

# DDR4 SDRAM Registered DIMM Based on 4Gb M-die

HMA451R7MFR8N  
HMA41GR7MFR8N  
HMA41GR7MFR4N  
HMA42GR7MFR4N

\*SK hynix reserves the right to change products or specifications without notice.

## Revision History

Revision No.	History	Draft Date	Remark
0.01	Priliminary Release	Jun.2013	Priliminary
0.1	2Rx8 Device information upadated	Mar. 2014	
1.0	IDD Specification updated	Jun. 2015	
1.1	Corrected Pin Assignments	Jul.2015	
1.2	Updated JEDEC Specification Deleted Speed Grade Table	Dec.2015	

## Description

SK hynix Registered DDR4 SDRAM DIMMs (Registered Double Data Rate Synchronous DRAM Dual In-Line Memory Modules) are low power, high-speed operation memory modules that use DDR4 SDRAM devices. These Registered SDRAM DIMMs are intended for use as main memory when installed in systems such as servers and workstations.

## Features

- Power Supply: VDD=1.2V (1.14V to 1.26V)
- VDDQ = 1.2V (1.14V to 1.26V)
- VPP - 2.5V (2.375V to 2.75V)
- VDDSPD=2.25V to 2.75V
- Functionality and operations comply with the DDR4 SDRAM datasheet
- 16 internal banks
- Bank Grouping is applied, and CAS to CAS latency (tCCD\_L, tCCD\_S) for the banks in the same or different bank group accesses are available
- Data transfer rates: PC4-2133, PC4-1866, PC4-1600
- Bi-Directional Differential Data Strobe
- 8 bit pre-fetch
- Burst Length (BL) switch on-the-fly BL8 or BC4(Burst Chop)
- Supports ECC error correction and detection
- On-Die Termination (ODT)
- Temperature sensor with integrated SPD
- This product is in compliance with the RoHS directive.
- Per DRAM Addressability is supported
- Internal Vref DQ level generation is available
- Write CRC is supported at all speed grades
- DBI (Data Bus Inversion) is supported(x8)
- CA parity (Command/Address Parity) mode is supported

## Ordering Information

Part Number	Density	Organization	Component Composition	# of ranks
HMA451R7MFR8N-TF	4GB	512Mx72	512Mx8(H5AN4G8NMFR)*9	1
HMA41GR7MFR8N-TF	8GB	1Gx72	512Mx8(H5AN4G8NMFR)*18	2
HMA41GR7MFR4N-TF	8GB	1Gx72	1Gx4(H5AN4G4NMFR)*18	1
HMA42GR7MFR4N-TF	16GB	2Gx72	1Gx4(H5AN4G4NMFR)*36	2

## Key Parameters

MT/s	Grade	tCK (ns)	CAS Latency (tCK)	tRCD (ns)	tRP (ns)	tRAS (ns)	tRC (ns)	CL-tRCD-tRP
DDR4-1600	-PB	1.25	11	13.75 (13.50)*	13.75 (13.50)*	35	48.75 (48.50)*	11-11-11
DDR4-1866	-RD	1.071	13	13.92 (13.50)*	13.92 (13.50)*	34	47.92 (47.50)*	13-13-13
DDR4-2133	-TF	0.938	15	14.06 (13.50)*	14.06 (13.50)*	33	47.06 (46.50)*	15-15-15

\*SK hynix DRAM devices support optional downbinning to CL13 and CL11. SPD setting is programmed to match.

## Address Table

		4GB(1Rx8)	8GB(2Rx8)	8GB(1Rx4)	16GB(2Rx4)
Bank Address	# of Bank Groups	4	4	4	4
	BG Address	BG0~BG1	BG0~BG1	BG0~BG1	BG0~BG1
	Bank Address in a BG	BA0~BA1	BA0~BA1	BA0~BA1	BA0~BA1
Row Address		A0~A14	A0~A14	A0~A15	A0~A15
Column Address		A0~ A9	A0~ A9	A0~ A9	A0~ A9
Page size		1 KB	1 KB	512B	512B

## Pin Descriptions

Pin Name	Description	Pin Name	Description
A0-A17 <sup>1</sup>	Register address input	SCL	I <sup>2</sup> C serial bus clock for SPD-TSE and register
BA0, BA1	Register bank select input	SDA	I <sup>2</sup> C serial data line for SPD-TSE and register
BG0, BG1	Register bank group select input	SA0-SA2	I <sup>2</sup> C slave address select for SPD-TSE and register
RAS_n <sup>2</sup>	Register row address strobe input	PAR	Register parity input
CAS_n <sup>3</sup>	Register column address strobe input	VDD	SDRAM core power supply
WE_n <sup>4</sup>	Register write enable input	C0, C1, C2	Chip ID lines for SDRAMx
CS0_n, CS1_n, CS2_n, CS3_n	DIMM Rank Select Lines input	12V	Optional Power Supply on socket but not used on RDIMM
CKE0, CEK1	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 SPD/TS positive power supply
DQ0-DQ63	DIMM memory data bus	ALERT_n	Register ALERT_n output
CB0-CB7	DIMM ECC check bits	VPP	SDRAM Supply
TDQS9_t-TDQS17_t TDQS9_c-TDQS17_c	Dummy loads for mixed populations of x4 based and x8 based RDIMMs.		
DQS0_t-DQS17_t	Data Buffer data strobes (positive line of differential pair)	DM0_n-DM8_n	Data Mask
DQS0_c-DQS17_c	Data Buffer data strobes (negative line of differential pair)	RESET_n	Set Register and SDRAMs to a Known State
DBI0_n-DBI8_n	Data Bus Inversion	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

1. Address A17 is only valid for 16Gbx4 based SDRAMs.
2. RAS\_n is a multiplexed function with A16.
3. CAS\_n is a multiplexed function with A15.
4. WE\_n is a multiplexed function with A14.

## Input/Output Functional Descriptions

Symbol	Type	Function
CK0_t, CK0_c, CK1_t, CK1_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, CEK1	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 synchronous for Self-Refresh exit. After VREFCA and Internal DQ Vref 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_t, CK_c, ODT and CKE, are disabled during power-down. Input buffers, excluding CKE, are disabled during Self-Refresh.
CS0_n, CS1_n, CS2_n, CS3_n	Input	Chip Select: All commands are masked when CS_n is registered HIGH. CS_n provides for external Rank selection. CS_n is considered part of the command code.
C0, C1, C2	Input	Chip ID: Chip ID is only used for 3DS for 2,4,8 high 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 RTT_NOM termination resistance internal to the DDR4 SDRAM. When enabled, ODT is only applied to each DQ, DQS_t, DQS_c, TDQS_t, and TDQS_c 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 are multi-function. For example, for activation with ACT_n Low, these are Addresses like A16, A15, and A14, but for non-activation command with ACT_n High, these are Command pins for Read, Write, and other commands defined in command truth table.
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.
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 which mode register is to be accessed during a MRS cycle.
A0 - A17	Input	Address Inputs: Provide the row address for ACTIVATE Commands and the column address for Read/Write commands to 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 16Gb x4 SDRAM configurations.

Symbol	Type	Function
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	CMOS 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.
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 data sheets to determine which DQ is used.
DQS0_t-DQS17_t, DQS0_c-DQS17_c	Input/ Output	Data Strobe: output with read data, input with write data. Edge-aligned with read data, centered in write data. The data strobe DQS_t is paired with differential signals DQS_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.
TDQS9_t-TDQS17_t, TDQS9_c-TDQS17_c	Input	Provides a dummy load for x8 based RDIMMs where mixed populations of x4 and x8 based RDIMMs are present.
DBI0_n-DBI8_n	Input/ Output	Provides for data bus inversion. Only possible for x8 based RDIMMs and where only x8 based RDIMMs are on a channel.
DM0_n-DM8_n	Input	Provides for masking of a byte on WRITE commands to the SDRAMs. Only Possible x8 based RDIMMs and where only x8 based RDIMMs are on a channel.
PAR	Input	Command and Address Parity Input : DDR4 Supports Even Parity check in SDRAMs with MR setting. Once it's enabled via Register in MR5, then SDRAM calculates Parity with ACT_n, RAS_n/A16, CAS_n/A15, WE_n/A14, BG0-BG1, BA0-BA1, A17-A0. Input parity should be maintained at the rising edge of the clock and at the same time as command & address, with CS_n LOW.
ALERT_n	Output (Input)	Alert: Is multi functions, such as CRC error flag or Command and Address Parity error flag, as on Output signal. If there is an error in the CRC, then ALERT_n goes LOW for the period time interval and goes back HIGH. If there is an error in the Command Address Parity Check, then ALERT_n goes LOW for a relatively long period until on going SDRAM internal recovery transaction is complete. During Connectivity Test mode, this pin functions as an input. Using this signal or not is dependent on the system.
RFU		Reserved for Future Use: No on-DIMM electrical connection is present.
NC		No Connect: No on-DIMM electrical connection is present.
VDD <sup>1</sup>	Supply	Power Supply: 1.2 V ± 0.06 V
VSS	Supply	Ground

Symbol	Type	Function
VTT	Supply	Power Supply for termination of Address, Command and Control, VDD/2.
12V	Supply	12V supply not used on RDIMMs.
VPP	Supply	SDRAM Activating Power Supply: 2.5V (2.375V min , 2.75V max)
VDDSPD	Supply	Power supply used to power the I2C bus on the SPD-TSE and register.
VREFCA	Supply	Reference voltage for CA

**Note:** For PC4, VDD is 1.2V. For PC4L, VDD is TBD.



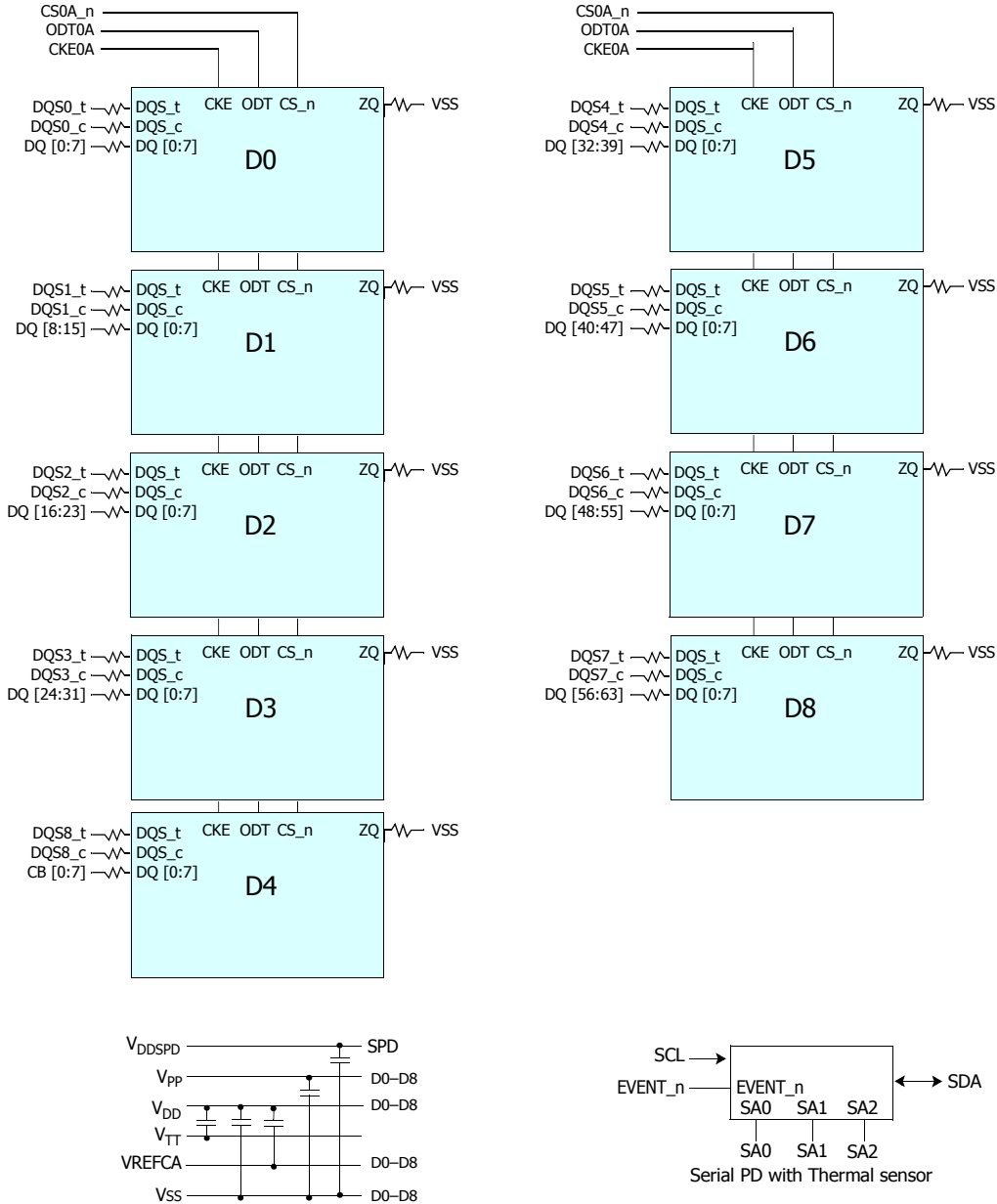
## Pin Assignments

Pin	Front Side Pin Label	Pin	Back Side Pin Label	Pin	Front Side Pin Label	Pin	Back Side Pin Label
1	NC	145	NC	74	CK0_t	218	CK1_t
2	VSS	146	VREFCA	75	CK0_c	219	CK1_c
3	DQ4	147	VSS	76	VDD	220	VDD
4	VSS	148	DQ5	77	VTT	221	VTT
5	DQ0	149	VSS	KEY			
6	VSS	150	DQ1				
7	TDQS9_t, DQS9_t, DM0_n, DBI0_n	151	VSS	78	EVENT_n	222	PARITY
8	TDQS9_c, DQS9_c	152	DQS0_c	79	A0	223	VDD
9	VSS	153	DQS0_t	80	VDD	224	BA1
10	DQ6	154	VSS	81	BA0	225	A10/AP
11	VSS	155	DQ7	82	RAS_n/A16	226	VDD
12	DQ2	156	VSS	83	VDD	227	RFU
13	VSS	157	DQ3	84	CS0_n	228	WE_n/A14
14	DQ12	158	VSS	85	VDD	229	VDD
15	VSS	159	DQ13	86	CAS_n/A15	230	NC
16	DQ8	160	VSS	87	ODT0	231	VDD
17	VSS	161	DQ9	88	VDD	232	A13
18	TDQS10_t, DQS10_t, DM1_n, DBI1_n	162	VSS	89	CS1_n, NC	233	VDD
19	TDQS10_c, DQS10_c	163	DQS1_c	90	VDD	234	A17
20	VSS	164	DQS1_t	91	ODT1, NC	235	NC, C2
21	DQ14	165	VSS	92	VDD	236	VDD
22	VSS	166	DQ15	93	C0, CS2_n, NC	237	NC, CS3_n, C1
23	DQ10	167	VSS	94	VSS	238	SA2
24	VSS	168	DQ11	95	DQ36	239	VSS
25	DQ20	169	VSS	96	VSS	240	DQ37
26	VSS	170	DQ21	97	DQ32	241	VSS
27	DQ16	171	VSS	98	VSS	242	DQ33
28	VSS	172	DQ17	99	TDQS13_t, DQS13_t, DM4_n, DBI4_n	243	VSS
29	TDQS11_t, DQS11_t, DM2_n, DBI2_n	173	VSS	100	TDQS13_c, DQS13_c	244	DQS4_c
30	TDQS11_c, DQS11_c	174	DQS2_c	101	VSS	245	DQS4_t
31	VSS	175	DQS2_t	102	DQ38	246	VSS
32	DQ22	176	VSS	103	VSS	247	DQ39
33	VSS	177	DQ23	104	DQ34	248	VSS
34	DQ18	178	VSS	105	VSS	249	DQ35
35	VSS	179	DQ19	106	DQ44	250	VSS
36	DQ28	180	VSS	107	VSS	251	DQ45

Pin	Front Side Pin Label	Pin	Back Side Pin Label	Pin	Front Side Pin Label	Pin	Back Side Pin Label
37	VSS	181	DQ29	108	DQ40	252	VSS
38	DQ24	182	VSS	109	VSS	253	DQ41
39	VSS	183	DQ25	110	TDQS14_t, DQS14_t, DM5_n, DBI5_n	254	VSS
40	TDQS12_t, DQS12_t, DM3_n, DBI3_n	184	VSS	111	TDQS14_c, DQS14_c	255	DQS5_c
41	TDQS12_c, DQS12_c	185	DQS3_c	112	VSS	256	DQS5_t
42	VSS	186	DQS3_t	113	DQ46	257	VSS
43	DQ30	187	VSS	114	VSS	258	DQ47
44	VSS	188	DQ31	115	DQ42	259	VSS
45	DQ26	189	VSS	116	VSS	260	DQ43
46	VSS	190	DQ27	117	DQ52	261	VSS
47	CB4	191	VSS	118	VSS	262	DQ53
48	VSS	192	CB5	119	DQ48	263	VSS
49	CB0	193	VSS	120	VSS	264	DQ49
50	VSS	194	CB1	121	TDQS15_t, DQS15_t, DM6_n, DBI6_n	265	VSS
51	TDQS17_t, DQS17_t, DM8_n, DBI8_n	195	VSS	122	TDQS15_c, DQS15_c	266	DQS6_c
52	TDQS17_c, DQS17_c	196	DQS8_c	123	VSS	267	DQS6_t
53	VSS	197	DQS8_t	124	DQ54	268	VSS
54	CB6	198	VSS	125	VSS	269	DQ55
55	VSS	199	CB7	126	DQ50	270	VSS
56	CB2	200	VSS	127	VSS	271	DQ51
57	VSS	201	CB3	128	DQ60	272	VSS
58	RESET_n	202	VSS	129	VSS	273	DQ61
59	VDD	203	CKE1, NC	130	DQ56	274	VSS
60	CKE0	204	VDD	131	VSS	275	DQ57
61	VDD	205	RFU	132	TDQS16_t, DQS16_t, DM7_n, DBI7_n	276	VSS
62	ACT_n	206	VDD	133	TDQS16_c, DQS16_c	277	DQS7_c
63	BG0	207	BG1	134	VSS	278	DQS7_t
64	VDD	208	ALERT_n	135	DQ62	279	VSS
65	A12/BC_n	209	VDD	136	VSS	280	DQ63
66	A9	210	A11	137	DQ58	281	VSS
67	VDD	211	A7	138	VSS	282	DQ59
68	A8	212	VDD	139	SA0	283	VSS
69	A6	213	A5	140	SA1	284	VDDSPD
70	VDD	214	A4	141	SCL	285	SDA
71	A3	215	VDD	142	VPP	286	VPP
72	A1	216	A2	143	VPP	287	VPP
73	VDD	217	VDD	144	RFU	288	VPP

# Functional Block Diagram

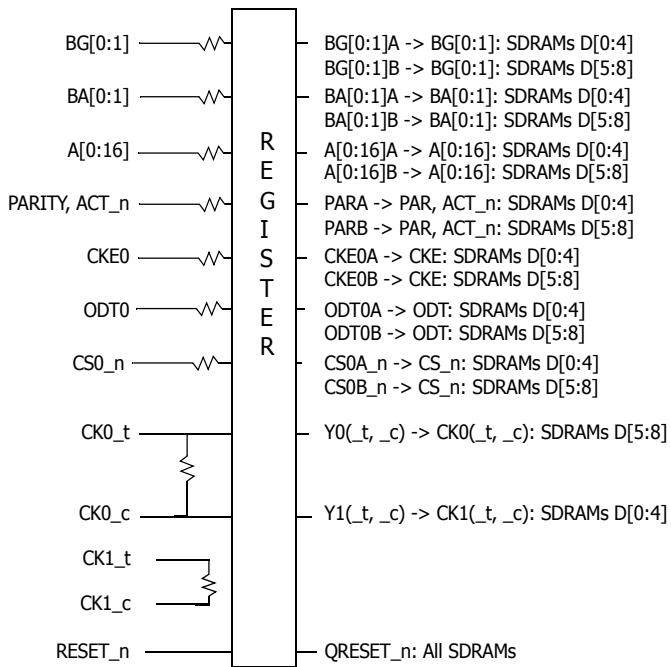
## 4GB, 512Mx72 Module(1Rank of x8) - page1



**Note:**

1. Unless otherwise noted, resistor values are  $15\Omega \pm 5\%$ .
2. See the Net Structure diagrams for all resistor associated with the command, address and control bus.
3. ZQ resistors are  $240\Omega \pm 1\%$ . For all other resistor values refer to the appropriate wiring diagram.

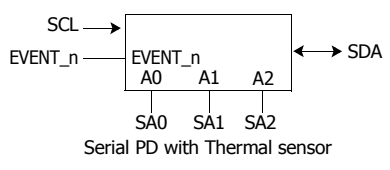
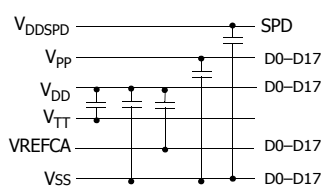
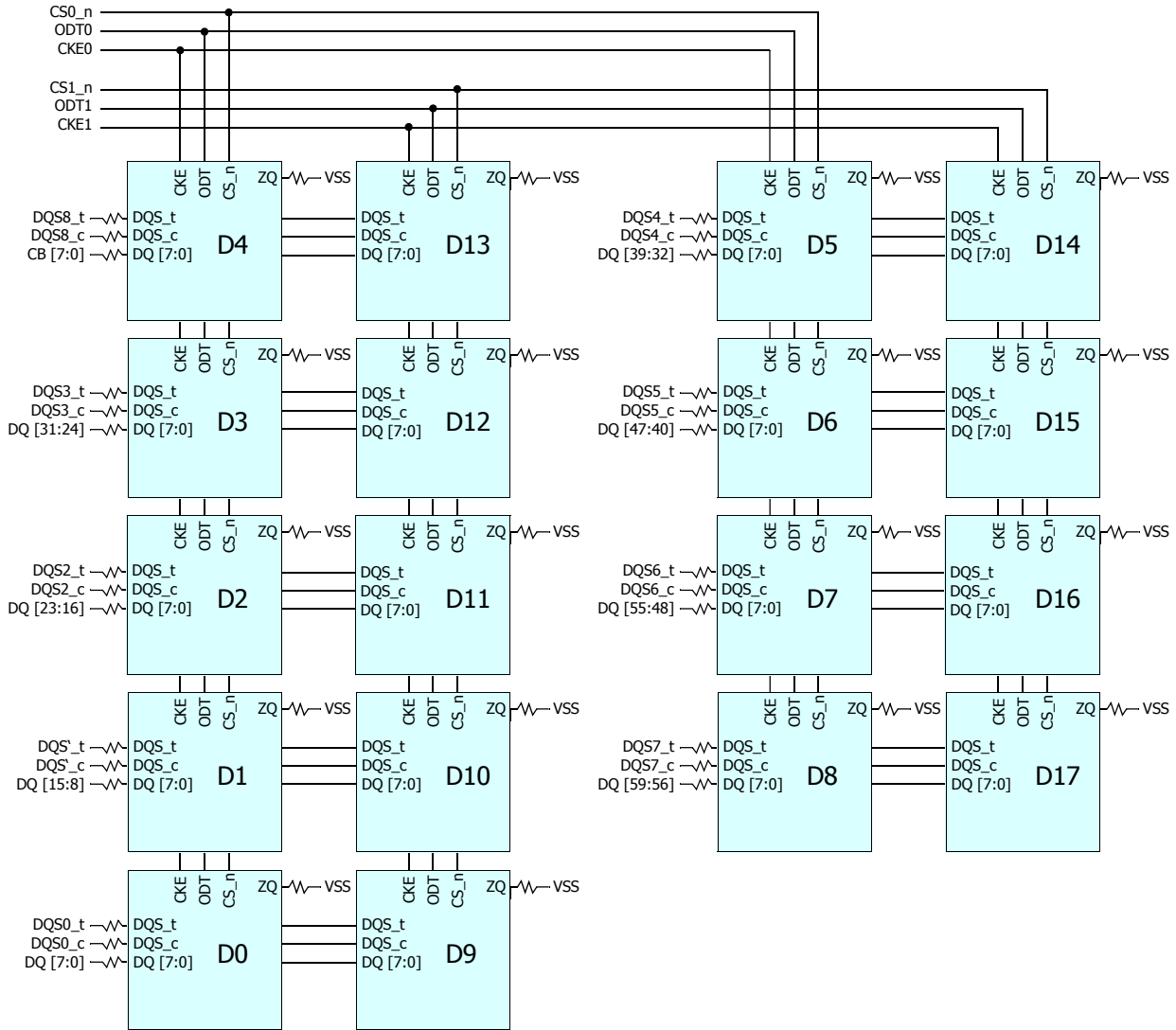
## 4GB, 512Mx72 Module(1Rank of x8) - page2



**Note:**

1. CK0\_t, CK0\_c terminated with  $120\ \Omega \pm 5\%$  resistor.
2. CK1\_t, CK1\_c terminated with  $120\ \Omega \pm 5\%$  resistor but not used.
3. Unless otherwise noted resistors are  $22\ \Omega \pm 5\%$ .
4. Register inputs CS1\_n, CS2\_n/C0 and CS3\_n/C1 are tied to VDD. Register inputs CS, ODT1 and CKE1 are tied to VSS.

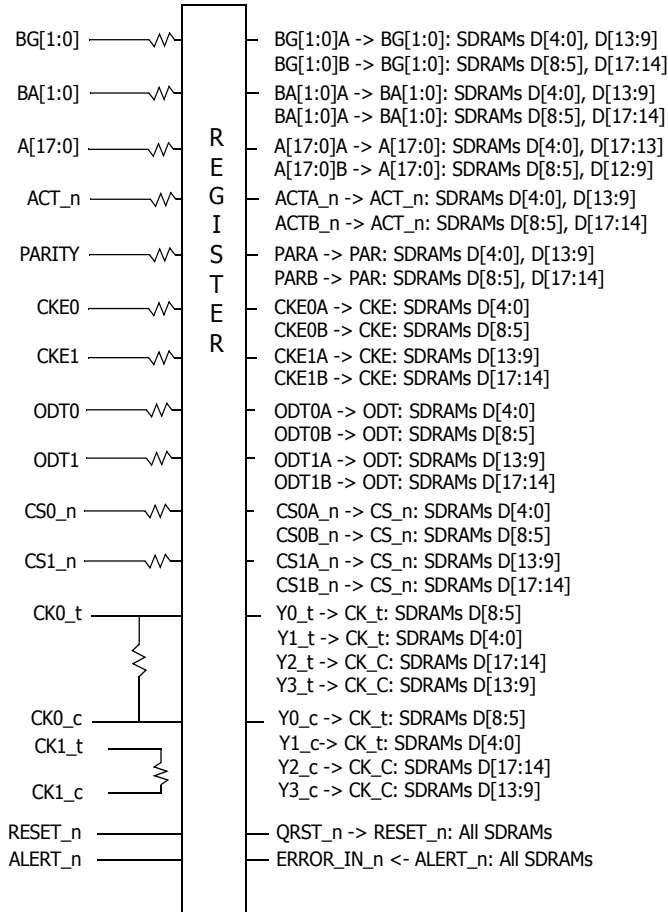
# 8GB, 1Gx72 Module(2Rank of x8) - page1



**Note:**

1. Unless otherwise noted, resistor values are 15Ω ±5%.
2. See the Net Structure diagrams for all resistor associated with the command, address and control bus.
- 3.ZQ resistors are 240Ω ±1%.For all other resistor values refer to the appropriate wiring diagram.

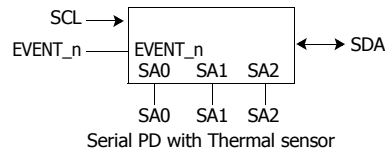
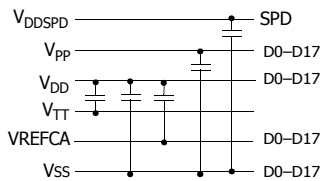
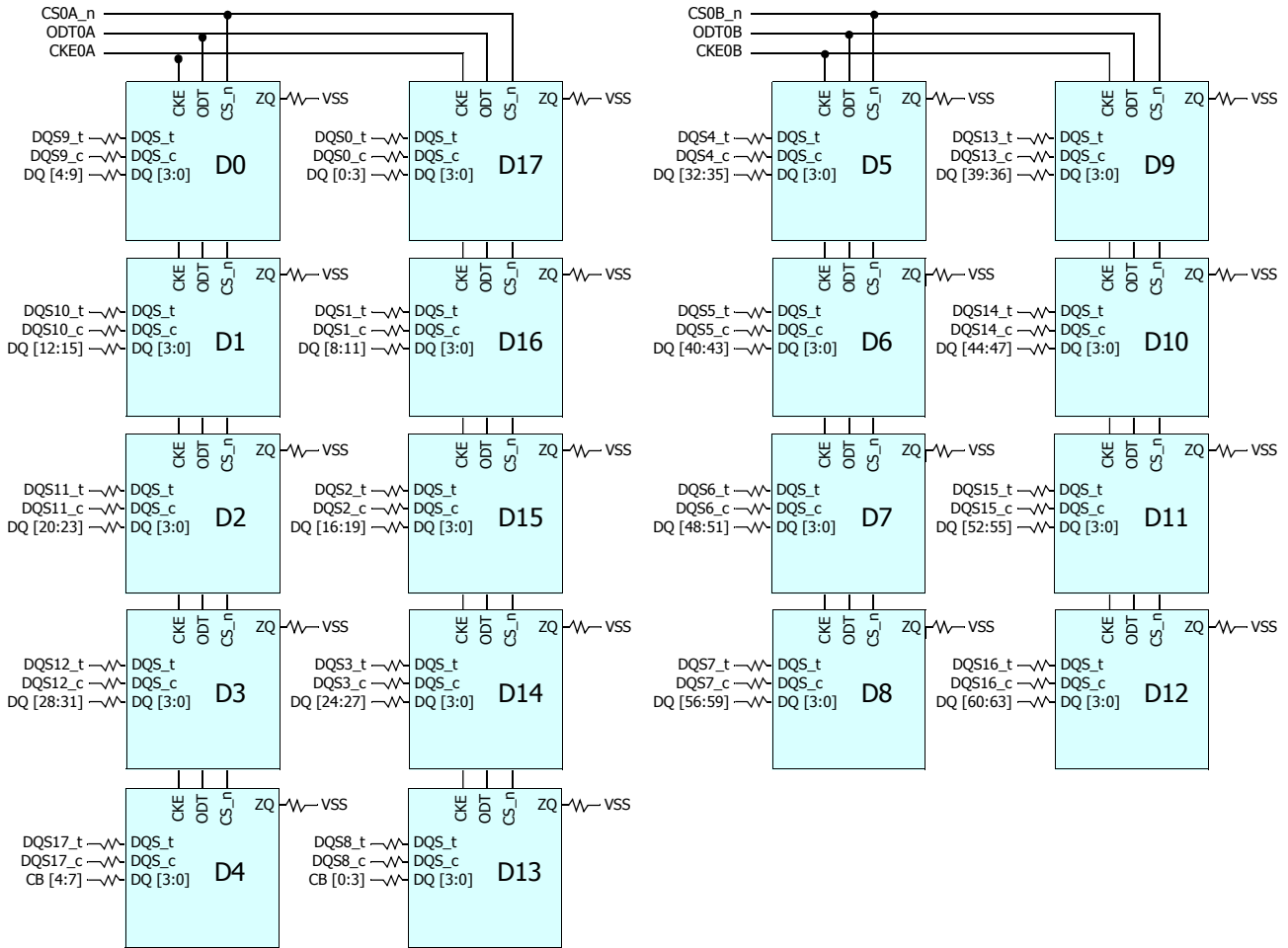
## 8GB, 1Gx72 Module(2Rank of x8) - page2



### Note:

1. CK0\_t, CK0\_c terminated with  $120\ \Omega \pm 5\%$  resistor.
2. CK1\_t, CK1\_c terminated with  $120\ \Omega \pm 5\%$  resistor but not used.
3. Unless otherwise noted resistors are  $22\ \Omega \pm 5\%$ .
4. Register inputs CS1\_n, CS2\_n/C0 and CS3\_n/C1 are tied to VDD. Register inputs CS, ODT1 and CKE1 are tied to VSS.

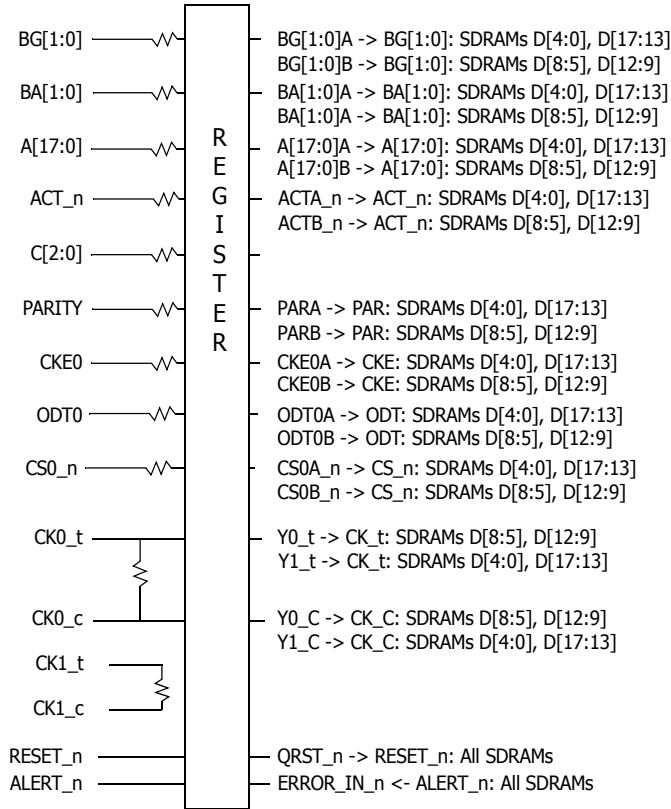
# 8GB, 1Gx72 Module(1Rank of x4) - page1



**Note:**

1. Unless otherwise noted, resistor values are 15Ω ±5%.
2. See the Net Structure diagrams for all resistor associated with the command, address and control bus.
- 3.ZQ resistors are 240Ω ±1%.For all other resistor values refer to the appropriate wiring diagram.

## 8GB, 1Gx72 Module(1Rank of x4) - page2

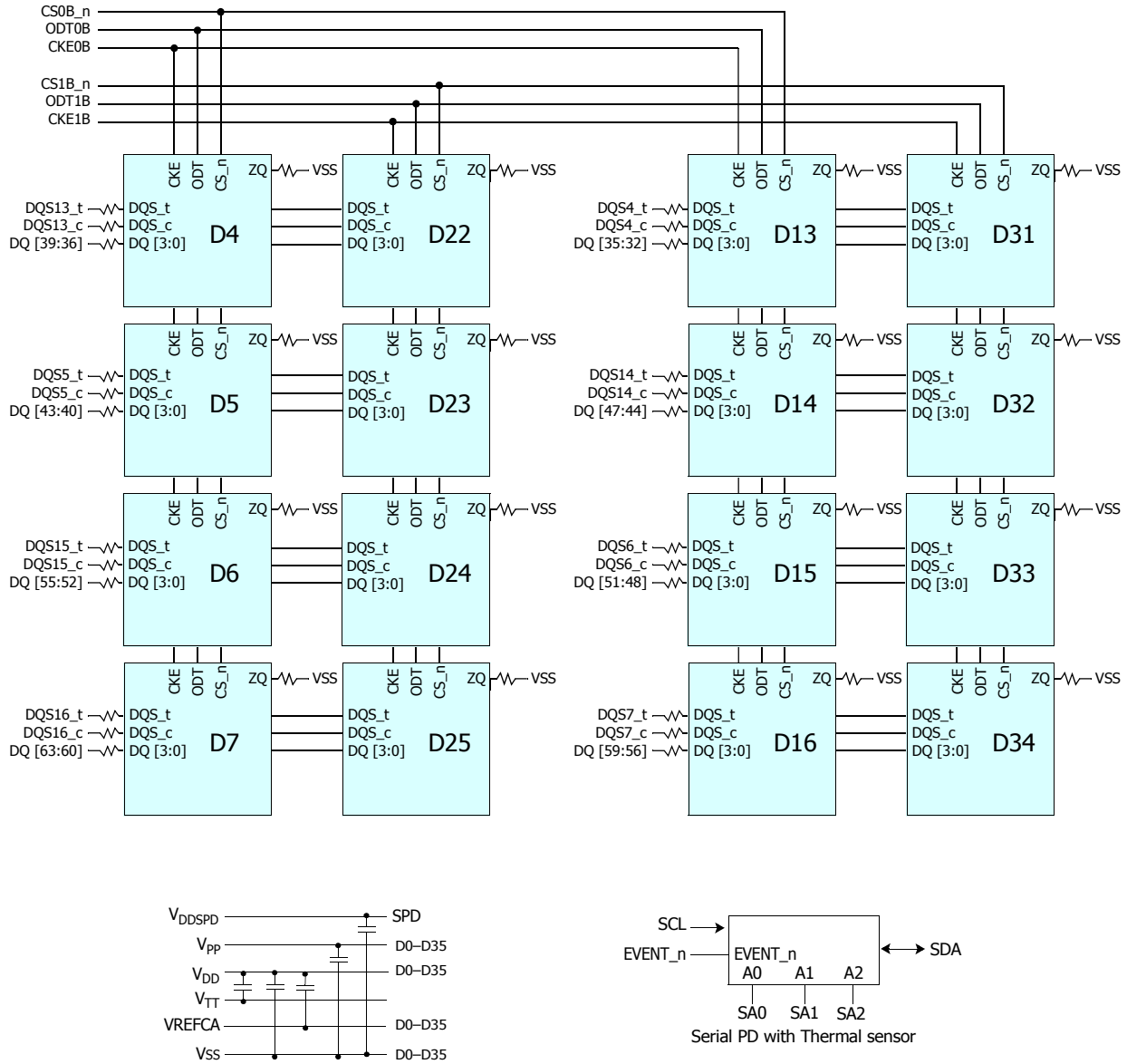


### Note:

1. CK0\_t, CK0\_c terminated with  $120\ \Omega \pm 5\%$  resistor.
2. CK1\_t, CK1\_c terminated with  $120\ \Omega \pm 5\%$  resistor but not used.
3. Unless otherwise noted resistors are  $22\ \Omega \pm 5\%$ .
4. Register inputs CS1\_n, CS2\_n/C0 and CS3\_n/C1 are tied to VDD. Register inputs CS, ODT1 and CKE1 are tied to VSS.



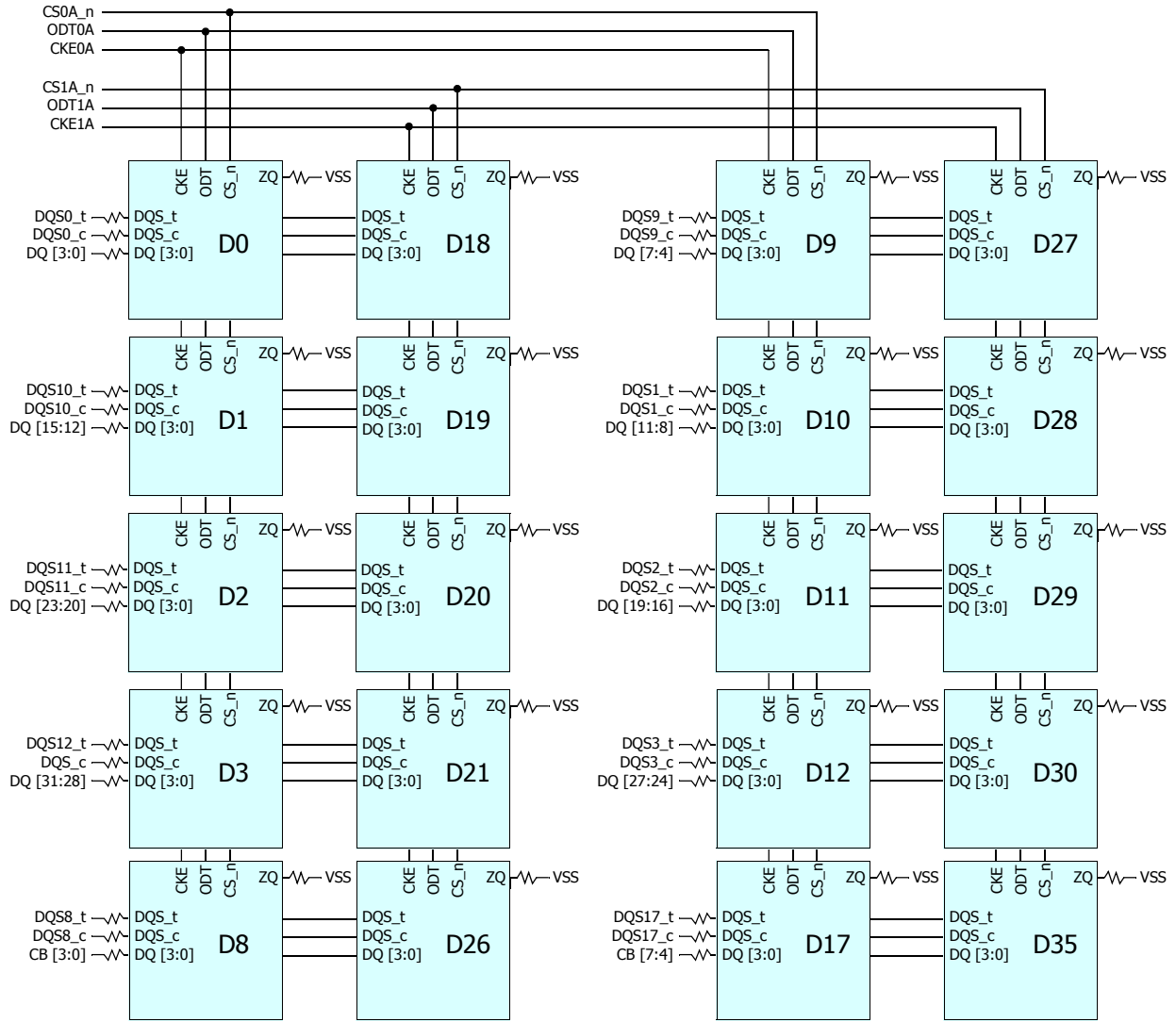
# 16GB, 2Gx72 Module(2Rank of x4) - page1



**Note:**

1. Unless otherwise noted, resistor values are  $15\Omega \pm 5\%$ .
2. See the Net Structure diagrams for all resistor associated with the command, address and control bus.
3. ZQ resistors are  $240\Omega \pm 1\%$ . For all other resistor values refer to the appropriate wiring diagram.

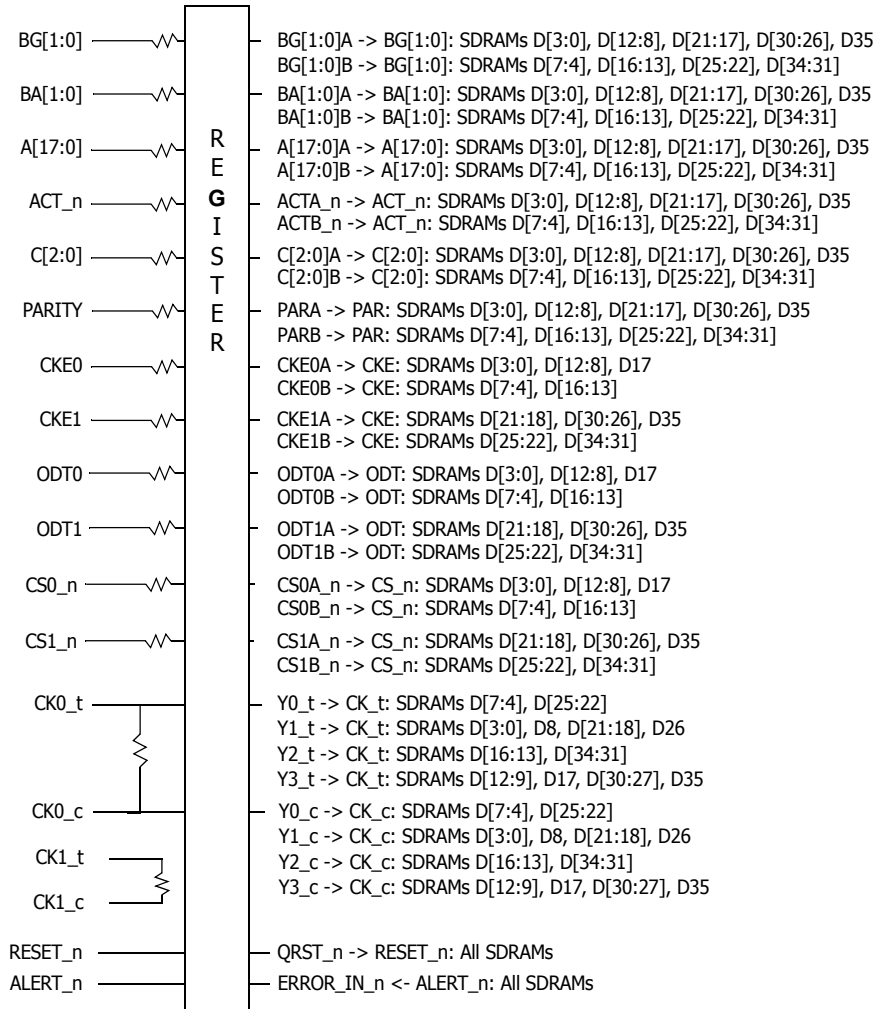
# 16GB, 2Gx72 Module(2Rank of x4) - page2



**Note:**

1. Unless otherwise noted, resistor values are  $15\Omega \pm 5\%$ .
2. See the Net Structure diagrams for all resistor associated with the command, address and control bus.
3. ZQ resistors are  $240\Omega \pm 1\%$ . For all other resistor values refer to the appropriate wiring diagram.

## 16GB, 2Gx72 Module(2Rank of x4) - page3



**Note:**

1. CK0\_t, CK0\_c terminated with 120Ω ±5% resistor.
2. CK1\_t, CK1\_c terminated with 120Ω ±5% resistor but not used.
3. Unless otherwise noted resistors are 22Ω ±5%.

## Absolute Maximum Ratings

### Absolute Maximum DC Ratings

#### Absolute Maximum DC Ratings

Symbol	Parameter	Rating	Units	NOTE
VDD	Voltage on VDD pin relative to Vss	-0.3 ~ 1.5	V	1,3
VDDQ	Voltage on VDDQ pin relative to Vss	-0.3 ~ 1.5	V	1,3
VPP	Voltage on VPP pin relative to Vss	-0.3 ~ 3.0	V	4
V <sub>IN</sub> , V <sub>OUT</sub>	Voltage on any pin except VREFCA relative to Vss	-0.3 ~ 1.5	V	1,3,5
T <sub>STG</sub>	Storage Temperature	-55 to +100	°C	1,2

#### NOTE :

- 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
- 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.
- 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; VREFCA may be equal to or less than 300 mV
- VPP must be equal or greater than VDD/VDDQ at all times
- Overshoot area above 1.5V is specified in DDR4 Device Operation.

### DRAM Component Operating Temperature Range

#### Temperature Range

Symbol	Parameter	Rating	Units	Notes
T <sub>OPER</sub>	Normal Operating Temperature Range	0 to 85	°C	1,2
	Extended Temperature Range	85 to 95	°C	1,3

#### Notes:

- 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.
- 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 - 85°C under all operating conditions.
- Some applications require operation of the DRAM in the Extended Temperature Range between 85°C and 95°C case temperature. Full specifications are guaranteed in this range, but the following additional conditions apply:
  - 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
  - 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).

## AC & DC Operating Conditions

### Recommended DC Operating Conditions

#### Recommended DC Operating Conditions

Symbol	Parameter	Rating			Unit	NOTE
		Min.	Typ.	Max.		
VDD	Supply Voltage	1.14	1.2	1.26	V	1,2,3
VDDQ	Supply Voltage for Output	1.14	1.2	1.26	V	1,2,3
VPP	Supply Voltage for DRAM Activating	2.375	2.5	2.75	V	3

**NOTE:**

1. 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.

## AC & DC Input Measurement Levels

### AC & DC Logic input levels for single-ended signals

#### Single-ended AC & DC input levels for Command and Address

Symbol	Parameter	DDR4-1600/1866/2133/ 2400		DDR4-2666/3200		Unit	NOTE
		Min.	Max.	Min.	Max.		
$V_{IH,CA}(DC75)$	DC input logic high	$V_{REFCA}^{+} - 0.075$	VDD	TBD	TBD	V	
$V_{IL,CA}(DC75)$	DC input logic low	VSS	$V_{REFCA}^{-} - 0.075$	TBD	TBD	V	
$V_{IH,CA}(AC100)$	AC input logic high	$V_{REF} + 0.1$	Note 2	TBD	TBD	V	1
$V_{IL,CA}(AC100)$	AC input logic low	Note 2	$V_{REF} - 0.1$	TBD	TBD	V	1
$V_{REFCA}(DC)$	Reference Voltage for ADD, CMD inputs	$0.49 * VDD$	$0.51 * VDD$	TBD	TBD	V	2,3

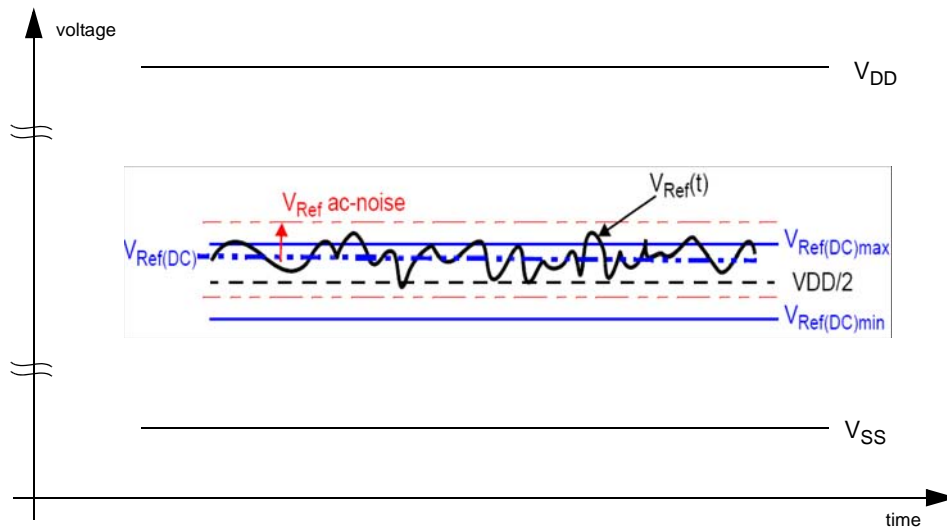
**NOTE :**

1. See "Overshoot and Undershoot Specifications"
2. The AC peak noise on VREFCA may not allow VREFCA to deviate from VREFCA(DC) by more than  $\pm 1\%$  VDD (for reference : approx.  $\pm 12mV$ )
3. For reference : approx.  $VDD/2 \pm 12mV$

## AC and DC Input Measurement Levels: $V_{REF}$ Tolerances

The DC-tolerance limits and ac-noise limits for the reference voltages  $V_{REFCA}$  is illustrated in Figure below. It shows a valid reference voltage  $V_{REF}(t)$  as a function of time. ( $V_{REF}$  stands for  $V_{REFCA}$ ).

$V_{REF}(DC)$  is the linear average of  $V_{REF}(t)$  over a very long period of time (e.g. 1 sec). This average has to meet the min/max requirement in Table X. Furthermore  $V_{REF}(t)$  may temporarily deviate from  $V_{REF}(DC)$  by no more than  $\pm 1\% V_{DD}$ .



**Illustration of  $V_{REF}(DC)$  tolerance and  $V_{REF}$  AC-noise limits**

The voltage levels for setup and hold time measurements  $V_{IH}(AC)$ ,  $V_{IH}(DC)$ ,  $V_{IL}(AC)$  and  $V_{IL}(DC)$  are dependent on  $V_{REF}$ .

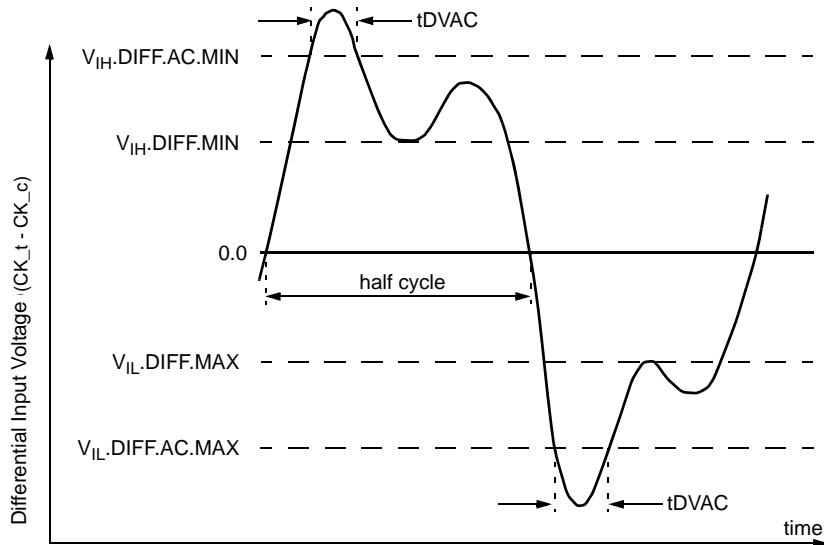
" $V_{REF}$ " shall be understood as  $V_{REF}(DC)$ , as defined in Figure above.

This clarifies, that DC-variations of  $V_{REF}$  affect the absolute voltage a signal has to reach to achieve a valid high or low level and therefore the time to which setup and hold is measured. System timing and voltage budgets need to account for  $V_{REF}(DC)$  deviations from the optimum position within the data-eye of the input signals.

This also clarifies that the DRAM setup/hold specification and derating values need to include time and voltage associated with  $V_{REF}$  AC-noise. Timing and voltage effects due to AC-noise on  $V_{REF}$  up to the specified limit ( $\pm 1\%$  of  $V_{DD}$ ) are included in DRAM timings and their associated deratings.

## AC and DC Logic Input Levels for Differential Signals

### Differential signal definition



**NOTE:**

1. Differential signal rising edge from  $V_{IL.DIFF.MAX}$  to  $V_{IH.DIFF.MIN}$  must be monotonic slope.
2. Differential signal falling edge from  $V_{IH.DIFF.MIN}$  to  $V_{IL.DIFF.MAX}$  must be monotonic slope.

### Definition of differential ac-swing and "time above ac-level" $t_{DVAC}$



## Differential swing requirements for clock (CK\_t - CK\_c) Differential AC and DC Input Levels

Symbol	Parameter	DDR4 -1600,1866,2133		DDR4 -2400,2666 & 3200		unit	NOTE
		min	max	min	max		
$V_{IHdiff}$	differential input high	+0.150	NOTE 3	TBD	NOTE 3	V	1
$V_{ILdiff}$	differential input low	NOTE 3	-0.150	NOTE 3	TBD	V	1
$V_{IHdiff}(AC)$	differential input high ac	$2 \times (V_{IH}(AC) - V_{REF})$	NOTE 3	$2 \times (V_{IH}(AC) - V_{REF})$	NOTE 3	V	2
$V_{ILdiff}(AC)$	differential input low ac	NOTE 3	$2 \times (V_{IL}(AC) - V_{REF})$	NOTE 3	$2 \times (V_{IL}(AC) - V_{REF})$	V	2

**NOTE :**

- Used to define a differential signal slew-rate.
- for CK\_t - CK\_c use  $V_{IH,CA}/V_{IL,CA}(AC)$  of ADD/CMD and  $V_{REFCA}$ ;
- These values are not defined; however, the differential signals CK\_t - CK\_c, need to be within the respective limits ( $V_{IH,CA}(DC)$  max,  $V_{IL,CA}(DC)$ min) for single-ended signals as well as the limitations for overshoot and undershoot.

### Allowed time before ringback (tDVAC) for CK\_t - CK\_c

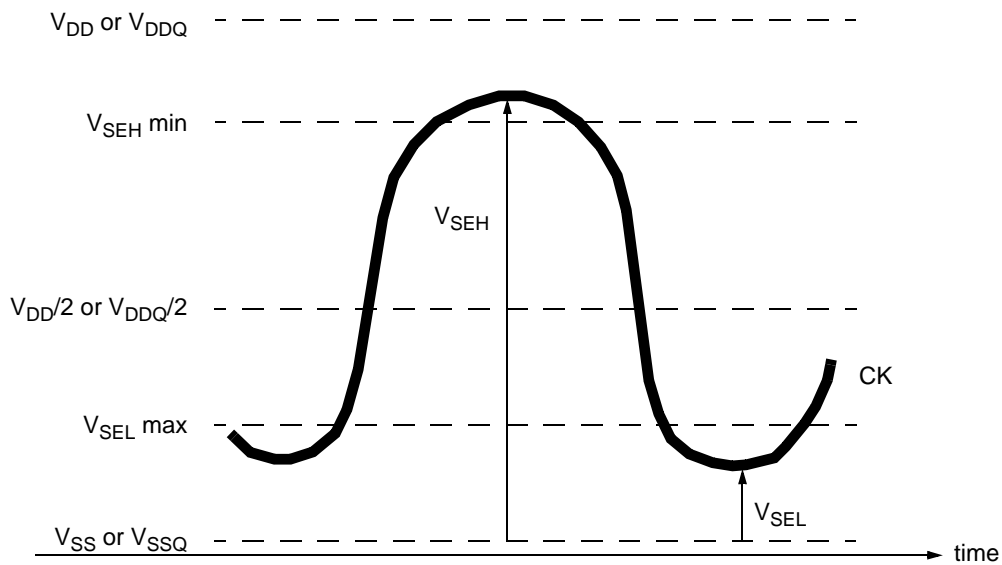
Slew Rate [V/ns]	tDVAC [ps] @ $ V_{IH/Ldiff}(AC)  = 200mV$		tDVAC [ps] @ $ V_{IH/Ldiff}(AC)  = TBDmV$	
	min	max	min	max
> 4.0	120	-	TBD	-
4.0	115	-	TBD	-
3.0	110	-	TBD	-
2.0	105	-	TBD	-
1.8	100	-	TBD	-
1.6	95	-	TBD	-
1.4	90	-	TBD	-
1.2	85	-	TBD	-
1.0	80	-	TBD	-
< 1.0	80	-	TBD	-

## Single-ended requirements for differential signals

Each individual component of a differential signal (CK<sub>t</sub>, CK<sub>c</sub>) has also to comply with certain requirements for single-ended signals.

CK<sub>t</sub> and CK<sub>c</sub> have to approximately reach V<sub>SEH</sub>min / V<sub>SEL</sub>max (approximately equal to the ac-levels (VIH.CA(AC) / VIL.CA(AC) ) for ADD/CMD signals) in every half-cycle.

Note that the applicable ac-levels for ADD/CMD might be different per speed-bin etc. E.g., if Different value than VIH.CA(AC100)/VIL.CA(AC100) is used for ADD/CMD signals, then these ac-levels apply also for the single-ended signals CK<sub>t</sub> and CK<sub>c</sub>



**Single-ended requirement for differential signals**

Note that, while ADD/CMD signal requirements are with respect to VrefCA, the single-ended components of differential signals have a requirement with respect to VDD / 2; this is nominally the same. The transition of single-ended signals through the ac-levels is used to measure setup time. For single-ended components of differential signals the requirement to reach V<sub>SEL</sub>max, V<sub>SEH</sub>min has no bearing on timing, but adds a restriction on the common mode characteristics of these signals.

### Single-ended levels for CK\_t, CK\_c

Symbol	Parameter	DDR4-1600/1866/2133		DDR4-2400/2666/3200		Unit	NOTE
		Min	Max	Min	Max		
V <sub>SEH</sub>	Single-ended high-level for CK_t, CK_c	(VDD/2) +0.100	NOTE3	TBD	NOTE3	V	1, 2
V <sub>SEL</sub>	Single-ended low-level for CK_t, CK_c	NOTE3	(VDD/2)- 0.100	NOTE3	TBD	V	1, 2

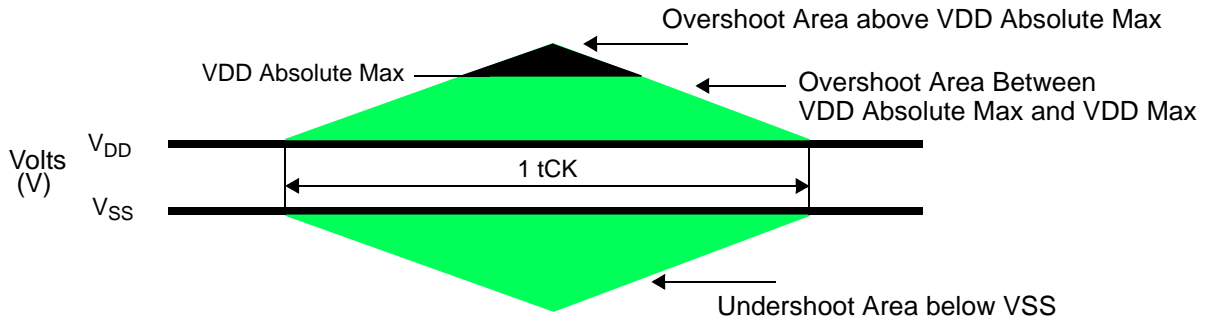
**NOTE :**

1. For CK\_t - CK\_c use V<sub>IH,CA</sub>/V<sub>IL,CA</sub>(AC) of ADD/CMD;
2. V<sub>IH</sub>(AC)/V<sub>IL</sub>(AC) for ADD/CMD is based on V<sub>REFCA</sub>;
3. These values are not defined, however the single-ended signals CK\_t - CK\_c need to be within the respective limits (V<sub>IH,CA</sub>(DC) max, V<sub>IL,CA</sub>(DC)min) for single-ended signals as well as the limitations for overshoot and undershoot.

## Address and Control Overshoot and Undershoot specifications

### AC overshoot/undershoot specification for Address, Command and Control pins

Parameter	Specification					Unit
	DDR4-1600	DDR4-1866	DDR4-2133	DDR4-2400	DDR4-2666	
Maximum peak amplitude above VDD Absolute Max allowed for overshoot area	0.06	0.06	0.06	0.06	TBD	V
Delta value between VDD Absolute Max and VDD Max allowed for overshoot area	0.24	0.24	0.24	0.24	TBD	V
Maximum peak amplitude allowed for undershoot area	0.3	0.3	0.3	0.3	TBD	V-ns
Maximum overshoot area per 1tCK Above Absolute Max	0.0083	0.0071	0.0062	0.0055	TBD	V-ns
Maximum overshoot area per 1tCK Between Absolute Max	0.2550	0.2185	0.1914	0.1699	TBD	V-ns
Maximum undershoot area per 1tCK Below VSS	0.2644	0.2265	0.1984	0.1762	TBD	V-ns
(A0-A13,A17,BG0-BG1,BA0-BA1,ACT_n,RAS_n/A16,CAS_n/A15,WE_n/A14,CS_n,CKE,ODT,C2-C0)						

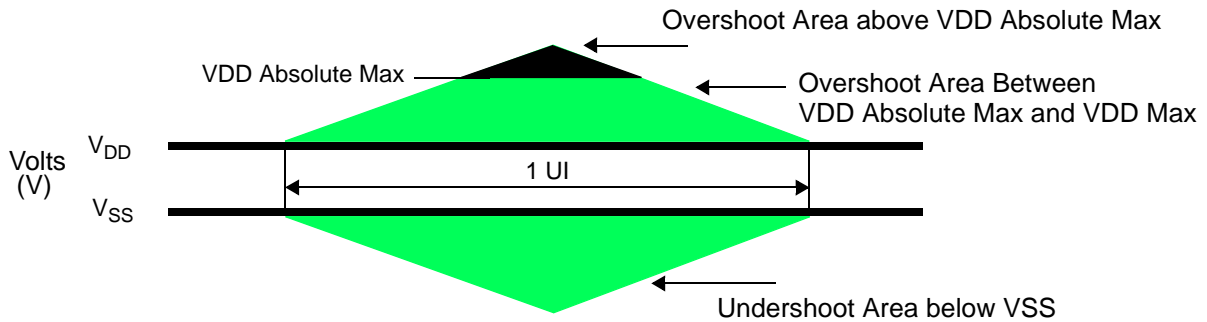


**Address,Command and Control Overshoot and Undershoot Definition**

## Clock Overshoot and Undershoot Specifications

### AC overshoot/undershoot specification for Clock

Parameter	Specification					Unit
	DDR4-1600	DDR4-1866	DDR4-2133	DDR4-2400	DDR4-2666	
Maximum peak amplitude above VDD Absolute Max allowed for overshoot area	0.06	0.06	0.06	0.06	TBD	V
Delta value between VDD Absolute Max and VDD Max allowed for overshoot area	0.24	0.24	0.24	0.24	TBD	V
Maximum peak amplitude allowed for undershoot area	0.3	0.3	0.3	0.3	TBD	V
Maximum overshoot area per 1UI Above Absolute Max	0.0038	0.0032	0.0028	0.0025	TBD	V-ns
Maximum overshoot area per 1UI Between Absolute Max	0.1125	0.0964	0.0844	0.0750	TBD	V-ns
Maximum undershoot area per 1UI Below VSS	0.1144	0.0980	0.0858	0.0762	TBD	V-ns
(CK_t, Ck_c)						



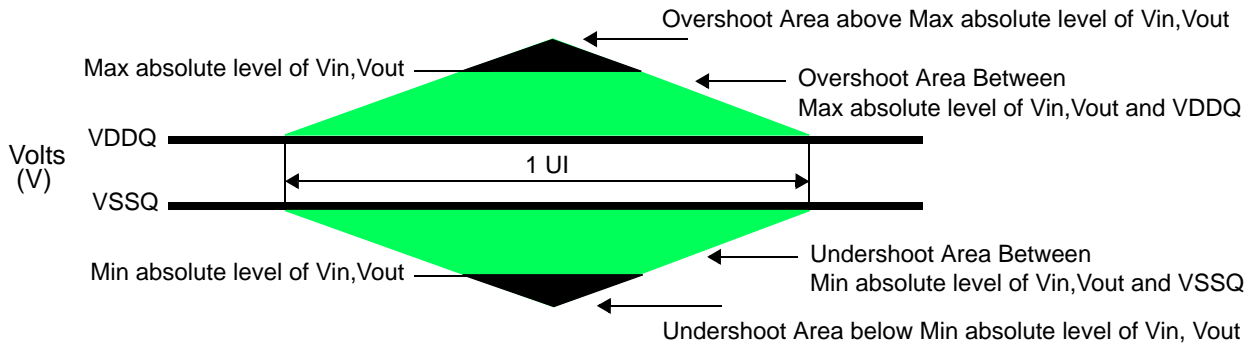
**Clock Overshoot and Undershoot Definition**

## Data, Strobe and Mask Overshoot and Undershoot Specifications

### AC overshoot/undershoot specification for Data, Strobe and Mask

Parameter	Specification					Unit
	DDR4-1600	DDR4-1866	DDR4-2133	DDR4-2400	DDR4-2666	
Maximum peak amplitude above Max absolute level of Vin,Vout	0.16	0.16	0.16	0.16	TBD	V
Overshoot area Between Max Absolute level of Vin, Vout and VDDQ Max	0.24	0.24	0.24	0.24	TBD	V
Undershoot area Between Min absolute level of Vin,Vout and VDDQ	0.30	0.30	0.30	0.30	TBD	V
Maximum peak amplitude below Min absolute level of Vin,Vout	0.10	0.10	0.10	0.10	TBD	V
Maximum overshoot area per 1UI Above Max absolute level of Vin,Vout	0.0150	0.0129	0.0113	0.0100	TBD	V-ns
Maximum overshoot area per 1UI Between Max absolute level of Vin,Vout and VDDQ Max	0.1050	0.0900	0.0788	0.0700	TBD	V-ns
Maximum undershoot area per 1UI Between Min absolute level of Vin,Vout and VSSQ	0.1050	0.0900	0.0788	0.0700	TBD	V-ns
Maximum undershoot area per 1UI Below Min absolute level of Vin,Vout	0.0150	0.0129	0.0113	0.0100	TBD	V-ns

(DQ, DQS\_t, DQS\_c, DM\_n, DBI\_n, TDQS\_t, TDQS\_c)



**Data, Strobe and Mask Overshoot and Undershoot Definition**

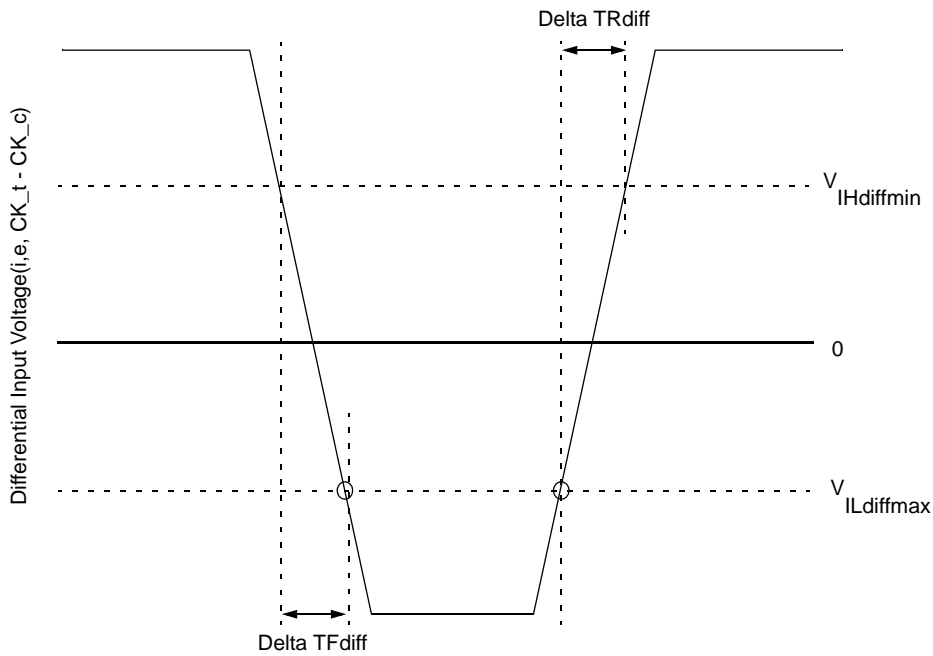
## Slew Rate Definitions

### Slew Rate Definitions for Differential Input Signals (CK)

Input slew rate for differential signals (CK<sub>t</sub>, CK<sub>c</sub>) are defined and measured as shown in Table and Figure below.

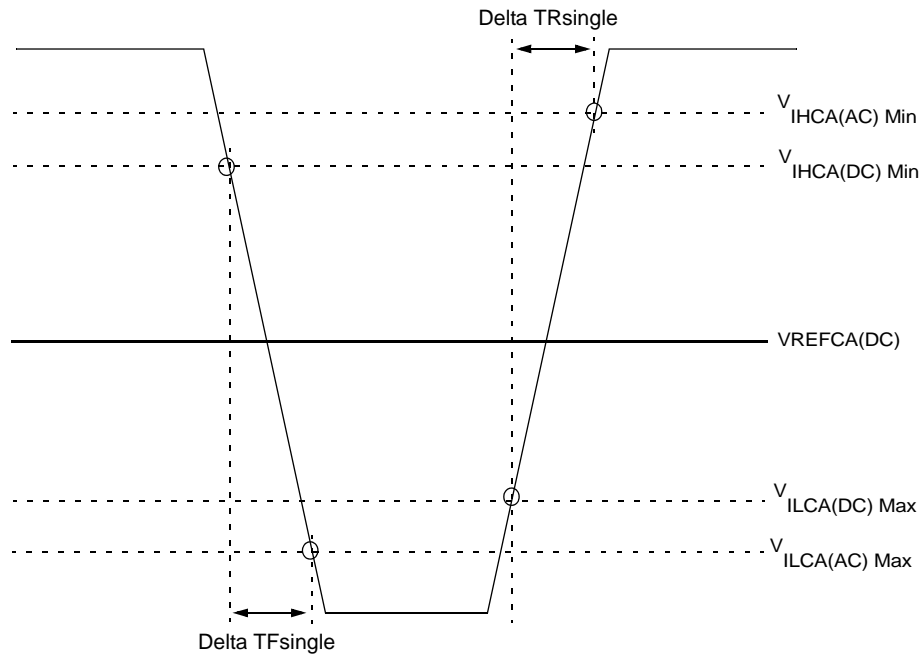
**Differential Input Slew Rate Definition**

Description			Defined by
	from	to	
Differential input slew rate for rising edge(CK <sub>t</sub> - CK <sub>c</sub> )	V <sub>ILdiffmax</sub>	V <sub>IHdiffmin</sub>	$[V_{IHdiffmin} - V_{ILdiffmax}] / \Delta TR_{diff}$
Differential input slew rate for falling edge(CK <sub>t</sub> - CK <sub>c</sub> )	V <sub>IHdiffmin</sub>	V <sub>ILdiffmax</sub>	$[V_{IHdiffmin} - V_{ILdiffmax}] / \Delta TF_{diff}$
NOTE: The differential signal (i.e.,CK <sub>t</sub> - CK <sub>c</sub> ) must be linear between these thresholds.			



**Differential Input Slew Rate Definition for CK<sub>t</sub>, CK<sub>c</sub>**

## Slew Rate Definition for Single-ended Input Signals (CMD/ADD)



### Single-ended Input Slew Rate definition for CMD and ADD

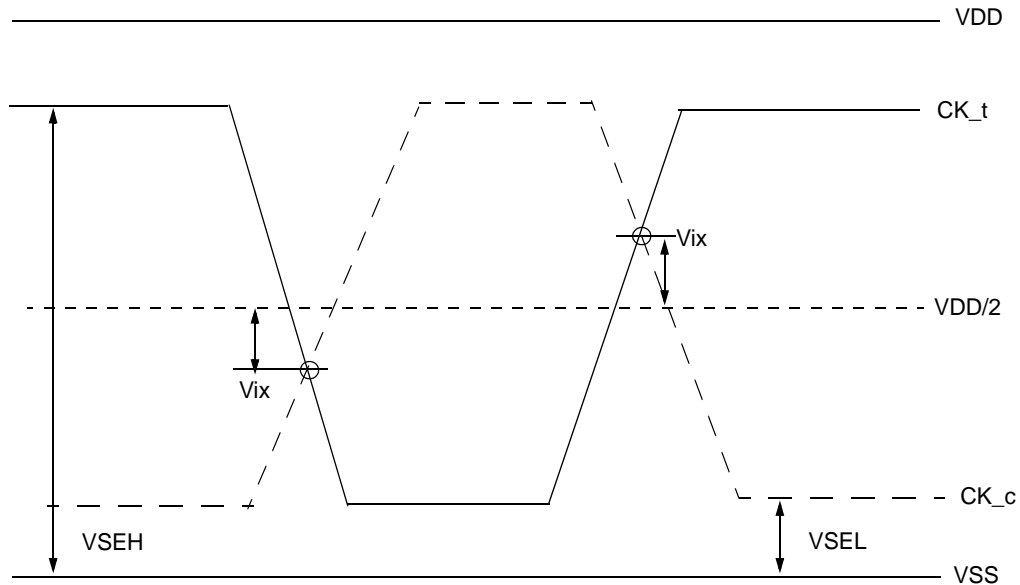
**NOTE :**

1. Single-ended input slew rate for rising edge =  $\{ V_{IHCA(AC)Min} - V_{ILCA(DC)Max} \} / \Delta T_{R single}$
2. Single-ended input slew rate for falling edge =  $\{ V_{IHCA(DC)Min} - V_{ILCA(AC)Max} \} / \Delta T_{F single}$
3. Single-ended signal rising edge from  $V_{ILCA(DC)Max}$  to  $V_{IHCA(DC)Min}$  must be monotonic slope.
4. Single-ended signal falling edge from  $V_{IHCA(DC)Min}$  to  $V_{ILCA(DC)Max}$  must be monotonic slope



## Differential Input Cross Point Voltage

To guarantee tight setup and hold times as well as output skew parameters with respect to clock, each cross point voltage of differential input signals (CK\_t, CK\_c) must meet the requirements in Table. The differential input cross point voltage VIX is measured from the actual cross point of true and complement signals to the midlevel between of VDD and VSS.



Vix Definition (CK)

### Cross point voltage for differential input signals (CK)

Symbol	Parameter	DDR4-1600/1866/2133			
		min		max	
-	Area of VSEH, VSEL	$VSEL \leq VDD/2 - 145mV$	$VDD/2 - 145mV \leq VSEL \leq VDD/2 - 100mV$	$VDD/2 + 100mV \leq VSEH \leq VDD/2 + 145mV$	$VDD/2 + 145mV \leq VSEH$
VIX(CK)	Differential Input Cross Point Voltage relative to VDD/2 for CK_t, CK_c	-120mV	$-(VDD/2 - VSEL) + 25mV$	$(VSEH - VDD/2) - 25mV$	120mV

Symbol	Parameter	DDR4-2400/2666/3200			
		min		max	
-	Area of VSEH, VSEL	TBD	TBD	TBD	TBD
VIX(CK)	Differential Input Cross Point Voltage relative to VDD/2 for CK_t, CK_c	TBD	TBD	TBD	TBD

## CMOS rail to rail Input Levels

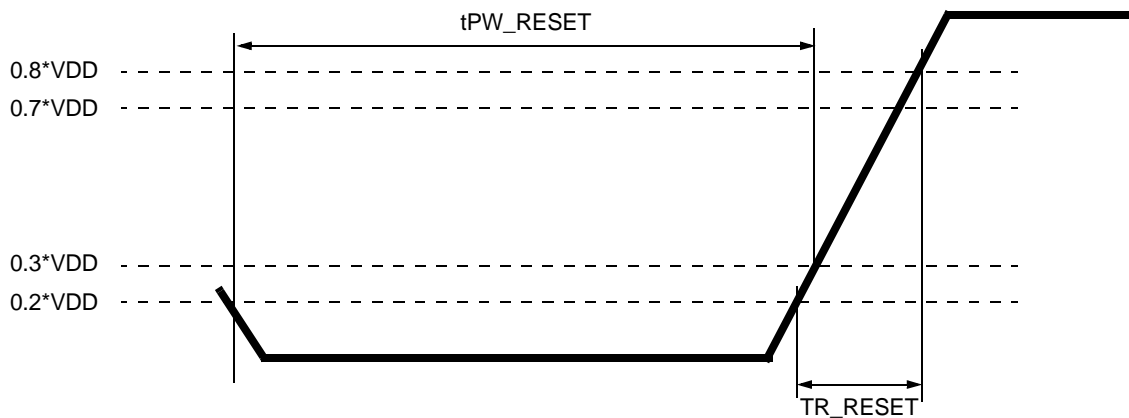
### CMOS rail to rail Input Levels for RESET\_n

#### CMOS rail to rail Input Levels for RESET\_n

Parameter	Symbol	Min	Max	Unit	NOTE
AC Input High Voltage	VIH(AC)_RESET	0.8*VDD	VDD	V	6
DC Input High Voltage	VIH(DC)_RESET	0.7*VDD	VDD	V	2
DC Input Low Voltage	VIL(DC)_RESET	VSS	0.3*VDD	V	1
AC Input Low Voltage	VIL(AC)_RESET	VSS	0.2*VDD	V	7
Rising time	TR_RESET	-	1.0	us	4
RESET pulse width	tPW_RESET	1.0	-	us	3,5

#### NOTE :

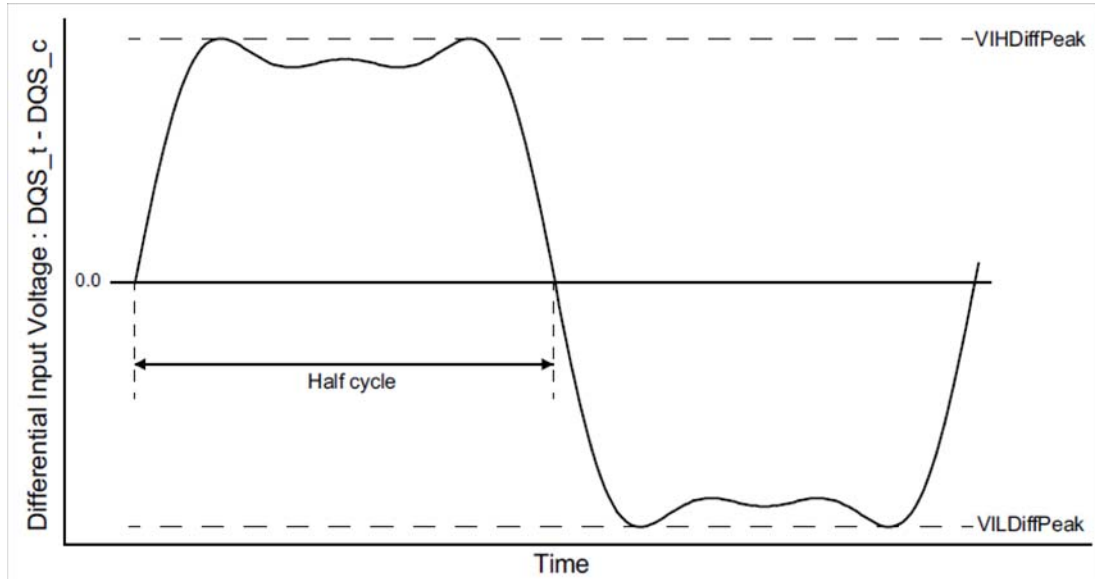
1. After RESET\_n is registered LOW, RESET\_n level shall be maintained below VIL(DC)\_RESET during tPW\_RESET, otherwise, SDRAM may not be reset.
2. Once RESET\_n is registered HIGH, RESET\_n level must be maintained above VIH(DC)\_RESET, otherwise, SDRAM operation will not be guaranteed until it is reset asserting RESET\_n signal LOW.
3. RESET is destructive to data contents.
4. No slope reversal(ringback) requirement during its level transition from Low to High.
5. This definition is applied only "Reset Procedure at Power Stable".
6. Overshoot might occur. It should be limited by the Absolute Maximum DC Ratings.
7. Undershoot might occur. It should be limited by Absolute Maximum DC Ratings



**RESET\_n Input Slew Rate Definition**

## AC and DC Logic Input Levels for DQS Signals

### Differential signal definition



Definition of differential DQS Signal AC-swing Level

### Differential swing requirements for DQS (DQS\_t - DQS\_c)

#### Differential AC and DC Input Levels for DQS

Symbol	Parameter	DDR4-1600,1866,2133		DDR4-2400		DDR4-2666,3200		Unit	Note
		Min	Max	Min	Max	Min	Max		
VIHDiffPeak	VIH.DIFF.Peak Voltage	186	Note2	TBD	TBD	TBD	TBD	mV	1
VILDiffPeak	VIL.DIFF.Peak Voltage	Note2	-186	TBD	TBD	TBD	TBD	mV	1

**NOTE :**

- Used to define a differential signal slew-rate.
- These values are not defined; however, the differential signals DQS\_t - DQS\_c, need to be within the respective limits Overshoot, Undershoot Specification for single-ended signals.

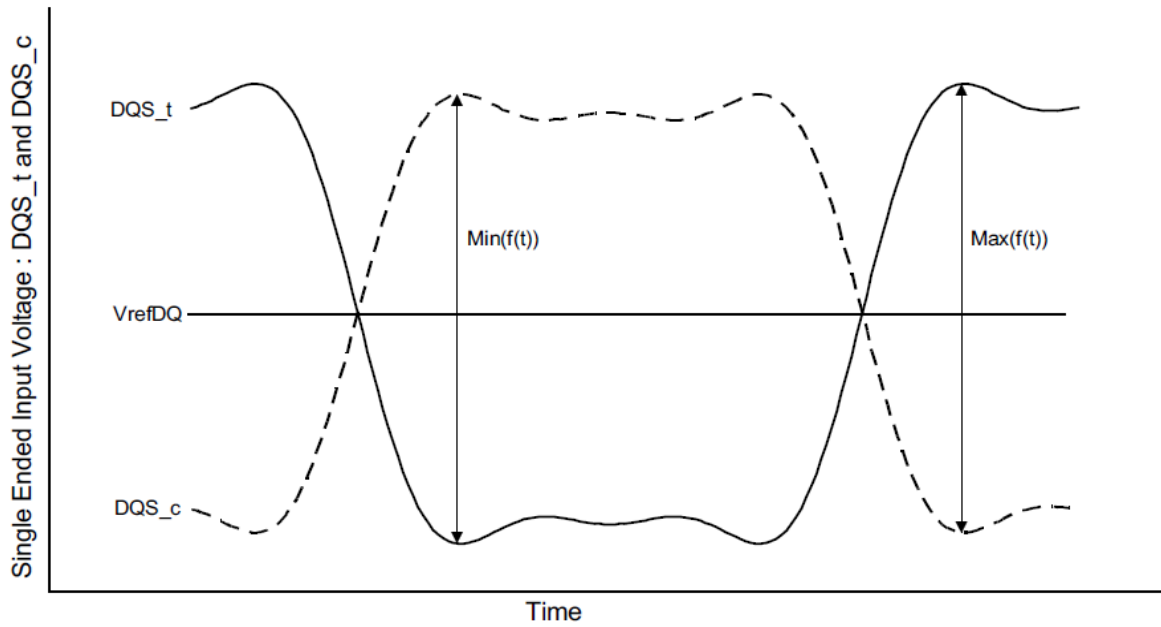
## Peak voltage calculation method

The peak voltage of Differential DQS signals are calculated in a following equation.

$$\text{VIH.DIFF.Peak Voltage} = \text{Max}(f(t))$$

$$\text{VIL.DIFF.Peak Voltage} = \text{Min}(f(t))$$

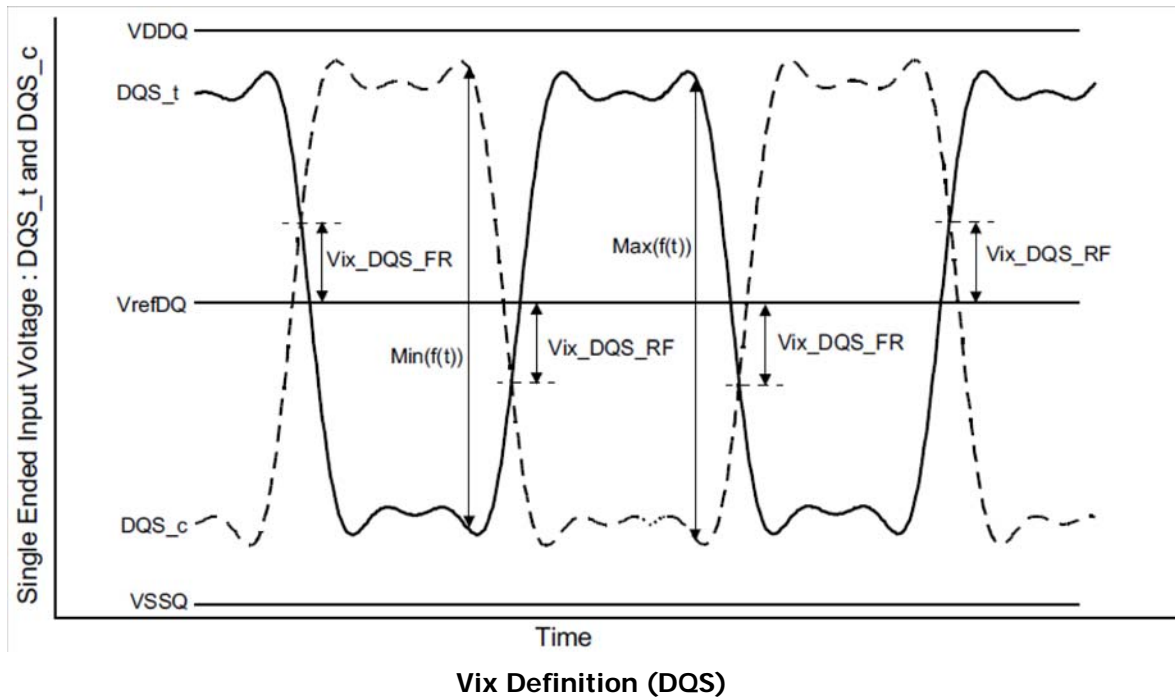
$$f(t) = \text{VDQS}_t - \text{VDQS}_c$$



Definition of differential DQS Peak Voltage

## Peak voltage calculation method

To guarantee tight setup and hold times as well as output skew parameters with respect to strobe, the cross point voltage of differential input signals (DQS<sub>t</sub>, DQS<sub>c</sub>) must meet the requirements in Table below. The differential input cross point voltage VIX is measured from the actual cross point of true and complement signals to the mid level that is VrefDQ.



### Cross point voltage for differential input signals (DQS)

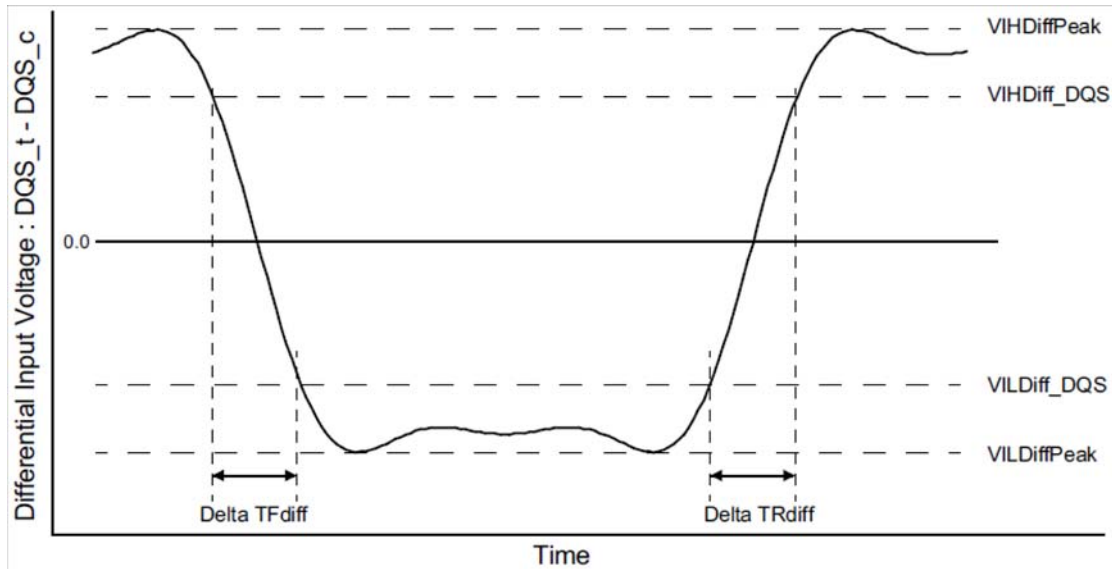
Symbol	Parameter	DDR4-1600,1866,2133		DDR4-2400		DDR4-2666,3200		Unit	Note
		Min	Max	Min	Max	Min	Max		
Vix_DOS_ratio	DQS Differential input cross point voltage ratio	-	25	-	25	TBD	TBD	%	1,2,3

**NOTE :**

1. The base level of Vix\_DQS\_FR/RF is VrefDQ that is DDR4 SDRAM internal setting value by Vref Training.
2. Vix\_DQS\_FR is defined by this equation :  $Vix\_DQS\_FR = |\text{Min}(f(t)) \times Vix\_DQS\_Ratio|$
3. Vix\_DQS\_RF is defined by this equation :  $Vix\_DQS\_RF = \text{Max}(f(t)) \times Vix\_DQS\_Ratio$

## Differential Input Slew Rate Definition

Input slew rate for differential signals (DQS\_t, DQS\_c) are defined and measured as shown in Figure below.



**NOTE :**

1. Differential signal rising edge from VILDiff\_DQS to VIHDiff\_DQS must be monotonic slope.
2. Differential signal falling edge from VIHDiff\_DQS to VILDiff\_DQS must be monotonic slope.

### Differential Input Slew Rate Definition for DQS\_t, DQS\_c

#### Differential Input Slew Rate Definition for DQS\_t, DQS\_c

Description			Defined by
	From	To	
Differential input slew rate for rising edge(DQS_t - DQS_c)	VILDiff_DQS	VIHDiff_DQS	$ VILDiff\_DQS - VIHDiff\_DQS /\Delta TRdiff$
Differential input slew rate for falling edge(DQS_t - DQS_c)	VIHDiff_DQS	VILDiff_DQS	$ VILDiff\_DQS - VIHDiff\_DQS /\Delta TFdiff$

### Differential Input Level for DQS\_t, DQS\_c

Symbol	Parameter	DDR4-1600,1866,2133		DDR4-2400		DDR4-2666,3200		Unit	Note
		Min	Max	Min	Max	Min	Max		
VIHDiff_DQS	Differential Input High	136	-	TBD	TBD	TBD	TBD	mV	
VILDiff_DQS	Differential Input Low	-	-136	TBD	TBD	TBD	TBD	mV	

### Differential Input Slew Rate for DQS\_t, DQS\_c

Symbol	Parameter	DDR4-1600,1866,2133		DDR4-2400		DDR4-2666,3200		Unit	Note
		Min	Max	Min	Max	Min	Max		
SRI <sub>diff</sub>	Differential Input Slew Rate	TBD	18	TBD	TBD	TBD	TBD	V/ns	

## AC and DC output Measurement levels

### Single-ended AC & DC Output Levels

#### Single-ended AC & DC output levels

Symbol	Parameter	DDR4-1600/1866/2133/ 2400/2666/3200	Units	NOTE
$V_{OH(DC)}$	DC output high measurement level (for IV curve linearity)	$1.1 \times V_{DDQ}$	V	
$V_{OM(DC)}$	DC output mid measurement level (for IV curve linearity)	$0.8 \times V_{DDQ}$	V	
$V_{OL(DC)}$	DC output low measurement level (for IV curve linearity)	$0.5 \times V_{DDQ}$	V	
$V_{OH(AC)}$	AC output high measurement level (for output SR)	$(0.7 + 0.15) \times V_{DDQ}$	V	1
$V_{OL(AC)}$	AC output low measurement level (for output SR)	$(0.7 - 0.15) \times V_{DDQ}$	V	1

**NOTE :**

1. The swing of  $\pm 0.15 \times V_{DDQ}$  is based on approximately 50% of the static single-ended output peak-to-peak swing with a driver impedance of  $RZQ/7\Omega$  and an effective test load of  $50\Omega$  to  $V_{TT} = V_{DDQ}$ .

### Differential AC & DC Output Levels

#### Differential AC & DC output levels

Symbol	Parameter	DDR4-1600/1866/ 2133/2400/2666/3200	Units	NOTE
$V_{OHdiff(AC)}$	AC differential output high measurement level (for output SR)	$+0.3 \times V_{DDQ}$	V	1
$V_{OLdiff(AC)}$	AC differential output low measurement level (for output SR)	$-0.3 \times V_{DDQ}$	V	1

**NOTE :**

1. The swing of  $\pm 0.3 \times V_{DDQ}$  is based on approximately 50% of the static differential output peak-to-peak swing with a driver impedance of  $RZQ/7\Omega$  and an effective test load of  $50\Omega$  to  $V_{TT} = V_{DDQ}$  at each of the differential outputs.



## Single-ended Output Slew Rate

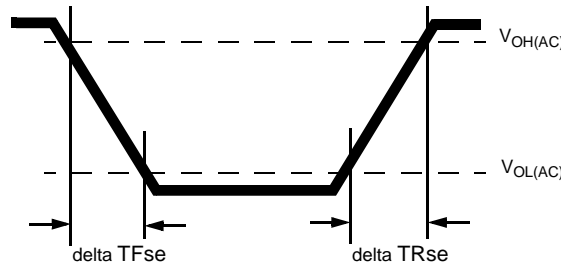
With the reference load for timing measurements, output slew rate for falling and rising edges is defined and measured between  $V_{OL(AC)}$  and  $V_{OH(AC)}$  for single ended signals as shown in Table and Figure below.

### Single-ended output slew rate definition

Description	Measured		Defined by
	From	To	
Single ended output slew rate for rising edge	$V_{OL(AC)}$	$V_{OH(AC)}$	$[V_{OH(AC)} - V_{OL(AC)}] / \Delta TR_{se}$
Single ended output slew rate for falling edge	$V_{OH(AC)}$	$V_{OL(AC)}$	$[V_{OH(AC)} - V_{OL(AC)}] / \Delta TF_{se}$

**NOTE :**

1. Output slew rate is verified by design and characterization, and may not be subject to production test.



Single-ended Output Slew Rate Definition

### Single-ended output slew rate

Parameter	Symbol	DDR4-1600		DDR4-1866		DDR4-2133		DDR4-2400		DDR4-2666		DDR4-3200		Units
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
Single ended output slew rate	SRQse	4	9	4	9	4	9	4	9	TBD	TBD	TBD	TBD	V/ns

Description: SR: Slew Rate

Q: Query Output (like in DQ, which stands for Data-in, Query-Output)

se: Single-ended Signals

For Ron = RZQ/7 setting

**NOTE:**

1. In two cases, a maximum slew rate of 12 V/ns applies for a single DQ signal within a byte lane.

-Case 1 is defined for a single DQ signal within a byte lane which is switching into a certain direction (either from high to low or low to high) while all remaining DQ signals in the same byte lane are static (i.e. they stay at either high or low).

-Case 2 is defined for a single DQ signal within a byte lane which is switching into a certain direction (either from high to low or low to high) while all remaining DQ signals in the same byte lane are switching into the opposite direction (i.e. from low to high or high to low respectively). For the remaining DQ signal switching into the opposite direction, the regular maximum limit of 9 V/ns applies

## Differential Output Slew Rate

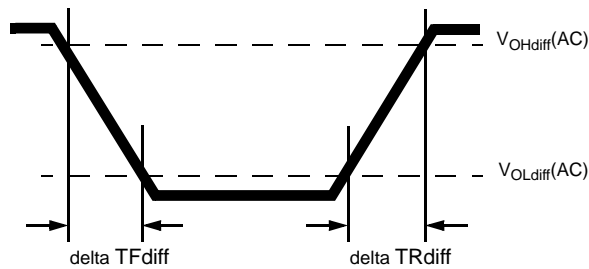
With the reference load for timing measurements, output slew rate for falling and rising edges is defined and measured between VOLdiff(AC) and VOHdiff(AC) for differential signals as shown in Table and Figure below.

### Differential output slew rate definition

Description	Measured		Defined by
	From	To	
Differential output slew rate for rising edge	VOLdiff(AC)	VOHdiff(AC)	$[V_{OHdiff(AC)} - V_{OLdiff(AC)}] / \Delta TR_{diff}$
Differential output slew rate for falling edge	VOHdiff(AC)	VOLdiff(AC)	$[V_{OHdiff(AC)} - V_{OLdiff(AC)}] / \Delta TF_{diff}$

**NOTE :**

1. Output slew rate is verified by design and characterization, and may not be subject to production test.



### Differential Output Slew Rate Definition

### Differential output slew rate

Parameter	Symbol	DDR4-1600		DDR4-1866		DDR4-2133		DDR4-2400		DDR4-2666		DDR4-3200		Units
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
Differential output slew rate	SRQdiff	8	18	8	18	8	18	8	18	TBD	TBD	TBD	TBD	V/ns

Description:

SR: Slew Rate

Q: Query Output (like in DQ, which stands for Data-in, Query-Output)

diff: Differential Signals

For Ron = RZQ/7 setting

## Single-ended AC & DC Output Levels of Connectivity Test Mode

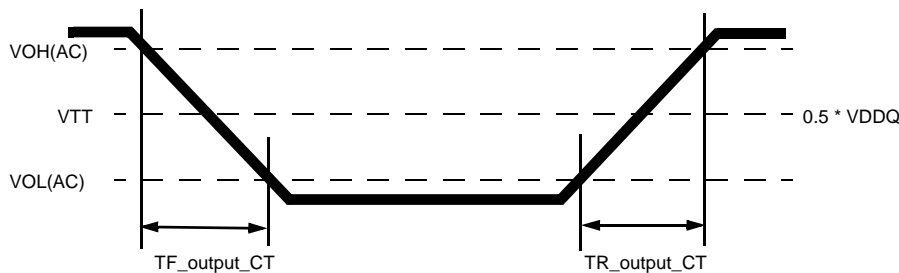
Following output parameters will be applied for DDR4 SDRAM Output Signal during Connectivity Test Mode.

### Single-ended AC & DC output levels of Connectivity Test Mode

Symbol	Parameter	DDR4-1600/1866/2133/ 2400/2666/3200	Unit	Note
$V_{OH}(DC)$	DC output high measurement level (for IV curve linearity)	$1.1 \times V_{DDQ}$	V	
$V_{OM}(DC)$	DC output mid measurement level (for IV curve linearity)	$0.8 \times V_{DDQ}$	V	
$V_{OL}(DC)$	DC output low measurement level (for IV curve linearity)	$0.5 \times V_{DDQ}$	V	
$V_{OB}(DC)$	DC output below measurement level (for IV curve linearity)	$0.2 \times V_{DDQ}$	V	
$V_{OH}(AC)$	AC output high measurement level (for output SR)	$V_{TT} + (0.1 \times V_{DDQ})$	V	1
$V_{OL}(AC)$	AC output below measurement level (for output SR)	$V_{TT} - (0.1 \times V_{DDQ})$	V	1

**NOTE :**

1. The effective test load is  $50\Omega$  terminated by  $V_{TT} = 0.5 \times V_{DDQ}$ .



### Differential Output Slew Rate Definition of Connectivity Test Mode

#### Single-ended output slew rate of Connectivity Test Mode

Parameter	Symbol	DDR4-1600/1866/2133/2400/2666/3200		Unit	Note
		Min	Max		
Output signal Falling time	$TF\_output\_CT$	-	10	ns/V	
Output signal Rising time	$TR\_output\_CT$	-	10	ns/V	

## Standard Speed Bins

### DDR4-1600 Speed Bins and Operations

Speed Bin			DDR4-1600K		Unit	NOTE	
CL-nRCD-nRP			11-11-11				
Parameter		Symbol	min	max			
Internal read command to first data		tAA	13.75 (13.50) <sup>5,9</sup>	18.00	ns	9	
Internal read command to first data with read DBI enabled		tAA_DBI	tAA(min) + 2nCK	tAA(max) + 2nCK	ns	9	
ACT to internal read or write delay time		tRCD	13.75 (13.50) <sup>5,9</sup>	-	ns	9	
PRE command period		tRP	13.75 (13.50) <sup>5,9</sup>	-	ns	9	
ACT to PRE command period		tRAS	35	9 x tREFI	ns	9	
ACT to ACT or REF command period		tRC	48.75 (48.50) <sup>5,9</sup>	-	ns	9	
	Normal	Read DBI					
CWL = 9	CL = 9	CL = 11 (Optional) <sup>5</sup>	tCK(AVG)	1.5  (Optional) <sup>5,9</sup>	1.6	ns	1,2,3,4,8, 11
	CL = 10	CL = 12	tCK(AVG)	Reserved			
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	10,11	
Supported CL Settings with read DBI			(11),13,14		nCK	10	
Supported CWL Settings			9,11		nCK		

## DDR4-1866 Speed Bins and Operations

Speed Bin			DDR4-1866M		Unit	NOTE	
CL-nRCD-nRP			13-13-13				
Parameter	Symbol		min	max			
Internal read command to first data	tAA		13.92 <sup>11</sup> (13.50) <sup>5,9</sup>	18.00	ns	9	
Internal read command to first data with read DBI enabled	tAA_DBI		tAA(min) + 2nCK	tAA(max) + 2nCK	ns	9	
ACT to internal read or write delay time	tRCD		13.92 (13.50) <sup>5,9</sup>	-	ns	9	
PRE command period	tRP		13.92 (13.50) <sup>5,9</sup>	-	ns	9	
ACT to PRE command period	tRAS		34	9 x tREFI	ns	9	
ACT to ACT or REF command period	tRC		47.92 (47.50) <sup>5,9</sup>	-	ns	9	
	Normal	Read DBI					
CWL = 9	CL = 9	CL = 11	tCK(AVG)	1.5	1.6	ns	1,2,3,4,8,9
		(Optional) <sup>5</sup>	tCK(AVG)	(Optional) <sup>5,9</sup>			
	CL = 10	CL = 12	tCK(AVG)	Reserved			
CWL = 9,11	CL = 10	CL = 12	tCK(AVG)	Reserved		ns	4
	CL = 11	CL = 13	tCK(AVG)	1.25	<1.5	ns	1,2,3,4,6
				(Optional) <sup>5,9</sup>			
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	10,11	
Supported CL Settings with read DBI			11,13,14,15,16		nCK	11	
Supported CWL Settings			9,10,11,12		nCK		

## DDR4-2133 Speed Bins and Operations

Speed Bin			DDR4-2133P		Unit	NOTE	
CL-nRCD-nRP			15-15-15				
Parameter	Symbol		min	max			
Internal read command to first data	tAA		14.06 <sup>11</sup> (13.50) <sup>5,9</sup>	18.00	ns	9	
Internal read command to first data with read DBI enabled	tAA_DBI		tAA(min)+3nCK	tAA(max)+3nCK	ns	9	
ACT to internal read or write delay time	tRCD		14.06 (13.50) <sup>5,9</sup>	-	ns	9	
PRE command period	tRP		14.06 (13.50) <sup>5,9</sup>	-	ns	9	
ACT to PRE command period	tRAS		33	9 x tREFI	ns	9	
ACT to ACT or REF command period	tRC		47.06 (46.50) <sup>5,9</sup>	-	ns	9	
	Normal	Read DBI					
CWL = 9	CL = 9	CL = 11 (Optional) <sup>5</sup>	tCK(AVG)	1.5	1.6	ns	1,2,3,4,8,11
			tCK(AVG)	(Optional) <sup>5,9</sup>			
	CL = 10	CL = 12	tCK(AVG)	Reserved		ns	1,2,3,8
CWL = 9,11	CL = 11	CL = 13	tCK(AVG)	1.25	<1.5	ns	1,2,3,4,7
			tCK(AVG)	(Optional) <sup>5,9</sup>			
	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) <sup>5,9</sup>			
	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	10,11	
Supported CL Settings with read DBI			(11),(13),14,(15),16,18,19		nCK		
Supported CWL Settings			9,10,11,12,14		nCK		

## Speed Bin Table Notes

### 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 and 2400 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. An application should use the next smaller JEDEC standard tCK(avg) value (1.5, 1.25, 1.071, 0.938 or 0.833 ns) when calculating CL [nCK] = tAA [ns] / tCK(avg) [ns], rounding up to the next 'Supported CL', where tAA = 12.5ns and tCK(avg) = 1.3 ns should only be used for CL = 10 calculation.
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 0.938 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. DDR4-1600 AC timing apply if DRAM operates at lower than 1600 MT/s data rate.
9. Parameters apply from tCK(avg)min to tCK(avg)max at all standard JEDEC clock period values as stated in the Speed Bin Tables.
10. CL number in parentheses, it means that these numbers are optional.
11. DDR4 SDRAM supports CL=9 as long as a system meets tAA(min).

## IDD and IDDQ Specification Parameters and Test Conditions

### IDD, IPP and IDDQ Measurement Conditions

In this chapter, IDD, IPP and IDDQ measurement conditions such as test load and patterns are defined. Figure shows the setup and test load for IDD, IPP and IDDQ measurements.

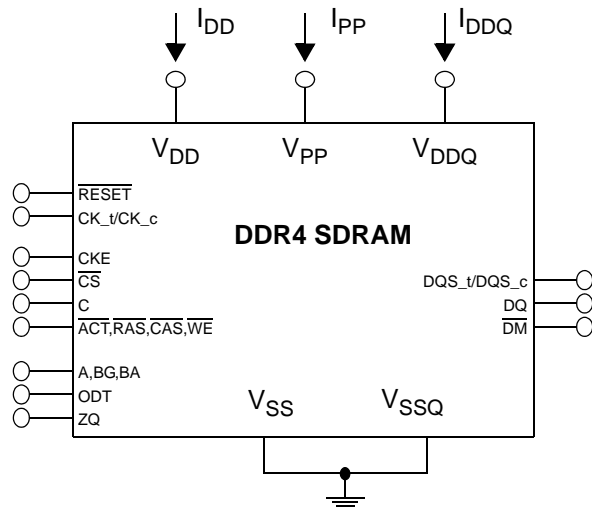
- IDD currents (such as IDD0, IDD0A, IDD1, IDD1A, IDD2N, IDD2NA, IDD2NL, IDD2NT, IDD2P, IDD2Q, IDD3N, IDD3NA, IDD3P, IDD4R, IDD4RA, IDD4W, IDD4WA, IDD5B, IDD5F2, IDD5F4, IDD6N, IDD6E, IDD6R, IDD6A, IDD7 and IDD8) are measured as time-averaged currents with all VDD balls of the DDR4 SDRAM under test tied together. Any IPP or IDDQ current is not included in IDD currents.
- IPP currents have the same definition as IDD except that the current on the VPP supply is measured.
- IDDQ currents (such as IDDQ2NT and IDDQ4R) are measured as time-averaged currents with all VDDQ balls of the DDR4 SDRAM under test tied together. Any IDD current is not included in IDDQ currents.

Attention: IDDQ values cannot be directly used to calculate IO power of the DDR4 SDRAM. They can be used to support correlation of simulated IO power to actual IO power as outlined in Figure 2. In DRAM module application, IDDQ cannot be measured separately since VDD and VDDQ are using one merged-power layer in Module PCB.

For IDD, IPP and IDDQ measurements, the following definitions apply:

- "0" and "LOW" is defined as  $V_{IN} \leq V_{ILAC}(\max)$ .
- "1" and "HIGH" is defined as  $V_{IN} \geq V_{IHAC}(\min)$ .
- "MID-LEVEL" is defined as inputs are  $V_{REF} = V_{DD} / 2$ .
- Timings used for IDD, IPP and IDDQ Measurement-Loop Patterns are provided in Table 1.
- Basic IDD, IPP and IDDQ Measurement Conditions are described in Table 2.
- Detailed IDD, IPP and IDDQ Measurement-Loop Patterns are described in Table 3 through Table 11.
- IDD Measurements are done after properly initializing the DDR4 SDRAM. This includes but is not limited to setting
  - RON = RZQ/7 (34 Ohm in MR1);
  - RTT\_NOM = RZQ/6 (40 Ohm in MR1);
  - RTT\_WR = RZQ/2 (120 Ohm in MR2);
  - RTT\_PARK = Disable;
  - Qoff = 0<sub>B</sub> (Output Buffer enabled) in MR1;
  - TDQS\_t disabled in MR1;
  - CRC disabled in MR2;
  - CA parity feature disabled in MR5;
  - Gear down mode disabled in MR3
  - Read/Write DBI disabled in MR5;
  - DM disabled in MR5
- Attention: The IDD, IPP and IDDQ Measurement-Loop Patterns need to be executed at least one time before actual IDD or IDDQ measurement is started.
- Define D = {CS\_n, ACT\_n, RAS\_n, CAS\_n, WE\_n} := {HIGH, LOW, LOW, LOW, LOW} ; apply BG/BA changes when directed.
- Define D# = {CS\_n, ACT\_n, RAS\_n, CAS\_n, WE\_n} := {HIGH, HIGH, HIGH, HIGH, HIGH} ; apply invert of BG/BA changes when directed above.





**NOTE:**

1. DIMM level Output test load condition may be different from above

Figure 1 - Measurement Setup and Test Load for IDD, IPP and IDDQ Measurements

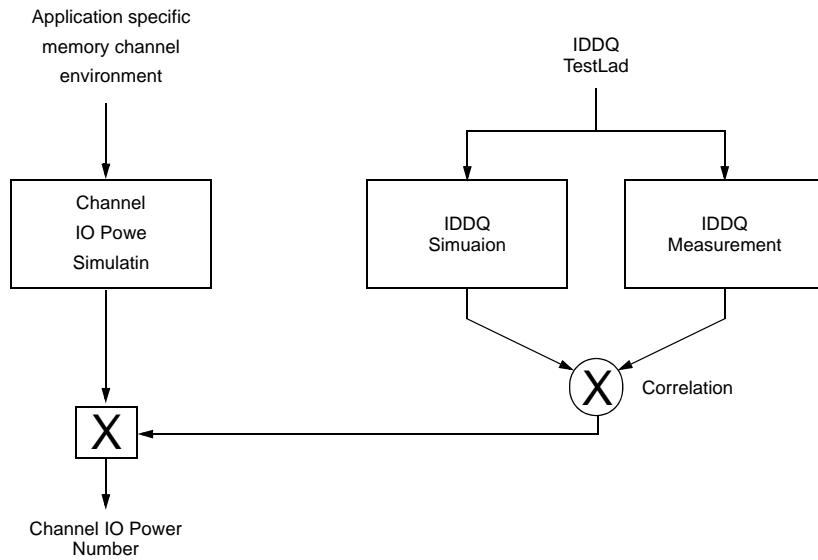


Figure 2 - Correlation from simulated Channel IO Power to actual Channel IO Power supported by IDDQ Measurement

**Table 1 -Timings used for IDD, IPP and IDDQ Measurement-Loop Patterns**

Symbol	DDR4-1600		DDR4-1866		DDR4-2133		DDR4-2400		Unit	
	11-11-11		13-13-13		15-15-15		17-17-17			
tCK	1.25		1.071		0.938		0.833		ns	
CL	11		13		15		17		nCK	
CWL	11		12		14		17		nCK	
nRCD	11		13		15		17		nCK	
nRC	39		45		51		56		nCK	
nRAS	28		32		36		39		nCK	
nRP	11		13		15		17		nCK	
nFAW	x4	16		16		16		16		nCK
	x8	20		22		23		26		nCK
	x16	28		28		32		36		nCK
nRRDS	x4	4		4		4		4		nCK
	x8	4		4		4		4		nCK
	x16	5		5		6		7		nCK
nRRDL	x4	5		5		6		6		nCK
	x8	5		5		6		6		nCK
	x16	6		6		7		8		nCK
tCCD_S	4		4		4		4		nCK	
tCCD_L	5		5		6		6		nCK	
tWTR_S	2		3		3		3		nCK	
tWTR_L	6		7		8		9		nCK	
nRFC 2Gb	128		150		171		193		nCK	
nRFC 4Gb	208		243		278		313		nCK	
nRFC 8Gb	280		327		374		421		nCK	
nRFC 16Gb	TBD		TBD		TBD		TBD		nCK	

**Table 2 -Basic IDD, IPP and IDDQ Measurement Conditions**

Symbol	Description
IDD0	<b>Operating One Bank Active-Precharge Current (AL=0)</b> CKE: High; External clock: On; tCK, nRC, nRAS, CL: see Table 1; BL: 8 <sup>1</sup> ; AL: 0; CS_n: High between ACT and PRE; Command, Address, Bank Group Address, Bank Address Inputs: partially toggling according to Table 3; Data IO: VDDQ; DM_n: stable at 1; Bank Activity: Cycling with one bank active at a time: 0,0,1,1,2,2,... (see Table 3); Output Buffer and RTT: Enabled in Mode Registers <sup>2</sup> ; ODT Signal: stable at 0; Pattern Details: see Table 3
IDD0A	<b>Operating One Bank Active-Precharge Current (AL=CL-1)</b> AL = CL-1, Other conditions: see IDD0
IPP0	<b>Operating One Bank Active-Precharge IPP Current</b> Same condition with IDD0
IDD1	<b>Operating One Bank Active-Read-Precharge Current (AL=0)</b> CKE: High; External clock: On; tCK, nRC, nRAS, nRCD, CL: see Table 1; BL: 8 <sup>1</sup> ; AL: 0; CS_n: High between ACT, RD and PRE; Command, Address, Bank Group Address, Bank Address Inputs, Data IO: partially toggling according to Table 4; DM_n: stable at 1; Bank Activity: Cycling with one bank active at a time: 0,0,1,1,2,2,... (see Table 4); Output Buffer and RTT: Enabled in Mode Registers <sup>2</sup> ; ODT Signal: stable at 0; Pattern Details: see Table 4
IDD1A	<b>Operating One Bank Active-Read-Precharge Current (AL=CL-1)</b> AL = CL-1, Other conditions: see IDD1
IPP1	<b>Operating One Bank Active-Read-Precharge IPP Current</b> Same condition with IDD1
IDD2N	<b>Precharge Standby Current (AL=0)</b> CKE: High; External clock: On; tCK, CL: see Table 1; BL: 8 <sup>1</sup> ; AL: 0; CS_n: stable at 1; Command, Address, Bank Group Address, Bank Address Inputs: partially toggling according to Table 5; Data IO: VDDQ; DM_n: stable at 1; Bank Activity: all banks closed; Output Buffer and RTT: Enabled in Mode Registers <sup>2</sup> ; ODT Signal: stable at 0; Pattern Details: see Table 5
IDD2NA	<b>Precharge Standby Current (AL=CL-1)</b> AL = CL-1, Other conditions: see IDD2N
IPP2N	<b>Precharge Standby IPP Current</b> Same condition with IDD2N
IDD2NT	<b>Precharge Standby ODT Current</b> CKE: High; External clock: On; tCK, CL: see Table 1; BL: 8 <sup>1</sup> ; AL: 0; CS_n: stable at 1; Command, Address, Bank Group Address, Bank Address Inputs: partially toggling according to Table 6; Data IO: VSSQ; DM_n: stable at 1; Bank Activity: all banks closed; Output Buffer and RTT: Enabled in Mode Registers <sup>2</sup> ; ODT Signal: toggling according to Table 6; Pattern Details: see Table 6
IDDQ2NT (Optional)	<b>Precharge Standby ODT IDDQ Current</b> Same definition like for IDD2NT, however measuring IDDQ current instead of IDD current
IDD2NL	<b>Precharge Standby Current with CAL enabled</b> Same definition like for IDD2N, CAL enabled <sup>3</sup>
IDD2NG	<b>Precharge Standby Current with Gear Down mode enabled</b> Same definition like for IDD2N, Gear Down mode enabled <sup>3</sup>
IDD2ND	<b>Precharge Standby Current with DLL disabled</b> Same definition like for IDD2N, DLL disabled <sup>3</sup>

IDD2N_par	<b>Precharge Standby Current with CA parity enabled</b> Same definition like for IDD2N, CA parity enabled <sup>3</sup>
IDD2P	<b>Precharge Power-Down Current CKE: Low; External clock: On; tCK, CL: see Table 1; BL: 8<sup>1</sup>; AL: 0; CS_n: stable at 1; Command, Address, Bank Group Address, Bank Address Inputs: stable at 0; Data IO: VDDQ; DM_n: stable at 1; Bank Activity: all banks closed; Output Buffer and RTT: Enabled in Mode Registers<sup>2</sup>; ODT Signal: stable at 0</b>
IPP2P	<b>Precharge Power-Down IPP Current</b> Same condition with IDD2P
IDD2Q	<b>Precharge Quiet Standby Current</b> CKE: High; External clock: On; tCK, CL: see Table 1; BL: 8 <sup>1</sup> ; AL: 0; CS_n: stable at 1; Command, Address, Bank Group Address, Bank Address Inputs: stable at 0; Data IO: VDDQ; DM_n: stable at 1; Bank Activity: all banks closed; Output Buffer and RTT: Enabled in Mode Registers <sup>2</sup> ; ODT Signal: stable at 0
IDD3N	<b>Active Standby Current</b> CKE: High; External clock: On; tCK, CL: see Table 1; BL: 8 <sup>1</sup> ; AL: 0; CS_n: stable at 1; Command, Address, Bank Group Address, Bank Address Inputs: partially toggling according to Table 5; Data IO: VDDQ; DM_n: stable at 1; Bank Activity: all banks open; Output Buffer and RTT: Enabled in Mode Registers <sup>2</sup> ; ODT Signal: stable at 0; Pattern Details: see Table 5
IDD3NA	<b>Active Standby Current (AL=CL-1)</b> AL = CL-1, Other conditions: see IDD3N
IPP3N	<b>Active Standby IPP Current</b> Same condition with IDD3N
IDD3P	<b>Active Power-Down Current</b> CKE: Low; External clock: On; tCK, CL: see Table 1; BL: 8 <sup>1</sup> ; AL: 0; CS_n: stable at 1; Command, Address, Bank Group Address, Bank Address Inputs: stable at 0; Data IO: VDDQ; DM_n: stable at 1; Bank Activity: all banks open; Output Buffer and RTT: Enabled in Mode Registers <sup>2</sup> ; ODT Signal: stable at 0
IPP3P	<b>Active Power-Down IPP Current</b> Same condition with IDD3P
IDD4R	<b>Operating Burst Read Current</b> CKE: High; External clock: On; tCK, CL: see Table 1; BL: 8 <sup>2</sup> ; AL: 0; CS_n: High between RD; Command, Address, Bank Group Address, Bank Address Inputs: partially toggling according to Table 7; Data IO: seamless read data burst with different data between one burst and the next one according to Table 7; DM_n: stable at 1; Bank Activity: all banks open, RD commands cycling through banks: 0,0,1,1,2,2,... (see Table 7); Output Buffer and RTT: Enabled in Mode Registers <sup>2</sup> ; ODT Signal: stable at 0; Pattern Details: see Table 7
IDD4RA	<b>Operating Burst Read Current (AL=CL-1)</b> AL = CL-1, Other conditions: see IDD4R
IDD4RB	<b>Operating Burst Read Current with Read DBI</b> Read DBI enabled <sup>3</sup> , Other conditions: see IDD4R
IPP4R	<b>Operating Burst Read IPP Current</b> Same condition with IDD4R
IDDQ4R (Optional)	<b>Operating Burst Read IDDQ Current</b> Same definition like for IDD4R, however measuring IDDQ current instead of IDD current
IDDQ4RB (Optional)	<b>Operating Burst Read IDDQ Current with Read DBI</b> Same definition like for IDD4RB, however measuring IDDQ current instead of IDD current

IDD4W	<b>Operating Burst Write Current</b> CKE: High; External clock: On; tCK, CL: see Table 1; BL: 8 <sup>1</sup> ; AL: 0; CS <sub>n</sub> : High between WR; <b>Command, Address, Bank Group Address, Bank Address Inputs</b> : partially toggling according to Table 8; <b>Data IO</b> : seamless write data burst with different data between one burst and the next one according to Table 8; <b>DM<sub>n</sub></b> : stable at 1; <b>Bank Activity</b> : all banks open, WR commands cycling through banks: 0,0,1,1,2,2,... (see Table 8); <b>Output Buffer and RTT</b> : Enabled in Mode Registers <sup>2</sup> ; <b>ODT Signal</b> : stable at HIGH; <b>Pattern Details</b> : see Table 8
IDD4WA	<b>Operating Burst Write Current (AL=CL-1)</b> AL = CL-1, Other conditions: see IDD4W
IDD4WB	<b>Operating Burst Write Current with Write DBI</b> Write DBI enabled <sup>3</sup> , Other conditions: see IDD4W
IDD4WC	<b>Operating Burst Write Current with Write CRC</b> Write CRC enabled <sup>3</sup> , Other conditions: see IDD4W
IDD4W <sub>par</sub>	<b>Operating Burst Write Current with CA Parity</b> CA Parity enabled <sup>3</sup> , Other conditions: see IDD4W
IPP4W	<b>Operating Burst Write IPP Current</b> Same condition with IDD4W
IDD5B	<b>Burst Refresh Current (1X REF)</b> CKE: High; External clock: On; tCK, CL, nRFC: see Table 1; BL: 8 <sup>1</sup> ; AL: 0; CS <sub>n</sub> : High between REF; <b>Command, Address, Bank Group Address, Bank Address Inputs</b> : partially toggling according to Table 9; <b>Data IO</b> : VDDQ; <b>DM<sub>n</sub></b> : stable at 1; <b>Bank Activity</b> : REF command every nRFC (see Table 9); <b>Output Buffer and RTT</b> : Enabled in Mode Registers <sup>2</sup> ; <b>ODT Signal</b> : stable at 0; <b>Pattern Details</b> : see Table 9
IPP5B	<b>Burst Refresh Write IPP Current (1X REF)</b> Same condition with IDD5B
IDD5F2	<b>Burst Refresh Current (2X REF)</b> tRFC=tRFC <sub>x2</sub> , Other conditions: see IDD5B
IPP5F2	<b>Burst Refresh Write IPP Current (2X REF)</b> Same condition with IDD5F2
IDD5F4	<b>Burst Refresh Current (4X REF)</b> tRFC=tRFC <sub>x4</sub> , Other conditions: see IDD5B
IPP5F4	<b>Burst Refresh Write IPP Current (4X REF)</b> Same condition with IDD5F4
IDD6N	<b>Self Refresh Current: Normal Temperature Range</b> T <sub>CASE</sub> : 0 - 85°C; <b>Low Power Array Self Refresh (LP ASR)</b> : Normal <sup>4</sup> ; CKE: Low; <b>External clock</b> : Off; CK <sub>t</sub> and CK <sub>c</sub> : LOW; CL: see Table 1; BL: 8 <sup>1</sup> ; AL: 0; CS <sub>n</sub> #, <b>Command, Address, Bank Group Address, Bank Address, Data IO</b> : High; <b>DM<sub>n</sub></b> : stable at 1; <b>Bank Activity</b> : Self-Refresh operation; <b>Output Buffer and RTT</b> : Enabled in Mode Registers <sup>2</sup> ; <b>ODT Signal</b> : MID-LEVEL
IPP6N	<b>Self Refresh IPP Current: Normal Temperature Range</b> Same condition with IDD6N
IDD6E	<b>Self-Refresh Current: Extended Temperature Range<sup>5)</sup></b> T <sub>CASE</sub> : 0 - 95°C; <b>Low Power Array Self Refresh (LP ASR)</b> : Extended <sup>4</sup> ; CKE: Low; <b>External clock</b> : Off; CK <sub>t</sub> and CK <sub>c</sub> : LOW; CL: see Table 1; BL: 8 <sup>1</sup> ; AL: 0; CS <sub>n</sub> , <b>Command, Address, Bank Group Address, Bank Address, Data IO</b> : High; <b>DM<sub>n</sub></b> : stable at 1; <b>Bank Activity</b> : Extended Temperature Self-Refresh operation; <b>Output Buffer and RTT</b> : Enabled in Mode Registers <sup>2</sup> ; <b>ODT Signal</b> : MID-LEVEL
IPP6E	<b>Self Refresh IPP Current: Extended Temperature Range</b> Same condition with IDD6E

IDD6R	<b>Self-Refresh Current: Reduced Temperature Range</b> $T_{CASE}$ : 0 - TBD (~35-45)°C; <b>Low Power Array Self Refresh (LP ASR)</b> : Reduced <sup>4</sup> ; <b>CKE</b> : Low; <b>External clock</b> : Off; <b>CK_t</b> and <b>CK_c#</b> : LOW; <b>CL</b> : see Table 1; <b>BL</b> : 8 <sup>1</sup> ; <b>AL</b> : 0; <b>CS_n#</b> , <b>Command</b> , <b>Address</b> , <b>Bank Group Address</b> , <b>Bank Address</b> , <b>Data IO</b> : High; <b>DM_n</b> :stable at 1; <b>Bank Activity</b> : Extended Temperature Self-Refresh operation; <b>Output Buffer and RTT</b> : Enabled in Mode Registers <sup>2</sup> ; <b>ODT Signal</b> : MID-LEVEL
IPP6R	<b>Self Refresh IPP Current: Reduced Temperature Range</b> <b>Same condition with IDD6R</b>
IDD6A	<b>Auto Self-Refresh Current</b> $T_{CASE}$ : 0 - 95°C; <b>Low Power Array Self Refresh (LP ASR)</b> : Auto <sup>4</sup> ; <b>CKE</b> : Low; <b>External clock</b> : Off; <b>CK_t</b> and <b>CK_c#</b> : LOW; <b>CL</b> : see Table 1; <b>BL</b> : 8 <sup>1</sup> ; <b>AL</b> : 0; <b>CS_n#</b> , <b>Command</b> , <b>Address</b> , <b>Bank Group Address</b> , <b>Bank Address</b> , <b>Data IO</b> : High; <b>DM_n</b> :stable at 1; <b>Bank Activity</b> : Auto Self-Refresh operation; <b>Output Buffer and RTT</b> : Enabled in Mode Registers <sup>2</sup> ; <b>ODT Signal</b> : MID-LEVEL
IPP6A	<b>Auto Self-Refresh IPP Current</b> <b>Same condition with IDD6A</b>
IDD7	<b>Operating Bank Interleave Read Current</b> <b>CKE</b> : High; <b>External clock</b> : On; <b>tCK</b> , <b>nRC</b> , <b>nRAS</b> , <b>nRCD</b> , <b>nRRD</b> , <b>nFAW</b> , <b>CL</b> : see Table 1; <b>BL</b> : 8 <sup>1</sup> ; <b>AL</b> : CL-1; <b>CS_n</b> : High between ACT and RDA; <b>Command</b> , <b>Address</b> , <b>Bank Group Address</b> , <b>Bank Address</b> <b>Inputs</b> : partially toggling according to Table 10; <b>Data IO</b> : read data bursts with different data between one burst and the next one according to Table 10; <b>DM_n</b> : stable at 1; <b>Bank Activity</b> : two times interleaved cycling through banks (0, 1, ...7) with different addressing, see Table 10; <b>Output Buffer and RTT</b> : Enabled in Mode Registers <sup>2</sup> ; <b>ODT Signal</b> : stable at 0; <b>Pattern Details</b> : see Table 10
IPP7	<b>Operating Bank Interleave Read IPP Current</b> <b>Same condition with IDD7</b>
IDD8	<b>Maximum Power Down Current</b> <b>TBD</b>
IPP8	<b>Maximum Power Down IPP Current</b> <b>Same condition with IDD8</b>

**NOTE :**

1. Burst Length: BL8 fixed by MRS: set MR0 [A1:0=00].
2. Output Buffer Enable
  - set MR1 [A12 = 0] : Qoff = Output buffer enabled
  - set MR1 [A2:1 = 00] : Output Driver Impedance Control = RZQ/7
  - RTT\_Nom enable
  - set MR1 [A10:8 = 011] : RTT\_NOM = RZQ/6
  - RTT\_WR enable
  - set MR2 [A10:9 = 01] : RTT\_WR = RZQ/2
  - RTT\_PARK disable
  - set MR5 [A8:6 = 000]
3. CAL enabled : set MR4 [A8:6 = 001] : 1600MT/s
  - 010] : 1866MT/s, 2133MT/s
  - 011] : 2400MT/s
  - Gear Down mode enabled :set MR3 [A3 = 1] : 1/4 Rate
  - DLL disabled : set MR1 [A0 = 0]
  - CA parity enabled :set MR5 [A2:0 = 001] : 1600MT/s,1866MT/s, 2133MT/s
  - 010] : 2400MT/s
  - Read DBI enabled : set MR5 [A12 = 1]
  - Write DBI enabled : set :MR5 [A11 = 1]
4. Low Power Array Self Refresh (LP ASR) : set MR2 [A7:6 = 00] : Normal
  - 01] : Reduced Temperature range
  - 10] : Extended Temperature range
  - 11] : Auto Self Refresh
5. IDD2NG should be measured after sync pulse(NOP) input.

**Table 3 - IDD0, IDD0A and IPP0 Measurement-Loop Pattern<sup>1</sup>**

CK_t /CK_c	CKE	Sub-Loop	Cycle Number	Command	CS_n	ACT_n	RAS_n/ A16	CAS_n/ A15	WE_n/ A14	ODT	C[2:0] <sup>3</sup>	BG[1:0] <sup>2</sup>	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data <sup>4</sup>			
toggling	Static High	0	0	ACT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-		
		1,2	D, D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	
		3,4	D_#, D_#	1	1	1	1	1	1	0	0	3 <sup>2</sup>	3	0	0	0	0	7	F	0	0	-	
		...	repeat pattern 1...4 until nRAS - 1, truncate if necessary																				
		nRAS	PRE	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
		...	repeat pattern 1...4 until nRC - 1, truncate if necessary																				
		1	1*nRC	repeat Sub-Loop 0, use $BG[1:0]^2 = 1$ , $BA[1:0] = 1$ instead																			
		2	2*nRC	repeat Sub-Loop 0, use $BG[1:0]^2 = 0$ , $BA[1:0] = 2$ instead																			
		3	3*nRC	repeat Sub-Loop 0, use $BG[1:0]^2 = 1$ , $BA[1:0] = 3$ instead																			
		4	4*nRC	repeat Sub-Loop 0, use $BG[1:0]^2 = 0$ , $BA[1:0] = 1$ instead																			
		5	5*nRC	repeat Sub-Loop 0, use $BG[1:0]^2 = 1$ , $BA[1:0] = 2$ instead																			
		6	6*nRC	repeat Sub-Loop 0, use $BG[1:0]^2 = 0$ , $BA[1:0] = 3$ instead																			
		7	7*nRC	repeat Sub-Loop 0, use $BG[1:0]^2 = 1$ , $BA[1:0] = 0$ instead																			
		8	8*nRC	repeat Sub-Loop 0, use $BG[1:0]^2 = 2$ , $BA[1:0] = 0$ instead																			
		9	9*nRC	repeat Sub-Loop 0, use $BG[1:0]^2 = 3$ , $BA[1:0] = 1$ instead																			
		10	10*nRC	repeat Sub-Loop 0, use $BG[1:0]^2 = 2$ , $BA[1:0] = 2$ instead																			
		11	11*nRC	repeat Sub-Loop 0, use $BG[1:0]^2 = 3$ , $BA[1:0] = 3$ instead																			
		12	12*nRC	repeat Sub-Loop 0, use $BG[1:0]^2 = 2$ , $BA[1:0] = 1$ instead																			
		13	13*nRC	repeat Sub-Loop 0, use $BG[1:0]^2 = 3$ , $BA[1:0] = 2$ instead																			
		14	14*nRC	repeat Sub-Loop 0, use $BG[1:0]^2 = 2$ , $BA[1:0] = 3$ instead																			
15	15*nRC	repeat Sub-Loop 0, use $BG[1:0]^2 = 3$ , $BA[1:0] = 0$ instead																					

**NOTE:**

- 1 .DQS\_t, DQS\_c are VDDQ.
2. BG1 is don't care for x16 device
3. C[2:0] are used only for 3DS device
4. DQ signals are VDDQ.



**Table 4 - IDD1 Measurement-Loop Pattern<sup>a)</sup>**

CK_t, CK_c	CKE	Sub-Loop	Cycle Number	Command	CS_n	ACT_n	RAS_n/A16	CAS_n/A15	WE_n/A14	ODT	C[2:0] <sup>3</sup>	BG[1:0] <sup>2</sup>	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data <sup>4</sup>			
toggling	Static High	0	0	ACT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-		
			1, 2	D, D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	
			3, 4	D#, D#	1	1	1	1	1	1	0	0	3 <sup>b</sup>	3	0	0	0	0	7	F	0	-	
			...	repeat pattern 1...4 until nRCD - AL - 1, truncate if necessary																			
			nRCD -AL	RD	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	D0=00, D1=FF D2=FF, D3=00 D4=FF, D5=00 D6=00, D7=FF
			...	repeat pattern 1...4 until nRAS - 1, truncate if necessary																			
			nRAS	PRE	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
			...	repeat pattern 1...4 until nRC - 1, truncate if necessary																			
			1	1*nRC + 0	ACT	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	-
			1*nRC + 1, 2	D, D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
		1*nRC + 3, 4	D#, D#	1	1	1	1	1	1	0	0	3 <sup>b</sup>	3	0	0	0	0	7	F	0	-		
		...	repeat pattern nRC + 1...4 until 1*nRC + nRAS - 1, truncate if necessary																				
		1*nRC + nRCD - AL	RD	0	1	1	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	D0=FF, D1=00 D2=00, D3=FF D4=00, D5=FF D6=FF, D7=00	
		...	repeat pattern 1...4 until nRAS - 1, truncate if necessary																				
		1*nRC + nRAS	PRE	0	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	-	
		...	repeat nRC + 1...4 until 2*nRC - 1, truncate if necessary																				
		2	2*nRC	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 0, BA[1:0] = 2 instead																			
		3	3*nRC	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 3 instead																			
		4	4*nRC	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 0, BA[1:0] = 1 instead																			
		5	5*nRC	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 2 instead																			
		6	6*nRC	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 0, BA[1:0] = 3 instead																			
		8	7*nRC	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 0 instead																			
		9	9*nRC	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 0 instead																			
		10	10*nRC	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 1 instead																			
11	11*nRC	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 2 instead																					
12	12*nRC	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 3 instead																					
13	13*nRC	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 1 instead																					
14	14*nRC	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 2 instead																					
15	15*nRC	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 3 instead																					
16	16*nRC	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 0 instead																					

**NOTE:**

1. DQS\_t, DQS\_c are used according to RD Commands, otherwise VDDQ
2. BG1 is don't care for x16 device
3. C[2:0] are used only for 3DS device
4. Burst Sequence driven on each DQ signal by Read Command. Outside burst operation, DQ signals are VDDQ.

**Table 5 - IDD2N, IDD2NA, IDD2NL, IDD2NG, IDD2ND, IDD2N\_par, IPP2, IDD3N, IDD3NA and IDD3P**

**Measurement-Loop Pattern<sup>1</sup>**

CK_t, CK_c	CKE	Sub-Loop	Cycle Number	Command	CS_n	ACT_n	RAS_n/A16	CAS_n/A15	WE_n/A14	ODT	C[2:0] <sup>3</sup>	BG[1:0] <sup>2</sup>	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data <sup>4</sup>		
toggling	Static High	0	0	D, D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
			1	D, D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			2	D#, D#	1	1	1	1	1	1	0	0	3 <sup>2</sup>	3	0	0	0	7	F	0	0	0
			3	D#, D#	1	1	1	1	1	1	0	0	3 <sup>2</sup>	3	0	0	0	7	F	0	0	0
		1	4-7	repeat Sub-Loop 0, use $BG[1:0]^2 = 1, BA[1:0] = 1$ instead																		
		2	8-11	repeat Sub-Loop 0, use $BG[1:0]^2 = 0, BA[1:0] = 2$ instead																		
		3	12-15	repeat Sub-Loop 0, use $BG[1:0]^2 = 1, BA[1:0] = 3$ instead																		
		4	16-19	repeat Sub-Loop 0, use $BG[1:0]^2 = 0, BA[1:0] = 1$ instead																		
		5	20-23	repeat Sub-Loop 0, use $BG[1:0]^2 = 1, BA[1:0] = 2$ instead																		
		6	24-27	repeat Sub-Loop 0, use $BG[1:0]^2 = 0, BA[1:0] = 3$ instead																		
		7	28-31	repeat Sub-Loop 0, use $BG[1:0]^2 = 1, BA[1:0] = 0$ instead																		
		8	32-35	repeat Sub-Loop 0, use $BG[1:0]^2 = 2, BA[1:0] = 0$ instead																		
		9	36-39	repeat Sub-Loop 0, use $BG[1:0]^2 = 3, BA[1:0] = 1$ instead																		
		10	40-43	repeat Sub-Loop 0, use $BG[1:0]^2 = 2, BA[1:0] = 2$ instead																		
		11	44-47	repeat Sub-Loop 0, use $BG[1:0]^2 = 3, BA[1:0] = 3$ instead																		
12	48-51	repeat Sub-Loop 0, use $BG[1:0]^2 = 2, BA[1:0] = 1$ instead																				
13	52-55	repeat Sub-Loop 0, use $BG[1:0]^2 = 3, BA[1:0] = 2$ instead																				
14	56-59	repeat Sub-Loop 0, use $BG[1:0]^2 = 2, BA[1:0] = 3$ instead																				
15	60-63	repeat Sub-Loop 0, use $BG[1:0]^2 = 3, BA[1:0] = 0$ instead																				

**NOTE :**

1. DQS\_t, DQS\_c are VDDQ.
2. BG1 is don't care for x16 device
3. C[2:0] are used only for 3DS device
4. DQ signals are VDDQ.

**Table 6 - IDD2NT and IDDQ2NT Measurement-Loop Pattern<sup>1</sup>**

CK_t, CK_c	CKE	Sub-Loop	Cycle Number	Command	CS_n	ACT_n	RAS_n/A16	CAS_n/A15	WE_n/A14	ODT	C[2:0] <sup>3</sup>	BG[1:0] <sup>2</sup>	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data <sup>4</sup>		
toggling	Static High	0	0	D, D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	
			1	D, D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
			2	D#, D#	1	1	1	1	1	1	0	0	3 <sup>2</sup>	3	0	0	0	7	F	0	0	-
			3	D#, D#	1	1	1	1	1	1	0	0	3 <sup>2</sup>	3	0	0	0	7	F	0	0	-
		1	4-7	repeat Sub-Loop 0, but ODT = 1 and $BG[1:0]^2 = 1$ , $BA[1:0] = 1$ instead																		
		2	8-11	repeat Sub-Loop 0, but ODT = 0 and $BG[1:0]^2 = 0$ , $BA[1:0] = 2$ instead																		
		3	12-15	repeat Sub-Loop 0, but ODT = 1 and $BG[1:0]^2 = 1$ , $BA[1:0] = 3$ instead																		
		4	16-19	repeat Sub-Loop 0, but ODT = 0 and $BG[1:0]^2 = 0$ , $BA[1:0] = 1$ instead																		
		5	20-23	repeat Sub-Loop 0, but ODT = 1 and $BG[1:0]^2 = 1$ , $BA[1:0] = 2$ instead																		
		6	24-27	repeat Sub-Loop 0, but ODT = 0 and $BG[1:0]^2 = 0$ , $BA[1:0] = 3$ instead																		
		7	28-31	repeat Sub-Loop 0, but ODT = 1 and $BG[1:0]^2 = 1$ , $BA[1:0] = 0$ instead																		
		8	32-35	repeat Sub-Loop 0, but ODT = 0 and $BG[1:0]^2 = 2$ , $BA[1:0] = 0$ instead																		
		9	36-39	repeat Sub-Loop 0, but ODT = 1 and $BG[1:0]^2 = 3$ , $BA[1:0] = 1$ instead																		
		10	40-43	repeat Sub-Loop 0, but ODT = 0 and $BG[1:0]^2 = 2$ , $BA[1:0] = 2$ instead																		
		11	44-47	repeat Sub-Loop 0, but ODT = 1 and $BG[1:0]^2 = 3$ , $BA[1:0] = 3$ instead																		
12	48-51	repeat Sub-Loop 0, but ODT = 0 and $BG[1:0]^2 = 2$ , $BA[1:0] = 1$ instead																				
13	52-55	repeat Sub-Loop 0, but ODT = 1 and $BG[1:0]^2 = 3$ , $BA[1:0] = 2$ instead																				
14	56-59	repeat Sub-Loop 0, but ODT = 0 and $BG[1:0]^2 = 2$ , $BA[1:0] = 3$ instead																				
15	60-63	repeat Sub-Loop 0, but ODT = 1 and $BG[1:0]^2 = 3$ , $BA[1:0] = 0$ instead																				

For x4 and x8 only

**NOTE :**

1. DQS\_t, DQS\_c are VDDQ.
2. BG1 is don't care for x16 device
3. C[2:0] are used only for 3DS device
4. DQ signals are VDDQ.

**Table 7 - IDD4R, IDDR4RA, IDD4RB and IDDO4R Measurement-Loop Pattern<sup>1</sup>**

CK_t, CK_c	CKE	Sub-Loop	Cycle Number	Command	CS_n	ACT_n	RAS_n/A16	CAS_n/A15	WE_n/A14	ODT	C[2:0] <sup>3</sup>	BG[1:0] <sup>2</sup>	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data <sup>4</sup>			
toggling	Static High	0	0	RD	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	D0=00, D1=FF D2=FF, D3=00 D4=FF, D5=00 D6=00, D7=FF		
			1	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	
			2,3	D#, D#	1	1	1	1	1	1	0	0	3 <sup>2</sup>	3	0	0	0	7	F	0	0	-	
		1	4	RD	0	1	1	0	1	0	0	0	1	1	0	0	0	7	F	0	0	D0=FF, D1=00 D2=00, D3=FF D4=00, D5=FF D6=FF, D7=00	
				5	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
				6,7	D#, D#	1	1	1	1	1	1	0	0	3 <sup>2</sup>	3	0	0	0	7	F	0	0	-
		2	8-11	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 0, BA[1:0] = 2 instead																			
		3	12-15	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 3 instead																			
		4	16-19	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 0, BA[1:0] = 1 instead																			
		5	20-23	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 2 instead																			
		6	24-27	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 0, BA[1:0] = 3 instead																			
		7	28-31	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 0 instead																			
		8	32-35	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 0 instead																			
		9	36-39	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 1 instead																			
		10	40-43	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 2 instead																			
		11	44-47	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 3 instead																			
12	48-51	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 1 instead																					
13	52-55	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 2 instead																					
14	56-59	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 3 instead																					
15	60-63	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 0 instead																					

**NOTE :**

1. DQS\_t, DQS\_c are used according to RD Commands, otherwise VDDQ.
2. BG1 is don't care for x16 device
3. C[2:0] are used only for 3DS device
4. Burst Sequence driven on each DQ signal by Read Command.

For x4 and x8 only

**Table 8 - IDD4W, IDD4WA, IDD4WB and IDD4W\_par Measurement-Loop Pattern<sup>1</sup>**

CK_t, CK_c	CKE	Sub-Loop	Cycle Number	Command	CS_n	ACT_n	RAS_n/A16	CAS_n/A15	WE_n/A14	ODT	C[2:0] <sup>3</sup>	BG[1:0] <sup>2</sup>	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data <sup>4</sup>	
toggling	Static High	0	0	WR	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	D0=00, D1=FF D2=FF, D3=00 D4=FF, D5=00 D6=00, D7=FF
			1	D	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	-
			2,3	D#, D#	1	1	1	1	1	1	0	3 <sup>2</sup>	3	0	0	0	7	F	0	-	
		1	4	WR	0	1	1	0	1	1	0	1	1	0	0	0	7	F	0	D0=FF, D1=00 D2=00, D3=FF D4=00, D5=FF D6=FF, D7=00	
				5	D	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	-
				6,7	D#, D#	1	1	1	1	1	1	0	3 <sup>2</sup>	3	0	0	0	7	F	0	-
		2	8-11	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 0, BA[1:0] = 2 instead																	
		3	12-15	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 3 instead																	
		4	16-19	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 0, BA[1:0] = 1 instead																	
		5	20-23	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 2 instead																	
		6	24-27	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 0, BA[1:0] = 3 instead																	
		7	28-31	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 0 instead																	
		8	32-35	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 0 instead																	
		9	36-39	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 1 instead																	
		10	40-43	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 2 instead																	
11	44-47	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 3 instead																			
12	48-51	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 1 instead																			
13	52-55	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 2 instead																			
14	56-59	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 3 instead																			
15	60-63	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 0 instead																			

**NOTE :**

1. DQS\_t, DQS\_c are used according to WR Commands, otherwise VDDQ.
2. BG1 is don't care for x16 device
3. C[2:0] are used only for 3DS device
4. Burst Sequence driven on each DQ signal by Write Command.

**Table 9 - IDD4WC Measurement-Loop Pattern<sup>1</sup>**

CK_t, CK_c	CKE	Sub-Loop	Cycle Number	Command	CS_n	ACT_n	RAS_n/A16	CAS_n/A15	WE_n/A14	ODT	C[2:0] <sup>c</sup>	BG[1:0] <sup>b</sup>	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data <sup>d</sup>		
toggling	Static High	0	0	WR	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	D0=00, D1=FF D2=FF, D3=00 D4=FF, D5=00 D6=00, D7=FF D8=CRC	
		1,2	D, D	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	-	
		3,4	D#, D#	1	1	1	1	1	1	1	0	3 <sup>2</sup>	3	0	0	0	0	7	F	0	-	
		5	WR	0	1	1	0	1	1	1	0	1	1	0	0	0	0	7	F	0	D0=FF, D1=00 D2=00, D3=FF D4=00, D5=FF D6=FF, D7=00 D8=CRC	
		6,7	D, D	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	-	
		8,9	D#, D#	1	1	1	1	1	1	1	0	3 <sup>2</sup>	3	0	0	0	0	7	F	0	-	
		2	10-14	repeat Sub-Loop 0, use $BG[1:0]^2 = 0$ , $BA[1:0] = 2$ instead																		
		3	15-19	repeat Sub-Loop 1, use $BG[1:0]^2 = 1$ , $BA[1:0] = 3$ instead																		
		4	20-24	repeat Sub-Loop 0, use $BG[1:0]^2 = 0$ , $BA[1:0] = 1$ instead																		
		5	25-29	repeat Sub-Loop 1, use $BG[1:0]^2 = 1$ , $BA[1:0] = 2$ instead																		
		6	30-34	repeat Sub-Loop 0, use $BG[1:0]^2 = 0$ , $BA[1:0] = 3$ instead																		
		7	35-39	repeat Sub-Loop 1, use $BG[1:0]^2 = 1$ , $BA[1:0] = 0$ instead																		
		8	40-44	repeat Sub-Loop 0, use $BG[1:0]^2 = 2$ , $BA[1:0] = 0$ instead																		
		9	45-49	repeat Sub-Loop 1, use $BG[1:0]^2 = 3$ , $BA[1:0] = 1$ instead																		
		10	50-54	repeat Sub-Loop 0, use $BG[1:0]^2 = 2$ , $BA[1:0] = 2$ instead																		
		11	55-59	repeat Sub-Loop 1, use $BG[1:0]^2 = 3$ , $BA[1:0] = 3$ instead																		
12	60-64	repeat Sub-Loop 0, use $BG[1:0]^2 = 2$ , $BA[1:0] = 1$ instead																				
13	65-69	repeat Sub-Loop 1, use $BG[1:0]^2 = 3$ , $BA[1:0] = 2$ instead																				
14	70-74	repeat Sub-Loop 0, use $BG[1:0]^2 = 2$ , $BA[1:0] = 3$ instead																				
15	75-79	repeat Sub-Loop 1, use $BG[1:0]^2 = 3$ , $BA[1:0] = 0$ instead																				

**NOTE :**

1. DQS\_t, DQS\_c are VDDQ.
2. BG1 is don't care for x16 device.
3. C[2:0] are used only for 3DS device.
4. Burst Sequence driven on each DQ signal by Write Command.

**Table 10 - IDD5B Measurement-Loop Pattern<sup>1</sup>**

CK_t, CK_c	CKE	Sub-Loop	Cycle Number	Command	CS_n	ACT_n	RAS_n/A16	CAS_n/A15	WE_n/A14	ODT	C[2:0] <sup>3</sup>	BG[1:0] <sup>2</sup>	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data <sup>4</sup>			
toggling	Static High	0	0	REF	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-		
		1	1	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	
			2	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
			3	D#, D#	1	1	1	1	1	1	0	0	3 <sup>2</sup>	3	0	0	0	0	7	F	0	0	-
			4	D#, D#	1	1	1	1	1	1	0	0	3 <sup>2</sup>	3	0	0	0	0	7	F	0	0	-
			4-7	repeat pattern 1...4, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 1 instead																			
			8-11	repeat pattern 1...4, use BG[1:0] <sup>2</sup> = 0, BA[1:0] = 2 instead																			
			12-15	repeat pattern 1...4, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 3 instead																			
			16-19	repeat pattern 1...4, use BG[1:0] <sup>2</sup> = 0, BA[1:0] = 1 instead																			
			20-23	repeat pattern 1...4, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 2 instead																			
			24-27	repeat pattern 1...4, use BG[1:0] <sup>2</sup> = 0, BA[1:0] = 3 instead																			
			28-31	repeat pattern 1...4, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 0 instead																			
			32-35	repeat pattern 1...4, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 0 instead																			
			36-39	repeat pattern 1...4, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 1 instead																			
			40-43	repeat pattern 1...4, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 2 instead																			
			44-47	repeat pattern 1...4, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 3 instead																			
			48-51	repeat pattern 1...4, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 1 instead																			
			52-55	repeat pattern 1...4, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 2 instead																			
			56-59	repeat pattern 1...4, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 3 instead																			
			60-63	repeat pattern 1...4, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 0 instead																			
			2	64 ... nRFC - 1	repeat Sub-Loop 1, Truncate, if necessary																		

**NOTE :**

1. DQS\_t, DQS\_c are VDDQ.
2. BG1 is don't care for x16 device.
3. C[2:0] are used only for 3DS device.
4. DQ signals are VDDQ.

**Table 11 - IDD7 Measurement-Loop Pattern<sup>1</sup>**

CK_t, CK_c	CKE	Sub-Loop	Cycle Number	Command	CS_n	ACT_n	RAS_n/A16	CAS_n/A15	WE_n/A14	ODT	C[2:0] <sup>3</sup>	BG[1:0] <sup>2</sup>	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data <sup>4</sup>			
toggling	Static High	0	0	ACT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-			
		1	1	RDA	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0	D0=00, D1=FF D2=FF, D3=00 D4=FF, D5=00 D6=00, D7=FF		
			2	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	
			3	D#	1	1	1	1	1	1	0	0	3 <sup>2</sup>	3	0	0	0	7	F	0	0	-	
			...	repeat pattern 2...3 until nRRD - 1, if nRRD > 4. Truncate if necessary																			
			1	nRRD	ACT	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	-
			nRRD + 1	RDA	0	1	1	0	1	0	0	0	1	1	0	0	1	0	0	0	0	0	D0=FF, D1=00 D2=00, D3=FF D4=00, D5=FF D6=FF, D7=00
			...	repeat pattern 2 ... 3 until 2*nRRD - 1, if nRRD > 4. Truncate if necessary																			
			2	2*nRRD	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 0, BA[1:0] = 2 instead																		
			3	3*nRRD	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 3 instead																		
			4	4*nRRD	repeat pattern 2 ... 3 until nFAW - 1, if nFAW > 4*nRRD. Truncate if necessary																		
			5	nFAW	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 0, BA[1:0] = 1 instead																		
			6	nFAW + nRRD	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 2 instead																		
			7	nFAW + 2*nRRD	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 0, BA[1:0] = 3 instead																		
			8	nFAW + 3*nRRD	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 1, BA[1:0] = 0 instead																		
			9	nFAW + 4*nRRD	repeat Sub-Loop 4																		
			10	2*nFAW	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 0 instead																		
			11	2*nFAW + nRRD	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 1 instead																		
			12	2*nFAW + 2*nRRD	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 2 instead																		
			13	2*nFAW + 3*nRRD	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 3 instead																		
	14	2*nFAW + 4*nRRD	repeat Sub-Loop 4																				
	15	3*nFAW	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 1 instead																				
	16	3*nFAW + nRRD	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 2 instead																				
	17	3*nFAW + 2*nRRD	repeat Sub-Loop 0, use BG[1:0] <sup>2</sup> = 2, BA[1:0] = 3 instead																				
	18	3*nFAW + 3*nRRD	repeat Sub-Loop 1, use BG[1:0] <sup>2</sup> = 3, BA[1:0] = 0 instead																				
	19	3*nFAW + 4*nRRD	repeat Sub-Loop 4																				
	20	4*nFAW	repeat pattern 2 ... 3 until nRC - 1, if nRC > 4*nFAW. Truncate if necessary																				

**NOTE :**

1. DQS\_t, DQS\_c are VDDQ.
2. BG1 is don't care for x16 device.
3. C[2:0] are used only for 3DS device.
4. Burst Sequence driven on each DQ signal by Read Command. Outside burst operation, DQ signals are VDDQ



## IDD Specifications

Module IDD values in the datasheet are only a calculation based on the component IDD spec and register power. The actual measurements may vary according to DQ loading cap.

### 4GB, 512M x 72 R-DIMM: HMA451R7MFR8N

Symbol	2133		unit	note
	IDD	IPP		
IDD0	720	47	mA	
IDD0A	720	47	mA	
IDD1	867	43	mA	
IDD1A	867	43	mA	
IDD2N	562	5	mA	
IDD2NA	521	7	mA	
IDD2NT	591	5	mA	
IDD2NL	522	7	mA	
IDD2NG	562	5	mA	
IDD2ND	547	7	mA	
IDD2NP	562	5	mA	
IDD2P	351	7	mA	
IDD2Q	562	7	mA	
IDD3N	680	47	mA	
IDD3NA	740	47	mA	
IDD3P	440	49	mA	
IDD4R	1283	47	mA	
IDD4RA	1303	47	mA	
IDD4RB	1293	47	mA	
IDD4W	1323	47	mA	
IDD4WA	1313	47	mA	
IDD4WB	1263	47	mA	
IDD4WC	1224	47	mA	
IDD4WP	1402	47	mA	
IDD5B	1601	391	mA	
IDD5F2	1413	313	mA	
IDD5F4	1235	238	mA	
IDD6N	115	14	mA	
IDD6E	144	20	mA	
IDD6R	75	13	mA	
IDD6A	154	128	mA	
IDD7	1828	203	mA	
IDD8	55	5	mA	

## 8GB, 1G x 72 R-DIMM: HMA41GR7MFR8N

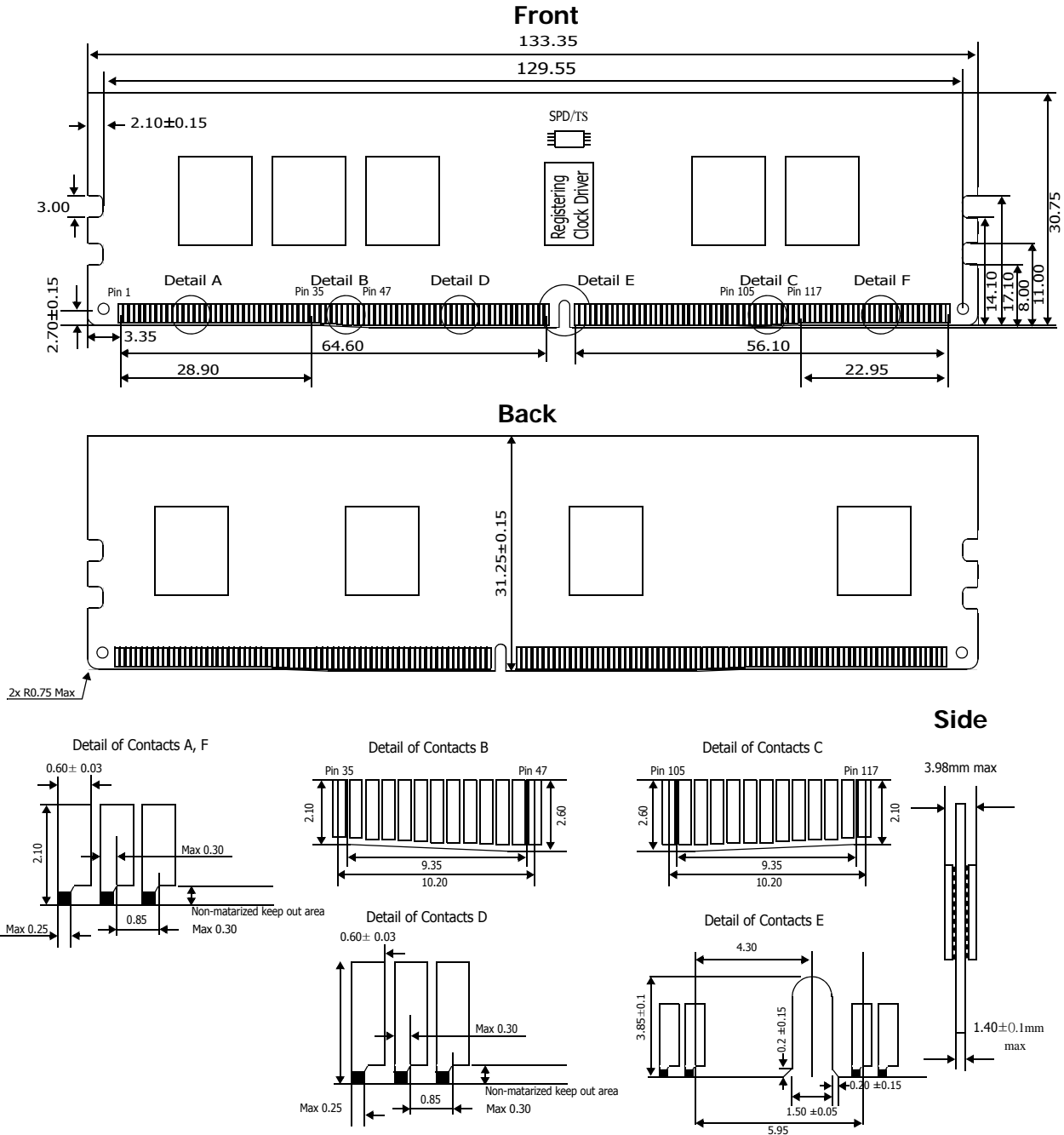
Symbol	2133		unit	note
	IDD	IPP		
IDD0	869	52	mA	
IDD0A	928	54	mA	
IDD1	1016	49	mA	
IDD1A	1075	50	mA	
IDD2N	710	11	mA	
IDD2NA	829	14	mA	
IDD2NT	770	11	mA	
IDD2NL	631	14	mA	
IDD2NG	710	11	mA	
IDD2ND	718	14	mA	
IDD2NP	710	11	mA	
IDD2P	460	14	mA	
IDD2Q	710	14	mA	
IDD3N	948	94	mA	
IDD3NA	1067	94	mA	
IDD3P	638	97	mA	
IDD4R	1432	52	mA	
IDD4RA	1511	54	mA	
IDD4RB	1442	52	mA	
IDD4W	1471	52	mA	
IDD4WA	1521	54	mA	
IDD4WB	1412	52	mA	
IDD4WC	1372	52	mA	
IDD4WP	1551	52	mA	
IDD5B	1750	396	mA	
IDD5F2	1562	319	mA	
IDD5F4	1383	243	mA	
IDD6N	224	29	mA	
IDD6E	283	40	mA	
IDD6R	144	25	mA	
IDD6A	303	256	mA	
IDD7	1976	209	mA	
IDD8	105	11	mA	

## 8GB, 1G x 72 R-DIMM: HMA41GR7MFR4N

Symbol	2133		unit	note
	IDD	IPP		
IDD0	968	52	mA	
IDD0A	987	54	mA	
IDD1	1174	49	mA	
IDD1A	1174	50	mA	
IDD2N	710	11	mA	
IDD2NA	809	14	mA	
IDD2NT	770	11	mA	
IDD2NL	631	14	mA	
IDD2NG	562	11	mA	
IDD2ND	718	14	mA	
IDD2NP	710	11	mA	
IDD2P	460	14	mA	
IDD2Q	710	14	mA	
IDD3N	948	94	mA	
IDD3NA	1067	94	mA	
IDD3P	638	97	mA	
IDD4R	2105	52	mA	
IDD4RA	2145	54	mA	
IDD4RB	2125	52	mA	
IDD4W	2184	52	mA	
IDD4WA	2165	54	mA	
IDD4WB	2065	52	mA	
IDD4WC	1986	52	mA	
IDD4WP	2343	52	mA	
IDD5B	2789	396	mA	
IDD5F2	2413	319	mA	
IDD5F4	2057	243	mA	
IDD6N	224	29	mA	
IDD6E	283	40	mA	
IDD6R	144	25	mA	
IDD6A	303	256	mA	
IDD7	2659	209	mA	
IDD8	105	11	mA	

# Module Dimensions

## 512Mx72 - HMA451R7MFR8N

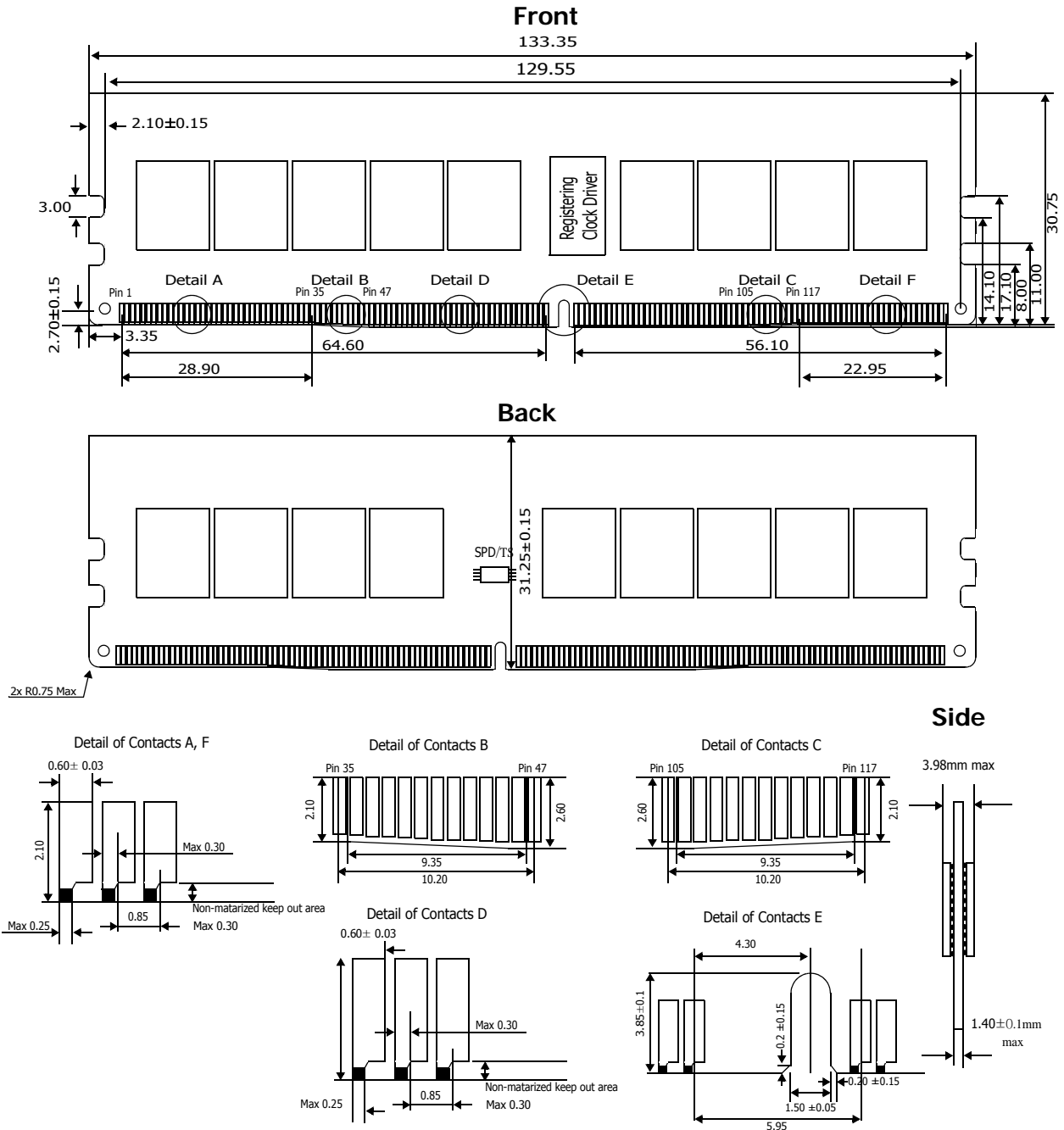


**Note:**

1. ±0.13 tolerance on all dimensions unless otherwise stated.

Units: millimeters

# 1Gx72 - HMA41GR7MFR8N

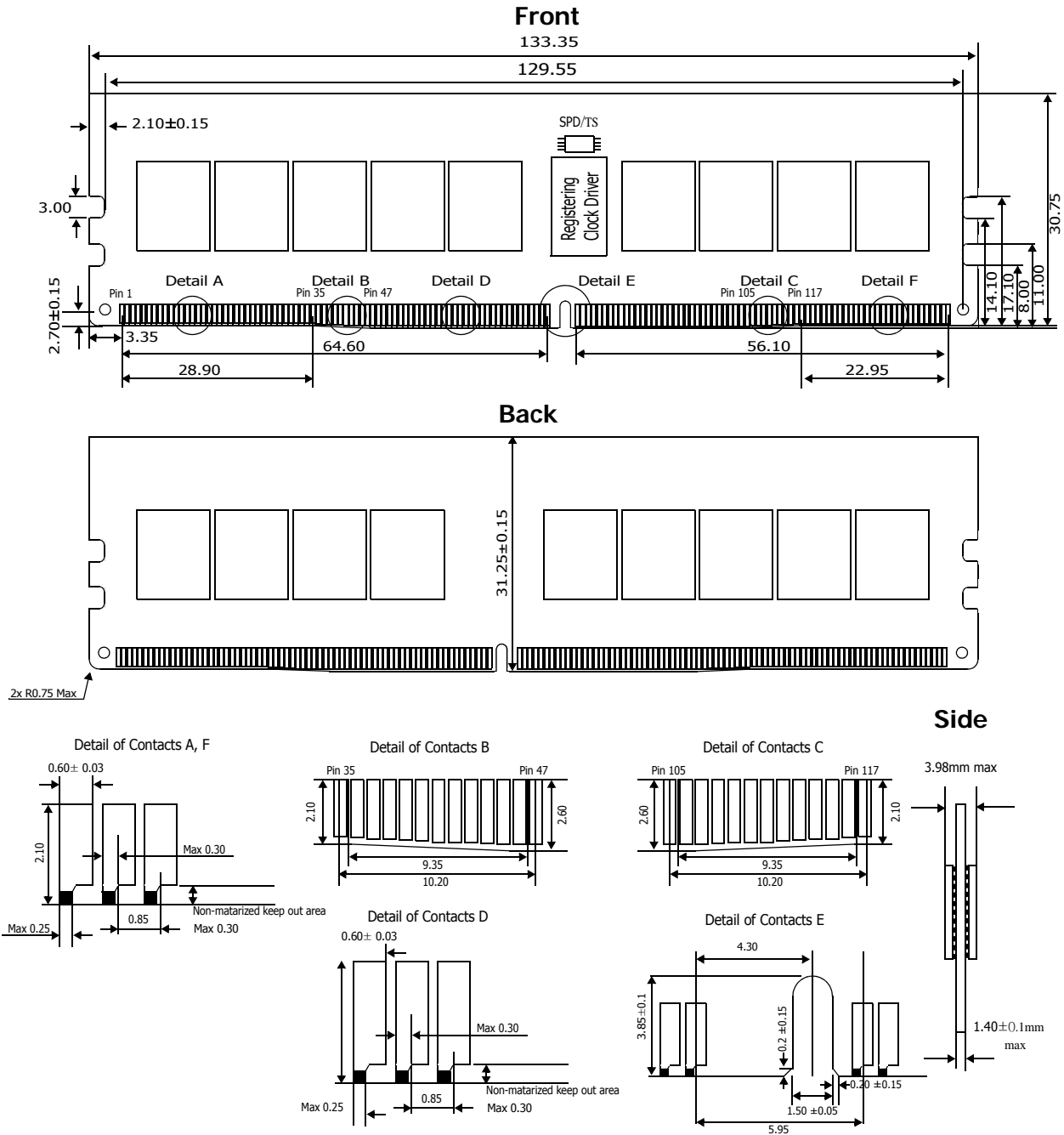


**Note:**

1. ±0.13 tolerance on all dimensions unless otherwise stated.

Units: millimeters

# 1Gx72 - HMA41GR7MFR4N



**Note:**

1. ±0.13 tolerance on all dimensions unless otherwise stated.

Units: millimeters

