock (SCL)	89
7.4.2	Serial Data (SDA)	89
7.5	System Management Access	89
7.5.1	Target Address	90
7.5.2	Supported SidebandBus Commands	90
7.5.3	Register Access Protocols	91
7.5.4	Sequence for Switching from I2C Mode to I3C Basic	93
7.5.5	Parity Error Checking	93
7.5.6	PEC Support	94
7.5.7	Sideband Control Word Read Protocol	94
7.5.8	Sideband Control Word Write Protocol	101
7.5.9	In-Band Interrupts	107
7.5.10	I/O Operation	110
7.6	I2C and I3C Basic Reset	111
7.6.1	Sideband Interface and DRST_n RCD Reset Events	111
7.7	I2C Bus Clear	112
7.8	I2C Bus Error Handling	112
7.9	Error Handling in I3C Basic	112
7.9.1	Write Command Data Packet Error Handling - PEC Is Disabled	112
7.9.2	Read Command Data Packet Error Handling - PEC Is Disabled	113
7.9.3	Write Command Data Packet Error Handling - PEC Is Enabled	113
7.9.4	Read Command Data Packet Error Handling - PEC Is Enabled	114
7.9.5	CCC Packet Error Handling	114
7.10	Supported I3C Basic Common Command Codes (CCCs)	115
7.10.1	Enable/Disable Events Command (ENEC/DISEC) Operation	115
7.10.2	Reset Dynamic Address Assignment Command (RSTDAA) Operation	117
7.10.3	Set All Addresses to Static Address Command (SETAASA) Operation	117
7.10.4	Get Device Status Command (GETSTATUS) Operation	118
7.10.5	Get Device Capability Command (DEVCAP) Operation	119
7.10.6	Set HID Command (SETHID) Operation	120
7.10.7	Configure SPD Hub and All Devices behind Hub Command (DEVCTRL) Operation	121
8	Control Words	125
8.1	Reading Control Words	126
8.2	Control Word Decoding	127
8.3	Control Word Decoding	128
8.4	Paged Control Word Decoding	130

Contents (cont'd)

8.4.1	Page 0 DFE Paged Control Word Decoding	130
8.4.2	Page 1 DFE Paged Control Word Decoding	131
8.4.3	Page 2 DFE Paged Control Word Decoding	132
8.4.4	Page 3 Manufacturing ID Control Word Decoding	133
8.4.5	Page 4 VHost Paged Control Word Decoding	134
8.4.6	Page 5 Per-bit QCA Output Delay Control Word Decoding	135
8.5	Sticky Bits	136
8.5.1	Direct	136
8.5.2	Paged	136
8.6	Mode and Command Control Words	137
8.6.1	RW00 - Global Features Control Word.....	137
8.6.2	RW01 - Parity, CMD Blocking, and Alert Control Word Global Control Word CA ..	138
8.6.3	RW02 - Host Interface Training Mode Global Control Word	139
8.6.4	RW03 - DRAM & DB Interface Training Modes Global Control Word.....	140
8.6.5	RW04 - Command Space Global Control Word.....	141
8.7	Clocking Control Words.....	142
8.7.1	RW05 - DIMM Operating Speed Global Control Word.....	142
8.7.2	RW06 - Fine Granularity DIMM Operating Speed Global Control Word	143
8.8	Validation and Lockout Control Words	144
8.8.1	RW07 - Validation Pass-Through and Lockout Protection Global Control Word	144
8.9	Output Enable Control Words	145
8.9.1	RW08 - Clock Driver Enable Control Word.....	145
8.9.2	RW09 - Output Address and Control Enable Control Word	145
8.10	Output Driver Strengths	146
8.10.1	RW0A - QCK Signals Driver Characteristics Control Word.....	146
8.10.2	RW0C - QxCA and QxCS_n Signals Driver Characteristics Control Word	146
8.10.3	RW0D - Data Buffer Interface Driver Characteristics Control Word	147
8.11	Output Slew Rate Control	148
8.11.1	RW0E - QCK, QCA and QCS Output Slew Rate Control Word.....	148
8.11.2	RW0F - BCK, BCOM and BCS Output Slew Rate Control Word.....	149
8.12	Input Bus Termination Strengths.....	149
8.12.1	RW10 - IBT Global Control Word.....	149
8.13	Timing Control Words	150
8.13.1	RW11 - Command Latency Adder Configuration Control Word.....	150
8.13.2	RW12 - QACK Output Delay Control Word	150
8.13.3	RW13 - QBCK Output Delay Control Word	151
8.13.4	RW14 - QCKK Output Delay Control Word	151
8.13.5	RW15 - QDCK Output Delay Control Word	152
8.13.6	RW17 - QACS0_n Output Delay Control Word.....	152
8.13.7	RW18 - QACS1_n Output Delay Control Word.....	153
8.13.8	RW19 - QBCS0_n Output Delay Control Word.....	153
8.13.9	RW1A - QBCS1_n Output Delay Control Word.....	154
8.13.10	RW1B - QACA Output Delay Control Word	154
8.13.11	RW1C - QBCA Output Delay Control Word.....	155
8.13.12	RW1D - BCS_n and BCOM[2:0] Output Delay Control Word.....	155

Contents (cont'd)

8.13.13	RW1E - BCK Output Delay Control Word.....	156
8.14	RW[24:20] - Error Log Register	156
8.15	SidebandBus	157
8.15.1	RW25 - SidebandBus Global Control Word.....	157
8.16	RX Loopback.....	158
8.16.1	RW26 - RX Loopback Global Control Word.....	158
8.16.2	RW27 - Loop-back I/O Global Control Word	159
8.17	SidebandBus Error Status.....	159
8.17.1	RW28: I2C & I3C Basic Error Status Global Word	159
8.17.2	RW29: I2C & I3C Basic Clear Error Status Global Word.....	160
8.17.3	RW2A: Vendor Specific Global Word.....	160
8.18	DFE Control Words.....	161
8.18.1	RW30 - DFE_Vref Range Limit Global Status Word.....	161
8.18.2	RW31 - DFE Configuration Control Word.....	161
8.18.3	RW32 - DPAR and DCA[6:0] DFE Training Mode Control Word.....	162
8.18.4	RW33 - Additional Filtering for DFE Training Mode Control Word.....	162
8.18.5	RW34 - LFSR DFE Training Mode Control Word.....	163
8.18.6	RW35 - LFSR State for DFE Training Mode Control Word	163
8.18.7	RW36 - DFETM Inner Loop Start Value Control Word	164
8.18.8	RW37 - DFETM Outer Loop Start Value Control Word.....	164
8.18.9	RW38 - DFETM Inner Loop Current Value Control Word.....	164
8.18.10	RW39 - DFETM Outer Loop Current Value Control Word	165
8.18.11	RW3A - DFETM Inner and Outer Loop Step Size Control Word.....	165
8.18.12	RW3B - DFETM Inner Loop Number of Increments Control Word.....	166
8.18.13	RW3C - DFETM Outer Loop Number of Increments Control Word.....	166
8.18.14	RW3D - DFETM Inner Loop Current Increment Control Word	166
8.18.15	RW3E - DFETM Outer Loop Current Increment Control Word.....	167
8.18.16	RW3F - DFE Vref Range Selection Control Word.....	167
8.19	Vref Control Words.....	168
8.19.1	RW[47:40] - Internal VrefCA Control Word.....	168
8.19.2	RW[49:48] - Internal VrefCS Control Word.....	169
8.19.3	RW4A - DERROR_IN_n Vref Control Word	169
8.20	Loop-Back Vref and Input Delay Control.....	170
8.20.1	RW4B - Loop-Back Vref Control Word.....	170
8.20.2	RW4C - Loop-Back Input Delay Control Word	171
8.20.3	RW4D - DCA Selection in the Enhanced DCATM XOR Control Word	171
8.20.4	RW4E - DCS Selection in the Enhanced DCATM XOR Control Word	172
8.21	CTLE Control Words	172
8.21.1	RW50 - CTLE Configuration Global Control Word.....	172
8.21.2	RW51 - CTLE Per-Pin Disable Control Word.....	173
8.21.3	RW52 - CTLE Parameter Set A Control Word.....	173
8.21.4	RW53 - CTLE Parameter Set B Control Word.....	174
8.21.5	RW54 - Per-Pin CTLE Parameter Set Selection Control Word.....	174
8.22	Read and Paging Control Words	175
8.22.1	RW5E - CW Read Pointer Control Word	175

Contents (cont'd)

8.22.2	RW5F - CW Page Control Word	175
8.23	DFE Paged Control Words	176
8.23.1	PG[1:0]RW[60, 68, 70, 78] - DPAR and DCA[6:0] Receiver DFE Gain Offset	176
8.23.2	PG[1:0]RW[61, 69, 71, 79] - DPAR and DCA[6:0] Receiver DFE Tap 1 Coefficients	177
8.23.3	PG[1:0]RW[62, 6A, 72, 7A]- DPAR and DCA[6:0] Receiver DFE Tap 2 Coefficients	179
8.23.4	PG[1:0]RW[63, 6B, 73, 7B] - DPAR and DCA[6:0] Receiver DFE Tap 3 Coefficients	180
8.23.5	PG[1:0]RW[64, 6C, 74, 7C]- DPAR and DCA[6:0] Receiver DFE Tap 4 Coefficients	181
8.23.6	PG[1:0]RW[65, 6D, 75, 7D]- DPAR and DCA[6:0] Receiver DFE Tap 5 Coefficients	182
8.23.7	PG[1:0]RW[66, 6E, 76, 7E]- DPAR and DCA[6:0] Receiver DFE Tap 6 Coefficients	183
8.23.8	PG[2]RW[60, 64, 68, 6C, 70, 74, 78, 7C] DFE Error Counter Lower 8 Bits	184
8.23.9	PG[2]RW[61, 65, 69, 6D, 71, 75, 79, 7D] - DFE Error Counter Upper 8 Bits.....	184
8.23.10	PG[2]RW[62, 66, 6A, 6E, 72, 76, 7A, 7E] - DFE Vref	185
8.23.11	PG[2]RW[63, 67, 6B, 6F, 73, 77, 7B, 7F] - LFSR Seed for DFE Training Mode Control Word.....	186
8.24	OTP Paged Global Control Words	187
8.24.1	PG[3]RW60 - Date Code Byte 0 Global Word.....	187
8.24.2	PG[3]RW61 - Date Code Byte 1 Global Word.....	187
8.24.3	PG[3]RW62 - Date Code Byte 2 Global Word.....	188
8.24.4	PG[3]RW63 - Vendor Specific Unique Unit Code Byte 0 Global Word.....	188
8.24.5	PG[3]RW64 - Vendor Specific Unique Unit Code Byte 1 Global Word.....	188
8.24.6	PG[3]RW65 - Vendor Specific Unique Unit Code Byte 2 Global Word.....	189
8.24.7	PG[3]RW66 - Vendor Specific Unique Unit Code Byte 3 Global Word.....	189
8.24.8	PG[3]RW67 - Vendor Specific Unique Unit Code Byte 4 Global Word.....	189
8.24.9	PG[3]RW68 - Vendor Specific Unique Unit Code Byte 5 Global Word.....	189
8.24.10	PG[3]RW69 - Vendor Specific Unique Unit Code Byte 6 Global Word.....	190
8.24.11	PG[3]RW6A - Vendor ID Byte 0 Global Word	190
8.24.12	PG[3]RW6B - Vendor ID Byte 1 Global Word	190
8.24.13	PG[3]RW6C - Device ID Byte 0 Global Word.....	191
8.24.14	PG[3]RW6D - Device ID Byte 1 Global Word.....	191
8.24.15	PG[3]RW6E - Vendor Revision ID Global Word.....	191
8.25	VHost Paged Control Words	192
8.25.1	PG[4]RW[6E,6C,6A,68,66,64,62,60] - VHost Cmd[3:0] CA[7:0] Control Word	192
8.25.2	PG[4]RW[6F,6D,6B,69,67,65,63,61] - VHost Cmd[3:0] CS[1:0]/CA[13:8] Control Word	192
8.25.3	PG[4]RW70 - VHost [1:0] Cmd to Cmd Delay Control Word	193
8.25.4	PG[4]RW71 - VHost [3:2]Cmd to Cmd Delay Control Word	193
8.25.5	PG[4]RW72 - VHost Repeat Mode Control Word	194
8.25.6	PG[4]RW73 - VHost Start and Stop Global Control Word	194
8.26	PG[5]RW[7B:60] Per-bit QCA Output Delay Control Words	195

Contents (cont'd)

9	Absolute Maximum Ratings	196
10	Electrical - Timing Requirements	197
10.1	Operating Electrical Characteristics	197
10.2	Input Timing Requirements	198
10.3	Output Timing Requirements	204
11	VrefCA and Vref CS Specifications.....	207
11.1	DFE_Vref INL Tolerance.....	212
11.2	Measurement Steps.....	215
11.3	DFE Tap Coefficient and Gain Adjustment Tolerances (DNL and INL)	216
12	AC and DC Global Definitions.....	217
12.1	Transmitter (Tx), Receiver (Rx), and Channel Definitions.....	217
12.1.1	Bit Error Rate	218
12.1.2	General Equation	218
12.1.3	Minimum Bit Error Rate (BER) Requirements.....	219
12.1.4	Unit Interval and Jitter Definitions.....	219
12.1.5	Unit Interval.....	219
12.1.6	UI Jitter Definition	220
12.1.7	UI-UI Jitter Definition.....	220
12.1.8	Accumulated Jitter (Over “N” UI)	221
13	Electrical - Input AC and DC Specifications	222
13.1	Input Clock Architecture	222
13.1.1	Input Clock SSC and PLL Loop Filter	222
13.1.2	Input Slew Rate for Differential Clock	222
13.1.3	Differential Input Clock Cross Point Voltage	223
13.2	Input Voltage Levels for DERROR_IN_n Signals	224
13.3	Overshoot and Undershoot Specifications	224
13.4	Input Bus Termination (IBT) Characteristics for DCA, DPAR, DCS, and DERROR_IN_n.....	225
13.5	DLBD and DLBS Loopback Input Termination	226
13.6	Input CMOS Rail-to-Rail Levels for DRST_n.....	227
13.7	Differential Input Clock and DCA Voltage Sensitivity	228
13.7.1	Differential Input Clock and DCA Voltage Sensitivity Parameter	228
13.8	Input Clock Jitter	230
13.8.1	Overview	230
13.8.2	Specification for RCD Input Clock Jitter	231
13.9	RX Clock Jitter Sensitivity	231
13.9.1	Rx Clock Jitter Sensitivity Specification.....	233
13.9.2	Test Conditions for RX Clock Jitter Sensitivity Tests	235
13.10	Input Stressed Eye	236
13.10.1	Overview	236
13.10.2	Input Stressed Eye Parameters	236
13.11	DCS Input Receiver Specification.....	237
13.11.1	DCS Input Receiver Voltage Margin and AC Timing by Speed Bin	238
13.12	DLBD Input Receiver Specification	239

Contents (cont'd)

14	Electrical - Output AC and DC Specifications	241
14.1	Single-Ended Output Slew Rate	241
14.2	Output Clock Differential Slew Rate	243
14.3	Differential Output Clock Cross Point Voltage.....	244
14.4	QCK, QCA, QCS, BCK, BCOM and BCS Output Slew Rate Specifications per Control Words Settings	245
14.5	Output R-on Drive Specifications per Drive Strength Setting	246
14.6	Output Driver and Termination Resistor Temperature and Supply Voltage Sensitivity	249
14.7	Output Clock Driver Characteristics	250
14.8	Differential Output Clock Driver Jitter Characteristics.....	254
14.8.1	Overview	254
14.8.2	Output Clock Jitter Parameters.....	255
14.9	ALERT_n Output Driver DC Electrical Characteristic.....	255
15	IDD Specification Parameters	256
15.1	IDD Specification Parameters and Test Conditions.....	256
16	Input/Output Capacitance	260
16.1	Electrostatic Discharge Sensitivity Characteristics	262
17	SidebandBus Interface Electrical and Timing Specifications	263
17.1	Operating Conditions.....	263
17.2	Measurement Test Conditions.....	263
17.3	DC Electrical Characteristics	264
17.4	AC Electrical Characteristics	265
18	Test Circuits and Switching Waveforms.....	272
18.1	Alert Output Voltage Measurement Information	272
18.2	DDR5RCD03 Reference Load	273
19	Reference to other Applicable JEDEC Standards and Publications.....	274

Contents (cont'd)

List of Tables

	Page
Table 1 — Ball Assignment -240 ball FCBGA, 14 x 19 Grid, TOP VIEW	3
Table 2 — Terminal Functions	4
Table 3 — DCS - QxCS Mapping	8
Table 4 — ODT Encoding on the Chip Select.....	8
Table 5 — DIMM Termination Write.....	9
Table 6 — DIMM Termination Read	9
Table 7 — Command Address Rates	14
Table 8 — DDR CA Mapping DCA to QCA.....	15
Table 9 — Blocking Commands on Parity Error.....	24
Table 10 — DFE Tap Configurations	26
Table 11 — DFE Gain and Tap Total Control Word Range	26
Table 12 — DFE Gain and Tap Coefficient Step Parameters Required per Speed Bin	26
Table 13 — Supported CTLE Parameter Value Combinations	31
Table 14 — DDR5RCD03 Device Initialization Sequence at Power-on Ramping 1	40
Table 15 — DDR5RCD03 Device Initialization Sequence when Power and Clock are Stable 1	42
Table 16 — ODT Control during Power Down Mode	44
Table 17 — Sample Evaluation for Intermediate Output[0]	53
Table 18 — Sample Evaluation for Intermediate Output[1]	53
Table 19 — Sample Evaluation for Final DCSTM Output	54
Table 20 — DCA Training Mode Output	58
Table 21 — BCOM Bus Mapping	61
Table 22 — Post-cursor Bias Ctrl Definition	64
Table 23 — Control Words Duplicated for Frequency Context Support.....	70
Table 24 — List of Signals for Data Buffer Control Signals.....	72
Table 25 — BCOM Bus Mapping	73
Table 26 — Data Buffer Control Bus Command Truth Table	74
Table 27 — Data Buffer PG[1:0] Rank Training Control Word Decoding	75
Table 28 — WR/RD Burst Length Processing	76
Table 29 — MRR Burst Length Processing	77
Table 30 — PBA Enumerate ID Programming Burst Length Processing	77
Table 31 — Multi-cycle Sequence for MRW Commands.....	78
Table 32 — Multi-cycle Sequence for MRR Commands.....	79
Table 33 — Short MRR Command for SDR Training	80
Table 34 — MRR Read Format for Data Buffer Return	80
Table 35 — MRR Read Format for Data Buffer Return with Read CRC Enabled.....	80
Table 36 — Multi-cycle Sequence for WR Commands	83
Table 37 — Multi-cycle Sequence for RD Commands.....	85
Table 38 — Multi-cycle Sequence for PDE Commands	86
Table 39 — Multi-cycle Sequence for MPC Commands	86
Table 40 — Multi-cycle Sequence for NOP/PDX Commands	87
Table 41 — SidebandBus Command Format in I2C Mode.....	90
Table 42 — SidebandBus Command Format in I3C Basic Mode.....	91
Table 43 — SidebandBus Protocol Addressing Fields	92
Table 44 — SidebandBus Address Map	92
Table 45 — Double Word Byte Order for SidebandBus Control Word Access	93
Table 46 — Status Field Encoding for SidebandBus Reads.....	95

Contents (cont'd)

Table 47 — I2C Read Command Packet Example (Block Mode, PEC Disabled, Legacy Format)	95
Table 48 — I2C Read Command Packet Example (Block Mode, PEC Enabled, Legacy Format)	96
Table 49 — I2C Read Command Packet Example (Block Mode, PEC Disabled, Optimized Format)	96
Table 50 — I2C Read Command Packet Example (Byte Mode, PEC Disabled, Legacy Format)	97
Table 51 — I2C Read Command Packet Example (Byte Mode, PEC Enabled, Legacy Format)	98
Table 52 — I3C Basic Read Command Packet Example (PEC Disabled).....	99
Table 53 — I3C Basic Read Command Packet Example (Block Mode, PEC Enabled).....	100
Table 54 — I3C Basic Read Command Packet Example with IBI Header and No Pending Interrupt (Block Mode, PEC Enabled).....	101
Table 55 — I2C Write Command Packet Example (Write DWord, Block Mode, PEC Disabled)	102
Table 56 — I2C Write Command Packet Example (Write DWord, Block Mode, PEC Enabled)	102
Table 57 — I2C Write Command Packet Example (Write Byte, Block Mode, PEC Disabled)	102
Table 58 — I2C Write Command Packet Example (Write Word, Block Mode, PEC Enabled)	103
Table 59 — I2C Write Command Packet Example (Write DWord, Byte Mode, PEC Disabled)	103
Table 60 — I2C Write Command Packet Example (Write Word, Byte Mode, PEC Enabled)	104
Table 61 — I3C Basic Write Command Packet Example (Write DWord, PEC Disabled)	105
Table 62 — I3C Basic Write Command Packet Example (Write DWord, Block Mode, PEC Enabled)...	105
Table 63 — I3C Basic Write Command Packet Example (Write Byte, PEC Disabled)	106
Table 64 — I3C Basic Write Command Packet Example (Write Word, Block Mode, PEC Enabled)	106
Table 65 — I3C Basic Write Command Packet Example with IBI Header and No Pending Interrupt (Write Word, Block Mode, PEC Enabled).....	107
Table 66 — Interrupt Response (PEC Disabled).....	109
Table 67 — Interrupt Response (PEC Enabled).....	109
Table 68 — RCD Device Dynamic I/O Operation Mode Switching; I3C Basic Mode	110
Table 69 — Supported I3C Basic Common Command Codes (CCCs)	115
Table 70 — ENEC/DISEC CCC (I3C Basic, Broadcast, PEC Disabled)	116
Table 71 — ENEC/DISEC CCC (I3C Basic, Broadcast, PEC Enabled)	116
Table 72 — ENEC/DISEC CCC (I3C Basic, Direct, PEC Disabled)	116
Table 73 — ENEC/DISEC CCC (I3C Basic, Direct, PEC Enabled)	116
Table 74 — RSTDAA CCC (I3C Basic, Broadcast, PEC Disabled).....	117
Table 75 — RSTDAA CCC (I3C Basic, Broadcast, PEC Enabled).....	117
Table 76 — SETAASA CCC (I2C, Broadcast)	117
Table 77 — GETSTATUS MSb-LSb Format	118
Table 78 — GETSTATUS CCC (I3C Basic, Direct, PEC Disabled)	118
Table 79 — GETSTATUS CCC (I3C Basic, Direct, PEC Enabled)	119
Table 80 — DEVCAP CCC (I3C Basic, Direct, PEC Disabled)	119
Table 81 — DEVCAP CCC (I3C Basic, Direct, PEC Enabled).....	120
Table 82 — DEVCAP MSb-LSb Format	120
Table 83 — SETHID CCC (I2C, Broadcast).....	120
Table 84 — DEVCTRL Command Operation (I2C or I3C Basic, Broadcast, PEC Disabled)	121
Table 85 — DEVCTRL Command Operation (I3C Basic, Broadcast, PEC Enabled).....	122
Table 86 — DEVCTRL Command Definition	123
Table 87 — DEVCTRL Command Definition	124
Table 88 — DEVCTRL Command Example (I3C Basic, Broadcast, PEC Enabled)	124
Table 89 — Control Word Addressing.....	125
Table 90 — RCD and DB Control Word Spaces.....	126
Table 91 — Control Word Read Sequence	126
Table 92 — DDR MRW Command to RCD	127
Table 93 — Control Word Decoding.....	128

Contents (cont'd)

Table 94 — Page 0 DFE Control Word Decoding.....	130
Table 95 — Page 1 DFE Control Word Decoding.....	131
Table 96 — Page 2 DFE Control Word Decoding.....	132
Table 97 — Page 3 Manufacturing ID Control Word Decoding	133
Table 98 — Page4 VHost Control Word Decoding,,.....	134
Table 99 — Page 5 Per-bit QCA Output Delay Control Word Decoding	135
Table 100 — RW00 - Global Features Control Word.....	137
Table 101 — RW01 - Parity, CMD Blocking, and Alert Global Control Word	138
Table 102 — ALERT_n Pulse Width for Parity Error (DDR5-3200 ~ 5600)	139
Table 103 — ALERT_n Pulse Width for Parity Error (DDR5-6000 ~ 6400)	139
Table 104 — RW02: Host Interface Training Mode Global Control Word.....	139
Table 105 — RW03: DRAM & DB Interface Training Modes Global Control Word	140
Table 106 — RW04: Command Space Global Control Word definition.....	141
Table 107 — RW05: DIMM Operating Speed Global Control Word	142
Table 108 — RW06: Fine Granularity DIMM Operating Speed Global Control Word.....	143
Table 109 — RW07: Validation Pass-Through and Lockout Protection Global Control Word	144
Table 110 — RW08: Clock Driver Enable Control Word	145
Table 111 — RW09: Output Address and Control Enable Control Word	145
Table 112 — RW0A: QCK Signals Driver Characteristics Control Word	146
Table 113 — RW0C: QxCA and QxCS_n Signals Driver Characteristics Control Word.....	146
Table 114 — RW0D: Data Buffer Interface Driver Characteristics Control Word	147
Table 115 — RW0E - QCK, QCA and QCS Output Slew Rate Control Word	148
Table 116 — RW0F - BCK, BCOM and BCS Output Slew Rate Control Word	149
Table 117 — RW10: IBT Global Control Word.....	149
Table 118 — RW11: Command Latency Adder Configuration Control Word.....	150
Table 119 — RW12: QACK Output Delay Control Word	150
Table 120 — RW13: QBCK Output Delay Control Word	151
Table 121 — RW14: QCKK Output Delay Control Word	151
Table 122 — RW15: QDCK Output Delay Control Word	152
Table 123 — RW17: QACS0_n Output Delay Control Word.....	152
Table 124 — RW18: QACS1_n Output Delay Control Word.....	153
Table 125 — RW19: QBCS0_n Output Delay Control Word	153
Table 126 — RW1A: QBCS1_n Output Delay Control Word	154
Table 127 — RW1B: QACA Output Delay Control Word.....	154
Table 128 — RW1C: QBCA Output Delay Control Word	155
Table 129 — RW1D: BCS_n and BCOM[2:0] Output Delay Control Word.....	155
Table 130 — RW1E: BCK Output Delay Control Word.....	156
Table 131 — RW[24:20]: Error Log Register Encoding for DDR Mode, ...	156
Table 132 — RW25: SidebandBus Global Control Word	157
Table 133 — RW[24:20]: Error Log Register Encoding for SDR Mode, ...	157
Table 134 — RW26: RX Loopback Global Control Word.....	158
Table 135 — RW27: Loop-back I/O Global Control Word.....	159
Table 136 — RW28: I2C and I3C Basic Error Status Global Word.....	159
Table 137 — RW29: I2C and I3C Basic Clear Error Status Global Word	160
Table 138 — RW2A: Vendor Specific Global Word	160
Table 139 — RW30: DFE_Vref Range Limit Global Status Word	161
Table 140 — RW31: DFE Configuration Control Word	161
Table 141 — RW32 DPAR and DCA[6:0] DFE Training Mode Control Word.....	162
Table 142 — RW33 Additional Filtering for DFE Training Mode Control Word.....	162

Contents (cont'd)

Table 143 — RW34 LFSR DFE Training Mode Control Word	163
Table 144 — RW35 LFSR State for DFE Training Mode Control Word.....	163
Table 145 — RW36 DFETM Inner Loop Start Value Control Word	164
Table 146 — RW37 DFETM Outer Loop Start Value Control Word.....	164
Table 147 — RW38 DFETM Inner Loop Current Value Control Word.....	164
Table 148 — RW39 DFETM Outer Loop Current Value Control Word.....	165
Table 149 — RW3A DFETM Inner and Outer Loop Step Size Control Word	165
Table 150 — RW3B DFETM Inner Loop Number of Increments Control Word	166
Table 151 — RW3C DFETM Outer Loop Number of Increments Control Word	166
Table 152 — RW3D DFETM Inner Loop Current Increment Control Word.....	166
Table 153 — RW3E DFETM Outer Loop Current Increment Control Word	167
Table 154 — RW3F DFE Vref Range Selection Control Word	167
Table 155 — RW[47:40]: Internal VrefCA Control Word.....	168
Table 156 — RW[49:48]: Internal VrefCS Control Word	169
Table 157 — RW4A: DERROR_IN_n Vref Control Word.....	169
Table 158 — RW4B: Loop-Back Vref Control Word.....	170
Table 159 — RW4C: Loop-Back Input Delay Control Word.....	171
Table 160 — RW4D: DCA Selection in the Enhanced DCATM XOR Control Word	171
Table 161 — RW4E: DCS Selection in the Enhanced DCATM XOR Control Word.....	172
Table 162 — RW50 - CTLE Configuration Global Control Word.....	172
Table 163 — RW51 - CTLE Per-Pin Disable Control Word.....	173
Table 164 — RW52 - CTLE Parameter Set A Control Word	173
Table 165 — RW53 - CTLE Parameter Set B Control Word	174
Table 166 — RW54 - Per-Pin CTLE Parameter Set Selection Control Word.....	174
Table 167 — RW5E - CW Read Pointer Control Word	175
Table 168 — RW5F - CW Page Control Word.....	175
Table 169 — PG[1:0]RW[60, 68, 70, 78]: DPAR and DCA[6:0] Receiver DFE Gain Offset Adjustment	176
Table 170 — PG[1:0]RW[61, 69, 71, 79]: DPAR and DCA[6:0] Receiver DFE Tap 1 Coefficients	177
Table 171 — PG[1:0]RW[62, 6A, 72, 7A]: DPAR and DCA[6:0] Receiver DFE Tap 2 Coefficients	179
Table 172 — PG[1:0]RW[63, 6B, 73, 7B]: DPAR and DCA[6:0] Receiver DFE Tap 3 Coefficients.....	180
Table 173 — PG[1:0]RW[64, 6C, 74, 7C]: DPAR and DCA[6:0] Receiver DFE Tap 4 Coefficients.....	181
Table 174 — PG[1:0]RW[65, 6D, 75, 7D]: DPAR and DCA[6:0] Receiver DFE Tap 5 Coefficients	182
Table 175 — PG[1:0]RW[66, 6E, 76, 7E]: DPAR and DCA[6:0] Receiver DFE Tap 6 Coefficients	183
Table 176 — PG[2][60, 64, 68, 6C, 70, 74, 78, 7C]- DFE Error Counter Lower 8 Bit	184
Table 177 — PG[2][61, 65, 69, 6D, 71, 75, 79, 7D] DFE Error Counter Upper 8 Bit	184
Table 178 — PG[2]RW[62, 66, 6A, 6E, 72, 76, 7A, 7E]: DFE Vref	185
Table 179 — PG[2]RW[63, 67, 6B, 6F, 73, 77, 7B, 7F] LFSR Seed for DFE Training Mode Control Word	186
Table 180 — PG[3]RW60: Date Code Byte 0 Global Word	187
Table 181 — PG[3]RW61: Date Code Byte 1 Global Word	187
Table 182 — PG[3]RW62: Date Code Byte 2 Global Word	188
Table 183 — PG[3]RW63: Vendor Specific Unique Unit Code Byte 0 Global Word	188
Table 184 — PG[3]RW64: Vendor Specific Unique Unit Code Byte 1 Global Word	188
Table 185 — PG[3]RW65: Vendor Specific Unique Unit Code Byte 2 Global Word	189
Table 186 — PG[3]RW66: Vendor Specific Unique Unit Code Byte 3 Global Word	189
Table 187 — PG[3]RW67: Vendor Specific Unique Unit Code Byte 4 Global Word	189
Table 188 — PG[3]RW68: Vendor Specific Unique Unit Code Byte 5 Global Word	189
Table 189 — PG[3]RW69: Vendor Specific Unique Unit Code Byte 6 Global Word	190

Contents (cont'd)

Table 190 — PG[3]RW6A: Vendor ID Byte 0 Global Word.....	190
Table 191 — PG[3]RW6B: Vendor ID Byte 1 Global Word.....	190
Table 192 — PG[3]RW6C: Device ID Byte 0 Global Word.....	191
Table 193 — PG[3]RW6D: Device ID Byte 1 Global Word.....	191
Table 194 — PG[3]RW6E: Vendor Revision ID Global Word	191
Table 195 — PG[4]RW[6E,6C,6A,68,66,64,62,60] - VHost Cmd[3:0] CA[7:0] Control Word	192
Table 196 — PG[4]RW[6F,6D,6B,69,67,65,63,61] - VHost Cmd[3:0] CA[7:0] Control Word.....	192
Table 197 — PG[4]RW70 - VHost [1:0] Cmd to Cmd Delay Control Word.....	193
Table 198 — PG[4]RW71 - VHost [3:2] Cmd to Cmd Delay Control Word.....	193
Table 199 — PG[4]RW72 - VHost Repeat Mode Control Word	194
Table 200 — PG[4]RW73 - VHost Start and Stop Global Control Word	194
Table 201 — PG[5]RW[7B:60] Per-bit QCA Output Delay Control Word	195
Table 202 — Absolute Maximum Ratings over Operating Free-air Temperature Range ¹	196
Table 203 — Operating Electrical Characteristics	197
Table 204 — Input Timing Requirements	198
Table 205 — Output Timing Requirements.....	204
Table 206 — Internal VrefCA and VrefCS Specifications	211
Table 207 — DFE_Vref Specification.....	214
Table 208 — DFE_Vref INL Tolerance.....	214
Table 209 — Estimated Number of Transmitted Bits (n) for Confidence Level of 70% to 99.5%	218
Table 210 — Minimum BER Requirements for RX and TX Timing and Voltage Tests.....	219
Table 211 — SSC and PLL Loop Filter Characteristics.....	222
Table 212 — Differential Input Slew Rate Definition for DCK_t/DCK_c	222
Table 213 — Differential Input Slew Rate DCK_t/DCK_c	223
Table 214 — Cross Point Voltage (VIX) for Differential Input Signals (DCK)	224
Table 215 — Input Voltage Levels for DERROR_IN_n Signals	224
Table 216 — IBT Electrical Characteristics for DCA, DPAR, DCS, and DERROR_IN_n.....	225
Table 217 — Electrical Characteristics for DLBD and DLBS Input Termination	226
Table 218 — CMOS Rail-to-Rail Input Levels for DRST_n	227
Table 219 — Rx Input Voltage Sensitivity Parameters for DDR5-3200 to 6400.....	229
Table 220 — Input Clock Differential Jitter	231
Table 221 — Rx Clock Jitter Sensitivity Option-1 Specification for DDR5-3200 to 6400	233
Table 222 — Rx Clock Jitter Sensitivity Option-2 Specification for DDR5-3200 to 6400	234
Table 223 — Rx Clock Jitter Sensitivity Specification for DDR5-3200 to 6400	235
Table 224 — Test Conditions for Rx Stressed Eye Tests for DDR5-3200 to 6400.....	236
Table 225 — DCS Input Receiver Voltage Margin and AC Timing by Speed Bin	238
Table 226 — Loopback RX Receiver Voltage Margin and AC Timing by Speed Bin.....	240
Table 227 — Output Single-ended Slew Rate Definition	241
Table 228 — Output Single-Ended Edge Rates Over Specified Operating Temperature Range	242
Table 229 — Output Clock Differential Slew Rate Definition for QnCK_t / QnCK_c and BnCK_t / BnCK_c.....	243
Table 230 — Output Differential Edge Rates.....	243
Table 231 — Output Cross Point Voltage for QnCK_t/QnCK_c and BCK_t/BCK_c.....	244
Table 232 — QCK, QCA, QCS, BCK, BCOM and BCS Output Slew Rate	245
Table 233 — Output Ron Drive.....	246
Table 234 — Output Driver DC Electrical Characteristics, Entire Operating Temperature Range	247
Table 235 — Output Driver and Termination Resistor Sensitivity Definition	249
Table 236 — Output Driver and Termination Resistor Temperature and Voltage Sensitivity.....	249
Table 237 — Output Clock Driver Characteristics at Application Mode (Frequency Band 1).....	250



Contents (cont'd)

Table 238 — Output Clock Driver Characteristics at Test Mode (Frequency Band 2).....	251
Table 239 — Tx QCK Jitter Specifications for DDR5-3200 to 5600	255
Table 240 — ALERT_n Output Driver DC Electrical Characteristics.....	255
Table 241 — Basic IDD Measurement Conditions	258
Table 242 — IDD3NA, IDD3NB, IDD3P1, and IDD3P2 Measurement-Loop Pattern	258
Table 243 — IDD4A, IDD4B Measurement-Loop Pattern.....	259
Table 244 — Silicon Pad I/O Capacitance Values.....	260
Table 245 — Package Electrical Parameters	261
Table 246 — Electrostatic Discharge Sensitivity Characteristics	262
Table 247 — Operating Conditions for the SidebandBus Interface	263
Table 248 — AC Measurement Conditions for SidebandBus Interface.....	263
Table 249 — Output Ron Spec	264
Table 250 — Input Parameters for SidebandBus Interface	264
Table 251 — DC Characteristics for SidebandBus Interface	264
Table 252 — AC Characteristics for SidebandBus Interface	265

Contents (cont'd)

List of Figures

	Page
Figure 1 — Ball Configuration, TOP VIEW	2
Figure 2 — RCD Output Inversion.....	10
Figure 3 — Latency Equalizer Delays.....	11
Figure 4 — Validation Pass-Through Mode - DDR.....	14
Figure 5 — Validation Pass-Through Mode - SDR1	14
Figure 6 — RCD DCA and QCA Ports.....	15
Figure 7 — One UI DRAM Command Timing Diagram.....	16
Figure 8 — Two UI DRAM Command Timing Diagram	16
Figure 9 — DDR CA Multi-Command Timing Diagram Example	17
Figure 10 — Qn Output Skew	17
Figure 11 — SDR1 Mode Example of DRAM WR Command with $RW00[1] = 0$	18
Figure 12 — SDR2 Mode Example of DRAM WR Command with $RW00[1] = 1$	19
Figure 13 — 1 UI DRAM Command with Parity Checking Enabled and $CLA = 0$	20
Figure 14 — SDR Mode 1 UI DRAM Command with Parity Checking Enabled and $CLA = 0$..	21
Figure 15 — Error in 1st UI of 2 UI DRAM Command with Parity Checking Enabled	22
Figure 16 — SDR Mode Error in 1st UI of 2 UI DRAM Command with Parity Checking Enabled.....	22
Figure 17 — Error in 2nd UI of 2 UI DRAM Command with Parity Checking Enabled.....	23
Figure 18 — SDR1 Mode Error in 2nd UI of 2 UI DRAM Command with Parity Checking Enabled.....	24
Figure 19 — HIGH-to-LOW Sweep: No DFE Applied	27
Figure 20 — HIGH-to-LOW Sweep: DFE Positive Bias Applied.....	27
Figure 21 — HIGH-to-LOW Sweep: DFE Negative Bias Applied	28
Figure 22 — LOW-to-HIGH Sweep: No DFE Applied	28
Figure 23 — LOW-to-HIGH Sweep: DFE Positive Bias Applied.....	28
Figure 24 — LOW-to-HIGH Sweep: DFE Negative Bias Applied	29
Figure 25 — RCD Loopback Ports.....	33
Figure 26 — External Loopback Timing Diagram.....	34
Figure 27 — Internal Loopback 2-Phase A and B Phase	34
Figure 28 — Loopback Output 2-Phase Timing Parameters.....	35
Figure 29 — Internal Loopback 4-Phase A, B, C, and D Phase.....	35
Figure 30 — Loopback Output 4-Phase Timing Parameters.....	36
Figure 31 — RCD03 Internal Loopback Mode Entry	36
Figure 32 — Timing of Clock and Data During Initialization Sequence	39
Figure 33 — Reset Initialization With Stable Power	41
Figure 34 — Power Down Mode Entry and Exit	45
Figure 35 — Self Refresh Entry Exit with Clock Stop With DCK Frequency Change	48
Figure 36 — Self Refresh Entry Exit with Clock Stop in SDR1 Mode With DCK Frequency Change.....	49
Figure 37 — Self Refresh Entry Exit with Clock Stop Without DCK Frequency Change	50

Contents (cont'd)

Figure 38 — Self Refresh Entry Exit with Clock Stop in SDR1 Mode Without DCK Frequency Change	51
Figure 39 — Self Refresh Entry and Exit without Clock Stop	52
Figure 40 — Timing Diagram for DCS Training Mode with Consecutive Output Samples=0	54
Figure 41 — Timing Diagram for DCS Training Mode with Output Sample Toggle	55
Figure 42 — Timing Diagram for QCSTM with Output Sample Toggle	56
Figure 43 — Timing Diagram for DCA Training Mode SMBus Exit	57
Figure 44 — Timing Diagram for DCA Training Mode Double CS Exit	58
Figure 45 — MRW example of MRW on DCS0 and CA Pass-Through on DCS1	59
Figure 46 — SDR CA Pass-Through mode	60
Figure 47 — BCOM PASS Through	61
Figure 48 — BCOM Pass-Through Mode when RCD is in SDR	62
Figure 49 — DFE Training Circuitry	63
Figure 50 — DFE Summer	63
Figure 51 — Logical Representation of the Galois LFSR of Polynomial $x^8+x^6+x^5+x^4+1$ for DCA Training	64
Figure 52 — LFSR CA DFE Training Pattern	65
Figure 53 — CA DFE UI Filter Pattern	65
Figure 54 — RCD Operation During DFE Parameter Sweep Acceleration	67
Figure 55 — RWUPD State Machine	69
Figure 56 — RWUPD Timing Diagram for Channel A	70
Figure 57 — Control Bus Termination	72
Figure 58 — Example BCOM WR Command	73
Figure 59 — MRW Command Sequence	78
Figure 60 — MRR Command Sequence to Data Buffer Address Space	79
Figure 61 — MRR Command Sequence to DRAM Address Space	81
Figure 62 — RD to MRR Command Sequence to Data Buffer Address Space	82
Figure 63 — WR to MRR Command Sequence to Data Buffer Address Space	83
Figure 64 — WRITE Timing	84
Figure 65 — READ Timing	85
Figure 66 — SidebandBus Wiring Diagram	89
Figure 67 — RCD Interrupt Request - Controller ACK followed by RCD IBI Payload	108
Figure 68 — RCD Interrupt Request - Controller NACK followed by STOP	108
Figure 69 — I2C or I3C Basic Reset	111
Figure 70 — $DxCSx_n$ Assertion during ALERT _n Pulse Width	138
Figure 71 — Vref Operating Range (Vrefmin, Vrefmax)	207
Figure 72 — Example of Vref Set Tolerance (only Max Case Shown) and Step Size	208
Figure 73 — Vref_time Timing Diagram	209
Figure 74 — Vref Step Single Step Size Increment Case	209
Figure 75 — Vref Step Single Step Size Decrement Case	210
Figure 76 — Vref Full Step from Vrefmin to Vrefmax Case	210
Figure 77 — Vref Full step from Vrefmax to Vrefmin Case	211
Figure 78 — Example of DFE_Vref INL Tolerance	212
Figure 79 — DFE_Vref_step Time Timing Diagram	213
Figure 80 — DFE_Vref Increment Case	213

Contents (cont'd)

Figure 81 — DFE_Vref Decrement Case.....	214
Figure 82 — Illustration Example of DFE_Vref INL Tolerance	215
Figure 83 — Example of Tap Coefficient and Gain Adjustment tolerances (DNL and INL).....	216
Figure 84 — UI Definition in Terms of Adjacent Edge Timings.....	219
Figure 85 — UI Definition Using Clock Waveforms.....	220
Figure 86 — UI Jitter of the “nth” UI Definition (in Terms of Ideal UI).....	220
Figure 87 — UI - UI Jitter Definitions	220
Figure 88 — Definition of Accumulated Jitter (over “N” UI).....	221
Figure 89 — Definition of UI	221
Figure 90 — Differential Input Slew Rate Definition for DCK_t/DCK_c.....	223
Figure 91 — VIX Definition (DCK)	224
Figure 92 — Input Bus Termination: Definition of Voltages and Currents	225
Figure 93 — DLBD and DLBS Termination: Definition of Voltages and Currents.....	226
Figure 94 — DRST_n Input Slew Rate Definition.....	227
Figure 95 — DRST_n Slope Reversal Definition	228
Figure 96 — Example of DDR5 Memory Interconnect	228
Figure 97 — VRx_CK.....	229
Figure 98 — VRx_DCA_V	230
Figure 99 — Host Driving Clock Signals to the RCD	230
Figure 100 — RCD RX Forward Clock for Jitter Sensitivity	232
Figure 101 — Example of Rx Stressed Test Setup in Presence of ISI, Jitter, and Crosstalk	236
Figure 102 — DCS Receiver (RX) Mask.....	237
Figure 103 — DCS TcIPW and SRIN_clVW Definition (for each Input Pulse)	237
Figure 104 — DLBD Receiver (RX) Mask.....	239
Figure 105 — DLBD Timings at the RCD.....	239
Figure 106 — DLBD TcIPW Definition (for each Input Pulse)	240
Figure 107 — Output Single-Ended Slew Rate Definition	241
Figure 108 — Differential Output Slew Rate Definition for QnCK_t / QnCK_c and BnCK_t / BnCK_c	243
Figure 109 — VOX Definition (QnCKx and BCK).....	244
Figure 110 — Output Driver: Definition of Voltages and Currents.....	246
Figure 111 — Definition for tstaoff and tdynoff in DDR Mode	252
Figure 112 — Definition for tstaoff and tdynoff in SDR Mode	253
Figure 113 — Clock Output (QxCK) Skew	254
Figure 114 — Example of QCK TX Interconnect.....	254
Figure 115 — Measurement Setup and Test Load for IDD Measurements	257
Figure 116 — Correlation from Simulated Channel IO Power to Actual Channel IO Power Supported by IDD Measurement	257
Figure 117 — AC Measurement I/O Waveform	263
Figure 118 — I2C and I3C Basic AC Input Timing Parameter Definitions	266
Figure 119 — I2C Bus AC Output Timing Parameter Definitions	267
Figure 120 — I3C Basic AC Output Timing Parameter Definitions	267
Figure 121 — Rise and Fall Timing Parameter Definitions.....	267
Figure 122 — Output Slew Rate Measurement Points.....	268
Figure 123 — Test Load for Output Slew Rate and Output Timing Measurement	268

Contents (cont'd)

Figure 124 — I3C Basic Hand-off Operation - RCD Open Drain (ACK) to Controller Push-Pull	268
Figure 125 — I3C Basic Hand-off Operation - Controller Open Drain (ACK) to RCD Push-Pull	269
Figure 126 — I3C Basic T=0 Transition from RCD Read Operation to Controller STOP Bit...	269
Figure 127 — I3C Basic T = 1 Transition from RCD Read Operation Interrupted by Controller Repeated START and STOP Bit.....	270
Figure 128 — Controller Push Pull to Target Open Drain Hand Off Operation.....	271
Figure 129 — Voltage Waveforms, tALERT Measurement.....	272
Figure 130 — Voltage Waveforms, tALERT_HL Measurement.....	272
Figure 131 — Voltage Waveforms, tDCSTM_ALERT_Window, and tDCATM_ALERT_Window Measurements.....	272
Figure 132 — Test Load.....	273

DDR5 REGISTERING CLOCK DRIVER DEFINITION (DDR5RCD03)

(From JEDEC Board Ballot JCB-23-03 formulated under the cognizance of JC-40.4, Registered and Fully Buffered Memory Support Logic, item number 342.98C).

1 Scope

This standard defines standard specifications of DC interface parameters, switching parameters, and test loading for definition of the DDR5 Registering Clock Driver (RCD) with parity for driving address and control nets on DDR5 RDIMM and LRDIMM applications. The DDR5RCD03 Device ID is DID = 0x0053.

The terms ‘Registering Clock Driver’, ‘RCD’, ‘register’, or ‘device’ are used interchangeably to refer to this device in the remainder of this document.

The purpose is to provide a standard for the DDR5RCD03 (see Note) logic device, for uniformity, multiplicity of sources, elimination of confusion, ease of device specification, and ease of use. DDR5RCD03 is backwards compatible with DDR5RCD02 and DDR5RCD01.

NOTE The designation DDR5RCD03 refers to the part designation of a series of commercial logic parts common in the industry. This designation is normally preceded by a series of manufacturer specific characters to make up a complete part designation.

2 Mechanical Outline

Package options include a 240-ball Flip-Chip Fine-Pitch BGA (FCBGA) with 0.60 mm/0.70 mm ball pitch, 14 x 19 grid. The package has a number of depopulated balls. Package size is 8.70 mm x 13.50 mm as defined in MO-330 Issue A, Variation 10013.50x8.70-70x6030-240A¹. The device pinout supports outputs on the top and outer left and right columns to support easy DIMM signal routing. Corresponding inputs are placed in a way to match the corresponding pin location on the connector.

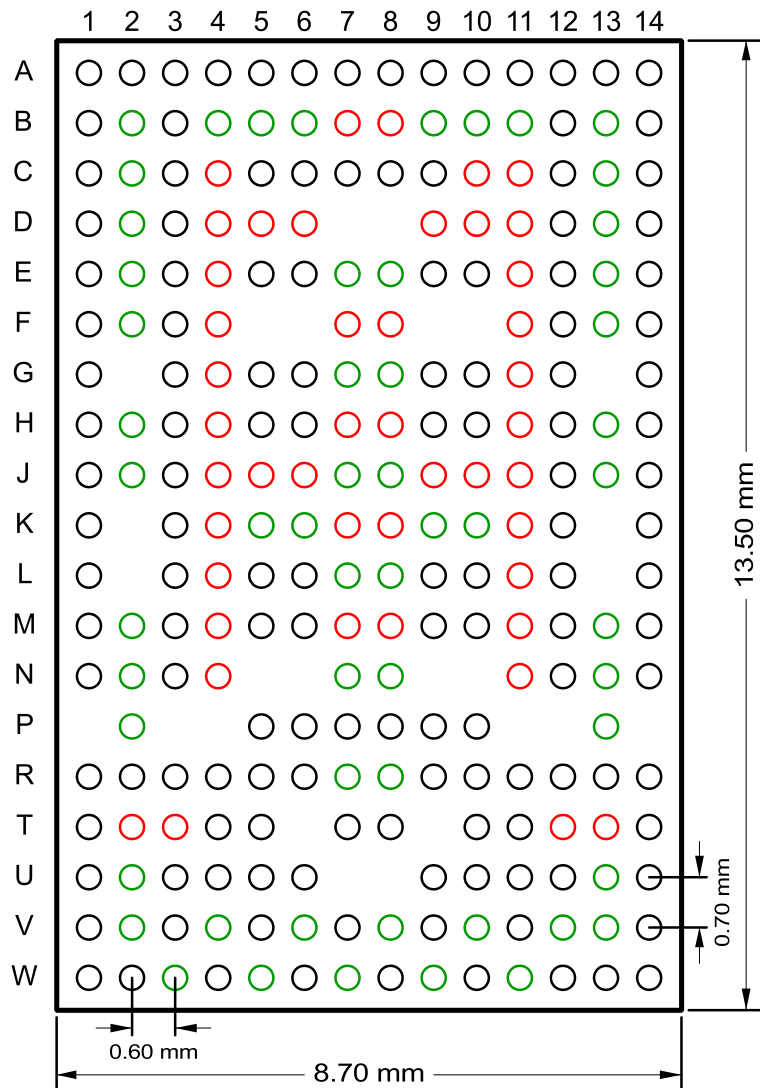


Figure 1 — Ball Configuration, TOP VIEW

Ball pitch: 0.60 mm x 0.70 mm, Size (ø 0.3 mm), SMD Pad SRO (ø 0.275 mm)
X-ray view from top side

1. This variation defines a maximum package thickness of 1.00 mm. The DDR5RCD03 must comply with a minimum thickness of 0.80 mm.

2.1 Pinout

Table 1 specifies the pinout for the DDR5RCD03.

Table 1 — Ball Assignment -240 ball FCBGA, 14 x 19 Grid, TOP VIEW

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
A	NU	QB CA7_A	QB CA3_A	QB CA13_A	QB CA11_A	QB CA12_A	QB CA10_A	QB CA10_B	QB CA12_B	QB CA11_B	QB CA13_B	QB CA3_B	QB CA7_B	NU	A
B	QB CA1_A	V _{SS}	QB CA9_A	V _{SS}	V _{SS}	V _{SS}	V _{DD}	V _{DD}	V _{SS}	V _{SS}	V _{SS}	QB CA9_B	V _{SS}	QB CA1_B	B
C	QB CA6_A	V _{SS}	QB CA8_A	V _{DD}	ZQ CAL	SCL	DERROR _IN_A_n	DERROR _IN_B_n	SDA	V _{DDIO}	V _{DD}	QB CA8_B	V _{SS}	QB CA6_B	C
D	QB CA5_A	V _{SS}	QB CA2_A	V _{DD}	V _{DD}	V _{DD}			V _{DD}	V _{DD}	V _{DD}	QB CA2_B	V _{SS}	QB CA5_B	D
E	QB CA0_A	V _{SS}	QB CA4_A	V _{DD}	QBCK _A_c	QBCK _A_t	V _{SS}	V _{SS}	QBCK _B_t	QBCK _B_c	V _{DD}	QB CA4_B	V _{SS}	QB CA0_B	E
F	QBCS0 _A_n	V _{SS}	QBCS1 _A_n	V _{DD}			V _{DD}	V _{DD}			V _{DD}	QBCS1 _B_n	V _{SS}	QBCS0 _B_n	F
G	QA CA11_A		QA CA13_A	V _{DD}	QDCK _A_c	QDCK _A_t	V _{SS}	V _{SS}	QDCK _B_t	QDCK _B_c	V _{DD}	QA CA13_B		QA CA11_B	G
H	QA CA9_A	V _{SS}	QA CA12_A	V _{DD}	RFU	RFU	V _{DD}	V _{DD}	RFU	RFU	V _{DD}	QA CA12_B	V _{SS}	QA CA9_B	H
J	QA CA10_A	V _{SS}	QA CA3_A	V _{DD}	V _{DD}	V _{DD}	V _{SS}	V _{SS}	V _{DD}	V _{DD}	V _{DD}	QA CA3_B	V _{SS}	QA CA10_B	J
K	QA CA6_A		QA CA7_A	V _{DD}	V _{SS}	V _{SS}	V _{DD}	V _{DD}	V _{SS}	V _{SS}	V _{DD}	QA CA7_B		QA CA6_B	K
L	QA CA1_A		QA CA4_A	V _{DD}	QA CA2_A	QA CA8_A	V _{SS}	V _{SS}	QA CA8_B	QA CA2_B	V _{DD}	QA CA4_B		QA CA1_B	L
M	QA CA5_A	V _{SS}	QA CA0_A	V _{DD}	QACK _A_c	QACK _A_t	V _{DD}	V _{DD}	QACK _B_t	QACK _B_c	V _{DD}	QA CA0_B	V _{SS}	QA CA5_B	M
N	QACS0 _A_n	V _{SS}	QACS1 _A_n	V _{DD}			V _{SS}	V _{SS}			V _{DD}	QACS1 _B_n	V _{SS}	QACS0 _B_n	N
P		V _{SS}			QCCK _A_c	QCCK _A_t	QLBD	QLBS	QCCK _B_t	QCCK _B_c			V _{SS}		P
R	BCS _A_n	BCOM1 _A	BCOM2 _A	BRST _A_n	BCK _A_c	BCK _A_t	V _{SS}	V _{SS}	BCK _B_t	BCK _B_c	BRST _B_n	BCOM2 _B	BCOM1 _B	BCS _B_n	R
T	BCOM0 _A	V _{DD}	V _{DD}	DCS1 _A_n	QRST _A_n		DCK_t	DCK_c		QRST _B_n	DCS0 _B_n	V _{DD}	V _{DD}	BCOM0 _B	T
U	DCA0 _A	V _{SS}	DCS0 _A_n	DLBD_A	DLBS_A	ALERT _n			DRST_n	DLBS_B	DLBD_B	DCS1 _B_n	V _{SS}	DPAR _B	U
V	DCA1 _A	V _{SS}	DCA3 _A	V _{SS}	DPAR _A	V _{SS}	DCA6 _A	V _{SS}	DCA1 _B	V _{SS}	DCA3 _B	V _{SS}	V _{SS}	DCA6 _B	V
W	NU	DCA2 _A	V _{SS}	DCA4 _A	V _{SS}	DCA5 _A	V _{SS}	DCA0 _B	V _{SS}	DCA2 _B	V _{SS}	DCA4 _B	DCA5 _B	NU	W
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	

2.2 Terminal Functions

Table 2 — Terminal Functions

Signal Group	Signal Name	Type	Description
Input Control bus	DCS[1:0]_[B:A]_n	POD V_{REF} based	Chip Select inputs to the RCD. Two inputs per DRAM channel.
Input Address and Command bus	DCA[6:0]_[B:A]	POD V_{REF} based	Command/Address bus inputs to the RCD. Separate sets per channel.
Parity input	DPAR_[B:A]	POD V_{REF} based	Command Address input parity is received on the DPAR pin and should maintain even parity across the CA inputs. DPAR is sampled at the rising and falling edges of the input clock.
Clock inputs	DCK_t/DCK_c	POD differential	Differential system clock input pair to the PLL. The clock is common to both RCD channels, CH_A and CH_B.
Loopback	DLBD_[B:A] DLBS_[B:A]	POD V_{REF} based	Loopback Inputs to RCD DLBD - loopback Data DLBS - loopback Strobe
Reset input	DRST_n	CMOS input	Active LOW asynchronous reset input. When LOW, it causes a reset of the internal latches and disables the outputs, thereby forcing the outputs to float.
Error input	DERROR_IN_[B:A]_n	Low voltage swing POD input	DRAM CRC ALERT_n output is connected to this input pin, which in turn is buffered and redriven to the ALERT_n output of the register. There is a separate signal per channel.
Data buffer control and communication outputs	BCS_[B:A]_n	POD	Data buffer chip selects. Indicate a valid command on the BCOM bus, and used to signal non-target termination. Separate per DRAM channel.
	BCOM[2:0]_[B:A]	POD	Data buffer command. The start of each command is signaled by an active chip select. Separate per DRAM channel.
	BRST_[B:A]_n	CMOS	Re-driven or CMD based reset. This is an asynchronous output. It is the responsibility of the RCD BRST to reset the DDR5 Data Buffer on all DIMM topologies.
	BCK_[B:A]_t BCK_[B:A]_c	POD differential	Differential clock output pair to the data buffer. Separate per DRAM channel.
Output Control bus	Q[B:A]CS[1:0]_[B:A]_n	POD	Chip Select signals to the DRAMs. 2 copies of each signal.
Output Address and Command bus	Q[B:A]CA[13:0]_[B:A]	POD	Command/Address bus outputs to the DRAMs, valid after the specified clock count and immediately following a rising edge of the clock. Two copies of each signal. When Output Inversion is enabled in RW00[5] , Copy B output signals get inverted during all commands other than Deselect. Both copies drive High during idle cycles (i.e., Deselect).
Clock outputs	Q[D:A]CK_[B:A]_t Q[D:A]CK_[B:A]_c	POD differential	Clock outputs to the DRAMs. Four copies per channel.
Loopback	QLBD QLBS	POD	Loopback outputs to Host QLBD - loopback Data QLBS - loopback Strobe
Reset output	QRST_[B:A]_n	CMOS	Re-driven or CMD based reset. This is an asynchronous output. It is the responsibility of the RCD QRST_n to reset the DDR5 SDRAM on all DIMM topologies. The QRST outputs are asserted at power up. RCD requires MRW to independently de-assert to allow staggering of sub-channels.
Error out	ALERT_n	POD	When LOW, this output indicates that a parity error was identified associated with the CA inputs when parity checking is enabled or that the DERROR_IN_n input was asserted, regardless of whether parity checking is enabled or not. One signal for the two channels.
SidebandBus ins ¹	SDA	Open drain or push-pull I/O ²	SidebandBus Data
	SCL	CMOS input ³	SidebandBus Clock
	V _{DDIO}	Power input	SidebandBus power input

Table 2 — Terminal Functions (cont'd)

Signal Group	Signal Name	Type	Description
Miscellaneous pins	V _{DD}	Power Input	Power supply voltage
	V _{SS}	Ground Input	Ground
	ZQCAL	Reference	Reference pin for driver calibration
	NU	Mechanical ball	Do not connect on PCB
	RFU[3:0]	I/O	Reserved for future use pins, must be left floating on DIMM and in RCD
NOTE 1 SA pins are not required for DDR5RCD03 as the address will be hard-coded. Refer to Section 7.5.1 for details.			
NOTE 2 SDA driver operation is dynamic. Depending on the SidebandBus mode of operation (I ² C RW25[5] = '0' or I3C Basic RW25[5] = '1'), and even on the specific step (byte or bit) of a SidebandBus transaction packet, the SDA output driver can operate either in open-drain mode or push-pull mode.			
NOTE 3 These inputs are 1.0 V inputs.			

Naming Convention:

Input Example:

DCAy_N - where 'y' is the signal number and 'N' is the sub-channel.

Output Example:

QxCAy_N - where 'y' is the signal number, 'x' is the output copy (A or B) and 'N' is the sub-channel.

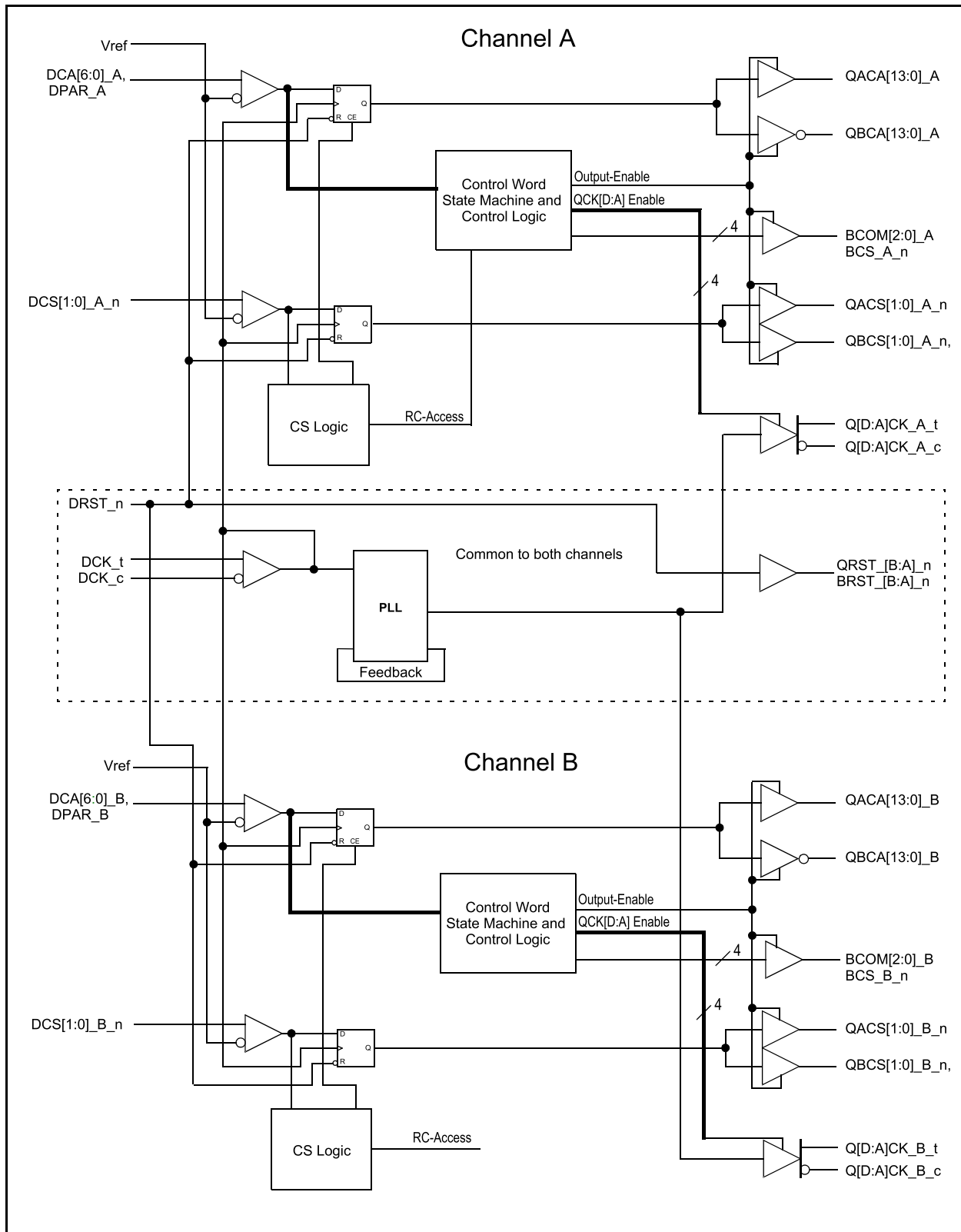
3 Device Standard

3.1 Description

The DDR5RCD03 is a registering clock driver used on DDR5 RDIMMs and LRDIMMs. Its primary function is to buffer the Command/Address (CA) bus, chip selects, and clock between the host controller and the DRAMs. It also creates a BCOM bus which controls the data buffers for LRDIMMs.

It contains two separate channels which have some common logic such as clocking, but otherwise operate independently of each other. Each channel has a 7-bit double data rate CA bus input, a single parity input, two chip select inputs, and produces two copies of 14-bit single data rate CA bus outputs, and two copies of the chip select outputs. The RCD has a common clock input and PLL, but produces separate clock outputs to the DRAM channels.

3.2 Logic Diagram Positive Logic



3.3 Register Operation

3.3.1 Chip Select Operation

The component has two chip select inputs per channel, DCS0_n and DCS1_n, and two copies of each chip select output, QCS0_A_n, QCS1_A_n, QCS0_B_n, and QCS1_B_n. Commands are sent to a single rank or multiple ranks, as determined by the DCS[1:0]_n inputs. The number of input chip selects matches the number of output chip selects in each of the two sets (A-outputs and B-outputs).

Table 3 — DCS - QxCS Mapping

Input CS	Output CS
DCS0_N_n	QxCS0_N_n
DCS1_N_n	QxCS1_N_n

3.3.2 ODT Operation

DDR5 does not have a separate ODT (On Die Termination) signal going to the DIMM or the DRAMs. The ODT control is encoded into the chip selects. All commands that utilize the data bus require 2UI on the DCA bus in order to transfer the appropriate number of command and addressing bits. This requirement is used to signal ODT control by how the chip selects are asserted for the two UI.

Table 4 — ODT Encoding on the Chip Select

DCS_n on 1st UI	DCS_n on 2nd UI	QxCS[1:0]_n	DRAM DQ Terminations
Active	Inactive	Target of command	Read: none (device drives data) Write: RTT_WR.
Active	Active	Non-Target Termination should be applied.	Read: RTT_NOM_RD Write: RTT_NOM_WR
Inactive	Inactive	DRAM ignores commands and the Parked termination will be maintained	RTT_PARK
Inactive	Active	Illegal	Illegal

The host controller will determine the termination at the time of the command, by activating the chip selects appropriately.

3.3.2.1 Data Buffer DQ Bus Termination in LRDIMM Application

The RCD supports DQ bus termination in LRDIMM applications. DDR5 does not have a discrete ODT signal. The ODT function is encoded on the Chip Select for RD, WR, and MRR commands. A RD, WR, MRW, or MRR command will normally have the BCS_n signal active for only the first UI of the command. The data buffers will terminate the host bus as is appropriate for the command (RTT_WR for write, and driving the bus for reads).

3.3.2.1 Data Buffer DQ Bus Termination in LRDIMM Application (cont'd)

The DIMM terminations for DRAM and Data Buffer are shown in Table 5 and Table 6.

Table 5 — DIMM Termination Write

DCS0		DCS1		BCS		DRAM Termination		Buffer Termination
1st UI	2nd UI	1st UI	2nd UI	1st UI	2nd UI	Rank 0	Rank 1	
L	H	H	H	L	H	RTT_WR	RTT_PARK	RTT_WR
L	H	L	L	L	H	RTT_WR	RTT_NOM_WR	RTT_WR
H	H	L	H	L	H	RTT_PARK	RTT_WR	RTT_WR
L	L	L	H	L	H	RTT_NOM_WR	RTT_WR	RTT_WR
L	L	H	H	L	L	RTT_NOM_WR	RTT_PARK	RTT_NOM_WR
H	H	L	L	L	L	RTT_PARK	RTT_NOM_WR	RTT_NOM_WR
L	L	L	L	L	L	RTT_NOM_WR	RTT_NOM_WR	RTT_NOM_WR

Table 6 — DIMM Termination Read

DCS0		DCS1		BCS		DRAM Termination		Buffer Termination
1st UI	2nd UI	1st UI	2nd UI	1st UI	2nd UI	Rank 0	Rank 1	Host-side DQ
L	H	H	H	L	H	Target	RTT_PARK	Target
L	H	L	L	L	H	Target	RTT_NOM_RD	Target
H	H	L	H	L	H	RTT_PARK	Target	Target
L	L	L	H	L	H	RTT_NOM_RD	Target	Target
L	L	H	H	L	L	RTT_NOM_RD	RTT_PARK	RTT_NOM_RD
H	H	L	L	L	L	RTT_PARK	RTT_NOM_RD	RTT_NOM_RD
L	L	L	L	L	L	RTT_NOM_RD	RTT_NOM_RD	RTT_NOM_RD

If the DCS_n signal is active during the 2nd UI of a command, it indicates a non-target termination for the DIMM. The command is targeting a different DIMM and the DRAMs or data buffers should terminate with either RTT_NOM_WR for writes or RTT_NOM_RD for reads.

For a non-target operation, the DRAMs or data buffers should remain in RTT_PARK, the command will not be sent on the BCOM bus at all. The RCD will not have received any DCS_n signals active in this case and will see Deselects.

3.3.3 QCA Bus Operation

Under normal operation, the RCD passes commands through from the D inputs to the Q outputs when a command is present on the bus, and drives HIGH on the QCA outputs when no command is being sent. The RCD passes the DCA bus through when either DCS input is active but there are exceptions to this:

- If the register detects a parity error and parity checking is enabled, the DCA bus is still passed through to DRAM and QCS is blocked.
- During the 2nd UI of a 2 UI command, the DCA bus must be passed through. There will only be a DCS signal active for the 2nd UI if a non-target termination is being signaled to a rank.
- When DRAM interface Block MR Mode is enabled [RW01\[1\]](#) = 0.
- When CA Pass-through mode is enabled [RW00\[2\]](#) = 1.

3.3.4 QCS Operation

Under normal operation the RCD passes the DCS signals through to the QCS outputs. There are several exceptions to this:

- If the register detects a parity error with parity checking enabled, on a one-cycle command or the 1st UI of two-cycle command, the DCS signal is not passed through, and the QCS outputs remain inactive.
- If the register detects a parity error with parity checking enabled, on the 2nd UI of a two-cycle command, the same QCS outputs that were active on the 1st UI will be active on the 2nd UI. This causes the command to be canceled in the DRAM. For read and write commands it causes the command to be converted to non-target termination.
- When DRAM interface Block MR Mode is enabled [RW01\[1\] = 0](#).
- When CA Pass-through mode is enabled [RW00\[2\] = 1](#).

3.3.5 Output Inversion and Mirroring

Output Inversion is enabled by default, after DRST_n is de-asserted, to reduce simultaneous output switching current.

- All QACA[13:0]_[B:A] outputs will follow the equivalent inputs. All QBCA[13:0]_[B:A] outputs will be inverted. In other words, when sending commands, the “B” copy will be the invert of the “A” copy.
- When no commands are being sent, both the “A” and “B” copies will drive HIGH.
- The DRAM devices connected to the “B” outputs will un-invert the signals internally before using them. This eliminates the need for the host controller to send separate MRW commands for the two CA output sets, and allows every CA output to be inverted on the “B” set.

Address mirroring is also handled by the DRAM device, so there is no RCD requirements for mirroring.

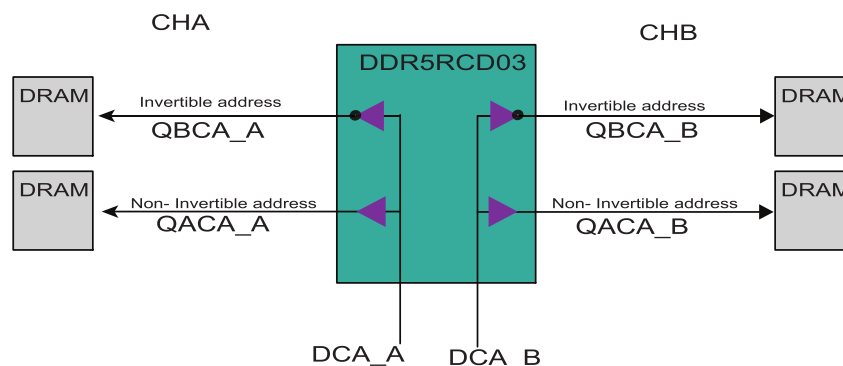


Figure 2 — RCD Output Inversion

3.3.6 ZQ Calibration

The RCD snoops the MPC command to initiate ZQ Calibration, which calibrates the output driver impedance across process, temperature, and voltage. ZQ Calibration occurs in the background of device operation.

There are two ZQ Calibration commands initiated with the MPC command: ZQCal Start, and ZQCal Latch. ZQCal Start initiates the RCD's calibration procedure, and ZQCal Latch captures the result and loads it into the RCD's drivers.

3.3.6 ZQ Calibration (cont'd)

A ZQCal Start command may be issued anytime the DDR5 SDRAM is not in a power-down state. There are two timing parameters associated with ZQ Calibration. t_{ZQCAL} is the time from when the ZQCal Start MPC command is sent to when the host can send the ZQCal Latch MPC command. t_{ZQLAT} is the time from when the ZQCal Latch MPC command is sent by the host to when the CA bus (and subsequently the DQ bus) can be used for normal operation. A ZQCal Latch Command may be issued anytime outside of power-down after t_{ZQCAL} has expired and all CA bus operations have completed. The CA Bus must maintain a Deselect state during t_{ZQLAT} to allow CA ODT calibration settings to be updated.

ZQCal commands are issued independently on a sub-channel level. After a ZQCal Start and until t_{ZQCAL} finishes, neither another ZQCal Start nor a ZQCal Latch is allowed on this same sub-channel.

To use the ZQ calibration function, a $240\ \Omega \pm 1\%$ tolerance external resistor must be connected between the ZQ pin and VSS.

3.3.7 Latency Equalization Support

3D Stacked SDRAMs have a higher CAS latency than monolithic devices. For greater platform flexibility, it is highly desirable to mix DIMMs with both 3DS and mono SDRAMs on the same DDR5 channel. Since memory controllers typically can only handle devices with equal CAS latencies in the same channel, it is required that the DDR5 register has a mechanism to increase the CAS latency of mono SDRAMs to match the CAS latency of 3DS SDRAMs. However, this mechanism only equalizes the DRAM latencies, not the total DIMM latencies. Hence, this DDR5 register mechanism does not by itself allow mixing DDR5 RDIMMs and LRDIMMs in the same channel.

To equalize different SDRAM latencies, the DDR5 register supports a programmable latency adder of 0 nCK, 1 nCK, 2 nCK, 3 nCK, or 4 nCK for all DRAM commands—see conceptual diagram in Figure 3. The power-up default is 0 nCK latency adder.

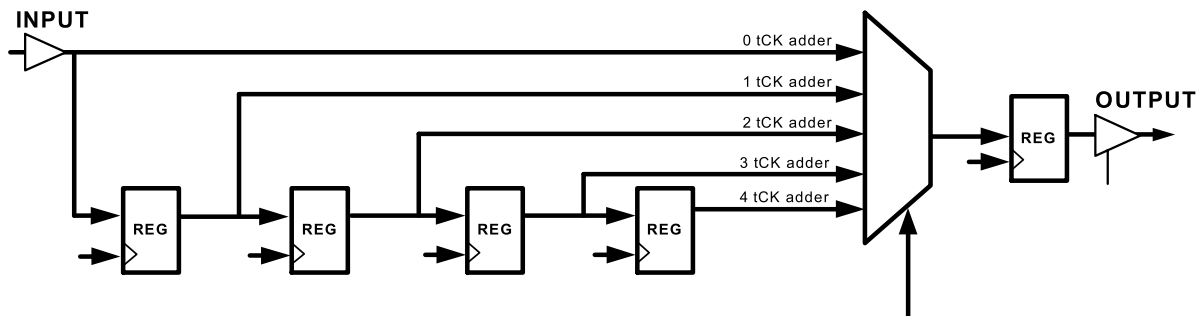


Figure 3 — Latency Equalizer Delays

With a latency adder enabled, the DDR5 register will delay assertion of the $QxCSy_N_n$ and $QxCy_N$ outputs by the corresponding number of clock cycles. The output timing is determined by the Command Latency Adder control word [RW11](#) regardless of whether the device has parity checking enabled or disabled.

3.3.8 Per-group Output Delay Control

The RCD supports output delay control for output signal groups defined and located in [RW12](#) to [RW1E](#). The output delay settings are incremental CK fractions of $1/64$ tCK. Each signal group can be enabled or disabled independently through RCD Control Words. The Host must wait t_{ODU} after the Output Delay Control Word has been written to a signal group before the output becomes stable.

3.3.8 Per-group Output Delay Control (cont'd)

The output delay feature controlled by [RW12](#) to [RW1E](#) is not supported when the RCD is configured in Test Frequency mode (Band 2, [RW05\[7\]](#) = 1) or in PLL bypass mode ([RW05\[3:0\]](#) = 1111).

3.3.9 Per-bit QCA Output Delay Control

In DDR5RCD03, fine adjustment of the phase of individual QCA bit lanes relative to QCK is required. For this purpose, the host controller can utilize the per-bit QCA output delay control words in [PG\[5\]RW\[7B:60\]](#) to control the phase of A-copy and B-copy QCA bits respectively. Since all bits within a copy are generally aligned by routing, only a small range of [0, 40 ps] is provided for fine-grained adjustment of individual bit lane delay differences. A positive delay in these control words means that the particular lane requires slightly more delay than the previously established QCA delay in [RW1B](#) and [RW1C](#) for the entire copy.

3.3.10 Power Down Operation

DDR5 does not have a separate CKE signal going to the DIMM or the DRAMs. Power Down Entry, including Self Refresh, is signaled via a single UI command. Following the Power Down Entry command, the CS signal effectively becomes the equivalent of the CKE signal. An inactive CS keeps the DRAM devices in the Power Down state. CS going active will take the DRAMs out of the Power Down state. A NOP command is placed on the CA bus along with CS going active so that no commands are executed by the DRAM devices. DRAMs can be put in Power Down mode with or without non-target ODT control, see Chapter 4.

3.3.11 VHost Mode

The Virtual Host mode or “VHost mode” allows a sequence of commands to be sent on the DRAM interface without receiving commands via the host interface. Commands to be sent on the DRAM interface are programmed by writing RCD control words. The intention is to operate this RCD feature via SidebandBus in a test environment. VHost mode is not intended for normal operation. A sequence of commands is programmed into the RCD, then executed by writing a START MRW bit.

Virtual host mode has the following features:

- Up to 4 commands may be programmed.
- Each command may be a 1 or 2 UI command.
- Control words specify the complete CA[13:0] bus and the two chip selects for each UI of the commands.
- There is a programmable number of clocks between commands, programmed separately for the spacing between each command.
- Command spacing can be 2, 4, 8, 16, 64, 256, or 1024 clock.
- Following the last command, the sequence may then optionally repeat starting at command 0, 1, 2, or 3.
- Shorter sequences can be supported by programming Deselects (neither chip select active) for some of the commands.
- Non-target termination can be signaled by programming the chip select to be active for both UI of a command that supports non-target termination.

Each command is programmed using four 8-bit control words, to specify the state of CA[13:0], CS0_n, and CS1_n for each of the 2 UI. For a 1UI command, the 2nd UI is programmed as a Deselect, with both chip selects inactive. Note that two back to back one UI commands can be programmed instead of a 2UI command, but these will always be back to back, with no programmable spacing.

There are four three-bit delay fields to specify the delay between commands 0 and 1, commands 1 and 2, commands 2 and 3, and command 3 to start of the repeat sequence.

3.3.11 VHost Mode (cont'd)

Following the execution of command 3, the sequence will optionally repeat. The sequence can repeat starting at any command (0 through 3) and will continue again through command 3.

16 control words specify the four commands (4 registers each). Two registers specify the gap between commands. One register specifies the command to repeat from and enables repeating. One register contains a start bit for each channel. Writing a 1 to a start bit begins the sequence on that channel. Writing a 0 stops the sequence. The sequencer is common to the two channels, so the sequence cannot be started on the two channels at different times. The commands operate in either 1N or 2N mode as specified by the existing 1N/2N mode bit. VHost Commands are sent across the BCOM bus to the data buffers. VHost is not supported during SRE/PDE/Initialization or when any training mode is enabled. The commands processed by the VHost logic are not interpreted by the RCD. For example, if the programmed commands include PDE or SRE, those commands will be sent to the DRAMs but they will not cause the RCD to power down. VHost settings can-not be modified while the VHost state machine is running. The RCD will auto stop after cmd3 executes if repeat is not enabled. RST, DCK signals must be applied on the host interface during VHost mode.

3.3.11.1 VHost Lockout Mode

When the RCD receives an In-band MRW to [RW01](#) the RCD will Lockout the VHost mode until the next DRST_n assertion. SMBus sideband write to RW01 will not trigger the lockout mechanism.

Suppliers must guarantee a permanent lock out with a fuse option.

3.3.12 Transparent Mode

The DDR5RCD03 supports a transparent mode feature of the data buffer that enables testing of LRDIMMs. The RCD will disable parity checking automatically when this mode is entered.

To enter transparent mode, the host first sends an MRW command with [RW82\[0\]](#) = 1 to enable transparent mode in the DDR5DB03. Then it sends an MRW command with [RW00\[7\]](#) = 1 to enable transparent mode in the RCD.

While in transparent mode, the DDR5DB03 does not interpret BCS_n and BCOM commands. For BCS_n input value of “1” and BCOM[2:0] input values of “111”, it directs the data flow from host interface to DRAM interface. For BCS_n input value of “1” and BCOM[2:0] input values of “000”, it directs the data flow from DRAM interface to host interface. Any other input values of BCS_n and BCOM[2:0] are invalid.

While in transparent mode, the RCD drives BCS_n statically to “1” and BCOM[2:0] statically to “111” (DES) when the DPAR input is LOW, and BCS_n to “1” and BCOM[2:0] to “000” when the DPAR input is HIGH. All output signals in the RCD, other than BCS_n and BCOM[2:0], continue working as they do in the normal mode of operation. In other words, all the RCD features and functions not directly related to DPAR, BCS_n and BCOM[2:0] remain operational in transparent mode. In addition, all the clock frequencies and PLL operational modes available in low-speed test mode and normal operation mode will be supported in transparent mode. Input DPAR_A controls outputs BCOM[2:0]_A and input DPAR_B controls outputs BCOM[2:0]_B, correspondingly.

To exit transparent mode, the host sends an MRW command with [RW00\[7\]](#) = 0 to exit RCD transparent mode following by issuing a Data Buffer reset command via [RW04](#) to exit DDR5DB03 transparent mode.

3.3.13 CA Validation Pass-Through Mode

To facilitate DRAM or RCD validation, the RCD will be required to support a validation pass-through mode. In this mode, the DCA signals are passed through to QCA, regardless of DCS assertion. In this mode, the DCS0_n and DCS1_n signals are passed through to QCS0_n and QCS1_n respectively, regardless of DCA signal state. Parity checking must be disabled prior to and during validation pass-through mode. Validation pass-through mode is entered when [RW07\[4\]](#)=1. When [RW07\[5\]](#)=1 in CA Validation Pass-through mode, all MRW which write to the RCD are blocked and further configuration is expected via the SMBus. This SMBus is not required to be driven by the controller.

3.3.13 CA Validation Pass-Through Mode (cont'd)

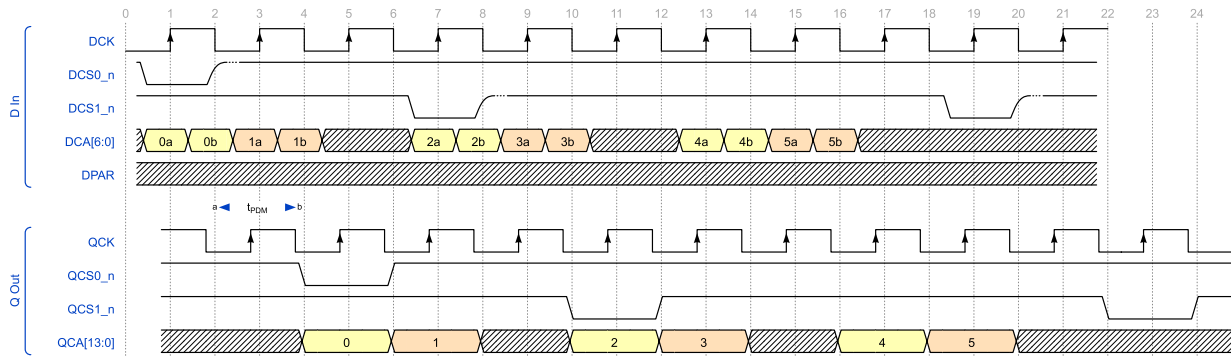


Figure 4 — Validation Pass-Through Mode - DDR

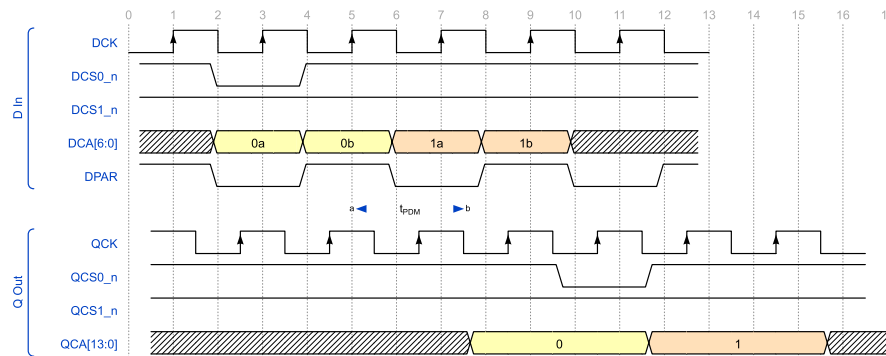


Figure 5 — Validation Pass-Through Mode - SDR1

Similar to CA Pass-Through Mode described in Section 5.2.4, when Validation Pass-Through Mode is enabled in SDR Mode, the DPAR signal will be used to indicate 1st UI QCA[6:0] (DPAR = LOW) and 2nd UI QCA[13:7] (DPAR = HIGH).

3.3.14 DRAM Interface and Data Buffer Interface Training Support

In order for the Host to train the DRAM and Data Buffer interfaces, the RCD will support two Pass Through modes: CA Pass-Through mode, described in Section 5.2.4, and BCOM Pass-Through mode, described in Section 5.2.6.

3.4 Command Address Bus

The DDR5RCD03 can support two data rates on the Host Command Address signals. The first setting is Double Data Rate (DDR) on the DCA with 1N timing on the QCA. The second is Single Data Rate (SDR) on DCA with 2N timing on the QCA to the DRAM interface. Chip Select is SDR for both settings on DCA and QCA.

Table 7 — Command Address Rates

RW00[1:0]	DCA	QCA
00	SDR1	2N timing (extra setup time)
01	DDR	1N timing
10	SDR2	2N timing (extra hold time)

3.4.1 Double Data Rate DCA

The DDR5 RCD will support DDR (Double Data Rate) on the host-interface DCA signals. The host-interface CA bus is 7 bits, plus parity. The DRAM-interface CA bus remains SDR (Single Data Rate) and is 14 bits and without parity. The RCD will expand the incoming host-interface 7-bit DCA bus to 14 bits on the DRAM interface. Table 8 shows the mapping of the incoming DCA bits to the output QCA. The Chip Selects remain SDR on both the host-interface and DRAM interface. The two channel DDR5RCD has six CA ports, two DCA input ports and four QCA output ports as shown in Figure 6.

Table 8 — DDR CA Mapping DCA to QCA

UI	DCA0	DCA1	DCA2	DCA3	DCA4	DCA5	DCA6
0	QCA0	QCA1	QCA2	QCA3	QCA4	QCA5	QCA6
1	QCA7	QCA8	QCA9	QCA10	QCA11	QCA12	QCA13

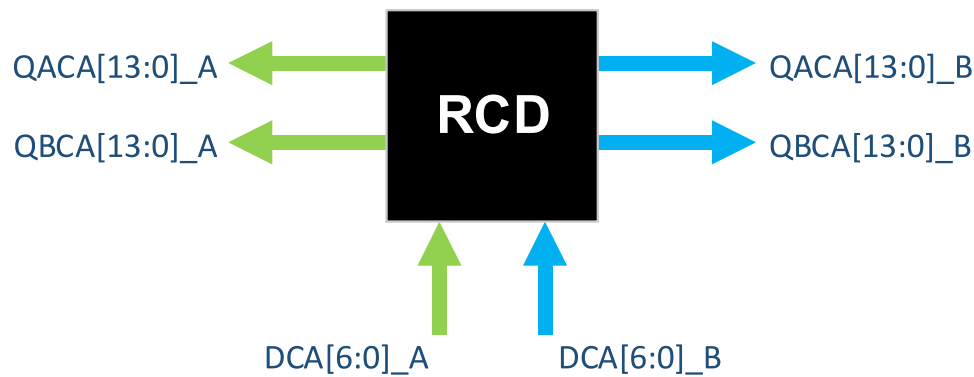
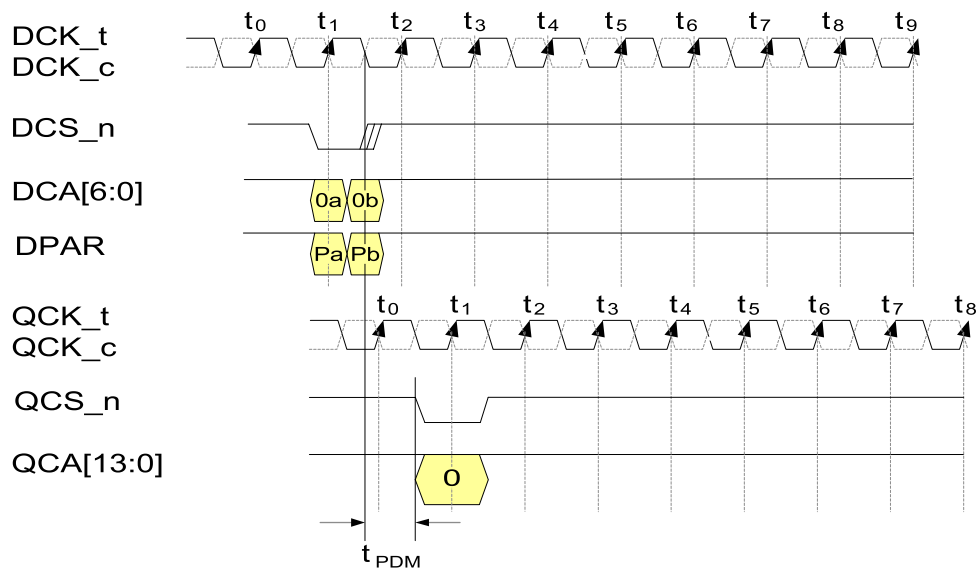


Figure 6 — RCD DCA and QCA Ports

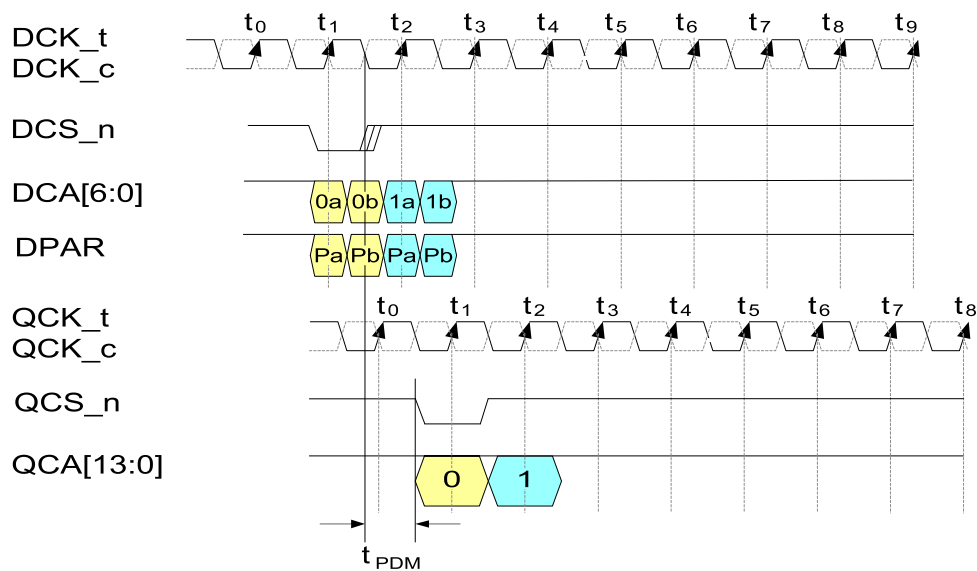
The timing diagrams in Figures 7, 8, and 9 show the timing relationship from the Dn inputs to the Qn outputs for a 1UI command, a 2UI command, and multiple commands.

3.4.1 Double Data Rate DCA (cont'd)



NOTE Timing Diagram for 0 nCK command latency adder.

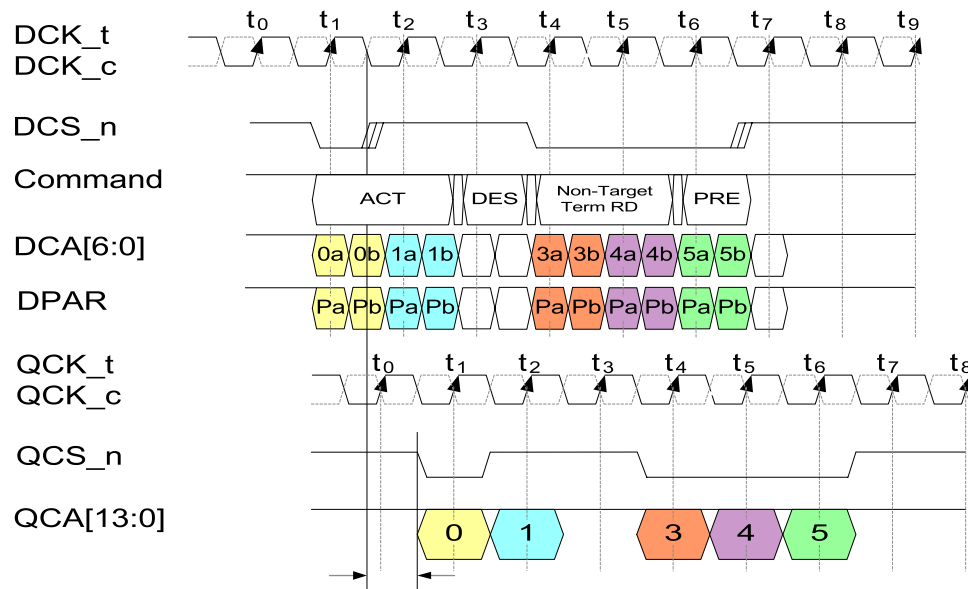
Figure 7 — One UI DRAM Command Timing Diagram



NOTE Timing Diagram for 0 nCK command latency adder.

Figure 8 — Two UI DRAM Command Timing Diagram

3.4.1 Double Data Rate DCA (cont'd)



NOTE Timing Diagram for 0 nCK command latency adder.

Figure 9 — DDR CA Multi-Command Timing Diagram Example

The DCS_n signal is SDR and is sampled by the RCD on the rising edge of DCK. See Section 13.11 for details on DCS input receiver electrical and timing parameters. The DDR5RCD must maintain output timings to the DRAM and comply with the output tolerance skew parameter t_{QSK} as shown in Figure 10.

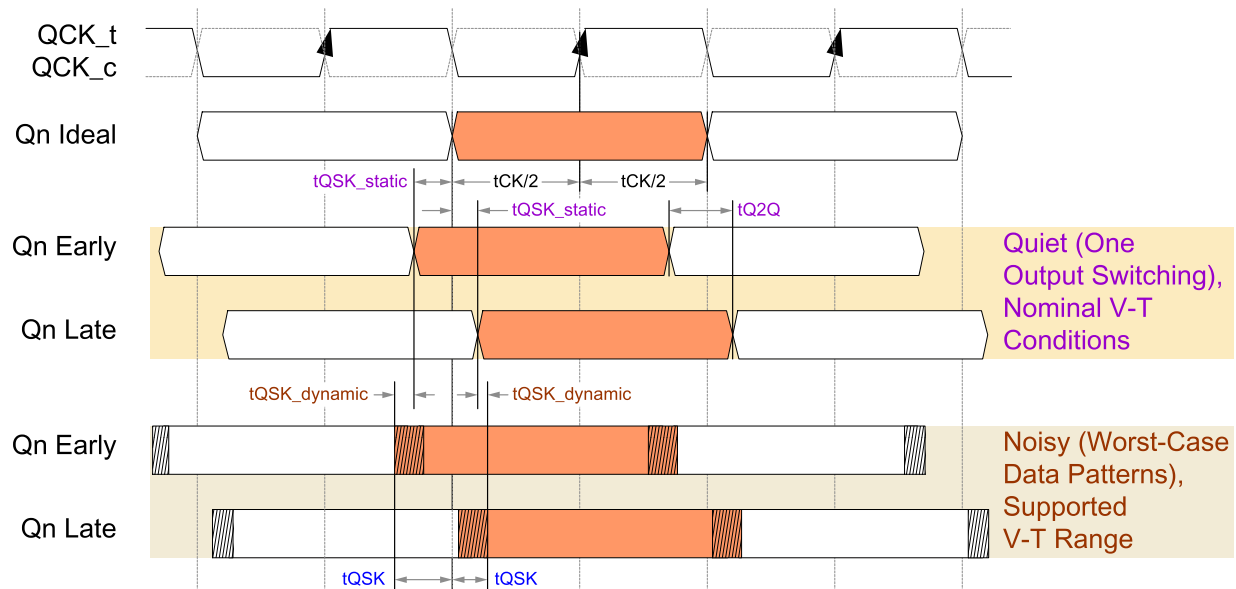


Figure 10 — Qn Output Skew

NOTE For Figure 10 outputs as specified in Table 205, “Output Timing Requirements1” Note 7.

3.4.2 Single Data Rate DCA

The DDR5RCD03 will support SDR (Single Data Rate) on the host-interface DCA signals. In this case, the RCD will apply 2N timing to the DRAM interface signals. This allows more setup or more hold time on the QCA bus. This mode is enabled when [RW00\[0\] = 0](#). DDR5 has defined two-cycle commands that require the RCD to capture the commands differently between DDR and SDR modes. In both modes, the first half of the command is sampled on the rising edge of clock when the chip select is active. In SDR mode, the second half of the command is sampled on the next rising clock edge. Non-target ODT signaling (through chip select inputs) is also delayed by a clock in SDR mode. For applications that require SDR on the Host interface but do not need extra setup time on the DRAM interface, QCS pulses can be pulled earlier by one clock cycle by setting [RW00\[1\] = 1](#).

The QCA will follow the DRAM specification for 2N mode.

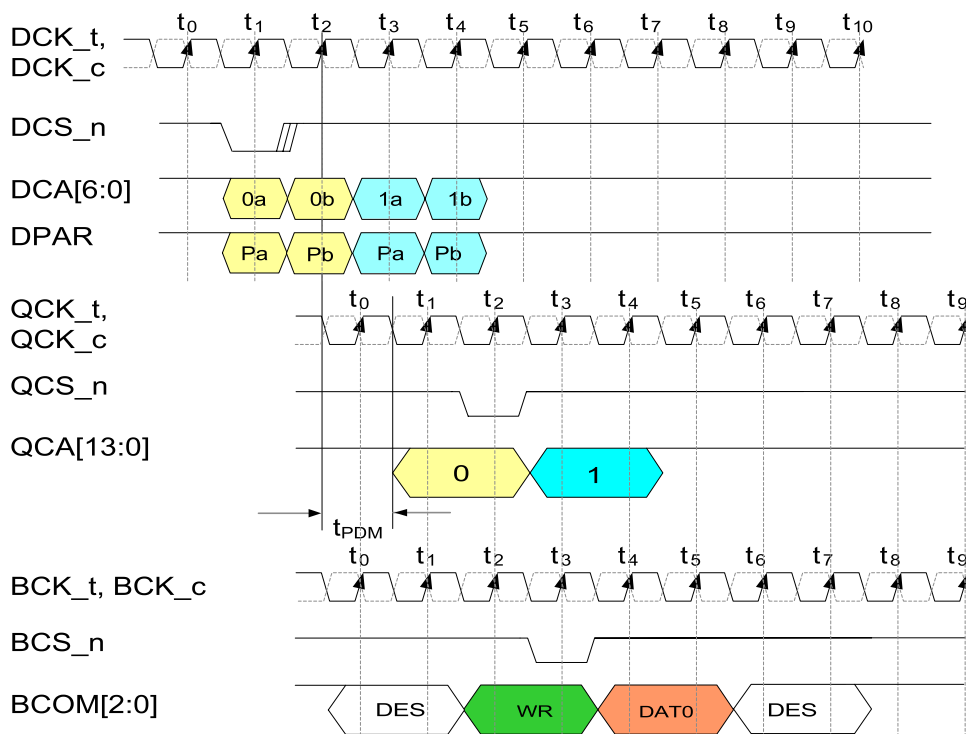


Figure 11 — SDR1 Mode Example of DRAM WR Command with [RW00\[1\] = 0](#)

3.4.2 Single Data Rate DCA (cont'd)

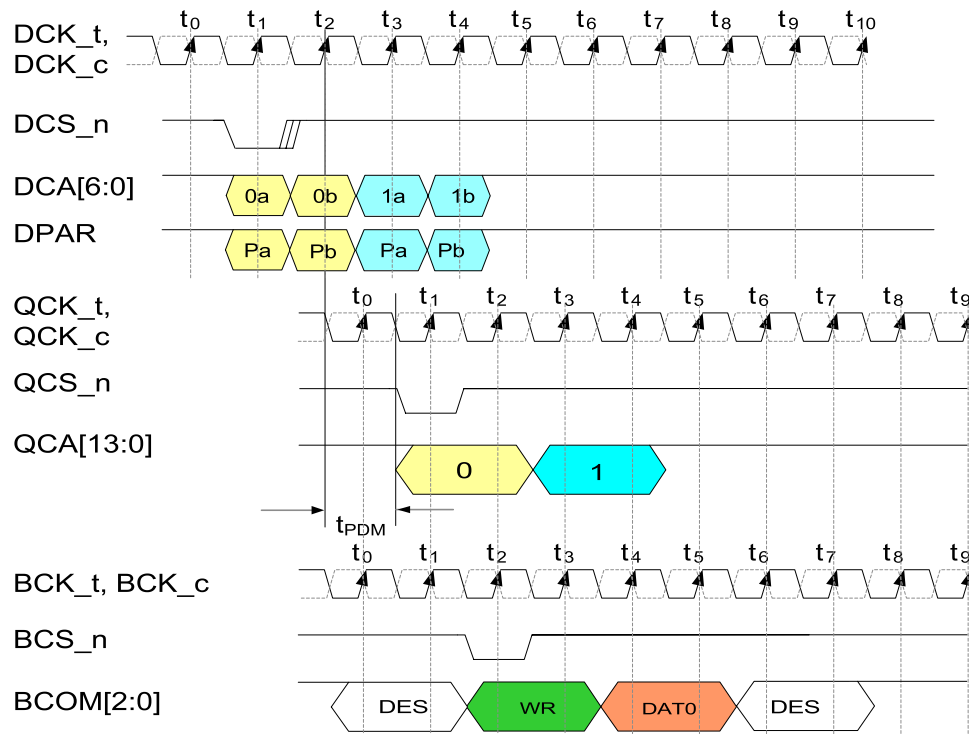


Figure 12 — SDR2 Mode Example of DRAM WR Command with $RW00[1] = 1$

3.4.3 SDR to DDR Transition

This mode will be set through SMBus during initialization between t_{STAB01} and t_{STAB02} , or after t_{STAB01} following Exit from Self Refresh Mode with Clock Stop (see Section 4.2.2). There is no transition during normal operation. Transitions for SDR to DDR or SDR1 to SDR2 occur prior to Host Interface Training.

3.5 Parity

The Parity function in DDR5 differs from DDR4 in several ways

- The parity signal is received on the same cycle as the command/address bits rather than one cycle later.
- 2UI DRAM commands require a different protocol to block commands when the parity error is on the 2nd UI.
- No parity signal is sent on to the DRAMs.

The convention of parity is even parity across the $DCA_N[6:0]$ and $DPAR_N$ signals. The Parity is checked separately per UI on the DCA bus.

Parity is checked separately on the two sub channels. A parity error on one sub channel does not affect the operation of the other sub channel.

When DDR Command Address Rate is selected, $RW00[0] = 1$, $ALERT_n$ will be asserted three or four input clocks after rising edge of first UI of DCA in which the erroneous command is registered.

In SDR mode, $RW00[0] = 0$, $ALERT_n$ will be asserted three or four input clocks after the rising edge corresponding to the second half of the erroneous command. This is the case regardless of the error being in the first, second or both halves.

3.5 Parity (cont'd)

If parity checking is disabled, the register forwards sampled commands to the outputs unconditionally, the command appears on the outputs regardless of whether a parity error occurred or not.

For single and 2 UI DRAM commands, if parity checking is enabled and there is no parity error, the register will forward the sampled commands to the outputs.

3.5.1 Single UI DRAM commands with Parity Enabled

For single UI DRAM commands, if parity checking is enabled and a parity error is detected on either UI of the DCA bus, the register will forward the command on QCA bus but will not assert any chip select to output.

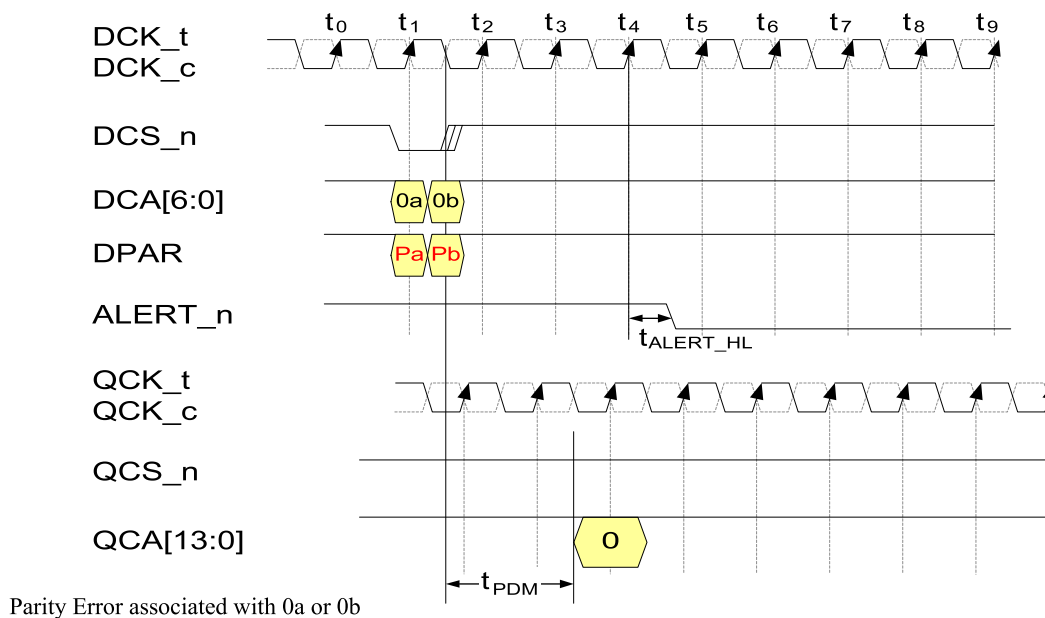


Figure 13 — 1 UI DRAM Command with Parity Checking Enabled and CLA = 0

3.5.1 Single UI DRAM commands with Parity Enabled (cont'd)

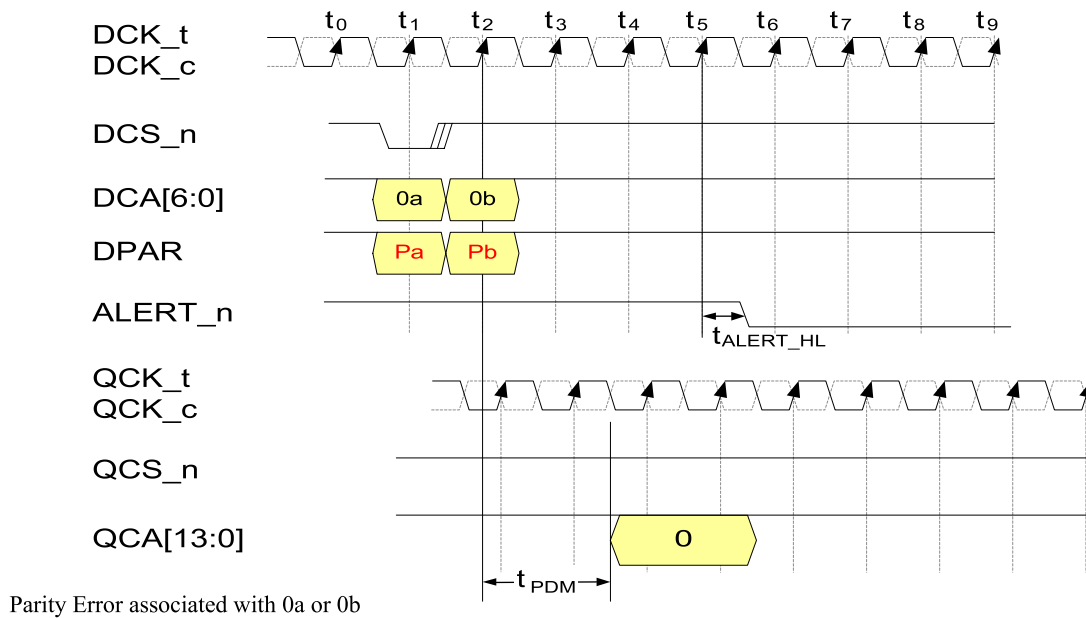
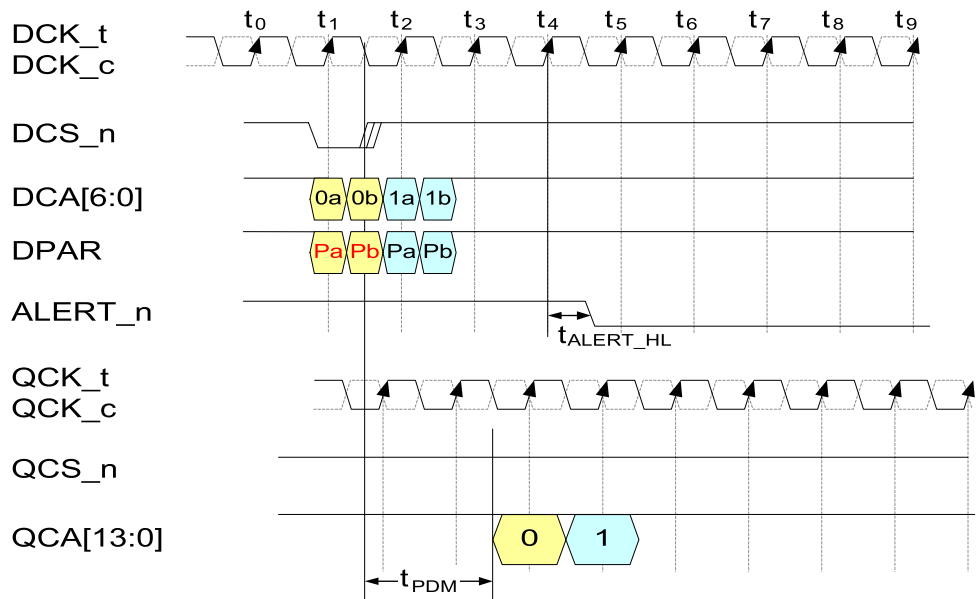


Figure 14 — SDR Mode 1 UI DRAM Command with Parity Checking Enabled and CLA = 0

3.5.2 2UI DRAM Commands with Parity Enabled

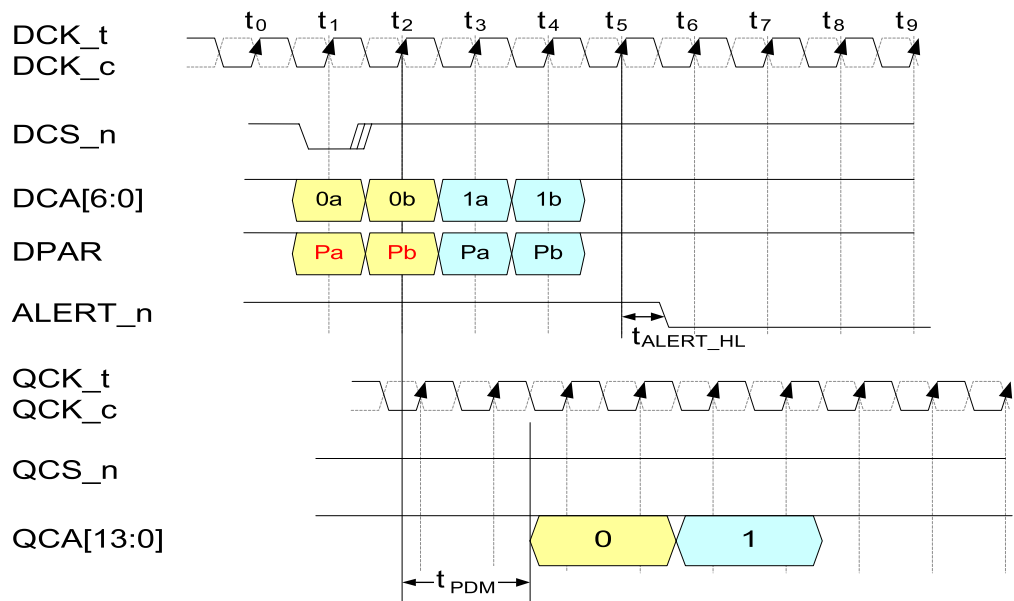
For 2UI DRAM commands, if parity checking is enabled and a parity error is detected on either UI of the DCA bus for the 1st UI of the DRAM command the register will forward the command on the QCA but will not assert any chip select output as shown in Figure 15.

3.5.2 2UI DRAM Commands with Parity Enabled (cont'd)



Parity Error associated with 0a or 0b

Figure 15 — Error in 1st UI of 2 UI DRAM Command with Parity Checking Enabled



Parity Error associated with 0a or 0b

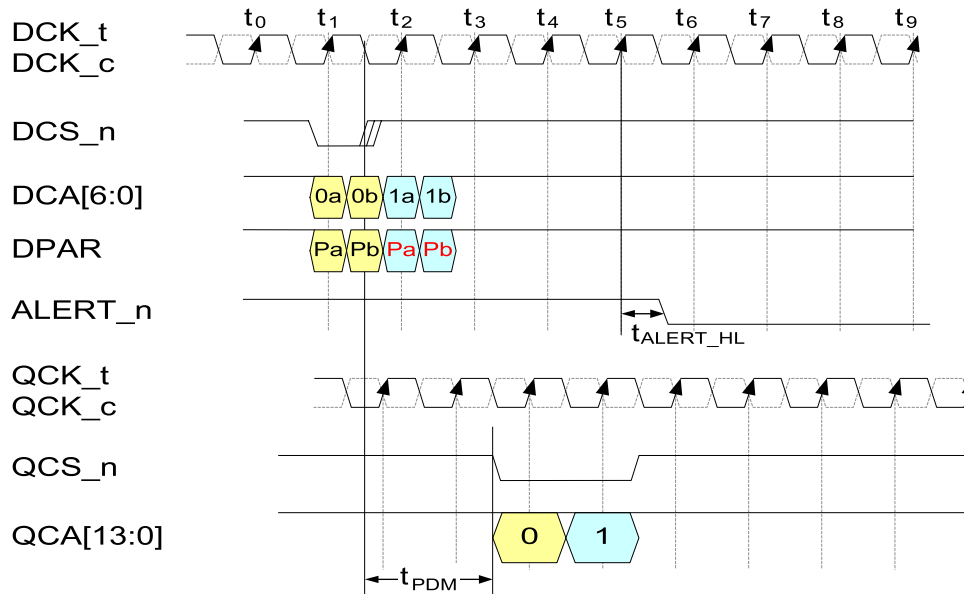
Figure 16 — SDR Mode Error in 1st UI of 2 UI DRAM Command with Parity Checking Enabled

3.5.2 2UI DRAM Commands with Parity Enabled (cont'd)

For 2UI DRAM commands, if the parity error occurs in either UI of the DCA bus for the 2nd UI of the DRAM command and the 1st had correct parity, the command will have already been sent to the DRAMs. In this case the command itself will be known to be correct, but the additional address information contained in the 2nd UI will be incorrect. In order to prevent the command from being executed by the DRAM the RCD will assert the chip select in the 2nd UI also for all ranks which received a chip select in the 1st UI as shown in Figure 17.

For RD, WR, and MRR commands this will convert the command to a non-target termination encoding. All ranks receiving the chip select will terminate for this command, but no rank will execute the command.

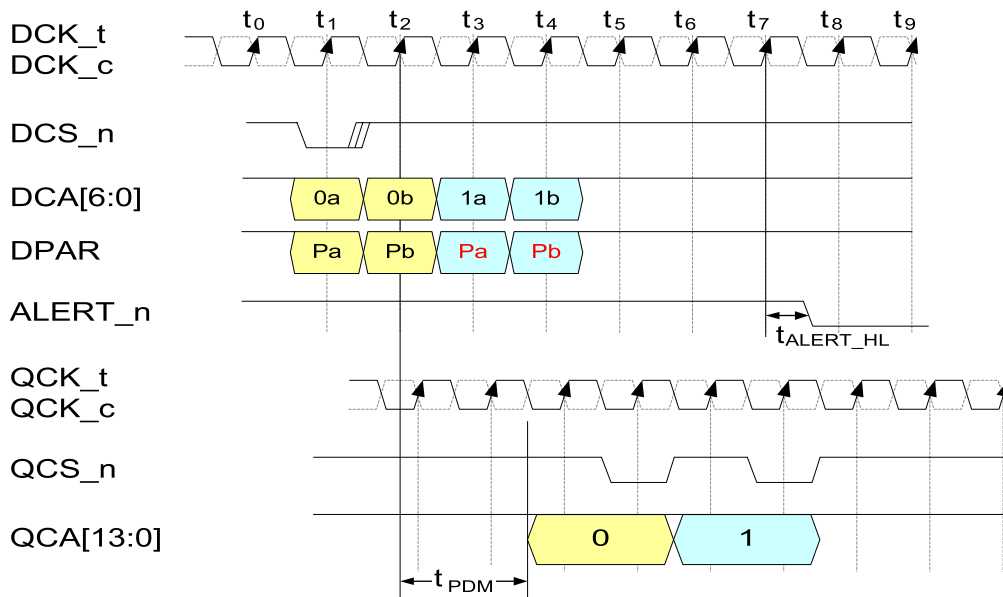
The only other 2 UI DRAM commands are the Activate, MRW, and Write Pattern commands. A DRAM seeing the chip select active for both UI of an Activate or Write Pattern command will ignore the command. Note that an MRW command will not use the data bus. The DRAM will not execute the MRW command if the chip select is asserted in both UI.



Parity Error associated with 1a or 1b

Figure 17 — Error in 2nd UI of 2 UI DRAM Command with Parity Checking Enabled

3.5.2 2UI DRAM Commands with Parity Enabled (cont'd)



Parity Error associated with 1a or 1b

Figure 18 — SDR1 Mode Error in 2nd UI of 2 UI DRAM Command with Parity Checking Enabled

If a parity error occurs on the 1st UI of a DRAM command, regardless of the command length, the command encoding itself may be corrupt. The register will be required to block all future commands until command forwarding is re-enabled. When commands are re-enabled, the register must not enable commands until it sees a UI with all CS inactive in order to avoid re-enabling in the middle of a command.

Table 9 — Blocking Commands on Parity Error

Parity Error on 1st DRAM UI	Parity Error on 2nd DRAM UI	Outputs
No	No	Command is forward to DRAM
No	Yes	First UI of command forward to DRAM. 2 nd UI of command forward to DRAM, but with QCS asserted on ALL ranks which received a DCS on the 1st UI. Future commands not sent until parity checking is re-enabled.
Yes	Yes or No	First UI and Second UI of the command forward to DRAM but QCS is not asserted. Future commands not sent until parity checking is re-enabled.

3.5.3 ALERT_n Assertion

The behavior of ALERT_n with parity checking disabled is the same as when parity checking is enabled with the exception that ALERT_n is never asserted as result of a CA parity error. However, when parity checking is disabled, ALERT_n can still be asserted as a result of an assertion of the DERROR_IN_n input.

After the RCD receives DPAR_N from the memory controller, it compares it with the data received on the CA inputs and indicates on its open-drain ALERT_n pin (active LOW) whether a parity error has occurred. The computation only takes place for data which is qualified by at least one of the DCS[1:0]_n signals being Active, or the 2nd UI of a 2UI DRAM Command.

3.5.3 ALERT_n Assertion (cont'd)

The convention of parity is even parity across the DCA and DPAR signals. Parity is checked independently for the two channels.

If a parity error occurs and parity checking is enabled in [RW01](#), the RCD sets the 'CA Parity Error Status' bit in [RW24](#) to '1' and disables parity checking. ALERT_n is asserted three or four input clocks after the erroneous command is registered.

If the 'CA Parity Error Status' bit is '0', the RCD logs the error by storing the erroneous command and address bits in the Error Log Register. ALERT_n stays asserted LOW until a 'Clear CA Parity Error Status' command is sent if the 'ALERT_n Assertion' bit in the Parity Control Word [RW01](#) is '0'. In this case the erroneous command and all subsequent commands are not forwarded (i.e., QxCsy_N_n are not asserted) to the DRAM until the memory controller issues a 'Clear CA Parity Error' command, which will also clear the 'CA Parity Error Status' bit in the Error Log Register.

If the 'ALERT_n Assertion' bit is '1', the ALERT_n pulse width is as defined in Table on page 139 with start of the ALERT_n pulse width counted from the third or fourth input clock edge after the 1st parity error. The erroneous command and all subsequent commands are not forwarded (i.e. QxCsy_N_n are not asserted) to the DRAM until the end of the ALERT_n pulse width. After the ALERT_n pulse, the device will automatically resume forwarding commands to the DRAM.

- If the 'ALERT_n Re-enable' bit is '0', parity checking remains disabled until a 'Clear CA Parity Error' command is sent, which will also clear the 'CA Parity Error Status' bit in the Error Log Register.
- If the 'ALERT_n Re-enable' bit is '1', the device will re-enable parity checking after the ALERT_n pulse. The 'CA Parity Error Status' bit will remain set. If a subsequent parity error is detected, the device will re-enter the parity error state and set the '> 1 Error' bit. The other bits in the Error Log Register are not updated on this subsequent error. Both the 'CA Parity Error Status' bit as well as the '> 1 Error' bit will be cleared by sending a 'Clear CA Parity Error' command.

3.6 DCA Decision Feedback Equalization

Since the DCA will be Double Data Rate the RCD will support a 6 Tap DFE on the DCA host-interface receivers. The 6-tap DFE subsystem consists of a gain amplifier, a DFE summer, 6 CA slicers (also called Taps) with outputs that loop back to the DFE summer, and a coefficient multiplier for each Tap. The gain control of the front end is used to ensure that the cursor or the current bit is in a congruent relationship with the ISI correction required for the channel. The taps C1, C2, C3, C4, C5, and C6 coefficients provide the corrections needed to the current bit by adding or subtracting the effects of ISI of the previous bits. The host can enable 1, 2, 3, 4, 5, or 6 taps in a consecutive order always starting with Tap 1 as shown in Table 10, "DFE Tap Configurations". DFE input gain adjustment and DFE Tap Coefficients 1 through 6 are set by control words located in PG[1:0]. These DFE control words allow programming of each parameter on a DCA I/O-specific basis, and they are intended to be trained by the host. The DDR5RCD03 device does not support adaptive DFE, and it only supports DFE when its DCA host interface is configured in DDR mode (i.e., [RW00\[0\]](#) = 1).

3.6.1 DFE Tap Configurations

Table 10 — DFE Tap Configurations

RW31 OP4	RW31 OP5	RW31 OP6	RW31 OP7	RW33 OP6	RW33 OP7	Tap 1	Tap 2	Tap 3	Tap 4	Tap 5	Tap 6
0	x	x	x	x	x	Disabled	Disabled ¹	Disabled ¹	Disabled ¹	Disabled ¹	Disabled ¹
1	0	x	x	x	x	Enabled	Disabled	Disabled ²	Disabled ²	Disabled ²	Disabled ²
1	1	0	x	x	x	Enabled	Enabled	Disabled	Disabled ³	Disabled ³	Disabled ³
1	1	1	0	x	x	Enabled	Enabled	Enabled	Disabled	Disabled ⁴	Disabled ⁴
1	1	1	1	0	x	Enabled	Enabled	Enabled	Enabled	Disabled	Disabled ⁵
1	1	1	1	1	0	Enabled	Enabled	Enabled	Enabled	Enabled	Disabled
1	1	1	1	1	1	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled

NOTE 1 DDR5RCD03 hardware disabled when RW31[4] = 0 and {RW31[7:5], RW33[7:6]} are don't care and ignored by the RCD.
NOTE 2 DDR5RCD03 hardware disabled when RW31[5] = 0 and {RW31[7:6], RW33[7:6]} are don't care and ignored by the RCD.
NOTE 3 DDR5RCD03 Hardware disabled when RW31[6] = 0, and {RW31[7], RW33[7:6]} are don't care and ignored by the RCD.
NOTE 4 DDR5RCD03 Hardware disabled when RW31[7] = 0, and RW33[7:6] are don't care and ignored by the RCD.
NOTE 5 DDR5RCD03 Hardware disabled when RW33[6] = 0, and RW33[7] is a don't care and ignored by the RCD.

3.6.2 DFE Gain and Tap Range

Table 11 — DFE Gain and Tap Total Control Word Range

DFE Parameter	Min	Max	Unit
Gain	-6	6	dB
Tap 1	- 150	150	mV
Tap 2	- 60	60	mV
Tap 3	- 45	45	mV
Tap 4	- 45	45	mV
Tap 5	- 45	45	mV
Tap 6	- 45	45	mV

Table 12 — DFE Gain and Tap Coefficient Step Parameters Required per Speed Bin

DFE Parameter	DDR5-3200 - 6400			Unit
	Min	Typ	Max	
DFE Gain Bias Step Size ^{1,2}	1.7	2	2.3	dB
DFE Gain Bias Tolerance (INL) ^{1,2}	- 0.5	-	0.5	dB
DFE Gain Bias Step Size Tolerance (DNL) ^{1,2}	- 0.3	-	0.3	dB
DFE Gain Bias Step Time ¹	-	-	300	ns
DFE Tap Bias Step Size ^{1,2}	1	3	5	mV

Table 12 — DFE Gain and Tap Coefficient Step Parameters Required per Speed Bin (cont'd)

DFE Parameter	DDR5-3200 - 6400			Unit
	Min	Typ	Max	
DFE Tap Bias Tolerance (INL) (-150 mV to 0 mV) ^{1,2}	Min ($V_{ideal} \times 115\%$, $V_{ideal} - 3 * LSB$) ^{3,4}	-	Max ($V_{ideal} \times 85\%$, $V_{ideal} + 3 * LSB$) ^{3,4}	mV
DFE Tap Bias Tolerance (INL) (0 mV to 150 mV) ^{1,2}	Min ($V_{ideal} \times 85\%$, $V_{ideal} - 3 * LSB$) ^{3,4}	-	Max ($V_{ideal} \times 115\%$, $V_{ideal} + 3 * LSB$) ^{3,4}	mV
DFE Tap Bias Step Size Tolerance (DNL) ²	- 66.67	-	66.67	% of Step Size
DFE Tap Bias Step Time	-	-	64	tCK
NOTE 1 Host Vref fixed at $0.75 \times V_{DD}$, typical Voltage-Temperature condition (i.e., $V_{DD} = 1.1$ V, 25 °C), and default gain setting.				
NOTE 2 These parameters are neither subject to silicon validation nor production testing.				
NOTE 3 V_{ideal} refers to the ideal DFE Tap value based on the setting.				
NOTE 4 $LSB = 3$ mV.				

3.6.3 DCA DFE Tap Measurement

When DFE taps are enabled, they add offset to the DFE summer, which affects the input to the slicer. The feedback to the taps may be positive or negative, based on the sign of the coefficient and the level of the input, resulting in four cases, all of which must be tested. Each tap is measured individually with other tap coefficients set to 0. Other combinations can be extrapolated from the results.

3.6.3.1 HIGH-to-LOW Transition Test Method

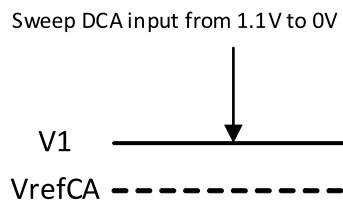
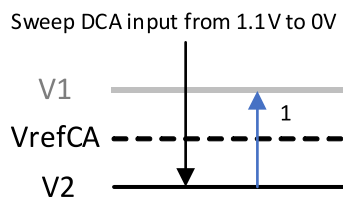


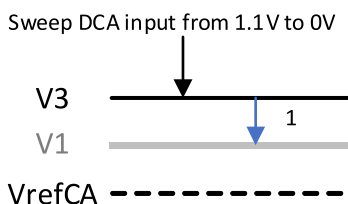
Figure 19 — HIGH-to-LOW Sweep: No DFE Applied



Note 1: Positive feedback results in an increase in voltage as seen by the slicer

Figure 20 — HIGH-to-LOW Sweep: DFE Positive Bias Applied

3.6.3.1 HIGH-to-LOW Transition Test Method (cont'd)



NOTE 1 Negative feedback results in an decrease in voltage as seen by the slicer

Figure 21 — HIGH-to-LOW Sweep: DFE Negative Bias Applied

1. Make sure VrefCA (RW[47:40]) is set to the default, DFE_Vref (PG[2]RW[62, 66, 6A, 6E, 72, 76, 7A, 7E]) is set to 0, power supply is 1.1 V, and DFE is disabled.
2. Sweep the input signal from 1.1 V to 0 V to find the lowest level that produces a stable HIGH output and record this input level as V1. No overshoot is allowed on the input. See Figure 19.
3. Enable DFE (RW31[0]). Enable the tap under test and all previous taps in RW31[7:4]. Set the coefficients for the previous taps to 0. All configuration in this procedure is via Sideband Bus access.
4. Configure the sign bit to 0 and the coefficient to n steps for the tap under test, where n is a loop variable.
5. Sweep the input signal from 1.1 V to 0 V to find the lowest level that produces a stable HIGH output and record this input level as V2. No overshoot is allowed on the input. See Figure 20.
6. The DFE Tap Bias $V(+) = (V1 - V2)$ for positive feedback. Validate $V(+)$ is within spec.
7. Configure the sign bit to 1 and the coefficient to n steps for the tap under test, where n is a loop variable.
8. Sweep the input signal from 1.1 V to 0 V to find the lowest level that produces a stable HIGH output and record this input level as V3. No overshoot is allowed on the input. See Figure 21.
9. The DFE Tap Bias $V(-) = (V1 - V3)$ for negative feedback. Validate $V(-)$ is within spec.
10. Repeat steps 4-9 until all the Tap steps for Taps 1-4 are measured.

3.6.3.2 LOW-to-HIGH Test Transition Method

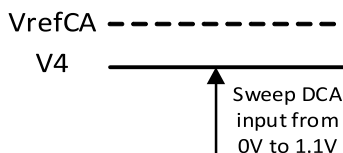
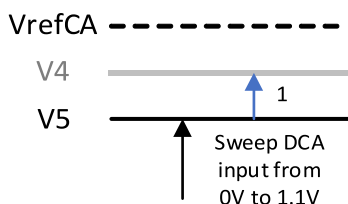


Figure 22 — LOW-to-HIGH Sweep: No DFE Applied



NOTE 1 Positive feedback results in an increase in voltage as seen by the slicer

Figure 23 — LOW-to-HIGH Sweep: DFE Positive Bias Applied