DDR4
ECC SOUDIMM
VR9FUxx72x8xxx

The Viking DDR4 SOUDIMM memory module offers lower operating voltages, higher module densities and faster speed categories than the prior DDR3 generation. JEDEC DDR4 (JESD79-4) has been defined to provide higher performance, with improved reliability and reduced power, thereby representing a significant achievement relative to previous DRAM memory technologies.

REVISION HISTORY

Revision	Release Date	Description of Change	Checked By (Full Name)
A	2/2/15	Initial release	Varadharajan Natarajan
B	3/29/15	Revise CAS Latency Addressing table for 4Gb Key timing parameters for 2400Mt/s speed. IDD/IPP values. Updated 8Gb Device IDD values. Change in page size. correct Min & Max values that were swapped. changes in values @ CWL -9. change in value for 2400 timing parameters	Varadharajan Natarajan
C	5/13/15	Revise block diagram	Chanhee Park
D	10/5/16	Revise logo and color scheme. Change VDD SPD can be from 2.2V to 3.6V	
E	4/26/18	Add 2666 PNs	
F	8/22/18	Add 32GB PNs using DDP	
G	5/12/2019	Add 32GB PNs using FPGA. Update addressing table	
H	7/12/2020	Add VR9FU2G7228KBPSA	
I	1/22/2021	Add VR9FU2G7228KBSSA	
J	10/24/2023	Add 3200 varients	

Legal Information

Legal Information

STATEMENT OF COMPLIANCE

Viking Technology, Sanmina Corporation ("Viking") shall use commercially reasonable efforts to provide components, parts, materials, products and processes to Customer that do not contain: (i) lead, mercury, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE) above 0.1% by weight in homogeneous material or (ii) cadmium above 0.01% by weight of homogeneous material, except as provided in any exemption(s) from RoHS requirements (including the most current version of the "Annex" to Directive 2002/95/EC of 27 January, 2003), as codified in the specific laws of the EU member countries. Viking strives to obtain appropriate contractual protections from its suppliers in connection with the RoHS Directives.

All printed circuit boards (PCBs) have a flammability rating of UL94V-0.

260 pin Ordering Information and Module Configuration

Viking Part Number	Voltage	Capacity	Module Configuration	Device Configuration	Device Package	Ranks	Speed	CAS Latency
VR9FU127228HBGyz	1.2V	4GB	512Mx72	512Mx8 (9)	4Gb FBGA	1	DDR4-14900	CL13 (13-13-13)
VR9FU127228HBHyz	1.2V	4GB	512Mx72	512Mx8 (9)	4Gb FBGA	1	DDR4-17000	CL15 (15-15-15)
VR9FU127228HBJyz	1.2V	4GB	512Mx72	512Mx8 (9)	4Gb FBGA	1	DDR4-19200	CL17 (17-17-17)
VR9FU127228HBKyz	1.2V	4GB	512Mx72	512Mx8 (9)	4Gb FBGA	1	DDR4-21300	CL19 (19-19-19)
VR9FU1G7228HBGyz	1.2V	8GB	1Gx72	512Mx8 (18)	4Gb FBGA	2	DDR4-14900	CL13 (13-13-13)
VR9FU1G7228HBHyz	1.2V	8GB	1Gx72	512Mx8 (18)	4Gb FBGA	2	DDR4-17000	CL15 (15-15-15)
VR9FU1G7228HBJyz	1.2V	8GB	1Gx72	512Mx8 (18)	4Gb FBGA	2	DDR4-19200	CL17 (17-17-17)
VR9FU1G7228HBKyz	1.2V	8GB	1Gx72	512Mx8 (18)	4Gb FBGA	2	DDR4-21300	CL19 (19-19-19)
VR9FU1G7228JBGyz	1.2V	8GB	1Gx72	1024Mx8 (9)	8Gb FBGA	1	DDR4-14900	CL13 (13-13-13)
VR9FU1G7228JBHyz	1.2V	8GB	1Gx72	1024Mx8 (9)	8Gb FBGA	1	DDR4-17000	CL15 (15-15-15)
VR9FU1G7228JBJyz	1.2V	8GB	1Gx72	1024Mx8 (9)	8Gb FBGA	1	DDR4-19200	CL17 (17-17-17)
VR9FU1G7228JBKyz	1.2V	8GB	1Gx72	1024Mx8 (9)	8Gb FBGA	1	DDR4-21300	CL19 (19-19-19)
VR9FU1G7228JBPyz	1.2V	8GB	1Gx72	1024Mx8 (9)	8Gb FBGA		DDR4-25600	CL22 (22-22-22)
VR9FU2G7228JBGyz	1.2V	16GB	2Gx72	1024Mx8 (18)	8Gb FBGA	2	DDR4-14900	CL13 (13-13-13)
VR9FU2G7228JBHyz	1.2V	16GB	2Gx72	1024Mx8 (18)	8Gb FBGA	2	DDR4-17000	CL15 (15-15-15)
VR9FU2G7228JBJyz	1.2V	16GB	2Gx72	1024Mx8 (18)	8Gb FBGA	2	DDR4-19200	CL17 (17-17-17)
VR9FU2G7228JBKyz	1.2V	16GB	2Gx72	1024Mx8 (18)	8Gb FBGA	2	DDR4-21300	CL19 (19-19-19)
VR9FU2G7228JBPyz	1.2V	16GB	2Gx72	1024Mx8 (18)	8Gb FBGA	2	DDR4-25600	CL22 (22-22-22)
VR9FU2G7228KBPyz	1.2V	16GB	2Gx72	2048Mx8 (9)	16Gb FBGA	1	DDR4-25600	CL22 (22-22-22)
VR9FU4G7228KEGyz	1.2V	32GB	4Gx72	2048Mx8 (18)	16Gb DDP	2	DDR4-14900	CL13 (13-13-13)
VR9FU4G7228KEHyz	1.2V	32GB	4Gx72	2048Mx8 (18)	16Gb DDP	2	DDR4-17000	CL15 (15-15-15)
VR9FU4G7228KEJyz	1.2V	32GB	4Gx72	2048Mx8 (18)	16Gb DDP	2	DDR4-19200	CL17 (17-17-17)
VR9FU4G7228KEKyz	1.2V	32GB	4Gx72	2048Mx8 (18)	16Gb DDP	2	DDR4-21300	CL19 (19-19-19)
VR9FU4G7228KBGyz	1.2V	32GB	4Gx72	2048Mx8 (18)	16Gb FBGA	2	DDR4-14900	CL13 (13-13-13)
VR9FU4G7228KBHyz	1.2V	32GB	4Gx72	2048Mx8 (18)	16Gb FBGA	2	DDR4-17000	CL15 (15-15-15)
VR9FU4G7228KBJyz	1.2V	32GB	4Gx72	2048Mx8 (18)	16Gb FBGA	2	DDR4-19200	CL17 (17-17-17)
VR9FU4G7228KBKyz	1.2V	32GB	4Gx72	2048Mx8 (18)	16Gb FBGA	2	DDR4-21300	CL19 (19-19-19)
VR9FU4G7228KBSyz	1.2V	32GB	4Gx72	2048Mx8 (18)	16Gb FBGA	2	DDR4-23400	CL21 (21-21-21)
VR9FU4G7228KBSSA	1.2V	32GB	4Gx72	2048Mx8 (18)	16Gb FBGA	2	DDR4-23400	CL21 (21-21-21)
VR9FU4G7228KBPxy	1.2V	32GB	4Gx72	2048Mx8 (18)	16Gb FBGA	2	DDR4-25600	CL22 (22-22-22)

Notes:

- For part numbers containing a lowercase x, contact Viking for the full PN.
- The lowercase letters y and z are wildcard characters that indicate DRAM vendor and die revisions and /or for customer specific locked BOMs. Refer to the Viking part number coversheet for details.

Features

- JEDEC Standard Power Supply
  - VDD = VDDQ = 1.2V± 5% (1.14V-1.26V)
  - External VPP = 2.5 Volt +10%, -5%
  - VDDSPD = 2.2V to 3.6V Volts
- 260 pin Small Outline Dual-In-Line Memory Module
- Edge finger connector ramp zone to reduce insertion force
- Point-to-Point topology to reduce loading
- Pseudo-open drain (POD12) DQ lines
- Internally generated VrefDQ
- ECC recovery from command and parity errors
- On-chip CA Parity detection for the command/address bus
- Programmable CAS Latency: 13, 15,17
- Programmable CAS Write Latency (CWL).
- Programmable Additive Latency (Posted CAS)
- Per DRAM addressability is supported
- Data Bus Inversion support for x8 devices
- Selectable Fixed burst chop (BC4) of 4 and burst length (BL8) of 8 on-the-fly (OTF) via the mode register set (MRS)
- 8n prefetch with 2 or 4 selectable bank groups: 16 banks (4 bank groups x 4 banks per bank group)
- Separate activation, read, write, refresh operations for each bank group
- 7 mode registers
- Dynamic On-Die-Termination (ODT) and ODT Park for improved signal integrity.
- Self Refresh and several Power Down Modes
- DLL-off mode for power savings
- System Level Timing Calibration Support via Write Leveling and Multi Purpose Register (MPR) Read Pattern
- Serial Presence Detect with EEPROM
- Two On-DIMM Thermal Sensors
- Asynchronous Reset
- Bidirectional Differentially Buffered Data Strobes(DQS)
- SOUDIMM dimensions per JEDEC MO-310 maximum limits
- RoHS Compliant

DDR4 SPEED BIN Nomenclature

Module Standard	SDRAM Standard	Clock
DDR4-14900	DDR4-1866	933 MHz
DDR4-17000	DDR4-2133	1066 MHz
DDR4-19200	DDR4-2400	1200 MHz
DDR4-21300	DDR4-2667	1333 MHz
DDR4-23400	DDR4-2933	1466 MHz
DDR4-25600	DDR4-3200	1600 MHz

Notes:

DDR4 Timing Summary

MT/s	tCK (ns)	CAS Latency (tCK)	tRCD (ns)	tRP (ns)	tRAS (ns)	tRC (ns)	CL-tRCD-tRP
DDR4-1866	1.071	13	13.92	13.92	34	47.92	13-13-13
DDR4-2133	0.93	15	14.06	14.06	33	47.05	15-15-15
DDR4-2400	0.83	17	14.16	14.16	32	46.16	17-17-17
DDR4-2666	0.75	22	14.25	14.25	32	46.25	19-19-19
DDR4-2933	0.682	21	14.32	14.32	32	46.32	21-21-21
DDR4-3200	0.625	22	13.75	13.75	32	45.75	22-22-22

Notes:

- CL = CAS Latency, tRCD = Activate –to-Command Time, tRP = Precharge Time. Refer to Speed Bin tables for details.

Addressing

		4GB(1Rx8) 512Mx8 DRAM	8GB(1Rx8) 1024Mx8 DRAM	16GB(2Rx8) 1024Mx8 DRAM	32GB(2Rx8) 2048Mx8 DRAM
Bank Address	**# of Bank Groups**	4	4	4	4
	BG Address	BG0~BG1	BG0~BG1	BG0~BG1	BG0~BG2
	Bank Address in a BG	BA0~BA1	BA0~BA1	BA0~BA1	BA0~BA2
Row Address		A0~A15	64K:A0~A16	64K:A0~A16	64K:A0~A17
Column Address		A0~ A9	A0~ A9	A0~ A9	A0~ A10
Page size		512B	512B	512B	512B
Refresh Count		4K	8K	8K	8K

Note:

- Micron datasheet specified 512B / 1KB as page size with “Die revision dependant”.
- In Hynix and Samsung Datasheet specfies 512B for x4 Device.
- A15 needed for 4GBit DRAM, A16 needed for 8GBit DRAM, A17 needed for 16GBit DRAM

DDR4 260-pin SOUDIMM Pin Wiring Assignments/Configurations

Pin#	Symbol	Pin#	Symbol	Pin#	Symbol	Pin#	Symbol	Pin#	Symbol	Pin#	Symbol
1	VSS	45	DQ21	89	VSS	133	A1	177	DQS4_c	221	DQS6_t
2	VSS	46	DQ20	90	VSS	134	EVENT_n	178	DM4_n/DBI4_n	222	VSS
3	DQ5	47	VSS	91	CB1, NC	135	VDD	179	DQS4_t	223	VSS
4	DQ4	48	VSS	92	CB0, NC	136	VDD	180	VSS	224	DQ54
5	VSS	49	DQ17	93	VSS	137	CK0_t	181	VSS	225	DQ55
6	VSS	50	DQ16	94	VSS	138	CK1_t	182	DQ39	226	VSS
7	DQ1	51	VSS	95	DQS8_c	139	CK0_c	183	DQ38	227	VSS
8	DQ0	52	VSS	96	DM8_n, DBI8_n, NC	140	CK1_c	184	VSS	228	DQ50
9	VSS	53	DQS2_c	97	DQS8_t	141	VDD	185	VSS	229	DQ51
10	VSS	54	DM2_n/DBI2_n	98	VSS	142	VDD	186	DQ35	230	VSS
11	DQS0_c	55	DQS2_t	99	VSS	143	PARITY	187	DQ34	231	VSS
12	DM0_n/DBI0_n	56	VSS	100	CB6, NC	144	A0	188	VSS	232	DQ60
13	DQS0_t	57	VSS	101	CB2, NC	145	BA1	189	VSS	233	DQ61
14	VSS	58	DQ22	102	VSS	146	A10_AP	190	DQ45	234	VSS
15	VSS	59	DQ23	103	VSS	147	VDD	191	DQ44	235	VSS
16	DQ6	60	VSS	104	CB7, NC	148	VDD	192	VSS	236	DQ57
17	DQ7	61	VSS	105	CB3, NC	149	CS0_n	193	VSS	237	DQ56
18	VSS	62	DQ18	106	VSS	150	BA0	194	DQ41	238	VSS
19	VSS	63	DQ19	107	VSS	151	WE_n/A14	195	DQ40	239	VSS
20	DQ2	64	VSS	108	RESET_n	152	RAS_n/A16	196	VSS	240	DQS7_c
21	DQ3	65	VSS	109	CKE0	153	VDD	197	VSS	241	DM7_n, DBI7_n, NC
22	VSS	66	DQ28	110	CKE1	154	VDD	198	DQS5_c	242	DQS7_t
23	VSS	67	DQ29	111	VDD	155	ODT0	199	DM5_n/DBI5_n	243	VSS
24	DQ12	68	VSS	112	VDD	156	A15/CAS_n	200	DQS5_t	244	VSS
25	DQ13	69	VSS	113	BG1	157	CS1_n	201	VSS	245	DQ62
26	VSS	70	DQ24	114	ACT_n	158	A13	202	VSS	246	DQ63
27	VSS	71	DQ25	115	BG0	159	VDD	203	DQ46	247	VSS
28	DQ8	72	VSS	116	ALERT_n	160	VDD	204	DQ47	248	VSS
29	DQ9	73	VSS	117	VDD	161	ODT1	205	VSS	249	DQ58
30	VSS	74	DQS3_c	118	VDD	162	C0/CS2_n/NC	206	VSS	250	DQ59
31	VSS	75	DM3_n/DBI3_n	119	A12	163	VDD	207	DQ42	251	VSS
32	DQS1_c,	76	DQS3_t	120	A11	164	VREFCA	208	DQ43	252	VSS
33	DM1_n/DBI1_n	77	VSS	121	A9	165	C1/CS3_n/NC	209	VSS	253	SCL
34	DQS1_t	78	VSS	122	A7	166	SA2	210	VSS	254	SDA
35	VSS	79	DQ30	123	VDD	167	VSS	211	DQ52	255	VDDSPD
36	VSS	80	DQ31	124	VDD	168	VSS	212	DQ53	256	SA0
37	DQ15	81	VSS	125	A8	169	DQ37	213	VSS	257	VPP
38	DQ14	82	VSS	126	A5	170	DQ36	214	VSS	258	VTT
39	VSS	83	DQ26	127	A6	171	VSS	215	DQ49	259	VPP
40	VSS	84	DQ27	128	A4	172	VSS	216	DQ48	260	SA1
41	DQ10	85	VSS	129	VDD	173	DQ33	217	VSS		
42	DQ11	86	VSS	130	VDD	174	DQ32	218	VSS		
43	VSS	87	CB5, NC	131	A3	175	VSS	219	DQS6_c		
44	VSS	88	CB4, NC	132	A2	176	VSS	220	DM6_n, DBI6_n, NC		

Notes:

- VPP is 2.5V DC
- A15 needed for 4GBit DRAM, A16 needed for 8GBit DRAM, A17 needed for 16GBit DRAM
- Only x8 and x16 DRAM support Data Mask (DM) and Data Bus Inversion (DBI). Only x8 DRAM support TDQS
- DM & DBI functions are supported with dedicated one pin labeled as DM_n/DBI_n
- The pin is bi-directional pin for DRAM. The DM_n/DBI _n pin is Active Low as DDR4 supports VDDQ reference termination.
- DM & DBI functions are programmable through DRAM Mode Register (MR). The MR bit location is bit A11 in MR1 and bit A12:A10 in MR5 . Write operation: Either DM or DBI function can be enabled but both functions cannot be enabled simultaneously. When both DM and DBI functions are disabled, DRAM turns off its input receiver and does not expect any

valid logic level. Read operation: Only DBI function applies. When DBI function is disabled, DRAM turns off its output driver and does not drive any valid logic level. DM & DBI functions are described in more detail on x8 based datasheets

PIN FUNCTION DESCRIPTION

Pin Name	Description	Pin Name	Description
A0-A17'	Register address input	SCL	I2C serial bus clock for SPD/TS and register
BA0, BA1	Register bank select input	SDA	I2C serial bus data line for SPD/TS and register
BG0, BG1	Register bank group select input	SA0-SA2	I2C slave address select for SPD/TS and register
RAS_n[2]	Register row address strobe input	PAR	Register parity input
CAS_n[3]	Register column address strobe input	VDD	SDRAM core power supply
WE_n[4]	Register write enable input		
CS0_n, CS1_n, CS2_n, CS3_n	DIMM Rank Select Lines input		
CKE0, CKE1	Register clock enable lines input	VREFCA	SDRAM command/address reference supply
ODT0, ODT1	Register on-die termination control lines input	VSS	Power supply return (ground)
ACT_n	Register input for activate input	VDDSPD	Serial SPDrTS positive power supply
DQ0-DQ63	DIMM memory data bus	ALERT_n	Register ALERT_n output
CB0-CB7	DIMM ECC check bits	Vpp	DRAM Activation Power Supply
TDQS9_t-TDQS17_t	Data Buffer data strobes (positive line of differential pair)		
TDQS9_c- TDQS17_c	Data Buffer data strobes (negative line of differential pair)	RESET_n	Set Register and SDRAMs to a Known state
		EVENT_n	SPD signals a thermal event has occurred.
CK0_t, CK1_t	Register clock input (positive line of differential pair)	Vtt	SDRAM I/O termination supply
CK0_c, CK1_c	Register clocks input (negative line of differential pair)	RFU	Reserved for future use

Notes:
1. Address A17 is only valid for 16GBit DRAM
2. RAS_n is a multiplexed function with A16. (A16 needed for 8GBit DRAM)
3. CAS_n is a multiplexed function with A15. (A15 needed for 4GBit DRAM)
4. WE_n is a multiplexed function with A14

Input/Output Functional Descriptions

Symbol	Type	Function
CK_t, CK_c	Input	Clock: CK_t and CK_c are differential clock inputs. All address and control input signals are sampled on the crossing of the positive edge of CK_t and negative edge of CK_c.
CKE0, (CKE1)	Input	Clock Enable: CKE HIGH activates, and CKE Low deactivates, internal clock signals and device input buffers and output drivers. Taking CKE Low provides Precharge Power-Down and Self-Refresh operation (all banks idle), or Active Power-Down (row Active in any bank). CKE is asynchronous for Self-Refresh exit. After VREFCA and VREFDQ have become stable during the power on and initialization sequence, they must be maintained during all operations (including Self-Refresh). CKE must be maintained high throughout read and write accesses. Input buffers, excluding CK, CK_c, ODT and CKE, are disabled during power-down. Input buffers, excluding CKE, are disabled during Self-Refresh.
CS0_n, (CS1_n)	Input	Chip Select: All commands are masked when CS_n is registered HIGH. CS_n provides for external Rank selection on systems with multiple Ranks. CS_n is considered part of the command code.
C0,C1,C2	Input	Chip ID: Chip ID is only used for 3DS for 2,4,8high stack via TSV to select each slice of stacked component. Chip ID is considered part of the command code.
ODT0, (ODT1)	Input	On Die Termination: ODT (registered HIGH) enables termination resistance internal to the DDR4 SDRAM. When enabled, ODT is only applied to each DQ, DQS_t, DQS_c and DM_n/DBI_n/TDQS_t,NU/TDQS_c (When TDQS is enabled via Mode Register A11=1 in MR1) signal for x8 configurations. For x16 configuration ODT is applied to each DQ, DQSU_c, DQSU_t, DQSL_t, DQSL_c, DMU_n, and DML_n signal. The ODT pin will be ignored if MR1 is programmed to disable RTT_NOM.
ACT_n	Input	Activation Command Input: ACT_n defines the Activation command being entered along with CS_n. The input into RAS_n/A16, CAS_n/A15 and WE_n/A14 will be considered as Row Address A16, A15 and A14.
RAS_n/A16, CAS_n/A15, WE_n/A14	Input	Command Inputs RAS_n/A16, CAS_n/A15 and WE_n/A14 (along with CS_n) define the command being entered. Those pins have multi function. For example, for activation with ACT_n Low, those are Addressing like A16,A15 and A14 but for non-activation command with ACT_n High, those are Command pins for Read, Write and other command defined in command truth table.
DM_n/DBI_n/ TDQS_t, (DMU_n/DBIU_n), (DML_n/DBIL_n)	Input/ Output	Input Data Mask and Data Bus Inversion: DM_n is an input mask signal for write data. Input data is masked when DM_n is sampled LOW coincident with that input data during a Write access. DM_n is sampled on both edges of DQS. DM is muxed with DBI function by Mode Register A10,A11,A12 setting in MR5. For x8 device, the function of DM or TDQS is enabled by Mode Register A11 setting in MR1. DBI_n is an input/output identifying whether to store/output the true or inverted data. If DBI_n is LOW, the data will be stored/output after inversion inside the DDR4 SDRAM and not inverted if DBI_n is HIGH. TDQS is only supported in x8.
BG0 - BG1	Input	Bank Group Inputs: BG0 - BG1 define to which bank group an Active, Read, Write or Precharge command is being applied. BG0 also determines which mode register is to be accessed during a MRS cycle. x4/8 have BG0 and BG1 but x16 has only BG0.

Input/Output Functional Descriptions (cont.)

Symbol	Type	Function
BA0 - BA1	Input	Bank Address Inputs: BA0 - BA1 define to which bank an Active, Read, Write or Precharge command is being applied. Bank address also determines if the mode register or extended mode register is to be accessed during a MRS cycle.
A0 - A17	Input	Address Inputs: Provided the row address for ACTIVATE Commands and the column address for Read/Write commands th select one location out of the memory array in the respective bank. (A10/AP, A12/BC_n, RAS_n/A16, CAS_n/A15 and WE_n/A14 have additional functions, see other rows. The address inputs also provide the op-code during Mode Register Set commands. A17 is only defined for the x4 configuration.
A10 / AP	Input	Auto-precharge: A10 is sampled during Read/Write commands to determine whether Autoprecharge should be performed to the accessed bank after the Read/Write operation. (HIGH: Autoprecharge; LOW: no Autoprecharge).A10 is sampled during a Precharge command to determine whether the Precharge applies to one bank (A10 LOW) or all banks (A10 HIGH). If only one bank is to be precharged, the bank is selected by bank addresses.
A12 / BC_n	Input	Burst Chop: A12 / BC_n is sampled during Read and Write commands to determine if burst chop (on-the-fly) will be performed. (HIGH, no burst chop; LOW: burst chopped). See command truth table for details.
RESET_n	Input	Active Low Asynchronous Reset: Reset is active when RESET_n is LOW, and inactive when RESET_n is HIGH. RESET_n must be HIGH during normal operation. RESET_n is a CMOS rail to rail signal with DC high and low at 80% and 20% of V_{DD}.
DQ	Input / Output	Data Input/ Output: Bi-directional data bus. If CRC is enabled via Mode register then CRC code is added at the end of Data Burst. Any DQ from DQ0~DQ3 may indicate the internal Vref level during test via Mode Register Setting MR4 A4=High. Refer to vendor specific datasheets to determine which DQ is used.
CB	Input / Output	Check Bit Input/ Output: Bi-directional ECC portion of data bus for x72 configurations
DQS_t, DQS_c, DQSU_t, DQSU_c, DQSL_t, DQSL_c	Input / Output	Data Strobe: output with read data, input with write data. Edge-aligned with read data, centered in write data. For x16, DQSL corresponds to the data on DQL0-DQL7; DQSU corresponds to the data on DQU0-DQU7. The data strobe DQS_t, DQSL_t, and DQSU_t are paired with differential signals DQS_c, DQSL_c, and DQSU_c, respectively, to provide differential pair signaling to the system during reads and writes. DDR4 SDRAM supports differential data strobe only and does not support single-ended.

Input/Output Functional Descriptions (cont.)

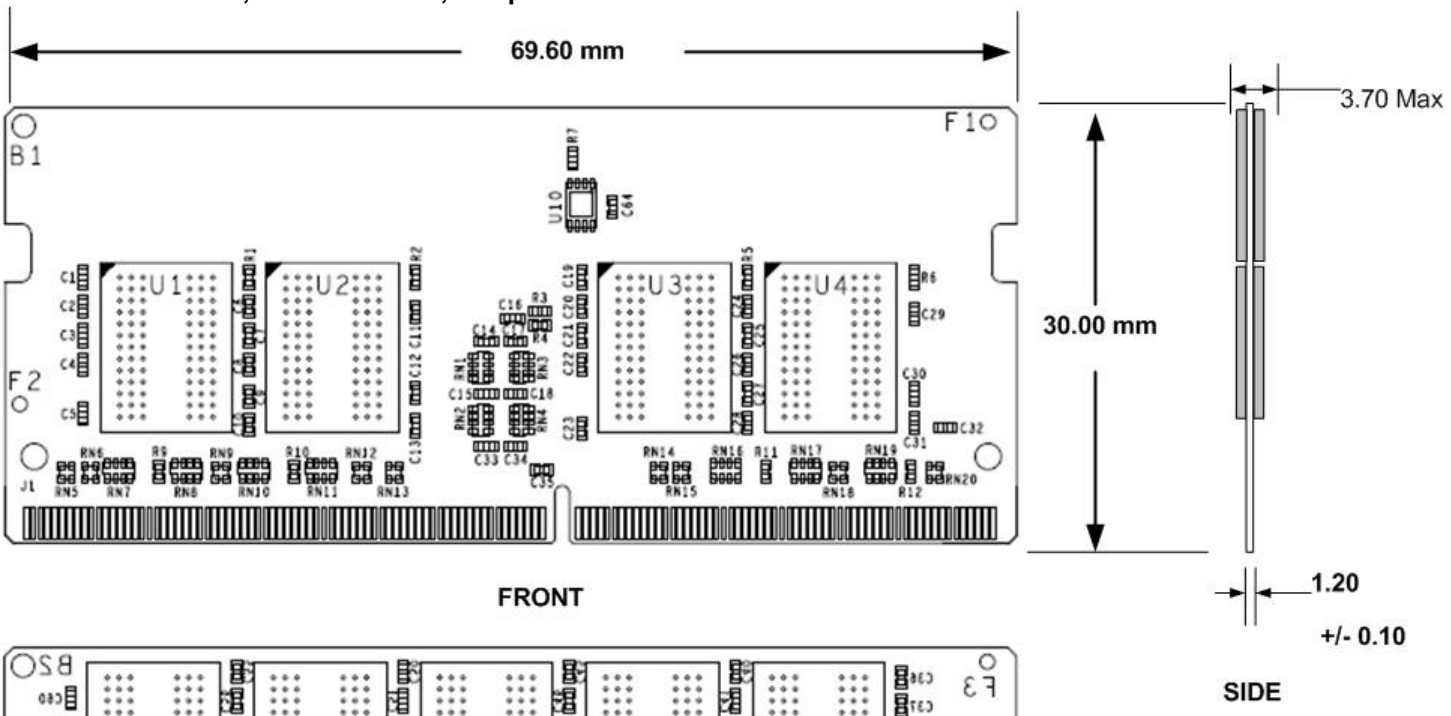
Symbol	Type	Function
ALERT_n	Output	Alert: It has multi functions such as CRC error flag, Command and Address Parity error flag. If there is error in CRC, then Alert_n goes LOW for the period time interval and goes back HIGH. IF there is error in Command Address Parity Check, then Alert_n goes LOW for relatively long period until on going DRAM internal recovery transaction to complete.
TEN	Input	Boundary Scan Mode Enable: Required on x16 devices and optional input on x4/x8 with densities equal to or greater than 8Gb. HIGH in this pin will enable boundary scan operation along with other pins. It is a CMOS rail to rail signal with DC high and low at 80% and 20% of VDD.
NC		No Connect: No internal electrical connection is present.
V_{DDQ}	Supply	DQ Power Supply: 1.2 V +/- 0.06 V
V_{SSQ}	Supply	DQ Ground
V_{DD}	Supply	Power Supply: 1.2 V +/- 0.06 V
V_{SS}	Supply	Ground
V_{pp}	Supply	DRAM Activation Power Supply: 2.5V (2.375V min , 2.75 max)
V_{REFCA}	Supply	Reference voltage for CA
ZQ	Supply	Reference Pin for ZQ calibration

Note:

The input only pins (BG0-BG-1, BA0-BA1, A0-A17, ACT_n, RAS_n,/A16, CAS_n/A15, WE_n/A14, CS_n, CKE, ODT, and RESET_n) do not supply termination.

MECHANICAL OUTLINE

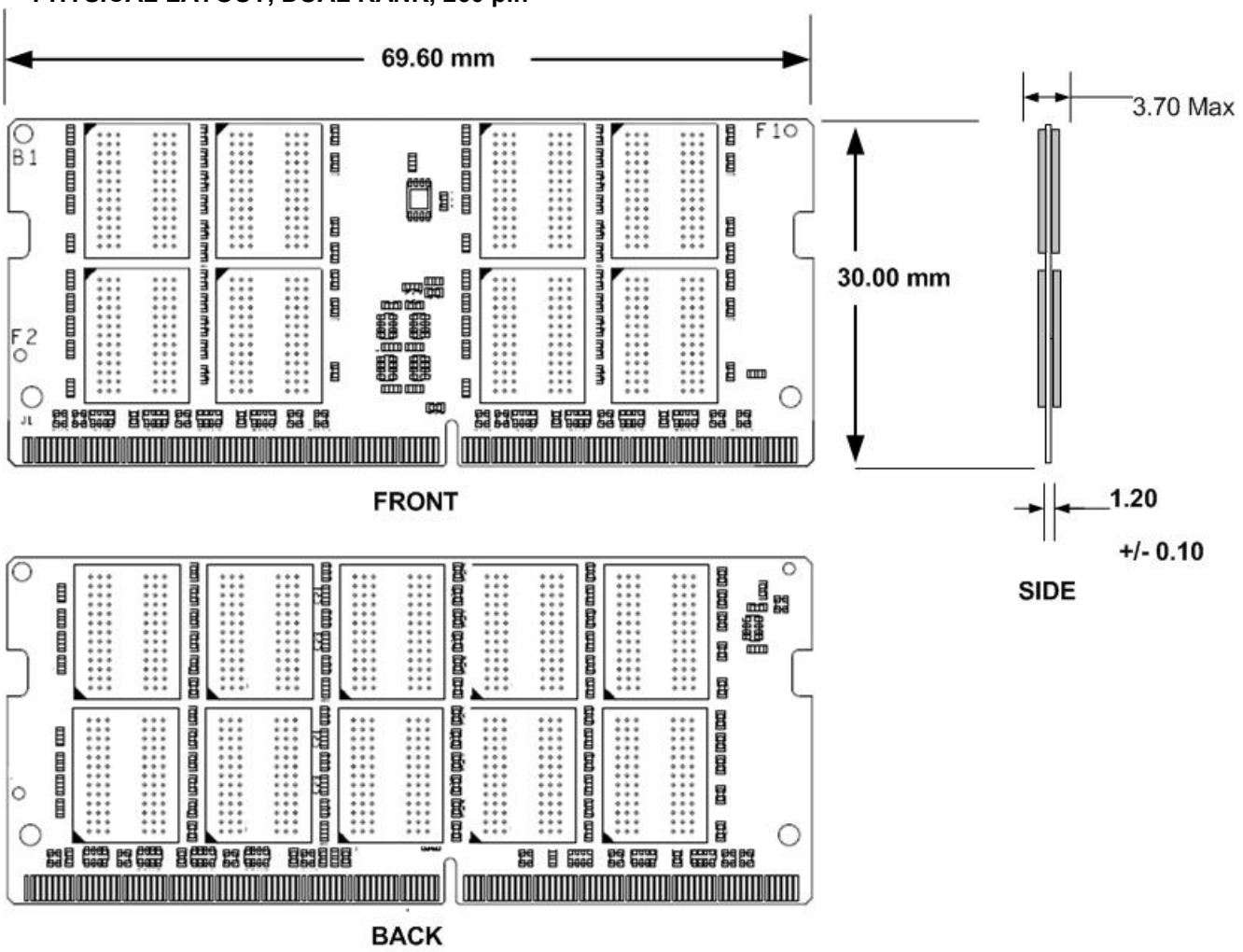
PHYSICAL LAYOUT, SINGLE RANK, 260 pin



Notes:

- All dimensions in mm (inches)
- Tolerance is +/- 0.0127, unless otherwise stated
- Refer to JEDEC Standard Mechanical Outline MO-310 for other details

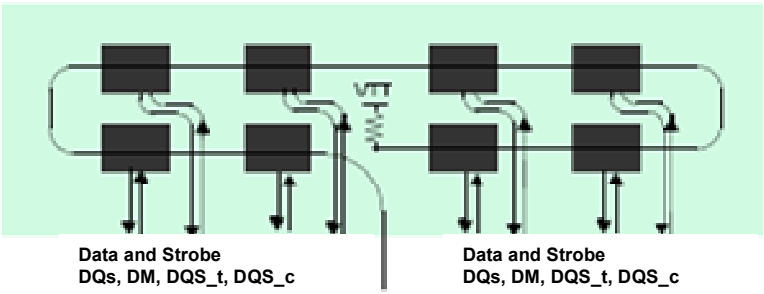
PHYSICAL LAYOUT, DUAL RANK, 260 pin

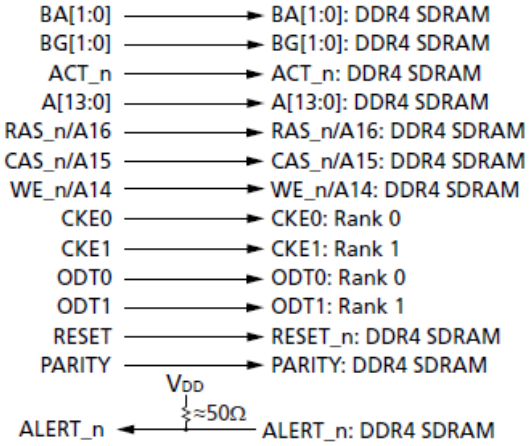


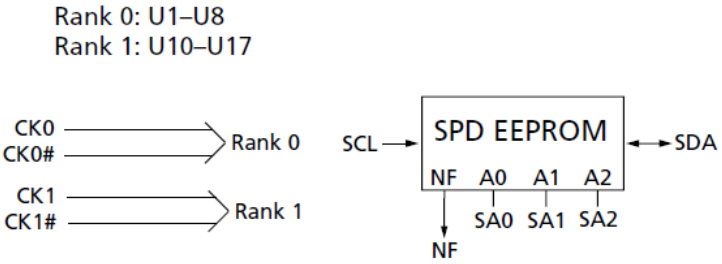
Notes:

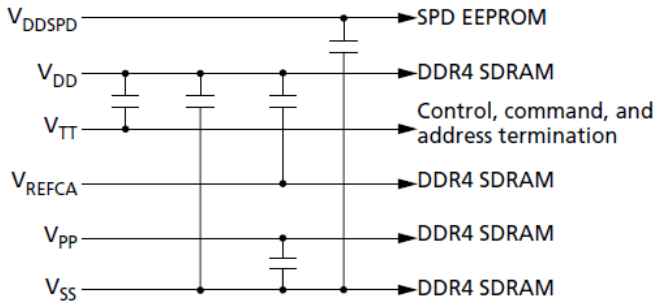
- All dimensions in mm (inches)
- Tolerance is +/- 0.0127, unless otherwise stated
- Refer to JEDEC Standard Mechanical Outline MO-310 for other details

FUNCTIONAL BLOCK DIAGRAM up to 16GB

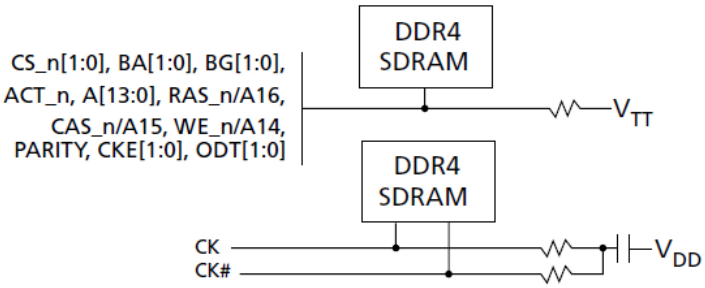








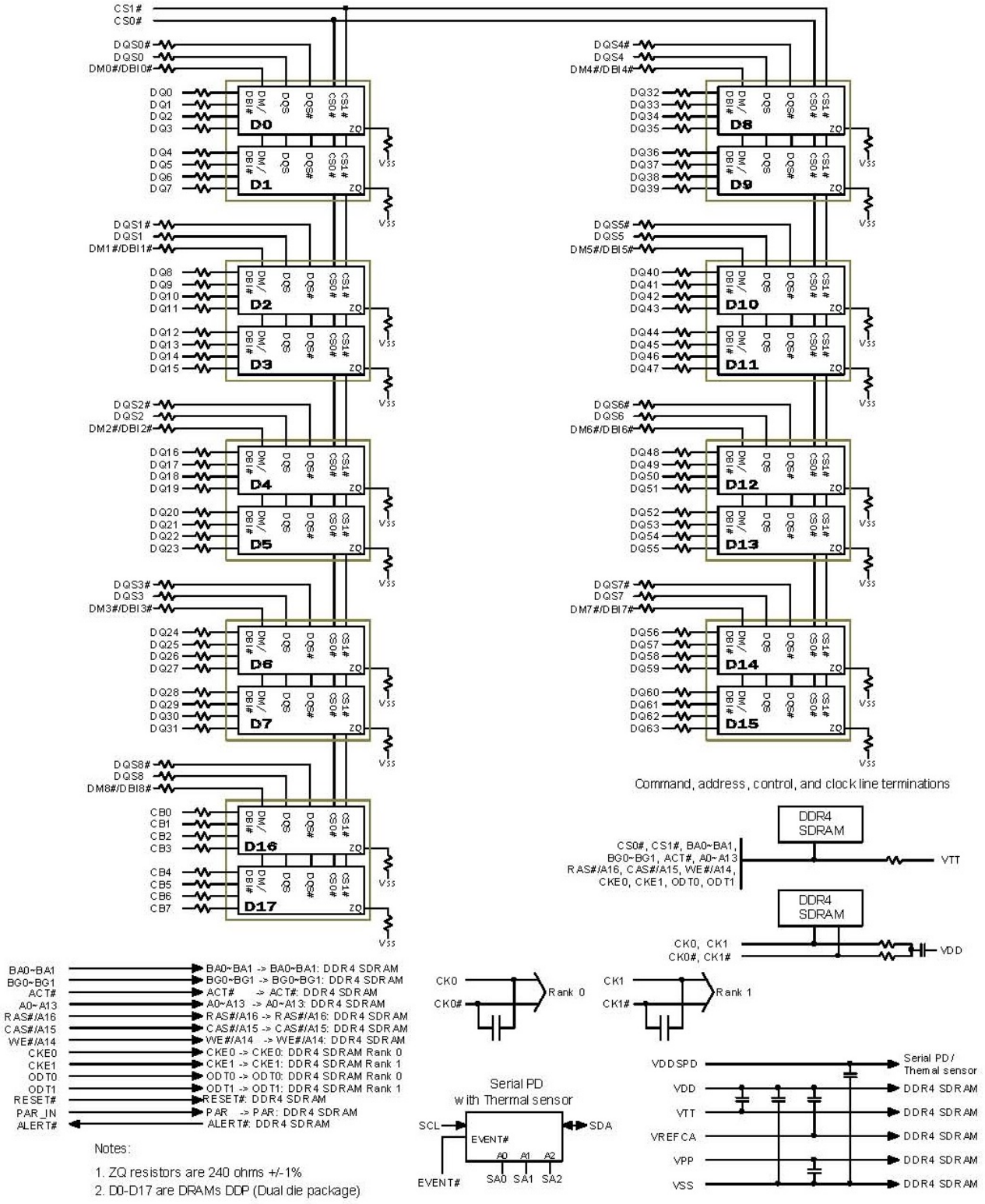
Clock, control, command, and address line terminations:



Notes:

- The ZQ ball on each DDR4 component is connected to an external 240Ω ±1% resistor that is tied to ground. It is used for the calibration of the component's ODT and output driver.

FUNCTIONAL BLOCK DIAGRAM for 32GB (Samsung 16Gb DDP: K4AAG045WB-MCRC)



Notes:

1. ZQ resistors are 240 ohms +/-1%
2. D0-D17 are DRAMs DDP (Dual die package)

DQ Internal Vref Specifications

Parameter	Symbol	Min	Typ	Max	Unit	NOTE
Vref Max operating point Range 1	Vref_max_R1	-	-	92%	VDDQ	1, 11
Vref Min operating point Range 1	Vref_min_R1	60%	-	-	VDDQ	1,11
Vref Max operating point Range 2	Vref_max_R2	-	-	77%	VDDQ	1, 11
Vref Min operating point Range 2	Vref_min_R2	45%	-	-	VDDQ	1,11
Vref Stepsize	Vref_step	0.50%	0.65%	0.80%	VDDQ	2
Vref Set Tolerance	Vref_set_tol	-1 .625%	0.00%	1.63%	VDDQ	3,4,6
		-0.15%	0.00%	0.15%	VDDQ	3,5,7
Vref Step Time	Vref_time-long	-	-	150	ns	9
	Vref_time-Short	-	-	60	ns	8
Vref Valid tolerance	Vref_val_tol	-0.15%	0.00%	0.15%	VDDQ	10

Notes:

1. JESD8-24 specifies Vref to be 70% of VDDQ. Vref DC voltage referenced to VDDQ_DC. VDDQ_DC is 1.2V
2. Vref stepsize increment/decrement range. Vref at DC level.
3. Vref_new = Vref_old+n*Vref_step; n=number of step; if increment use “+”; If decrement use “-”
4. The minimum value of Vref setting tolerance=Vref_new-1.625%*VDDQ.
   The maximum value of Vref setting tolerance=Vref_new+1.625%*VDDQ. For n>4
5. The maximum value of Vref setting tolerance=Vref_new-0.15%*VDDQ.
   The maximum value of Vref setting tolerance=Vref_new+0.15%*VDDQ. For n&4 tbd
6. Measured by recording the min and max values of the Vref output over the range, drawing a straight line between those points and comparing all other Vref output settings to that line
7. Measured by recording the min and max values of the Vref output across 4 consecutive steps(n=4), drawing a straight line between those points and comparing all other Vref output settings to that line
8. Time from MRS command to increment of decrement one step size for Vref
9. Time from MRS command to increment of decrement more than one step size up to full range of Vref
10. Only applicable for DRAM component level test/characterization purpose.
    Not applicable for normal mode of operation. Vref valid is to qualify the step times which will be characterized at the component level.
11. DRAM range1 or 2 set by MRS bit MR6,A6.

OVERVIEW OF DDR4 SOUDIMM MODULE OPERATION

The DDR4 architecture is generally a point-to-point topology with a dedicated channel design. The highest system performance levels can be achieved with DDR4-2133 and beyond, when the system is configured as 1 SOUDIMM Per Channel (1DPC). DDR4 has more features than DDR3 with a pseudo-open drain (POD12) 1.2v I/O for the data channel, trained Vref, bank groups and write CRC. The POD12 interface only applies to the data channel. The address command channel behave like DDR3 using mid-point termination and mid-point Vref. The new bank group interleaving feature in DDR4 maximizes data transfer bandwidth.

DDR4 DRAM use pseudo-open drain (POD12) 1.2v drivers with Vdd terminations on DQ lines to increase data rates; unlike DDR3 DRAM that uses stub-series terminated logic drivers, The DRAM addressing scheme in DDR4 is organized into bank groups, Side A and Side B. The host DDR4 memory controller interleaves (multiplexes) among the bank groups to achieve high data rates. DDR4 architecture is a 8n prefetch with bank groups, including the use of two or four selectable bank groups. This will permit the DDR4 memory devices to have separate activation, read, write or refresh operations simultaneously underway in each of the unique bank groups to improve overall memory efficiency and bandwidth, especially when small memory granularities are used.

The data written to the SOUDIMM is read back the same way. However when writing to the internal registers with a "load mode" operation, a specific address is required. This requires the controller to know if the rank is mirrored or not. There is a bit assignment in the SPD that indicates whether the module has been designed with a mirrored feature or not.

DDR4 offers ECC recovery from command and parity errors to prevent the host system from crashing. The use of CRC parity is an optional feature on address command and data; (Error command blocking when parity enabled and post CA parity. If the SOUDIMM does not support CRC, the values of 0x00 will fill the CRC table. The new CA parity feature on the command/address bus provides a low-cost method of verifying the integrity of command and address transfers over a link, for all operations.

Some of the main attributes of DDR4 memory are:
1) Internally generated VrefDQ and Calibration.
   VrefDQ is supplied by the DRAM internally.
   VrefCA is supplied by the board.
2) The ACT_n activate pin replaces RAS#, CAS#, and WE# commands,
3) Alert_n for error checking
4) Bank group Interleaving
5) Improved training modes upon power-up
5) Nominal and dynamic ODT: Improvements to the ODT protocol and a new Park Mode allow for a nominal termination and dynamic write termination without having to drive the ODT pin
6) DQ bus geardown mode for 2667 Mhz data rates and beyond
7) External VPP at 2.5V (for wordline boost)
8) 1.2V VDD power with power-saving features that include MPSM Maximum Power Savings Mode, Low Power Auto Self Refresh, Temperature Controlled Refresh, Fine Granularity Refresh, and CMD/ADDT latency. DLL off mode.

Important Note:
Longer boot-up times may be experienced in certain situations due to controller initiated functions such as VrefDQ calibration, write leveling and other trainings for the SOUDIMM.

DDR4 MODE REGISTERS

	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
MR0	RFU	Write Recovery and RTP			DLL Reset	Test Mode	CAS Latency CL			Burst Type	CL	Burst Length BL	
MR1	Qoff	TDQS	Rtt_NOM			Write Leveling	RFU	RFU	Additive Latency		Ron		DLL Enable
MR2	Write CRC	RFU	Rtt_WR		RFU	Auto Self Refresh		CWL			RFU	RFU	RFU
MR3	MPR Read Format		Write CMD Latency with CRC and DM		Fine Granularity Refresh			Temp Sensor	Per-DRAM Addr Mode	Gear down	MPR Enable	MPR Page	
MR4	Write Preamble	Read Preamble	Read Preamble Training Enable	Self Refresh Abort Enable	CS-to-Address Latency CAL			RFU	VrefDQ Monitor Enable	Temp Refresh Mode	Temp. Refresh Range	Max Power Down Enable	RFU
MR5	Read DBI Enable	Write DBI Enable	Data Mask Enable	Parity Persistent Error	Rtt_PARK			ODT input in Power Down	Panty Error Status	CRC Error Clear	CMD Address Parity Latency		
MR6	tCCD_L and tDLLK Timing			RFU	RFU	VrefDQ Training enable	VrefDQ Training Range	VretDQ Training Value					
MR7	**Manufacturing use only to program the RCD**												

Notes:

- Refer to JEDEC documentation for detail of the control/status bits

DC OPERATING CONDITIONS AND CHARACTERISTICS

ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Value	Unit	Notes
Voltage on any pin relative to GND	Vin, Vout	-0.3 ~ 1.5	V	1,
Voltage on VDD supply relative to GND	VDD	-0.3 ~ 1.5	V	1,3
Voltage on VDDQ supply relative to GND	VDDQ	-0.3 ~ 1.5	V	1,3
Voltage on VPP supply relative to GND	VPP	-0.3 ~ 3.0	V	4
Module operating temperature (ambient)	Topr	0 ~ 55	°C	1,5
Storage temperature	Tstg	-55 ~ +100	°C	1,2

Notes:

1. Permanent device damage may occur if 'ABSOLUTE MAXIMUM RATINGS' are exceeded. Functional operation should be restricted to recommended operating condition.
   Exposure to higher than recommended voltage for extended periods of time could affect device reliability. Stresses greater than those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability
2. Storage Temperature is the case surface temperature on the center/top side of the DRAM. For the measurement conditions, please refer to JESD51- 2 standard.
3. VDD and VDDQ must be within 300 mV of each other at all times and VREFCA must be not greater than 0.6 x VDDQ, When VDD and VDDQ are less than 500 mV; VREF may be equal to or less than 300 mV
4. VPP must be equal or greater than VDD/VDDQ at all times
5. Refer to JEDEC JC451 specification

DRAM Component Operating Temperature Range

Symbol	Parameter	Rating	Units	Note
Toper	Normal Operating Temperature Range	0 to 85	°C	1,2
	Extended Temperature Range	85 to 95	°C	1,3

Notes:

1. Operating Temperature TOPER is the case surface temperature on the center / top side of the DRAM. For measurement conditions, please refer to the JEDEC document JESD51-2.
2. The Normal Temperature Range specifies the temperatures where all DRAM specifications will be supported. During operation, the DRAM case temperature must be maintained between 0 - 85oC under all operating conditions.
   3. Some applications require operation of the DRAM in the Extended Temperature Range between 85oC and 95oC case temperature. Full specifications are guaranteed in this range, but the following additional conditions apply:
   a) Refresh commands must be doubled in frequency, therefore reducing the Refresh interval tREFI to 3.9 µs. It is also possible to specify a component with 1X refresh (tREFI to 7.8µs) in the Extended Temperature Range. Please refer to the DIMM SPD for option availability.
   b) If Self-Refresh operation is required in the Extended Temperature Range, then it is mandatory to either use the Manual Self-Refresh mode with Extended Temperature Range capability (MR2 A6 = 0b and MR2 A7 = 1b) or enable the optional Auto Self-Refresh mode (MR2 A6 = 1b and MR2 A7 = 0b). DDR4 SDRAMs support Auto Self-Refresh and in Extended Temperature Range and please refer to component datasheet and/or the DIMM SPD for tREFI requirements in the Extended Temperature Range

tREFI by Device Density

Parameter	Symbol		2Gb	4Gb	8Gb	16Gb	Units
Average periodic refresh interval	tREFI	0°C ≤ Tcase ≤ 85°C	7.8	7.8	7.8	7.8	µs
		85°C ≤ Tcase ≤ 95°C	3.9	3.9	3.9	3.9	µs

AC & DC Operating Conditions

DC OPERATING CONDITIONS AND CHARACTERISTICS (POD12)

Symbol	Parameter	Rating			Units	Notes
		Min	Typ	Max		
VDD	Supply Voltage VDD: PC4:1.2V±5%,	1.14	**1.2**	1.26	v	1,2,3
VDDQ	Supply Voltage for Output. Values in () are at 70% of VDD	1.14 (0.798)	1.2 (0.84)	1.26 (0.882)	v	1
VPP	2.5V +10%, -5%	2.375	2.5	2.75	v	3
VDDSPD	@2.5V	2.2	-	3.6	v	

Notes:

1. JESD8-24 specifies Vref to be 70% of VDDQ. Under all conditions VDDQ must be less than or equal to VDD.
2. VDDQ tracks with VDD. AC parameters are measured with VDD and VDDQ tied together.
3. DC bandwidth is limited to 20MHz.,
4. PODI2 1.2 V Pseudo Open Drain Interface has a VDDQ value of 1.2V but the reference voltage allows PODI2 to be used with other VDDQ values. POD12 signals have pull-up-only parallel input termination and have an asymmetric output drive impedance. For example, if the output drivers were using a 60 ohm pull-up drive impedance then the pull-down drivers would be expected to produce a 40 ohm pull-down drive impedance. PODI2 does not explicitly call for series termination resistors, so it is suitable for point-to-point as well as multi-drop stub environments which may require some additional termination.

DC CHARACTERISTICS, IDD CURRENTS

IDD DEFINITIONS

Symbol	Parameter
IDD0	One bank ACTIVATE-PRECHARGE current
IPP0	One bank ACTIVATE-PRECHARGE, Word Line Boost, IPP current
IDD1	One bank ACTIVATE-READ-PRECHARGE current
IDD2N	Precharge standby current
IDD2NT	Precharge standby ODT current
IDD2P	Precharge power-down current
IDD2Q	Precharge quiet standby current
IDD3N	Active standby current
IPP3N	Active standby IPP current
IDD3P	Active power-down current
IDD4R	Burst read current
IDDQ4R	Burst read IDDQ current
IDD4W	Burst write current
IDD5B	Burst refresh current (1x REF)
IPP5B	Burst refresh IPP current (1 x REF)
IDD6N	Self refresh current: Normal temperature range (0°C to +85°C)
IDD6E	Self refresh current: Extended temperature range (0°C to +95°C)
IDD6R	Self refresh current: Reduced temperature range (0°C to +45°C)
IDD6A	Auto self refresh current (25°C)
IDD6A	Auto self refresh current (45°C)
IDD6A	Auto self refresh current (75°C)
IDD7	Bank interleave read current
IPP7	Bank interleave read IPP current
IDD8	Maximum power-down current

Notes:

1) DDR4 IDD and IDDQ specs include the same DDR3 IDD and IDDQ specs with these exceptions:
   a. IDD2P0 and IDD2P1 are replaced with a single IDD2P. There's no longer any difference in power for the DLL because of better DLL power management inside the DRAM device without any benefit for using slow exit.
   b. IDD6 is renamed IDD6N Self Refresh Current: Normal Temperature Range
   c. IDD6ET is renamed IDD6E Self-Refresh Current: Extended Temperature Range
   d. IDD6TC is renamed IDD6AAut0 Self-Refresh Current
   e. IDD8 is redefined from (optional) RESET Low Current to IDD8 Maximum Power Down Current, TBD
2) IDD values are an average (not peak) current drawn throughout the entire time that it takes to execute the set of conditions specified by JEDEC standards.
3) Consult with Viking for tools to help specify the Total Design Power (TDP)

I_{DD6} Specification

Symbol	Temperature Range	Value	Unit	Notes
IDD6N	*0 - 85 °C*	22	*mA*	*3,4*
IDD6E	0 - 95 °C	33	mA	4,5,6
IDD6R	0 - 45°C	10	mA	4,6,9
IDD6A	0 °C ~ Ta	9	mA	4,6,7,8
	Tb ~ Ty	10	mA	4,6,7,8
	Tz ~ TOPERmax	16	mA	4,6,7,8

Notes:
1. Some IDD currents are higher for x16 organization due to larger page-size architecture.
2. Max. values for IDD currents considering worst case conditions of process, temperature and voltage.
3. Applicable for MR2 settings A6=0 and A7=0.
4. Supplier data sheets include a max value for IDD6.
5. Applicable for MR2 settings A6=0 and A7=1. IDD6ET is only specified for devices which support the Extended Temperature Range feature.
6. Refer to the supplier data sheet for the value specification method (e.g. max, typical) for IDD6ET and IDD6TC
7. Applicable for MR2 settings A6=1 and A7=0. IDD6TC is only specified for devices which support the Auto Self Refresh feature.
8. The number of discrete temperature ranges supported and the associated Ta - Tz values are supplier/design specific. Temperature ranges are specified for all supported values of TOPER. Refer to supplier data sheet for more information.
9. Applicable for MR2 settings TBD. IDD6R is verified by design and characterization, and may not be subject to production test.

IDD CURRENTS, SINGLE RANK, 4Gbit

Symbol	DDR4-1866	DDR4-2133	DDR4-2400	Units
IDD0	522	540	576	mA
IPP0	36	36	36	mA
IDD1	567	585	612	mA
IDD2N	396	414	450	mA
IDD2NT	450	486	522	mA
IDD2P	270	270	288	mA
IDD2Q	351	351	369	mA
IDD3N	549	567	603	mA
IPP3N	27	27	27	mA
IDD3P	396	396	396	mA
IDD4R	1260	1350	1440	mA
IDDQ4R	288	324	360	mA
IDD4W	1404	1584	1764	mA
IDD5B	1710	1710	1728	mA
IPP5B	198	198	198	mA
IDD6N	180	180	180	mA
IDD6E	243	243	243	mA
IDD6R	90	90	90	mA
IDD6A (25°C)	81	81	81	mA
IDD6A (45°C)	90	90	90	mA
IDD6A (75°C)	144	144	144	mA
IDD7	1440	1665	1890	mA
IPP7	90	108	126	mA
IDD8	162	162	162	mA

Notes:

1. Users should refer to the DRAM supplier data sheet and/or the DIMM SPD to determine if DDR4 SDRAM devices support the following options or requirements referred to in this material.
2. Values as per Micron Datasheet Revision “A”.

IDD CURRENTS, 2 RANK, 4Gbit

Symbol	DDR4-1866	DDR4-2133	DDR4-2400	Units
IDD0[1]	792	810	864	mA
IPP0[1]	306	306	324	mA
IDD1[1]	837	855	900	mA
IDD2N[2]	792	828	900	mA
IDD2NT[1]	720	756	810	mA
IDD2P[2]	540	540	576	mA
IDD2Q[2]	702	702	738	mA
IDD3N[2]	1098	1134	1206	mA
IPP3N[2]	54	54	54	mA
IDD3P[2]	792	792	792	mA
IDD4R[1]	1530	1620	1728	mA
IDDQ4R[1]	558	594	648	mA
IDD4W[1]	1674	1854	2052	mA
IDD5B[1]	1980	1980	2016	mA
IPP5B[1]	468	468	468	mA
IDD6N[2]	360	360	360	mA
IDD6E[2]	486	486	486	mA
IDD6R[2]	180	180	180	mA
IDD6A[2] (25°C)	162	162	162	mA
IDD6A[2] (45°C)	180	180	180	mA
IDD6A[2] (75°C)	288	288	288	mA
IDD7[1]	1710	1935	2178	mA
IPP7[1]	360	378	414	mA
IDD8[2]	324	324	324	mA

Notes:
1. One module rank in the active IDD/PP, the other rank in IDD2P/PP3N.
2. All ranks in this IDD/PP condition.
3. Values as per Micron Datasheet Revision “A.

IDD CURRENTS, SINGLE RANK, 8Gbit

Symbol	DDR4-2133	DDR4-2400	Units
	15-15-15	17-17-17	
	1.2V	1.2V	
IDD0	315	333	mA
IDD0A	333	351	mA
IDD1	450	477	mA
IDD1A	468	504	mA
IDD2N	198	207	mA
IDD2NA	225	234	mA
IDD2NT	225	234	mA
IDD2NL	135	153	mA
IDD2NG	198	207	mA
IDD2ND	180	189	mA
IDD2N_par	207	216	mA
IDD2P	144	144	mA
IDD2Q	180	189	mA
IDD3N	324	324	mA
IDD3NA	342	342	mA
IDD3P	189	198	mA
IDD4R	927	1017	mA
IDD4RA	963	1062	mA
IDD4RB	945	1044	mA
IDD4W	756	810	mA
IDD4WA	792	855	mA
IDD4WB	846	810	mA
IDD4WC	666	720	mA
IDD4W_par	828	891	mA
IDD5B	1971	1998	mA
IDD5F2	1386	1395	mA
IDD5F4	1152	1170	mA
IDD6N	207	207	mA
IDD6E	306	306	mA
IDD7	1530	1557	mA
IDD8	99	99	mA

Notes:

1. Users should refer to the DRAM supplier data sheet and/or the DIMM SPD to determine if DDR4 SDRAM devices support the following options or requirements referred to in this material.
2. Samsung D – Die referred for Idd values.

IDD CURRENTS, DUAL RANK, 8Gbit

Symbol	DDR4-2133	DDR4-2400	Units
	15-15-15	17-17-17	
	1.2V	1.2V	
IDD0[1]	459	477	mA
IDD0A[1]	477	495	mA
IDD1[1]	594	621	mA
IDD1A[1]	612	648	mA
IDD2N[2]	396	414	mA
IDD2NA[1]	369	378	mA
IDD2NT[1]	369	378	mA
IDD2NL[1]	279	297	mA
IDD2NG[1]	342	351	mA
IDD2ND[1]	324	333	mA
IDD2N_par[1]	351	360	mA
IDD2P[2]	288	288	mA
IDD2Q[2]	360	378	mA
IDD3N[2]	648	648	mA
IDD3NA[2]	684	684	mA
IDD3P[2]	378	396	mA
IDD4R[1]	1071	1161	mA
IDD4RA[1]	1107	1206	mA
IDD4RB[1]	1089	1188	mA
IDD4W[1]	900	954	mA
IDD4WA[1]	936	999	mA
IDD4WB[1]	990	954	mA
IDD4WC[1]	810	864	mA
IDD4W_par[1]	972	1035	mA
IDD5B[1]	2115	2142	mA
IDD5F2[1]	1530	1539	mA
IDD5F4[1]	1296	1314	mA
IDD6N[2]	414	414	mA
IDD6E[2]	612	612	mA
IDD7[1]	1674	1701	mA
IDD8[2]	198	198	mA

Notes:
1. One module rank in the active IDD/PP, the other rank in IDD2P/PP3N.
2. All ranks in this IDD/PP condition.
3. Users should refer to the DRAM supplier data sheet and/or the DIMM SPD to determine if DDR4 SDRAM devices support the following options or requirements referred to in this material.
4. Samsung D – Die referred for Idd values.

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IDD CURRENTS, DUAL RANK, 16Gbit DDP

Symbol	DDR4-2133	DDR4-2400	Units
	15-15-15	17-17-17	
	1.2V	1.2V	
IDD0[1]	929		mA
IDD0A[1]			mA
IDD1[1]	1156		mA
IDD1A[1]			mA
IDD2N[2]	648		mA
IDD2NA[1]			mA
IDD2NT[1]	702		mA
IDD2NL[1]			mA
IDD2NG[1]			mA
IDD2ND[1]			mA
IDD2N_par[1]			mA
IDD2P[2]	540		mA
IDD2Q[2]	612		mA
IDD3N[2]	900		mA
IDD3NA[2]	108		mA
IDD3P[2]	630		mA
IDD4R[1]	1935		mA
IDD4RA[1]			mA
IDD4RB[1]			mA
IDD4W[1]	1836		mA
IDD4WA[1]			mA
IDD4WB[1]			mA
IDD4WC[1]			mA
IDD4W_par[1]			mA
IDD5B[1]	4135		mA
IDD5F2[1]			mA
IDD5F4[1]			mA
IDD6N[2]	792		mA
IDD6E[2]	1188		mA
IDD7[1]	4136		mA
IDD8[2]	360		mA

Notes:
1. One module rank in the active IDD/PP, the other rank in IDD2P/PP3N.
2. All ranks in this IDD/PP condition.
3. Users should refer to the DRAM supplier data sheet and/or the DIMM SPD to determine if DDR4 SDRAM devices support the following options or requirements referred to in this material.

Input/Output Capacitance

Symbol	Parameter	DDR4-1600, 1867, 2133		DDR4-2400,2667		DDR4-3200		Units	Note
		Min	Max	Min	Max	Min	Max		
C_{IO}	Input/output capacitance	0.7	1.4	0.7	1.3	TBD	TBD	pF	1,2,3
C_{DIO}	Input/output capacitance delta	-0.1	0.1	-0.1	0.1	TBD	TBD	pF	1,2,3,11
C_{DDQS}	Input/output capacitance delta DQS and DQS#		0.05		0.05	TBD	TBD	pF	1,2,3,5
C_{CK}	Input capacitance, CK and CK#	0.2	0.8	0.2	0.8	TBD	TBD	pF	1,3
C_{DCK}	Input capacitance delta CK and CK#		0.05		0.05	TBD	TBD	pF	1,3,4
C_{I}	Input capacitance(CTRL, ADD, CMD pins only)	0.2	0.8	0.2	0.7	TBD	TBD	pF	1,3,6
C_{DI_CTRL}	Input capacitance delta(All CTRL pins only)	-0.1	0.1	-0.1	0.1	TBD	TBD	pF	1,3,7,8
$C_{DI\_ADD\_CMD}$	Input capacitance delta(All ADD/CMD pins only)	-0.1	0.1	-0.1	0.1	TBD	TBD	pF	1,2,9,10
C_{ALERT}	Input/output capacitance of ALERT	0.5	1.5	0.5	1.5	TBD	TBD	pF	1,3
C_{ZQ}	Input/output capacitance of ZQ	0.5	1.5	0.5	1.5	TBD	TBD	pF	1,3,12

Notes:

1. This parameter is not subject to production test. It is verified by design and characterization. The silicon only capacitance is validated by de-embedding the package L & C parasitic. The capacitance is measured with VDD, VDDQ, VSS, VSSQ applied with all other signal pins floating. Measurement procedure tbd.
2. DQ, DM, DQS_T, DQS_C, TDQS_T, TDQS_C. Although the DM, TDQS_T and TDQS_C pins have different functions, the loading matches DQ and DQS
3. This parameter applies to monolithic devices only; stacked/dual-die devices are not covered here.
4. Absolute value $C_{K\_T-CK\_C}$
5. Absolute value of $C_{IO(DQS\_T)}$-$C_{IO(DQS\_C)}$
6. C_I applies to ODT, CS_n, CKE, A0-A17, BA0-BA1, BG0-BG1, RAS_n, CAS_n, WE_n.
7. $C_{DI\ CTRL}$ applies to ODT, CS_n and CKE
8. $C_{DI\_CTRL} = C_{I(CTRL)}-0.5*(C_{I(CLK\_T)}+C_{I(CLK\_C)})$
9. $C_{DI\_ADD\_CMD}$ applies to, A0-A17, BA0-BA1, BG0-BG1, RAS_n, CAS_n, WE_n.
10. $C_{DI\_ADD\_CMD} = C_{I(ADD\_CMD)}-0.5*(C_{I(CLK\_T)}+C_{I(CLK\_C)})$
11. $C_{DIO} = C_{IO(DQ,DM)}-0.5*(C_{IO(DQS\_T)}+C_{IO(DQS\_C)})$
12. Maximum external load capacitance on ZQ pin: tbd pF

Input/Output Capacitance for 32GB

Symbol	Parameter	DDR4-1600, 1867, 2133		DDR4-2400,2667		DDR4-3200		Units	Note
		Min	Max	Min	Max	Min	Max		
C_{IO}	Input/output capacitance DQ, DQS, DM, CB	6.2	9.6			TBD	TBD	pF	
C_{In1}	Input capacitance (BA0/1,BG0/1, A*,RAS/CAS/WE	11.2	32.8			TBD	TBD	pF	
C_{in2}	Input capacitance (CKE0/1, ODT0/1, CS0/1	7.6	18.4			TBD	TBD	pF	
C_{in3}	Input capacitance, CK and CK#	7.6	18.4			TBD	TBD	pF	

DC and AC Specifications for the SMBus Interface

The specifications for the SMBus follow JEDEC standards.

Speed Bins by Speed Grade

DDR4-1600 Speed Bins and Operating Conditions

Speed Bin				DDR4-1600		Unit	NOTE
CL-nRCD-nRP				11-11-11			
Parameter			Symbol	Min	Max		
Internal read command to first data			tAA	13.75[14] (13.50)[5,12]	18	ns	
Internal read command to first data with read DBI enabled			tAA_DBI	tAA(min) + 2nCK	tAA(max) +2nCK	ns	
ACT to internal read or write delay time			tRCD	13.75 (13.50)[5,12]	-	ns	
PRE command period			tRP	13.75 (13.50)[5,12]	-	ns	
ACT to PRE command period			tRAS	35	9 x tREFI	ns	
ACT to ACT or REF command period			tRC	48.75 (48.50)[5,12]	-	ns	
	Normal	Read DBI					
CWL = 9	CL = 9	CL = 11 (Optional)[5]	tCK(AVG)	Reserved		ns	1,2,3,4,11 ,14
	CL = 10	CL = 12	tCK(AVG)	1.5	1.6	ns	1,2,3,4,11
CWL = 9,11	CL = 10	CL = 12	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 11	CL = 13	tCK(AVG)	1.25	<1.5	ns	1,2,3,4
	CL = 12	CL = 14	tCK(AVG)	1.25	<1.5	ns	1,2,3
Supported CL Settings				(9),11,12		nCK	13,14
Supported CL Settings with read DBI				(11),13,14		nCK	13
Supported CWL Settings				9,11		nCK	

DDR4-1866 Speed Bins and Operating Conditions

Speed Bin				DDR4-1866		Unit	NOTE
CL-nRCD-nRP				13-13-13			
Parameter			Symbol	Min	Max		
Internal read command to first data			tAA	13.92[14] (13.50)[5,12]	18	ns	
Internal read command to first data with read DBI enabled			tAA_DBI	tAA(min) + 2nCK	tAA(max) +2nCK	ns	
ACT to internal read or write delay time			tRCD	13.92 (13.50)[5,12]	-	ns	
PRE command period			tRP	13.92 (13.50)[5,12]	-	ns	
ACT to PRE command period			tRAS	34	9 x tREFI	ns	
ACT to ACT or REF command period			tRC	47.92 (47.50)[5,12]	-	ns	
	Normal	Read DBI					
CWL=9	CL=9	CL=11 (Optional)[5]	tCK(AVG)	Reserved		ns	1,2,3,4,11 ,14
	CL=10	CL=12	tCK(AVG)	1.5	1.6	ns	1,2,3,4,11
CWL=9,11	CL=10	CL=12	tCK(AVG)				4
	CL=11	CL=13	tCK(AVG)	1.25	<1.5	ns	1,2,3,4,6
				(Optional)[5,12]			
	CL=12	CL=14	tCK(AVG)	1.25	<1.5	ns	1,2,3,6
CWL=10,12	CL=12	CL=14	tCK(AVG)	Reserved		ns	1,2,3,4
	CL=13	CL=15	tCK(AVG)	1.071	<1.25	ns	1,2,3,4
	CL=14	CL=16	tCK(AVG)	1.071	<1.25	ns	1,2,3
Supported CL Settings				9,11,12,13,14		nCK	13,14
Supported CL Settings with read DBI				11,13,14 ,15,16		nCK	13
Supported CWL Settings				9,10,11,12		nCK	

DDR4-2133 Speed Bins and Operating Conditions

Speed Bin				DDR4-2133		Unit	NOTE
CL-nRCD-nRP				15-15-15			
Parameter			Symbol	Min	Max		
Internal read command to first data			tAA	14.06[14] (13.75)[5,12]	18	ns	
Internal read command to first data with read DBI enabled			tAA_DBI	tAA(min) + 3nCK	tAA(max) + 3nCK	ns	
ACT to internal read or write delay time			tRCD	14.06 (13.75)[5,12]	-	ns	
PRE command period			tRP	14.06 (13.75)[5,12]	-	ns	
ACT to PRE command period			tRAS	33	9 x tREFI	ns	
ACT to ACT or REF command period			tRC	47.06 (46.75)[5,12]	-	ns	
	Normal	Read DBI					
CWL = 9	CL = 9	CL = 11 (Optional)[5]	tCK(AVG)	Reserved		ns	1,2,3,4,11, 14
	CL = 10	CL = 12	tCK(AVG)	1.5	1.6	ns	1,2,3,11
CWL = 9,11	CL = 11	CL = 13	tCK(AVG)			ns	1,2,3,4,7
			tCK(AVG)	(Optional)[5,12]			
	CL = 12	CL = 14	tCK(AVG)	1.25	<1.5	ns	1,2,3,7
CWL = 10,12	CL = 13	CL = 15	tCK(AVG)	1.071	<1.25	ns	1,2,3,4,7
			tCK(AVG)	(Optional)[5,12]			
	CL = 14	CL = 16	tCK(AVG)	1.071	<1.25	ns	1,2,3,7
CWL = 11,14	CL = 14	CL = TBD	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 15	CL = TBD	tCK(AVG)	0.938	<1.071	ns	1,2,3,4
	CL = 16	CL = TBD	tCK(AVG)	0.938	<1.071	ns	1,2,3
Supported CL Settings				(9),(11),12,(13),14,15,16		nCK	13,14
Supported CL Settings with read DBI				(11),(13),14,(15),16,18,19		nCK	
Supported CWL Settings				9,10,11,12,14		nCK	

DDR4-2400 Speed Bins and Operating Conditions

Speed Bin				DDR4-2400		Unit	NOTE
CL-nRCD-nRP				17-17-17			
Parameter			Symbol	Min	Max		
Internal read command to first data			tAA	14.16[14] (13.75)[5,12]	18	ns	
Internal read command to first data with read DBI enabled			tAA_DBI	tAA(min) + 3nCK	tAA(max) + 3nCK	ns	
ACT to internal read or write delay time			tRCD	14.16 (13.75)[5,12]	-	ns	
PRE command period			tRP	14.16 (13.75)[5,12]	-	ns	
ACT to PRE command period			tRAS	32	9 x tREFI	ns	
ACT to ACT or REF command period			tRC	46.16 (45.75)[5,12]	-	ns	
	Normal	Read DBI					
CWL = 9	CL = 9	CL = 11 (Optional)[5]	tCK(AVG)	Reserved		ns	1,2,3,4,11, 14
	CL = 10	CL = 12	tCK(AVG)	1.5	1.6	ns	1,2,3,11
CWL = 9,11	CL = 11	CL = 13	tCK(AVG)			ns	1,2,3,4,7
			tCK(AVG)	(Optional)[5,12]			
	CL = 12	CL = 14	tCK(AVG)	1.25	<1.5	ns	1,2,3,7
CWL = 10,12	CL = 13	CL = 15	tCK(AVG)	1.071	<1.25	ns	1,2,3,4,7
			tCK(AVG)	(Optional)[5,12]			
	CL = 14	CL = 16	tCK(AVG)	1.071	<1.25	ns	1,2,3,7
CWL = 11,14	CL = 14	CL = 17	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 15	CL = 18	tCK(AVG)	0.938	<1.071	ns	1,2,3,4
	CL = 16	CL = 19	tCK(AVG)	0.938	<1.071	ns	1,2,3
CWL = 12,16	CL = 15	CL = 18	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 16	CL = 19	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 17	CL = 20	tCK(AVG)	0.833	<0.938	ns	1,2,3
	CL = 18	CL = 21	tCK(AVG)	0.833	<0.938	ns	1,2,3,4
Supported CL Settings				(10),(11),12,(13),14,15,16,17,18		nCK	13,14
Supported CL Settings with read DBI				(12),(13),14,(15),16,18,19,20,21		nCK	
Supported CWL Settings				9,10,11,12,14,16		nCK	

DDR4-2933 Speed Bins and Operating Conditions

Speed Bin				DDR4-2933		Unit	NOTE
CL-nRCD-nRP				21-21-21			
Parameter			Symbol	Min	Max		
Internal read command to first data			tAA	14.3214 (13.75)5,12	18.00	ns	12
Internal read command to first data with read DBI enabled			tAA_DBI	tAA(min) + 4nCK	tAA(max) + 4nCK	ns	12
ACT to internal read or write delay time			tRCD	14.32 (13.75)5,12	-	ns	12
PRE command period			tRP	14.32 (13.75)5,12	-	ns	12
ACT to PRE command period			tRAS	32	9 x tREFI	ns	12
ACT to ACT or REF command period			tRC	46.32 (45.75)5,12	-	ns	12
	Normal	Read DBI					
CWL = 9	CL = 9	CL = 11	tCK(AVG)	Reserved		ns	1,2,3,4,11
	CL = 10	CL = 12	tCK(AVG)	1.5	1.6	ns	1,2,3,11
CWL = 9,11	CL = 10	CL = 12	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 11	CL = 13	tCK(AVG)	1.25	<1.5	ns	1,2,3,4,13
	CL = 12	CL = 14	tCK(AVG)	1.25	<1.5	ns	1,2,3,15
CWL = 10,12	CL = 12	CL = 14	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 13	CL = 15	tCK(AVG)	1.071	<1.25	ns	1,2,3,4,15
	CL = 14	CL = 16	tCK(AVG)	1.071	<1.25	ns	1,2,3,15
CWL = 11,14	CL = 14	CL = 17	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 15	CL = 18	tCK(AVG)	0.937	<1.071	ns	1,2,3,4,15
	CL = 16	CL = 19	tCK(AVG)	0.937	<1.071	ns	1,2,3,15
CWL = 12.16	CL = 15	CL = 18	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 16	CL = 19	tCK(AVG)	Reserved		ns	1,2,3,4,15
	CL = 17	CL = 20	tCK(AVG)	0.833	0.937	ns	1,2,3,4,15
	CL = 18	CL = 21	tCK(AVG)	0.833	0.937	ns	1,2,3,15
CWL = 14,18	CL = 17	CL = 20	tCK(AVG	Reserved		ns	1,2,3,4
	CL = 18	CL = 21	tCK(AVG)	Reserved		ns	1,2,3,4,15
	CL = 19	CL = 22	tCK(AVG)	0.75	<0.833	ns	1,2,3,4,15
	CL = 20	CL = 23	tCK(AVG)	0.75	<0.833	ns	1,2,3,15
CWL = 16,20	CL = 19	CL = 23	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 20	CL = 24	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 21	CL = 26	tCK(AVG)	0.682	<0.75	ns	1,2,3,4
	CL = 22	CL = 26	tCK(AVG)	0.682	<0.75	ns	1,2,3
Supported CL Settings				10,(11),12,(13),14,(15),16,(17),18,(19),20, 21,22		nCK	13
Supported CL Settings with read DBI				12,(13),14,(15),16,(18),19,(20),21,(22),23, 25,26		nCK	13
Supported CWL Settings				9,10,11,12,14,15,16,18,20		nCK	

DDR4-3200 Speed Bins and Operating Conditions

Speed Bin				DDR4-3200		Unit	NOTE
CL-nRCD-nRP				22-22-22			
Parameter			Symbol	Min	Max		
Internal read command to first data			tAA	13.75	18.00	ns	12
Internal read command to first data with read DBI enabled			tAA_DBI	tAA(min) + 4nCK	tAA(max) + 4nCK	ns	12
ACT to internal read or write delay time			tRCD	13.75	-	ns	12
PRE command period			tRP	13.75	-	ns	12
ACT to PRE command period			tRAS	32	9 x tREFI	ns	12
ACT to ACT or REF com-mand period			tRC	45.75	-	ns	12
	Normal	Read DBI					
CWL = 9	CL = 9	CL = 11	tCK(AVG)	Reserved		ns	1,2,3,4,11
	CL = 10	CL = 12	tCK(AVG)	Reserved		ns	1,2,3,4,11
CWL = 9,11	CL = 10	CL = 12	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 11	CL = 13	tCK(AVG)	1.25	<1.5	ns	1,2,3,4,10
	CL = 12	CL = 14	tCK(AVG)	1.25	<1.5	ns	1,2,3,10
CWL = 10,12	CL = 12	CL = 14	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 13	CL = 15	tCK(AVG)	1.071	<1.25	ns	1,2,3,4,10
	CL = 14	CL = 16	tCK(AVG)	1.071	<1.25	ns	1,2,3,10
CWL = 11,14	CL = 14	CL = 17	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 15	CL = 18	tCK(AVG)	0.937	<1.071	ns	1,2,3,4,10
	CL = 16	CL = 19	tCK(AVG)	0.937	<1.071	ns	1,2,3,10
CWL = 12.16	CL = 15	CL = 18	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 16	CL = 19	tCK(AVG)	Reserved		ns	1,2,3,4,10
	CL = 17	CL = 20	tCK(AVG)	0.833	<0.937	ns	1,2,3,4,10
	CL = 18	CL = 21	tCK(AVG)	0.833	<0.937	ns	1,2,3,10
CWL = 14,18	CL = 17	CL = 20	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 18	CL = 21	tCK(AVG)	Reserved		ns	1,2,3,4,10
	CL = 19	CL = 22	tCK(AVG)	0.75	<0.833	ns	1,2,3,4,10
	CL = 20	CL = 23	tCK(AVG)	0.75	<0.833	ns	1,2,3,10
CWL = 16,20	CL = 20	CL = 24	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 22	CL = 26	tCK(AVG)	0.625	<0.75	ns	1,2,3,4
	CL = 24	CL = 28	tCK(AVG)	0.625	<0.75	ns	1,2,3
Supported CL Settings				10,11,12,13,14,15, 16,17,18,19,20,22, 24		nCK	13
Supported CL Settings with read DBI				12,13,14,15,16,18, 19,20,21,22,23,24, 26, 28		nCK	
Supported CWL Settings				9,10,11,12,14,16, 18,20		nCK	

Speed Bin Table Note

Absolute Specification

- VDDQ = VDD = 1.20V +/- 0.06 V
- VPP = 2.5V +0.25/-0.125 V

The values defined with above-mentioned table are DLL ON case.- DDR4-1600, 1866, 2133, 2400, 2933 and 3200 Speed Bin Tables are valid only when Geardown Mode is disabled.

1. The CL setting and CWL setting result in tCK(avg).MIN and tCK(avg).MAX requirements. When making a selection of tCK(avg), both need to be fulfilled: Requirements from CL setting as well as requirements from CWL setting.
2. tCK(avg).MIN limits: Since CAS Latency is not purely analog - data and strobe output are synchronized by the DLL - all possible intermediate frequencies may not be guaranteed. CL in clock cycle is calculated from tAA followingrounding algorithm defined in Section 13.5.
3. tCK(avg).MAX limits: Calculate tCK(avg) = tAA.MAX / CL SELECTED and round the resulting tCK(avg) down to the next valid speed bin (i.e. 1.5ns or 1.25ns or 1.071 ns or 0.937 ns or 0.833 ns). This result is tCK(avg).MAX corresponding

to CL SELECTED.
4. ‘Reserved’ settings are not allowed. User must program a different value.
5. 'Optional' settings allow certain devices in the industry to support this setting, however, it is not a mandatory feature. Refer to supplier's data sheet and/or the DIMM SPD information if and how this setting is supported.
6. Any DDR4-1866 speed bin also supports functional operation at lower frequencies as shown in the table which are not subject to Production Tests but verified by Design/Characterization.
7. Any DDR4-2133 speed bin also supports functional operation at lower frequencies as shown in the table which are not subject to Production Tests but verified by Design/Characterization.
8. Any DDR4-2400 speed bin also supports functional operation at lower frequencies as shown in the table which are not subject to Production Tests but verified by Design/Characterization.
9. Any DDR4-2666 speed bin also supports functional operation at lower frequencies as shown in the table which are not subject to Production Tests but verified by Design/Characterization.
10. Any DDR4-3200 speed bin also supports functional operation at lower frequencies as shown in the table which are not subject to Production Tests but verified by Design/Characterization.
11. DDR4-1600 AC timing apply if DRAM operates at lower than 1600 MT/s data rate.
12. DDR4-2400,2666,2933 and 3200Mbps speed bin support CL=10 if DRAM operate at 1333MT/s data rate.
13. Parameters apply from tCK(avg)min to tCK(avg)max at all standard JEDEC clock period values as stated in the Speed Bin Tables.
14. CL number in parentheses, it means that these numbers are optional.
15. DDR4 SDRAM supports CL=9 as long as a system meets tAA(min).
16. Each speed bin lists the timing requirements that need to be supported in order for a given DRAM to be JEDEC compliant. JEDEC compliance does not require support for all speed bins within a given speed. JEDEC compliance requires meeting the parameters for a least one of the listed speed bins.

Timing Parameters by Speed Grade

Speed		DDR4-1600		DDR4-1866		DDR4-2133		DDR4-2400		DDR4-2666		DDR4-2933		Units	NOTE
Parameter	Symbol	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX		
ACTIVATE to ACTIVATE Command delay to same bank group for 2KB page size	tRRD_L(2K)	Max(4nCK, 7.5ns)		Max(4nCK, 6.4ns)		Max(4nCK, 6.4ns)		Max(4nCK,6.4ns)	-	Max(4nCK,6.4ns)	-	Max(4nCK,6.4ns)	-	nCK	34
ACTIVATE to ACTIVATE Command delay to same bank group for 1KB page size	tRRD_L(1K)	Max(4nCK, 6ns)		Max(4nCK, 5.3ns)		Max(4nCK, 5.3ns)		Max(4nCK,4.9ns)	-	Max(4nCK,4.9ns)	-	Max(4nCK,4.9ns)	-	nCK	34
ACTIVATE to ACTIVATE Command delay to same bank group for 1/2KB page size	tRRD_L(1/2K)	Max(4nCK, 6ns)		Max(4nCK, 5.3ns)		Max(4nCK, 5.3ns)		Max(4nCK,4.9ns)	-	Max(4nCK,4.9ns)	-	Max(4nCK,4.9ns)	-	nCK	34
Four activate window for 2KB page size	tFAW_2K	Max(28nCK,35ns)		Max(28nCK,30ns)		Max(28nCK,30ns)		Max(28nCK,30ns)	-	Max(28nCK,30ns)	-	Max(28nC K,30ns)	-	ns	34
Four activate window for 1KB page size	tFAW_1K	Max(20nCK,25ns)		Max(20nCK,23ns)		Max(20nCK,21ns)		Max(20nCK,21ns)	-	Max(20nCK,21ns)	-	Max(20nC K,21ns)	-	ns	34
Four activate window for 1/2KB page size	tFAW_1/2K	Max(16nCK,20ns)		Max(16nCK,17ns)		Max(16nCK,15ns)		Max(16nCK,13ns)	-	Max(16nCK,12ns)	-	Max (16nCK, 10.875ns)	-	ns	34
Delay from start of internal write transaction to internal read command for different bank group	tWTR_S	max(2nCK, 2.5ns)	-	max(2nCK, 2.5ns)	-	max(2nCK, 2.5ns)	-	Max (2nCK,2.5 ns)	-	Max (2nCK,2.5 ns)	-	Max (2nCK, 2.5ns)	-	ns	1,2,e,34
Delay from start of internal write transaction to internal read command for same bank group	tWTR_L	max(4nCK, 7.5ns)	-	max(4nCK, 7.5ns)	-	max(4nCK, 7.5ns)	-	max (4nCK,7.5 ns)	-	max (4nCK,7.5 ns)	-	max (4nCK,7.5 n s)	-		1,34
Internal READ Command to PRE-CHARGE Command delay	tRTP	max(4nCK, 7.5ns)	-	max(4nCK, 7.5ns)	-	max(4nCK, 7.5ns)	-	max (4nCK,7.5 ns)	-	max (4nCK,7.5 ns)	-	max (4nCK,7.5 n s)	-		
WRITE recovery time	tWR	15	-	15	-	15	-	15	-	15	-	15	-	ns	1
Write recovery time when CRC and DM are enabled	tWR_CRC_DM	tWR+max (4nCK,3.75ns)	-	tWR+max (5nCK,3.75ns)	-	tWR+max (5nCK,3.75ns)	-	tWR+max (5nCK,3.75ns)	-	tWR+max (5nCK,3.75ns)	-	tWR+max (5nCK,3.75 ns)	-	ns	1, 28

Speed		DDR4-1600		DDR4-1866		DDR4-2133		DDR4-2400		DDR4-2666		DDR4-2933		Units	NOTE
Parameter	Symbol	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX		
Delay from start of internal write transaction to internal read command for different bank group with both CRC and DM enabled	tWTR_S_CRC_DM	tWTR_S+ max (4nCK,3.75ns)	-	tWTR_S+ max (5nCK,3.75ns)	-	tWTR_S+ max (5nCK,3.75ns)	-	tWTR_S+ max (5nCK,3.75ns)	-	tWTR_S+ max (5nCK,3.75ns)	-	tWTR_S+ max (5nCK,3.75 ns)	-	ns	2, 29, 34
Delay from start of internal write transaction to internal read command for same bank group with both CRC and DM enabled	tWTR_L_CRC_DM	tWTR_L+max (4nCK,3.75ns)	-	tWTR_L+max (5nCK,3.75ns)	-	tWTR_L+max (5nCK,3.75ns)	-	tWTR_L+m ax (5nCK,3.75ns)	-	tWTR_L+m ax (5nCK,3.75ns)	-	tWTR_L+m ax (5nCK,3.75 ns)	-	ns	3,30, 34
DLL locking time	tDLLK	597	-	597	-	768	-	768	-	1024	-	1024	-	nCK	
Mode Register Set command cycle time	tMRD	8	-	8	-	8	-	8	-	8	-	8	-	nCK	
Mode Register Set command update delay	tMOD	max(24nCK,15ns)	-	max(24nCK,15ns)	-	max(24nCK,15ns)	-	max(24nC K,15ns)	-	max(24nCK,15ns)	-	max(24nC K,15ns)	-	nCK	50
Multi-Purpose Register Recovery Time	tMPRR	1	-	1	-	1	-	1	-	1	-	1	-	nCK	33
Multi Purpose Register Write Recov-ery Time	tWR_MPR	tMOD (min) + AL + PL	-	tMOD (min) + AL + PL	-	tMOD (min) + AL + PL	-	tMOD (min) + AL + PL	-	tMOD (min) + AL + PL	-	tMOD (min) + AL + PL	-		
Auto precharge write recovery + pre-charge time	tDAL(min)	Programmed WR + roundup (tRP / tCK(avg))													nCK
DQ0 or DQL0 driven to 0 set-up time to first DQS rising edge	tPDA_S	0.5	-	0.5	-	0.5	-	0.5	-	0.5	-	0.5	-	UI	45,47
DQ0 or DQL0 driven to 0 hold time from last DQS falling edge	tPDA_H	0.5	-	0.5	-	0.5	-	0.5	-	0.5	-	0.5	-	UI	46,47
CS_n to Command Address Latency															
CS_n to Command Address Latency	tCAL	max(3 nCK, 3.748 ns)	-	max(3 nCK, 3.748 ns)	-	max(3 nCK, 3.748 ns)	-	max(3 nCK, 3.748 ns)	-	max(3 nCK, 3.748 ns)	-	max(3 nCK, 3.748 ns)	-	nCK	
Mode Register Set command cycle time in CAL mode	tMRD_tCAL	tMOD+ tCAL	-	tMOD+ tCAL	-	tMOD+ tCAL	-	tMOD+ tCAL	-	tMOD+ tCAL	-	tMOD+ tCAL	-	nCK	
Mode Register Set update delay in CAL mode	tMOD_tCAL	tMOD+ tCAL	-	tMOD+ tCAL	-	tMOD+ tCAL	-	tMOD+ tCAL	-	tMOD+ tCAL	-	tMOD+ tCAL	-	nCK	
DRAM Data Timing															
DQS_t, DQS_c to DQ skew, per group, per access	tDQSQ	-	0.16	-	0.16	-	0.16	-	0.17	-	0.18	-	0.19	tCK(avg)/ 2	13,18,39,49

Speed		DDR4-1600		DDR4-1866		DDR4-2133		DDR4-2400		DDR4-2666		DDR4-2933		Units	NOTE
Parameter	Symbol	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX		
DQ output hold time per group, per access from DQS_t, DQS_c	tQH	0.76	-	0.76	-	0.76	-	0.74	-	0.74	-	0.72	-	tCK(avg)/ 2	13,17,18,39,49
Data Valid Window per device, per UI: (tQH - tDQSQ) of each UI on a given DRAM	tDVWd	0.63	-	0.63	-	0.64	-	0.64	-	0.64	-	0.64	-	UI	17,18,39,49
Data Valid Window, per pin, per UI: (tQH - tDQSQ) each UI on a pin of a given DRAM	tDVWp	0.66	-	0.66	-	0.69	-	0.72	-	0.72	-	0.72	-	UI	17,18,39,49
DQ low impedance time from CK_t, CK_c	tLZ(DQ)	-450	225	-390	195	-360	180	-330	175	-310	170	-280	165	ps	39
DQ high impedance time from CK_t, CK_c	tHZ(DQ)	-	225	-	195	-	180	-	175	-	170	-	165	ps	39
Data Strobe Timing															
DQS_t, DQS_c differential READ Pre-amble (1 clock preamble)	tRPRE	0.9	NOTE 44	0.9	NOTE44	0.9	NOTE44	0.9	NOTE 44	0.9	NOTE 44	0.9	NOTE 44	tCK	40
DQS_t, DQS_c differential READ Preamble (2 clock preamble)	tRPRE2	NA	NA	NA	NA	NA	NA	1.8	NOTE 44	1.8	NOTE 44	1.8	NOTE 44	tCK	41
DQS_t, DQS_c differential READ Postamble	tRPST	0.33	NOTE 45	0.33	NOTE 45	0.33	NOTE 45	0.33	NOTE 45	0.33	NOTE 45	0.33	NOTE 45	tCK	
DQS_t, DQS_c differential output high time	tQSH	0.4	-	0.4	-	0.4	-	0.4	-	0.4	-	0.4	-	tCK	21
DQS_t, DQS_c differential output low time	tQSL	0.4	-	0.4	-	0.4	-	0.4	-	0.4	-	0.4	-	tCK	20
DQS_t, DQS_c differential WRITE Preamble (1 clock preamble)	tWPRE	0.9	-	0.9	-	0.9	-	0.9	-	0.9	-	0.9	-	tCK	42
DQS_t, DQS_c differential WRITE Preamble (2 clock preamble)	tWPRE2	NA		NA		NA		1.8	-	1.8	-	1.8	-	tCK	43
DQS_t, DQS_c differential WRITE Postamble	tWPST	0.33	-	0.33	-	0.33	-	0.33	-	0.33	-	0.33	-	tCK	

Speed		DDR4-1600		DDR4-1866		DDR4-2133		DDR4-2400		DDR4-2666		DDR4-2933		Units	NOTE
Parameter	Symbol	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX		
DQS_t and DQS_c low-impedance time (Referenced from RL-1)	tLZ(DQS)	-450	225	-390	195	-360	180	-330	175	-310	170	-280	165	ps	
DQS_t and DQS_c high-impedance time (Referenced from RL+BL/2)	tHZ(DQS)	-	225	-	195	-	180	-	175	-	170	-	165	ps	
DQS_t, DQS_c differential input low pulse width	tDQSL	0.46	0.54	0.46	0.54	0.46	0.54	0.46	0.54	0.46	0.54	0.46	0.54	tCK	
DQS_t, DQS_c differential input high pulse width	tDQSH	0.46	0.54	0.46	0.54	0.46	0.54	0.46	0.54	0.46	0.54	0.46	0.54	tCK	
DQS_t, DQS_c rising edge to CK_t, CK_c rising edge (1 clock preamble)	tDQSS	-0.27	0.27	-0.27	0.27	-0.27	0.27	-0.27	0.27	-0.27	0.27	-0.27	0.27	tCK	42
DQS_t, DQS_c rising edge to CK_t, CK_c rising edge (2 clock preamble)	tDQSS2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	tCK	43
DQS_t, DQS_c falling edge setup time to CK_t, CK_c rising edge	tDSS	0.18	-	0.18	-	0.18	-	0.18	-	0.18	-	0.18	-	tCK	
DQS_t, DQS_c falling edge hold time from CK_t, CK_c rising edge	tDSH	0.18	-	0.18	-	0.18	-	0.18	-	0.18	-	0.18	-	tCK	
DQS_t, DQS_c rising edge output timing location from rising CK_t, CK_c with DLL On mode	tDQSCK (DLL On)	-225	225	-195	195	-180	180	-175	175	-170	170	-165	165	ps	37,38,39
DQS_t, DQS_c rising edge output variance window per DRAM	tDQSCKI (DLL On)	-	370	-	330	-	310	-	290	-	270	-	265	ps	37,38,39
MPSM Timing															
Command path disable delay upon MPSM entry	tMPED	tMOD(min) + tCPDED(min)	-	tMOD(min) + tCPDED(min)	-	tMOD(min) + tCPDED(min)	-	tMOD(min) + tCPDED(min)	-	tMOD(min) + tCPDED(min)	-	tMOD(min) + tCPDED(min)	-		
Valid clock requirement after MPSM entry	tCKMPE	tMOD(min) +tCPDED(min)	-	tMOD(min) + tCPDED(min)	-	tMOD(min) + tCPDED(min)	-	tMOD(min) + tCPDED(min)	-	tMOD(min) + tCPDED(min)	-	tMOD(min) +tCPDED(min)	-		
Valid clock requirement before MPSM exit	tCKMPX	tCKSRX(min)	-	tCKSRX(min)	-	tCKSRX(min)	-	tCKSRX(min)	-	tCKSRX(min)	-	tCKSRX(min)	-		

Speed		DDR4-1600		DDR4-1866		DDR4-2133		DDR4-2400		DDR4-2666		DDR4-2933		Units	NOTE
Parameter	Symbol	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX		
Exit MPSM to commands not requir-ing a locked DLL	tXMP	tXS(min)	-	tXS(min)	-	tXS(min)	-	tXS(min)	-	tXS(min)	-	tXS(min)	-		
Exit MPSM to commands requiring a locked DLL	tXMPDLL	tXMP(min) + tXS-DLL(min)	-	tXMP(min) + tXS-DLL(min)	-	tXMP(min) +tXS-DLL(min)	-	tXMP(min) + tXS-DLL(min)	-	tXMP(min) + tXS-DLL(min)	-	tXMP(min) + tXSDLL(min)	-		
CS setup time to CKE	tMPX_S	tIS(min) + tIH(min)	-	tIS(min) + tIH(min)	-	tIS(min) + tIH(min)	-	tIS(min) + tIH(min)	-	tIS(min) + tIH(min)	-	tIS(min) + tIH(min)	-		
CS_n High hold time to CKE rising edge	tMPX_HH	tXP(min)	-	tXP(min)	-	tXP(min)	-	tXP(min)	-	tXP(min)	-	tXP(min)	-		
CS_n Low hold time to CKE rising edge	tMPX_LH	12	tXMP-10ns	12	tXMP-10ns	12	tXMP-10ns	12	tXMP-10ns	12	tXMP-10ns	12	tXMP-10ns	ns	51
Calibration Timing															
Power-up and RESET calibration time	tZQinit	1024	-	1024	-	1024	-	1024	-	1024	-	1024	-	nCK	
Normal operation Full calibration time	tZQoper	512	-	512	-	512	-	512	-	512	-	512	-	nCK	
Normal operation Short calibration time	tZQCS	128	-	128	-	128	-	128	-	128	-	128	-	nCK	
Reset/Self Refresh Timing															
Exit Reset from CKE HIGH to a valid command	tXPR	max (5nCK,tRFC(min)+ 10ns)	-	max (5nCK,tRFC(min)+ 10ns)	-	max (5nCK,tRFC(min)+10ns)	-	max (5nCK,tRFC(min)+10 ns)	-	max (5nCK,tRFC(min)+10 ns)	-	max (5nCK,tRFC(min)+10 ns)	-	nCK	
Exit Self Refresh to commands not requiring a locked DLL	tXS	tRFC(min) +10ns	-	tRFC(min) +10ns	-	tRFC(min) +10ns	-	tRFC(min) +10ns	-	tRFC(min) +10ns	-	tRFC(min) +10ns	-	nCK	
SRX to commands not requiring a locked DLL in Self Refresh ABORT	tX-S_ABORT(min)	tRFC4(min)+10ns	-	tRFC4(min)+10ns	-	tRFC4(min)+10ns	-	tRFC4(min)+10ns	-	tRFC4(min)+10ns	-	tRFC4(min)+10ns	-	nCK	
Exit Self Refresh to ZQCL,ZQCS and MRS (CL,CWL,WR,RTP and Gear Down)	tXS_FAST (min)	tRFC4(min)+10ns	-	tRFC4(min)+10ns	-	tRFC4(min)+10ns	-	tRFC4(min)+10ns	-	tRFC4(min)+10ns	-	tRFC4(min)+10ns	-	nCK	
Exit Self Refresh to commands re-quiring a locked DLL	tXSDLL	tDLLK(min)	-	tDLLK (min)	-	tDLLK(min)	-	tDLLK(min)	-	tDLLK(min)	-	tDLLK(min)	-	nCK	
Minimum CKE low width for Self re-fresh entry to exit timing	tCKESR	tCKE(min) +1nCK	-	tCKE(min) +1nCK	-	tCKE(min) +1nCK	-	tCKE(min) +1nCK	-	tCKE(min) +1nCK	-	tCKE(min) +1nCK	-	nCK	

Speed		DDR4-1600		DDR4-1866		DDR4-2133		DDR4-2400		DDR4-2666		DDR4-2933		Units	NOTE
Parameter	Symbol	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX		
Minimum CKE low width for Self re-fresh entry to exit timing with CA Par-ity enabled	tCKESR_ PAR	tCKE (min) + 1nCK +PL	-	tCKE(min) + 1nCK +PL	-	tCKE(mi n) + 1nCK+P L	-	tCKE(min) + 1nCK+PL	-	tCKE(min) + 1nCK+PL	-	tCKE(min) + 1nCK+PL	-	nCK	
Valid Clock Requirement after Self Refresh Entry (SRE) or Power-Down Entry (PDE)	tCKSRE	max(5nCK , 10ns)	-	max(5 nCK, 10ns)	-	max(5n CK, 10ns)	-	max (5nCK,10 n s)	-	max (5nCK,10 n s)	-	max (5nCK,10 n s)	-	nCK	
Valid Clock Requirement after Self Refresh Entry (SRE) or Power-Down when CA Parity is enabled	tCKS-RE_PAR	max (5nC K,10 n s)+P L	-	max (5nCK ,10n s)+PL	-	max (5nCK,1 0n s)+PL	-	max (5nCK,10 n s)+PL	-	max (5nCK,10 n s)+PL	-	max (5nCK,10 n s)+PL	-	nCK	
Valid Clock Requirement before Self Refresh Exit (SRX) or Power-Down Exit (PDX) or Reset Exit	tCKSRX	max(5nCK , 10ns)	-	max(5 nCK, 10ns)	-	max(5n CK, 10ns)	-	max (5nCK,10 n s)	-	max (5nCK,10 n s)	-	max (5nCK,10 n s)	-	nCK	
Power Down Timing															
Exit Power Down with DLL on to any valid command; Exit Precharge Pow-er Down with DLL frozen to com-mands not requiring a locked DLL	tXP	max (4nC K,6ns)	-	max (4nCK ,6ns)	-	max (4nCK,6 ns)	-	max (4nCK,6n s)	-	max (4nCK,6n s)	-	max (4nCK,6n s)	-	nCK	
CKE minimum pulse width	tCKE	max (3nC K, 5ns)	-	max (3nCK , 5ns)	-	max (3nCK, 5ns)	-	max (3nCK, 5ns)	-	max (3nCK, 5ns)	-	max (3nCK, 5ns)	-	nCK	31,32
Command pass disable delay	tCPDED	4	-	4	-	4	-	4	-	4	-	4	-	nCK	
Power Down Entry to Exit Timing	tPD	tCKE (min)	9*tRE FI	tCKE(min)	9*tREFI	tCKE(mi n)	9*tREFI	tCKE(min)	9*tREFI	tCKE(min)	9*tREFI	tCKE(min)	9*tREFI	nCK	6
Timing of ACT command to Power Down entry	tACTPDEN	1	-	1	-	2	-	2	-	2	-	2	-	nCK	7
Timing of PRE or PREA command to Power Down entry	tPRPDEN	1	-	1	-	2	-	2	-	2	-	2	-	nCK	7
Timing of RD/RDA command to Pow-er Down entry	tRDPDEN	RL+4 +1	-	RL+4 +1	-	RL+4+1	-	RL+4+1	-	RL+4+1	-	RL+4+1	-	nCK	

Speed		DDR4-1600		DDR4-1866		DDR4-2133		DDR4-2400		DDR4-2666		DDR4-2933		Units	NOTE
Parameter	Symbol	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX		
Timing of WR command to Power Down entry (BL8OTF, BL8MRS, BC4OTF)	tWRPDEN	WL+4+(tWR/tCK(avg))	-	WL+4+(tWR/tCK(avg))	-	WL+4+(tWR/tCK(avg))	-	WL+4+(tWR/tCK(avg))	-	WL+4+(tWR/tCK(avg))	-	WL+4+(tWR/tCK(avg))	-	nCK	4
Timing of WRA command to Power Down entry (BL8OTF, BL8MRS, BC4OTF)	tWRAPDEN	WL+4+WR +1	-	WL+4+WR +1	-	WL+4+WR +1	-	WL+4+WR +1	-	WL+4+WR +1	-	WL+4+WR +1	-	nCK	5
Timing of WR command to Power Down entry (BC4MRS)	tWRP-BC4DEN	WL+2+(tWR/tCK(avg))	-	WL+2+(tWR/tCK(avg))	-	WL+2+(tWR/tCK(avg))	-	WL+2+(tWR/tCK(avg))	-	WL+2+(tWR/tCK(avg))	-	WL+2+(tWR/tCK(avg))	-	nCK	4
Timing of WRA command to Power Down entry (BC4MRS)	tWRAP-BC4DEN	WL+2+WR +1	-	WL+2+WR +1	-	WL+2+WR +1	-	WL+2+WR +1	-	WL+2+WR +1	-	WL+2+WR +1	-	nCK	5
Timing of REF command to Power Down entry	tREFPDEN	1	-	1	-	2	-	2	-	2	-	2	-	nCK	7
Timing of MRS command to Power Down entry	tMRSPDEN	tMOD(min)	-	tMOD(min)	-	tMOD(min)	-	tMOD(min)	-	tMOD(min)	-	tMOD(min)	-		
PDA Timing															
Mode Register Set command cycle time in PDA mode	tMRD_PDA	max(16nCK,10ns)	-	max(16nCK,10ns)	-	max(16nCK,10ns)	-	max(16nCK,10ns)	-	max(16nCK,10ns)	-	max(16nCK,10ns)	-	nCK	
Mode Register Set command update delay in PDA mode	tMOD_PDA	tMOD	tMOD	tMOD	tMOD	tMOD	tMOD								
ODT Timing															
Asynchronous RTT turn-on delay (Power-Down with DLL frozen)	tAONAS	1.0	9.0	1.0	9.0	1.0	9.0	1.0	9.0	1.0	9.0	1.0	9.0	ns	
Asynchronous RTT turn-off delay (Power-Down with DLL frozen)	tAOFAS	1.0	9.0	1.0	9.0	1.0	9.0	1.0	9.0	1.0	9.0	1.0	9.0	ns	
RTT dynamic change skew	tADC	0.3	0.7	0.3	0.7	0.3	0.7	0.3	0.7	0.28	0.72	0.26	0.74	tCK(avg)	
Write Leveling Timing															
First DQS_t/DQS_c rising edge after write leveling mode is programmed	tWLMRD	40	-	40	-	40	-	40	-	40	-	40	-	nCK	12

Speed		DDR4-1600		DDR4-1866		DDR4-2133		DDR4-2400		DDR4-2666		DDR4-2933		Units	NOTE
Parameter	Symbol	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX		
DQS_t/DQS_c delay after write level-ing mode is programmed	tWLDQSEN	25	-	25	-	25	-	25	-	25	-	25	-	nCK	12
Write leveling setup time from rising CK_t, CK_c crossing to rising DQS_t/ DQS_c crossing	tWLS	0.13	-	0.13	-	0.13	-	0.13	-	0.13	-	0.13	-	tCK(avg)	
Write leveling hold time from rising DQS_t/DQS_c crossing to rising CK_t, CK_c crossing	tWLH	0.13	-	0.13	-	0.13	-	0.13	-	0.13	-	0.13	-	tCK(avg)	
Write leveling output delay	tWLO	0	9.5	0	9.5	0	9.5	0	9.5	0	9.5	0	9.5	ns	
Write leveling output error	tWLOE	0	2	0	2	0	2	0	2	0	2	0	2	ns	
CA Parity Timing															
Commands not guaranteed to be ex-ecuted during this time	tPAR_UN-KNOWN	-	PL	-	PL	-	PL	-	PL	-	PL	-	PL		
Delay from errant command to ALERT_n assertion	tPAR_ALERT_ON	-	PL+6ns	-	PL+6ns	-	PL+6ns	-	PL+6ns	-	PL+6ns	-	PL+6ns		
Pulse width of ALERT_n signal when asserted	tPAR_ALERT_PW	48	96	56	112	64	128	72	144	80	160	88	176	nCK	
Time from when Alert is asserted till controller must start providing DES commands in Persistent CA parity mode	tPAR_ALERT_RSP	-	43	-	50	-	57	-	64	-	71	-	78	nCK	
Parity Latency	PL	4	4	4	5	5	6	nCK							
CRC Error Reporting															
CRC error to ALERT_n latency	tCRC_ALERT	3	13	3	13	3	13	3	13	3	13	3	13	ns	
CRC ALERT_n pulse width	CRC_ALERT_PW	6	10	6	10	6	10	6	10	6	10	6	10	nCK	
Geardown timing															
Exit RESET from CKE HIGH to a val-id MRS geardown (T2/Reset)	tXPR_GEAR	-	-	-	-	-	-	-	-	tXPR	-	tXPR	-		
CKE High Assert to Gear Down En-able time(T2/CKE)	tXS_GEAR	-	-	-	-	-	-	-	-	tXS	-	tXS	-		

Speed		DDR4-1600		DDR4-1866		DDR4-2133		DDR4-2400		DDR4-2666		DDR4-2933		Units	NOTE
Parameter	Symbol	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX		
MRS command to Sync pulse time(T3)	tSYNC_GEAR	-	-	-	-	-	-	-	-	tMOD + 4tCK	-	tMOD + 4tCK	-		27
Sync pulse to First valid com-mand(T4)	tCMD_GEAR	-	-	-	-	-	-	-	-	tMOD	-	tMOD	-		27
Geardown setup time	tGEAR_setup	-	-	-	-	-	-	-	-	2	-	2	-	nCK	
Geardown hold time	tGEAR_hold	-	-	-	-	-	-	-	-	2	-	2	-	nCK	
tREFI															
tRFC1 (min)	2Gb	160	-	160	-	160	-	160	-	160	-	160	-	ns	34
	4Gb	260	-	260	-	260	-	260	-	260	-	260	-	ns	34
	8Gb	350	-	350	-	350	-	350	-	350	-	350	-	ns	34
tRFC2 (min)	2Gb	110	-	110	-	110	-	110	-	110	-	110	-	ns	34
	4Gb	160	-	160	-	160	-	160	-	160	-	160	-	ns	34
	8Gb	260	-	260	-	260	-	260	-	260	-	260	-	ns	34
tRFC4 (min)	2Gb	90	-	90	-	90	-	90	-	90	-	90	-	ns	34
	4Gb	110	-	110	-	110	-	110	-	110	-	110	-	ns	34
	8Gb	160	-	160	-	160	-	160	-	160	-	160	-	ns	34

Speed		DDR4-3200		Units	Note
Parameter	Symbol	MIN	MAX		
Clock Timing					
Minimum Clock Cycle Time (DLL off mode)	tCK(DLL_OFF)	8	-	ns	23
Average Clock Period	tCK(avg)			ps	
Average high pulse width	tCH(avg)	0.48	0.52	tCK(avg)	
Average low pulse width	tCL(avg)	0.48	0.52	tCK(avg)	
Absolute Clock Period	tCK(abs)	tCK(avg)min + tJIT(per)min_tot	tCK(avg)max + tJIT(per)max_tot	tCK	
Absolute clock HIGH pulse width	tCH(abs)	0.45	-	tCK(avg)	24
Absolute clock Low pulse width	tCL(abs)	0.45	-	tCK(avg)	25
Clock Period Jitter- total	JIT(per)_tot	-0.1	0.1	UI	26
Clock Period Jitter- deterministic	JIT(per)_dj			UI	27
Clock Period Jitter during DLL locking period	tJIT(per, lck)			UI	
Cycle to Cycle Period Jitter	tJIT(cc)_tot	0.2		UI	26

Speed		DDR4-3200		Units	Note
Parameter	Symbol	MIN	MAX		
Cycle to Cycle Period Jitter-deterministic	tJIT(cc)_dj			UI	27
Cycle to Cycle Period Jitter during DLL locking period	tJIT(cc, lck)			UI	
Duty cycle Jitter	tJIT(duty)			UI	
Cumulative error across 2 cycles	tERR(2per)			UI	
Cumulative error across 3 cycles	tERR(3per)			UI	
Cumulative error across 4 cycles	tERR(4per)			UI	
Cumulative error across 5 cycles	tERR(5per)			UI	
Cumulative error across 6 cycles	tERR(6per)			UI	
Cumulative error across 7 cycles	tERR(7per)			UI	
Cumulative error across 8 cycles	tERR(8per)			UI	
Cumulative error across 9 cycles	tERR(9per)			UI	
Cumulative error across 10 cycles	tERR(10per)			UI	
Cumulative error across 11 cycles	tERR(11per)			UI	
Cumulative error across 12 cycles	tERR(12per)			UI	
Cumulative error across n = 13, 14 ... 49, 50 cycles	tERR(nper)			UI	
Command and Address Timing					
CAS_n to CAS_n command delay for same bank group	tCCD_L		-	nCK	
CAS_n to CAS_n command delay for different bank group	tCCD_S		-	nCK	
ACTIVATE to ACTIVATE Command delay to different bank group for 2KB page size	tRRD_S(2K)		-	nCK	
ACTIVATE to ACTIVATE Command delay to different bank group for 1KB page size	tRRD_S(1K)		-	nCK	
ACTIVATE to ACTIVATE Command delay to different bank group for 1/2KB page size	tRRD_S(1/2K)		-	nCK	

Speed		DDR4-3200		Units	Note
Parameter	Symbol	MIN	MAX		
ACTIVATE to ACTIVATE Command delay to same bank group for 2KB page size	tRRD_L(2K)		-	nCK	
ACTIVATE to ACTIVATE Command delay to same bank group for 1KB page size	tRRD_L(1K)		-	nCK	
ACTIVATE to ACTIVATE Command delay to same bank group for 1/KB page size	tRRD_L(1/2K)		-	nCK	
Four activate window for 2KB page size	tFAW_2K			ns	
Four activate window for 1KB page size	tFAW_1K			ns	
Four activate window for 1KB page size	tFAW_1/2K			ns	
Delay from start of internal write transaction to internal read command for different bank group	tWTR_S		-		1,2,e
Delay from start of internal write transaction to internal read command for same bank group	tWTR_L		-		1
Internal READ Command to PRECHARGE Command delay	tRTP		-		
WRITE recovery time	tWR		-	ns	1
WRITE recovery time when CRC and DM are enabled	tWR_CRC_DM		-	ns	1,29
Delay from start of internal write transaction to internal read command for different bank groups with both CRC and OM enabled	tWTR_S_ CRC_DM		-	ns	2,30

Speed		DDR4-3200		Units	Note
Parameter	Symbol	MIN	MAX		
Delay from start of internal write transaction to internal read command for same bank group with both CRC and OM enabled	tWTR_L_ CRC_DM		-	ns	3,31
DLL locking time	tDLLK			nCK	
Mode Register Set command cycle time	tMRD		-	nCK	
Mode Register Set command update delay	tMOD		-		
Multi-Purpose Register Recovery Time	tMPRR		-	nCK	
Multi-Purpose Register Write Recovery Time	tWR_MPR		-		
CS_n to Command Address Latency					
CS_n to Command Address Latency	tCAL		-	nCK	
DRAM Data Timing					
DQS_t,DQS_c to DQ skew, per group, per access	tDQSQ	-	tbd	tCK(avg)/2	14,1,9
DQS_t,DQS_c to DQ skew deterministic, per group, per access	tDQSQ	-	tbd	tCK(avg)/2	15,1,7,19
DQ output hold time from DQS_t,DQS_c	tQH		-	tCK(avg)/2	14,1,8,19
DQ output hold time deterministic from DQS_t, DQS_c	tQH		-	UI	15,1,7,19
DQS_t,DQS_c to DQ Skew total, per group, per access; DBI enabled	tDQSQ	-	tbd	UI	14,20
DQ output hold time total from DQS_t, DQS_c; DBI enabled	tQH	TBD	-	UI	14,20
DQ to DQ offset , per group, per access refer- enced to DQS_t, DQS_c	tDQSQ	TBD	TBD	UI	16, 17
Data Strobe Timing					
DQS_t,DQS_c differential output high time	tQSH	TBD	TBD	tCK(avg)/2	22

Speed		DDR4-3200		Units	Note
Parameter	Symbol	MIN	MAX		
DQS_t,DQS_c differential output low time	tQSL	TBD	TBD	tCK(avg)/2	21
MPSM Timing					
Command path disable delay upon MPSM entry	tMPED		-		
Valid clock requirement after MPSM entry	tCKMPE		-		
Valid clock requirement before MPSM exit	tCKMPX		-		
Exit MPSM to commands not requiring a locked DLL	tXMP		-		
Exit MPSM to commands requiring a locked DLL	tXMPDLL		-		
CS setup time to CKE	tMPX_S		-		
CS hold time to CKE	tMPX_H		-		
Calibration Timing					
Power-up and RESET calibration time	tZQinit		-	nCK	
Normal operation Full calibration time	tZQoper		-	nCK	
Normal operation Short calibration time	tZQCS		-	nCK	
Reset/Self Refresh Timing					
Exit Reset from CKE HIGH to a valid command	tXPR		-		
Exit Self Refresh to commands not requiring a locked DLL	tXS		-		
SRX to commands not requiring a locked DLL in Self Refresh ABORT	tXS_ABORT(min)		-		
Exit Self Refresh to ZQCL,ZQCS and MRS (CL,CWL,WR,RTP and Gear Down)	tXS_FAST (min)		-		
Exit Self Refresh to commands requiring a locked DLL	tXSDLL		-		
Minimum CKE low width for Self refresh entry to exit timing	tCKESR		-		

Speed		DDR4-3200		Units	Note
Parameter	Symbol	MIN	MAX		
Valid Clock Requirement after Self Refresh Entry (SRE) or Power-Down Entry (PDE)	tCKSRE		-		
Valid Clock Requirement after Self Refresh Entry (SRE) or Power-Down when CA Parity is enabled	tCKSRE_PAR		-		
Valid Clock Requirement before Self Refresh Exit (SRX) or Power-Down Exit (PDX) or Reset Exit	tCKSRX		-		
Power Down Timing					
Exit Power Down with DLL on to any valid command; Exit Precharge Power Down with DLL frozen t commands not requiring a locked DLL	tXP		-		
Exit Precharge Power Down with DLL frozen to commands requiring a locked DLL	tXPDLL		-		3
CKE minimum pulse width	tCKE		-		32,33
Command pass disable delay	tCPDED		-		
Power Down Entry to Exit Timing	tPD		9*tREFI		6
Timing of ACT command to Power Down entry	tACTPDEN		-		7
Timing of PRE or PREA command to Power Down entry	tPRPDEN		-		7
Timing of RD/RDA command to Power Down entry	tRDPDEN		-	nCK	
Timing of WR command to Power Down entry (BL8OTF, BL8MRS, BC4OTF)	tWRPDEN		-	nCK	4

Speed		DDR4-3200		Units	Note
Parameter	Symbol	MIN	MAX		
Timing of WRA command to Power Down entry (BL8OTF, BL8MRS, BC4OTF)	tWRAPDEN		-	nCK	5
Timing of WR command to Power Downentry (BC4MRS)	tWRPBC4DEN		-	nCK	4
Timing of WRA command to Power Down entry (BC4MRS)	tWRAPBC4DEN		-	nCK	5
Timing of REF command to Power Down entry	tREFPDEN		-	nCK	7,8
Timing of MRS command to Power Down entry	tMRSPDEN		-		
PDA Timing					
Mode Register Set command cycle time in PDA mode	tMRD_PDA	max(16nCK,10ns)	-		
Mode Register Set command update delay in PDA mode	tMOD_PDA	tMOD			
ODT Timing					
Asynchronous RTT turn-on delay (Power-Down with DLL frozen)	tAONAS			ns	
Asynchronous RTT turn-off delay (Power-Down with DLL frozen)	tAOFAS			ns	
RTT dynamic change skew	tADC			tCK(avg)	
Write Leveling Timing					
First DQS_t/DQS_n rising edge after write leveling mode is programmed	tWLMRD			nCK	13
DQS_t/DQS_n delay after write leveling mode is programmed	tWLDQSEN			nCK	13
Write leveling setup time from rising CK_t, CK_c crossing to rising DQS_t/DQS_n crossing	tWLS			tCK(avg)	

Speed		DDR4-3200		Units	Note
Parameter	Symbol	MIN	MAX		
Write leveling hold time from rising DQS_t/DQS_n crossing to rising CK_t, CK_ crossing	tWLH			tCK(avg)	
Write leveling output delay	tWLO			ns	
Write leveling output error	tWLOE			ns	
CA Parity Timing					
Commands not guaranteed to be executed during this time	tPAR_UNKNOWN				
Delay from errant command to ALERT_n assertion	tPAR_ALERT_ON				
Pulse width of ALERT_n signal when asserted	tPAR_ALERT_PW			nCK	
Time from when Alert is asserted till controller must start providing DES commands in Persistent CA parity mode	tPAR_ALERT_RSP			nCK	
Parity Latency [1715.64, JC42.3C]	PL			nCK	
CRC Error Reporting					
CRC error to ALERT_n latency	tCRC_ALERT			ns	
CRC ALERT_n pulse width	CRC_ALERT_PW			nCK	
Write recovery time when CRC and DM are enabled	tWR_CRC_DM			ns	10
delay from start of internal write transaction to internal delay from start of internal write transaction to internal read command for different bank group with both CRC and DM enabled	tWTR_S_CRC_DM			ns	11

Speed		DDR4-3200		Units	Note
Parameter	Symbol	MIN	MAX		
delay from start of internal write transaction to internal delay from start of internal write transaction to internal read command for same bank group with both CRC and DM enabled	tWTR_L_CRC_DM			ns	12
Geardown timing					
Exit RESET from CKE HIGH to a valid MRS geardown (T2/Reset)	tXPR_GEAR				
CKE HIGH Assert Geardown Enable time(T2/CKE)	tXS_GEAR				
MRS command to Sync pulse time(T3)	tSYNC_GEAR				28
Sync pulse to First valid command(T4)	tCMD_GEAR	tMOD			28
Geardown setup time	tGEAR_setup	2	-	nCK	
Geardown hold time	tGEAR_hold	2	-	nCK	
tREFI					
tRFC1 (min)	2Gb	160	-	ns	
	4Gb	260	-	ns	
	8Gb	350	-	ns	
	16Gb	TBD	-	ns	
tRFC2 (min)	2Gb	110	-	ns	
	4Gb	160	-	ns	
	8Gb	260	-	ns	
	16Gb	TBD	-	ns	
tRFC4 (min	2Gb	90	-	ns	
	4Gb	110	-	ns	
	8Gb	160	-	ns	
	16Gb	TBD	-	ns	

Notes

1) Start of internal write transaction is defined as follows :
   For BL8 (Fixed by MRS and on-the-fly) : Rising clock edge 4 clock cycles after WL.
   For BC4 (on-the-fly) : Rising clock edge 4 clock cycles after WL.
   For BC4 (fixed by MRS) : Rising clock edge 2 clock cycles after WL.
2) A separate timing parameter will cover the delay from write to read when CRC and DM are simultaneously enabled
3) Commands requiring a locked DLL are: READ (and RAP) and synchronous ODT commands.

4) tWR is defined in ns, for calculation of tWRPDEN it is necessary to round up tWR/tCK following rounding algorithm defined in "19.1 Rounding Algorithms".
5) WR in clock cycles as programmed in MR0.
6) tREFI depends on TOPER.
7) CKE is allowed to be registered low while operations such as row activation, precharge, autoprecharge or refresh are in progress, but power-down IDD spec will not be applied until finishing those operations.
8) For these parameters, the DDR4 SDRAM device supports tnPARAM[nCK]=RU{tPARAM[ns]/tCK(avg)[ns]}, which is in clock cycles assuming all input clock jitter specifications
are satisfied.
9) When CRC and DM are both enabled, tWR_CRC_DM is used in place of tWR.
10) When CRC and DM are both enabled tWTR_S_CRC_DM is used in place of tWTR_S.
11) When CRC and DM are both enabled tWTR_L_CRC_DM is used in place of tWTR_L.
12) The max values are system dependent.
13) DQ to DQS total timing per group where the total includes the sum of deterministic and random timing terms for a specified BER.
14) The deterministic component of the total timing.
15) DQ to DQ static offset relative to strobe per group.
16) This parameter will be characterized and guaranteed by design.
17) When the device is operated with the input clock jitter, this parameter needs to be derated by the actual tjit(per)_total of the input clock. (output deratings are relative to the SDRAM input clock).
18) DRAM DBI mode is off.
19) DRAM DBI mode is enabled. Applicable to x8 and x16 DRAM only.
20) tQSL describes the instantaneous differential output low pulse width on DQS_t - DQS_c, as measured from on falling edge to the next consecutive rising edge
21) tQSH describes the instantaneous differential output high pulse width on DQS_t - DQS_c, as measured from on falling edge to the next consecutive rising edge
22) There is no maximum cycle time limit besides the need to satisfy the refresh interval tREFI
23) tCH(abs) is the absolute instantaneous clock high pulse width, as measured from one rising edge to the following falling edge
24) tCL(abs) is the absolute instantaneous clock low pulse width, as measured from one falling edge to the following rising edge
25) Total jitter includes the sum of deterministic and random jitter terms for a specified BER. .
26) The deterministic jitter component out of the total jitter. This parameter is characterized and guaranteed by design.
27) This parameter has to be even number of clocks
28) When CRC and DM are both enabled, tWR_CRC_DM is used in place of tWR.
29) When CRC and DM are both enabled tWTR_S_CRC_DM is used in place of tWTR_S.
30) When CRC and DM are both enabled tWTR_L_CRC_DM is used in place of tWTR_L.
31) After CKE is registered LOW, CKE signal level shall be maintained below VILDC for tCKE specification (Low pulse width).
32) After CKE is registered HIGH, CKE signal level shall be maintained above VIHDC for tCKE specification (HIGH pulse width).
33) Defined between end of MPR read burst and MRS which reloads MPR or disables MPR function.
34) Parameters apply from tCK(avg)min to tCK(avg)max at all standard JEDEC clock period values as stated in the Speed Bin Tables.
35) This parameter must keep consistency with Speed-Bin Tables shown in section 10.
36) DDR4-1600 AC timing apply if DRAM operates at lower than 1600 MT/s data rate. UI=tCK(avg).min/2.
37) applied when DRAM is in DLL ON mode.
38) Assume no jitter on input clock signals to the DRAM.
39) Value is only valid for RONNOM = 34 ohms.
40) 1tCK toggle mode with setting MR4:A11 to 0.
41) 2tCK toggle mode with setting MR4:A11 to 1, which is valid for DDR4-2400/2666 and 2933 speed grade.
42) 1tCK mode with setting MR4:A12 to 0.
43) 2tCK mode with setting MR4:A12 to 1, which is valid for DDR4-2400/2666 and 2933 speed grade.
44) The maximum read preamble is bounded by tLZ(DQS)min on the left side and tDQSCK(max) on the right side. See Figure “Clock to Data Strobe Relationship” in Operation datasheet. Boundary of DQS Low-Z occur one cycle earlier in 2tCK toggle mode which is illustrated in “Read Preamble” section.
45) DQ falling signal middle-point of transferring from High to Low to first rising edge of DQS diff-signal cross-point
46) last falling edge of DQS diff-signal cross-point to DQ rising signal middle-point of transferring from Low to High
47) VrefDQ value must be set to either its midpoint or Vcent_DQ(midpoint) in order to capture DQ0 or DQL0 low level for entering PDA mode.
48) The maximum read postamble is bound by tDQSCK(min) plus tQSH(min) on the left side and tHZ(DQS)max on the right side. See Figure “Clock to Data Strobe Relationship”
in Operation datasheet.
49) Reference level of DQ output signal is specified with a midpoint as a widest part of Output signal eye which should be approximately 0.7 * VDDQ as a center level of the static single-ended output peak-to-peak swing with a driver impedance of 34 ohms and an effective test load of 50 ohms to VTT = VDDQ.
50) For MR7 commands, the minimum delay to a subsequent non-MRS command is 5nCK.
51) tMPX_LH(max) is defined with respect to actual tXMP in system as opposed to tXMP(min).