

DDR4 SDRAM SO-DIMM

Based on 4Gb A-die

HMA425S6AFR6N

HMA451S6AFR8N

HMA451S7AFR8N

HMA41GS6AFR8N

HMA41GS7AFR8N

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

Revision History

Revision No.	History	Draft Date	Remark
0.1	Initial Release	Dec.2014	
0.2	Changed development plan	Jan.2015	
0.21	Module dimension Update (Detail-A : 0.125->1.125)	Feb.2015	
1.0	IDD Specification update Changed maximum VDDSPD from 2.75V to 3.6	May.2015	
1.1	Revised CWL value	Jun.2015	
1.2	Corrected Pin Assignments	Jul.2015	
1.3	Added development plan (1Rx16)	Aug.2015	
1.4	Changed Module Dimension	Oct.2015	
1.5	Updated JEDEC Specification Deleted Speed Grade Table	Dec.2015	
1.6	Updated IDD Specification(1Rx16)	Dec.2015	
1.7	Updated 2133Mbps (tCK(min) : 0.938ns->0.937ns) Updated JEDEC Specification	Mar.2016	

Description

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

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 3.6V
- 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: PC4-2400, 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

Ordering Information

Part Number	Density	Organization	Component Composition	# of ranks
HMA425S6AFR6N-TF/UH	2GB	256Mx64	256Mx16(H5AN4G6NAFR)*4	1
HMA451S6AFR8N-TF/UH	4GB	512Mx64	512Mx8(H5AN4G8NAFR)*8	1
HMA451S7AFR8N-TF/UH	4GB	512Mx72	512Mx8(H5AN4G8NAFR)*9	1
HMA41GS6AFR8N-TF/UH	8GB	1Gx64	512Mx8(H5AN4G8NAFR)*16	2
HMA41GS7AFR8N-TF/UH	8GB	1Gx72	512Mx8(H5AN4G8NAFR)*18	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	0.937	15	14.06 (13.50)*	14.06 (13.50)*	33	47.06 (46.50)*	15-15-15
DDR4-2400	-UH	0.833	17	14.16 (13.75)*	14.16 (13.75)*	32	46.16 (45.75)*	17-17-17

*SK hynix DRAM devices support optional downbinning to CL15, CL13 and CL11. SPD setting is programmed to match.

Address Table

		2GB(1Rx16)	4GB(1Rx8)	8GB(2Rx8)	4GB(1Rx8)	8GB(2Rx8)
Bank Address	# of Bank Groups	4	4	4	4	4
	BG Address	BG0	BG0~BG1	BG0~BG1	BG0~BG1	BG0~BG1
	Bank Address in a BG	BA0~BA1	BA0~BA1	BA0~BA1	BA0~BA1	BA0~BA1
Row Address		A0~A14	A0~A14	A0~A14	A0~A14	A0~A14
Column Address		A0~ A9	A0~ A9	A0~ A9	A0~ A9	A0~ A9
Page size		2 KB	1 KB	1 KB	1 KB	1 KB

Pin Descriptions

Pin Name	Description	Pin Name	Description
A0-A16	SDRAM address bus	SCL	I ² C serial bus clock for SPD/TS
BA0, BA1	SDRAM bank select	SDA	I ² C serial bus data line for SPD/TS
BG0, BG1	SDRAM bank group select	SA0-SA2	I ² C slave address select for SPD/TS
RAS _n ¹	SDRAM row address strobe	PARITY	SDRAM parity input
CAS _n ²	SDRAM column address strobe	VDD	SDRAM I/O & core power supply
WE _n ³	SDRAM write enable	VPP	SDRAM activating power supply
CS0 _n , CS1 _n , CS2 _n , CS3 _n	Rank Select Lines	C0, C1	Chip ID lines for 3DS components
CKE0, CEK1	SDRAM clock enable lines	VREFCA	SDRAM command/address reference supply
ODT0, ODT1	SDRAM on-die termination control lines	VSS	Power supply return (ground)
ACT _n	SDRAM activate	VDDSPD	Serial SPD/TS positive power supply
DQ0-DQ63	DIMM memory data bus	ALERT _n	SDRAM ALERT _n
CB0-CB7	DIMM ECC check bits		
DQS0 _t -DQS8 _t	SDRAM data strobes (positive line of differential pair)	RESET _n	Set SDRAMs to a Known State
DQS0 _c -DQS8 _c	SDRAM data strobes (negative line of differential pair)	EVENT _n	SPD signals a thermal event has occurred
DM0 _n -DM8 _n , DBI0 _n -DBI8 _n	SDRAM data masks/data bus inversion (x8-based x72 DIMMs)	VTT	Termination supply for the Address, Command and Control bus
CK0 _t , CK1 _t	SDRAM clocks (positive line of differential pair)	NC	No connection
CK0 _c , CK1 _c	SDRAM clocks (negative line of differential pair)		

1. RAS_n is a multiplexed function with A16.
2. CAS_n is a multiplexed function with A15.
3. 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, CKE1	Input	Clock Enable: CKE HIGH activates and CKE LOW deactivates internal clock signals and device input buffers and output drivers. Taking CKE LOW provides Precharge Power-Down and Self-Refresh operation (all banks idle), or Active Power-Down (row Active in any bank). CKE is 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 on systems with multiple Ranks. CS_n is considered part of the command code.
C0, C1	Input	Chip ID: Chip ID is only used for 3DS for 2 and 4 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 and DM_n/DBI_n, signal. The ODT pin will be ignored if MR1 is programmed to disable RTT_NOM.
ACT_n	Input	Activation Command Input: ACT_n defines the Activation command being entered along with CS_n. The input into RAS_n/A16, CAS_n/A15 and WE_n/A14 will be considered as Row Address A16, A15, and A14.
RAS_n/A16, CAS_n/A15, WE_n/A14	Input	Command Inputs: RAS_n/A16, CAS_n/A15 and WE_n/A14 (along with CS_n) define the command being entered. Those pins have multi function. For example, for activation with ACT_n Low, 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 command defined in command truth table.
DM_n/DBI_n	Input/ Output	Input Data Mask and Data Bus Inversion: DM_n is an input mask signal for write data. Input data is masked when DM_n is sampled LOW coincident with that input data during a Write access. DM_n is sampled on both edges of DQS. DM is muxed with DBI function. DBI_n is an input/output identifying whether to store/output the true or inverted data. If DBI_n is LOW, the data will be stored/output after inversion inside the DDR4 SDRAM and not inverted if DBI_n is HIGH.
BG0-BG1	Input	Bank Group Inputs: BG0 - BG1 define 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. For x4/8 based SDRAMs, BG0 and BG1 are valid. For x16 based SDRAM components, only BG0 is valid.
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.

Symbol	Type	Function
A0 - A16	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.
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.
DQS_t, DQS_c,	Input/ Output	Data Strobe: output with read data, input with write data. Edge-aligned with read data, centered in write data. DDR4 SDRAMs support differential data strobe only and does not support single-ended.
PARITY	Input	Command and Address Parity Input : DDR4 Supports Even Parity check in DRAMs with MR setting. Once it's enabled via Register in MR5, then DSRAM calculates Parity with ACT_n, RAS_n/A16, CAS_n/A15, WE_n/A14, BG0-BG1, BA0-BA1, A16-A0. Input parity should be maintained at the rising edge of the clock and at the same time with command & address with CS_n LOW.
ALERT_n	Output	ALERT: It has multiple functions, such as CRC error flag or Command and Address Parity error flag, as an Output signal. If there is an error in CRC, then ALERT_n goes LOW for the period time interval and goes back HIGH. If there is an error in Command Address Parity Check, then ALERT_n goes LOW for relatively long period until on going DRAM internal recovery transaction is complete. During Connectivity Test mode, this pin functions as an input. Use of this signal or not is dependent on the system.
SA0-SA1	Input	Device address for the SPD.
RFU		Reserved for Future Use. No on DIMM electrical connection is present.
NC		No Connect: No on DIMM electrical connection is present.
VDD ¹	Supply	Power Supply: 1.2 V +/- 0.06 V
VSS	Supply	Ground
VTT ²	Supply	Power Supply : 0.6V

Symbol	Type	Function
VPP	Supply	DRAM Activating Power Supply: 2.5V (2.375V min , 2.75V max)
VREFCA	Supply	Reference voltage for CA
VDDSPD	Supply	Power supply used to power the I2C bus on the SPD.

Note:

1. For PC4, VDD 1.2V. For PC4L VDD is TBD.
2. For PC4, VTT is 0.6V. For PC4L VTT is TBD.

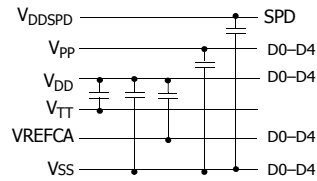
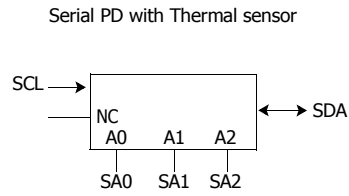
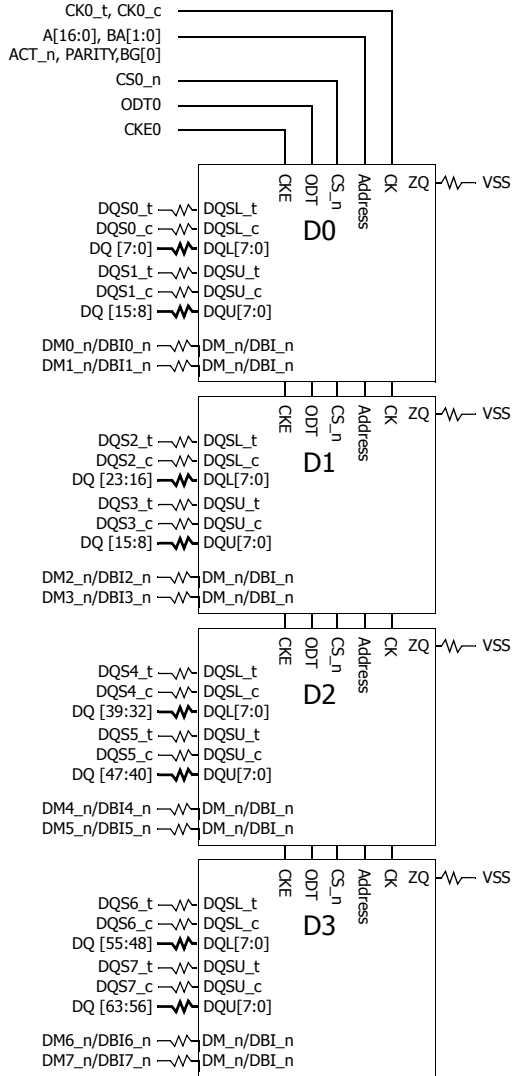
Pin Assignments

Pin	Front Side Pin Label	Pin	Back Side Pin Label	Pin	Front Side Pin Label	Pin	Back Side Pin Label
1	VSS	2	VSS	131	A3	132	A2
3	DQ5	4	DQ4	133	A1	134	EVENT_n
5	VSS	6	VSS	135	VDD	136	VDD
7	DQ1	8	DQ0	137	CK0_t	138	CK1_t
9	VSS	10	VSS	139	CK0_c	140	CK1_c
11	DQS0_c	12	DM0_n, DBI0_n	141	VDD	142	VDD
13	DQS0_t	14	VSS	143	PARITY	144	A0
15	VSS	16	DQ6	KEY			
17	DQ7	18	VSS				
19	VSS	20	DQ2	145	BA1	146	A10/AP
21	DQ3	22	VSS	147	VDD	148	VDD
23	VSS	24	DQ12	149	CS0_n	150	BA0
25	DQ13	26	VSS	151	A14/WE_n	152	A16/RAS_n
27	VSS	28	DQ8	153	VDD	154	VDD
29	DQ9	30	VSS	155	ODT0	156	A15/CAS_n
31	VSS	32	DQS1_c	157	CS1_n	158	A13
33	DM1_n, DBI1_n	34	DQS1_t	159	VDD	160	VDD
35	VSS	36	VSS	161	ODT1	162	C0, CS2_n, NC
37	DQ15	38	DQ14	163	VDD	164	VREFCA
39	VSS	40	VSS	165	C1, CS3_n, NC	166	SA2
41	DQ10	42	DQ11	167	VSS	168	VSS
43	VSS	44	VSS	169	DQ37	170	DQ36
45	DQ21	46	DQ20	171	VSS	172	VSS
47	VSS	48	VSS	173	DQ33	174	DQ32
49	DQ17	50	DQ16	175	VSS	176	VSS
51	VSS	52	VSS	177	DQS4_c	178	DM4_n, DBI4_n
53	DQS2_c	54	DM2_n, DBI2_n	179	DQS4_t	180	VSS
55	DQS2_t	56	VSS	181	VSS	182	DQ39
57	VSS	58	DQ22	183	DQ38	184	VSS
59	DQ23	60	VSS	185	VSS	186	DQ35
61	VSS	62	DQ18	187	DQ34	188	VSS
63	DQ19	64	VSS	189	VSS	190	DQ45
65	VSS	66	DQ28	191	DQ44	192	VSS
67	DQ29	68	VSS	193	VSS	194	DQ41
69	VSS	70	DQ24	195	DQ40	196	VSS
71	DQ25	72	VSS	197	VSS	198	DQS5_c
73	VSS	74	DQS3_c	199	DM5_n, DBI5_n	200	DQS5_t
75	DM3_n, DBI3_n	76	DQS3_t	201	VSS	202	VSS

Pin	Front Side Pin Label	Pin	Back Side Pin Label	Pin	Front Side Pin Label	Pin	Back Side Pin Label
77	VSS	78	VSS	203	DQ46	204	DQ47
79	DQ30	80	DQ31	205	VSS	206	VSS
81	VSS	82	VSS	207	DQ42	208	DQ43
83	DQ26	84	DQ27	209	VSS	210	VSS
85	VSS	86	VSS	211	DQ52	212	DQ53
87	CB5, NC	88	CB4, NC	213	VSS	214	VSS
89	VSS	90	VSS	215	DQ49	216	DQ48
91	CB1, NC	92	CB0, NC	217	VSS	218	VSS
93	VSS	94	VSS	219	DQS6_c	220	DM6_n, DBI6_n
95	DQS8_c	96	DM8_n, DBI8_n	221	DQS6_t	222	VSS
97	DQS8_t	98	VSS	223	VSS	224	DQ54
99	VSS	100	CB6, NC	225	DQ55	226	VSS
101	CB2, NC	102	VSS	227	VSS	228	DQ50
103	VSS	104	CB7, NC	229	DQ51	230	VSS
105	CB3, NC	106	VSS	231	VSS	232	DQ60
107	VSS	108	RESET_n	233	DQ61	234	VSS
109	CKE0	110	CKE1	235	VSS	236	DQ57
111	VDD	112	VDD	237	DQ56	238	VSS
113	BG1	114	ACT_n	239	VSS	240	DQS7_c
115	BG0	116	ALERT_n	241	DM7_n, DBI7_n	242	DQS7_t
117	VDD	118	VDD	243	VSS	244	VSS
119	A12	120	A11	245	DQ62	246	DQ63
121	A9	122	A7	247	VSS	248	VSS
123	VDD	124	VDD	249	DQ58	250	DQ59
125	A8	126	A5	251	VSS	252	VSS
127	A6	128	A4	253	SCL	254	SDA
129	VDD	130	VDD	255	VDDSPD	256	SA0
				257	VPP	258	VTT
				259	VPP	260	SA1

Functional Block Diagram

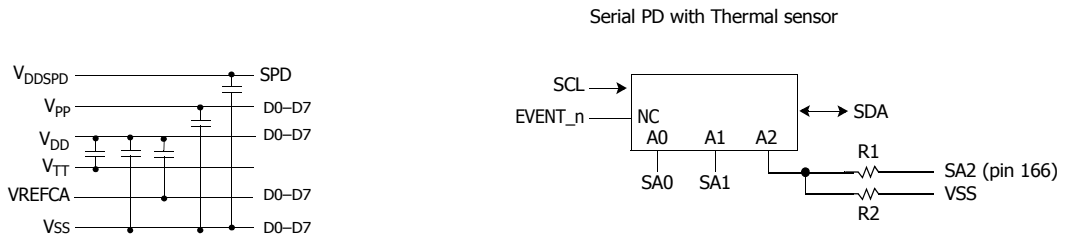
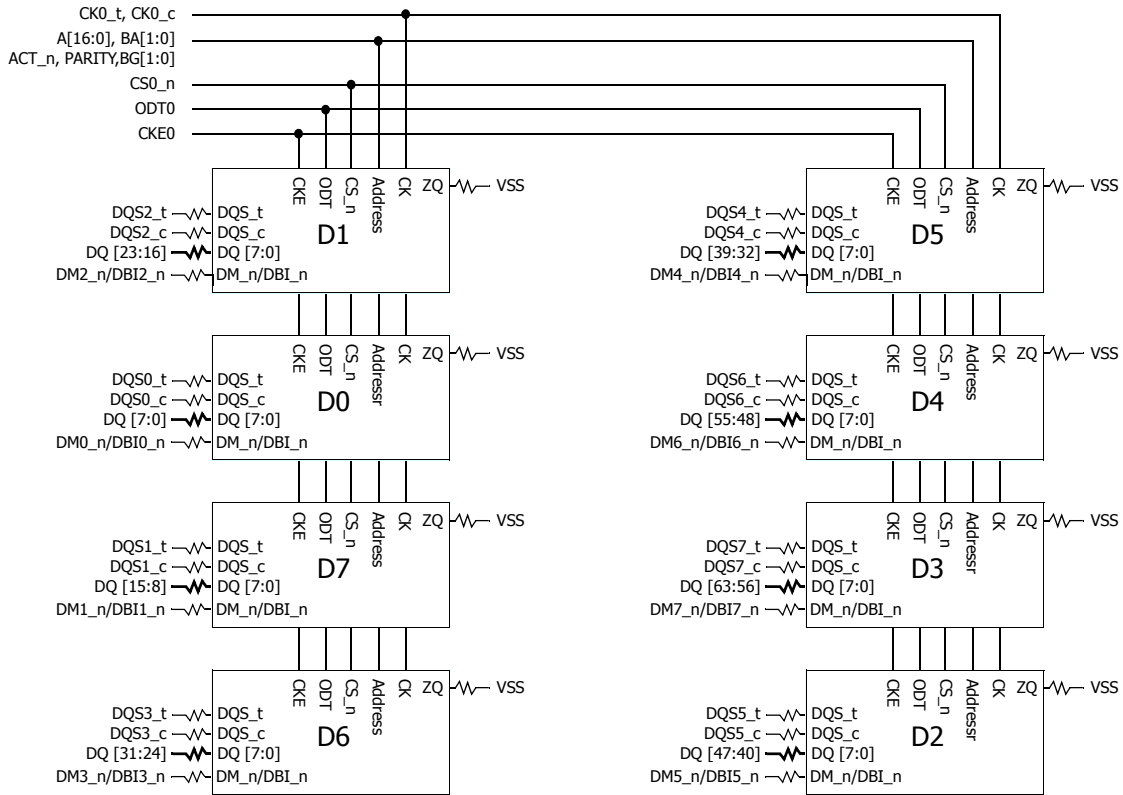
2GB, 256Mx64 Module(1Rank of x16)



Note:

1. Unless otherwise noted, resistor values are $15\Omega \pm 5\%$.
2. ZQ resistors are $240\Omega \pm 1\%$. For all other resistor values refer to the appropriate wiring diagram.
3. CK1_t, CK1_c terminated with $75\Omega \pm 5\%$ resistor.

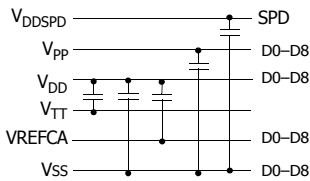
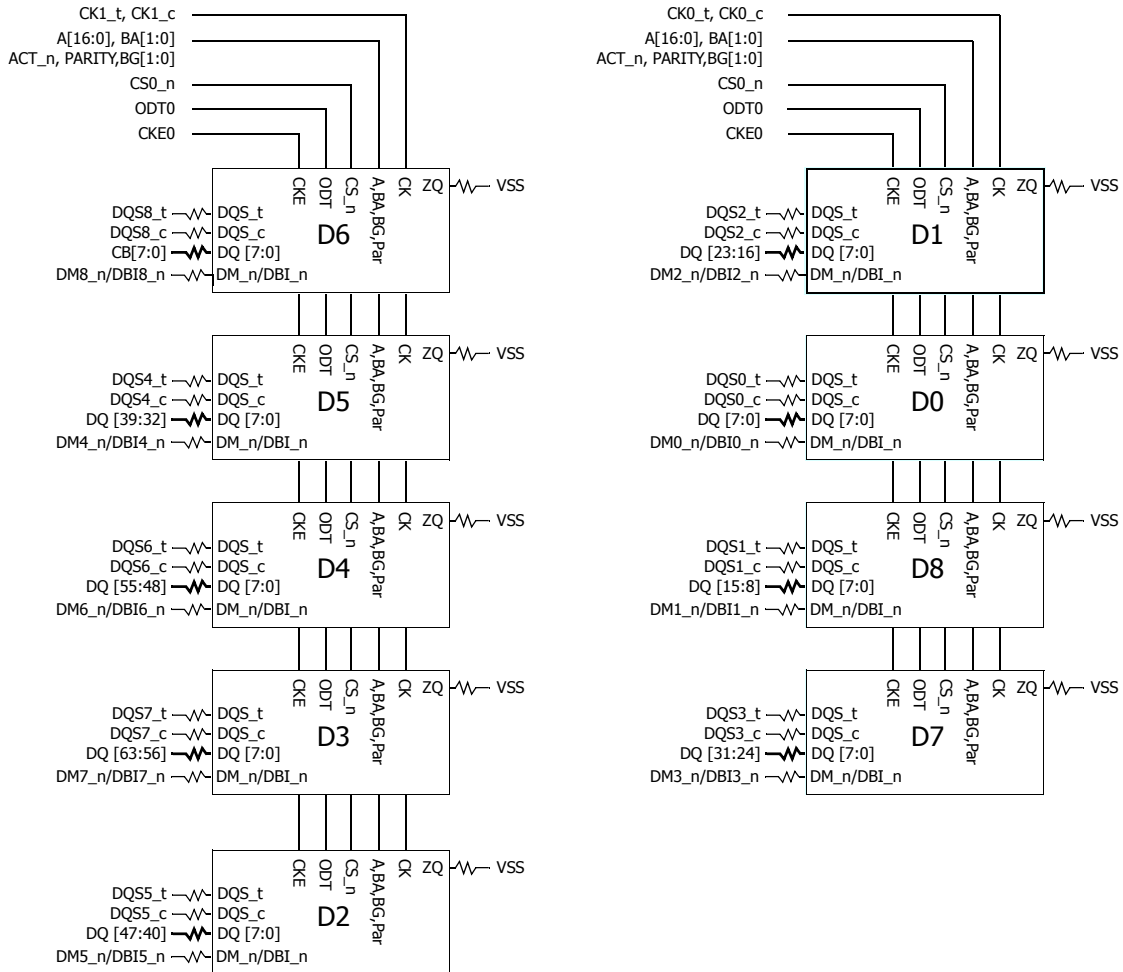
4GB, 512Mx64 Module(1Rank of x8)



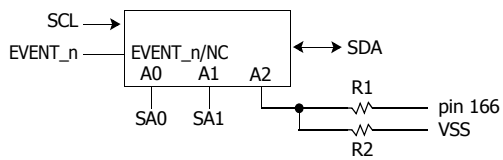
Note:

1. Unless otherwise noted, resistor values are $15\Omega \pm 5\%$.
2. ZQ resistors are $240\Omega \pm 1\%$. For all other resistor values refer to the appropriate wiring diagram.
3. To connect the SPD A2 input to the edge connector pin 166 install R1. To tie the SPD input A2 to ground install R2. Do not install both R1 and R2. The values for R1 and R2 are not critical. Any value less than 100 Ohms may be used.

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



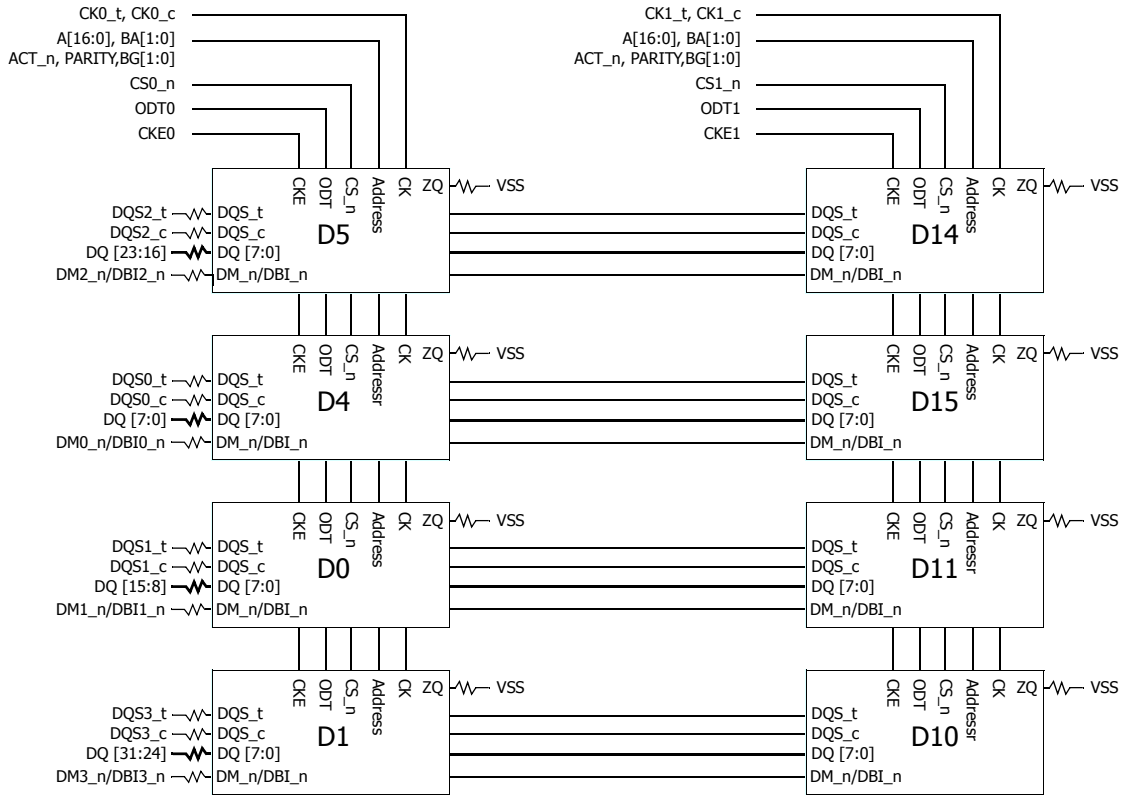
Serial PD with Thermal sensor



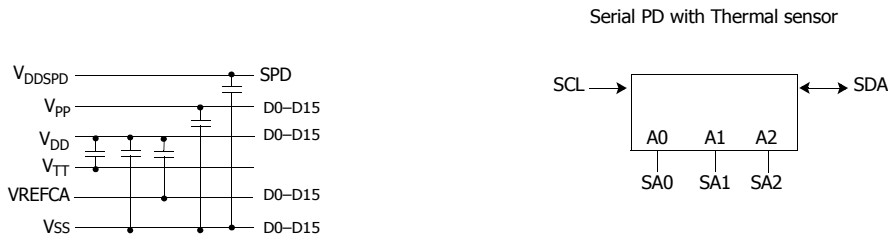
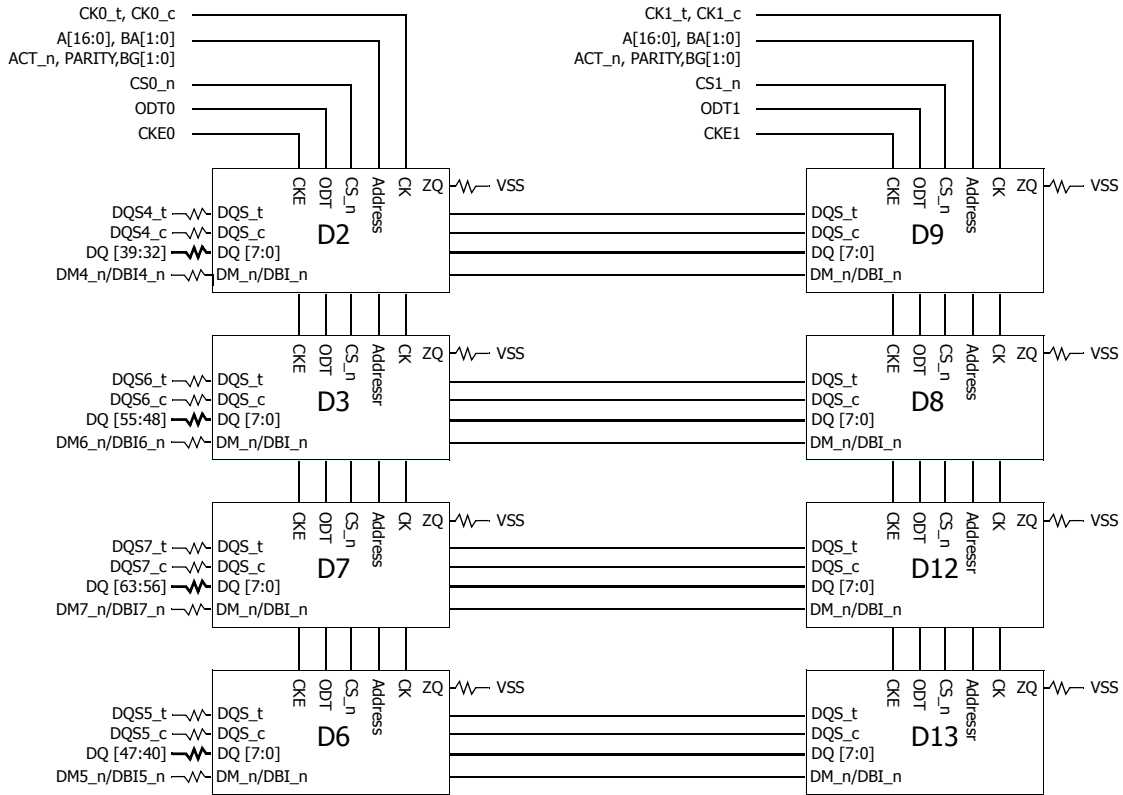
Note:

1. Unless otherwise noted, resistor values are $15\Omega \pm 5\%$.
2. ZQ resistors are $240\Omega \pm 1\%$. For all other resistor values refer to the appropriate wiring diagram.
3. To connect the SPD A2 input to the edge connector pin 166 install R1. To tie the SPD input A2 to ground install R2. Do not install both R1 and R2. The values for R1 and R2 are not critical. Any value less than 100 Ohms may be used.

8GB, 1Gx64 Module(2Rank of x8) - page1



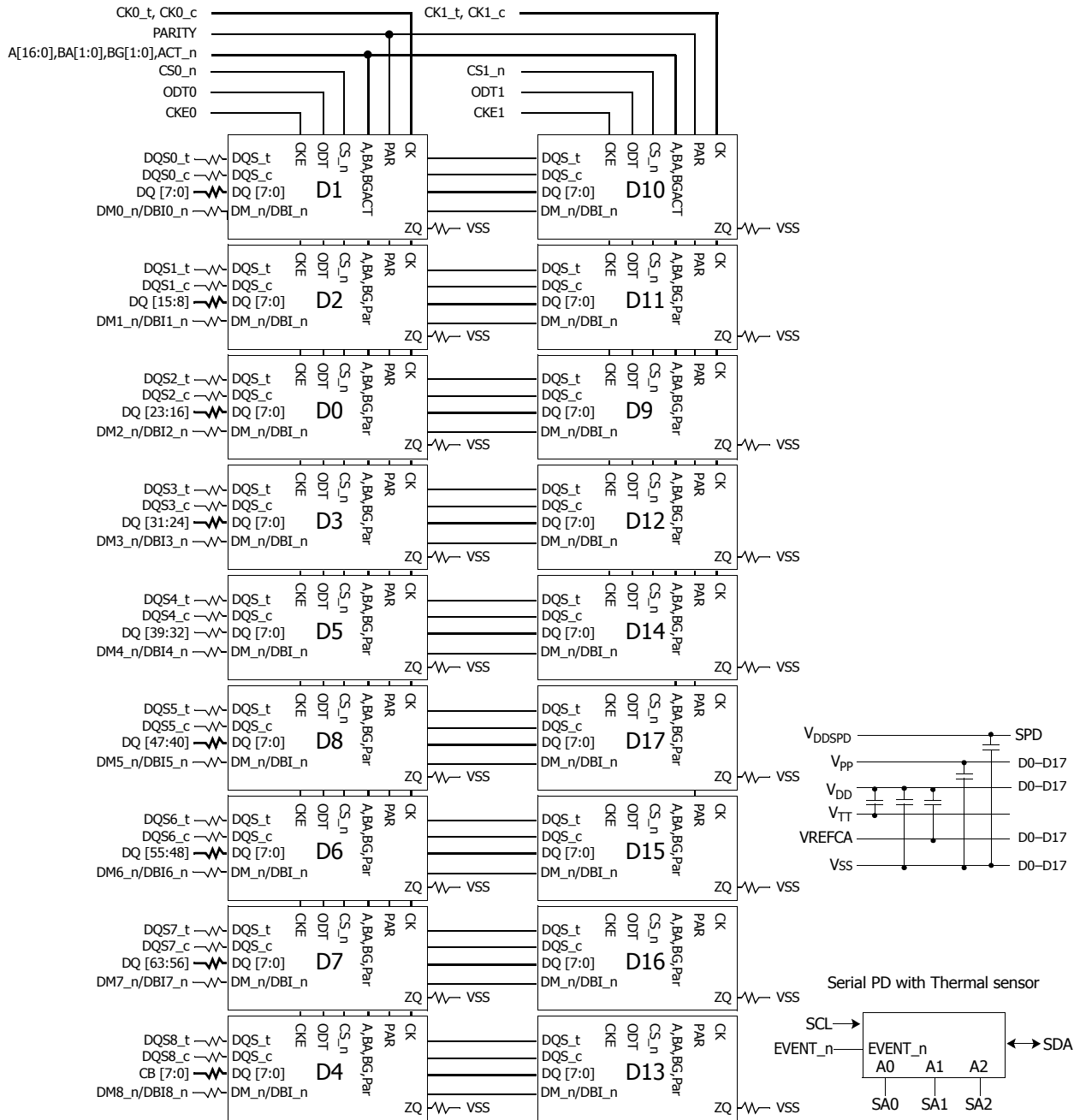
8GB, 1Gx64 Module(2Rank of x8) - page2



Note:

1. Unless otherwise noted, resistor values are $15\ \Omega \pm 5\%$.
2. ZQ resistors are $240\ \Omega \pm 1\%$. For all other resistor values refer to the appropriate wiring diagram.
3. SDRAMs for ODD ranks (D8 to D15), which are placed on the back side of the module use the address mirroring for A4-A3, A6-A5, A8-A7, A13-A11, BA1-BA0 and BG1-BG0. More detail can be found in the DDR4 SODIMM Common Section of the Design Specification.

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



Note:

1. DQ-to-I/O wiring is shown as recommended but may be changed.
2. Unless otherwise noted, resistor values are $15\Omega \pm 5\%$.
3. See the Net Structure diagrams for all resistors associated with the command, address and control bus.
4. ZQ resistors are $240\Omega \pm 1\%$. For all other resistor values refer to the appropriate wiring diagram.

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 _{IN} , V _{OUT}	Voltage on any pin except VREFCA relative to Vss	-0.3 ~ 1.5	V	1,3,5
T _{STG}	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 JEDEC 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 _{OPER}	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 $\pm 1\% V_{DD}$.

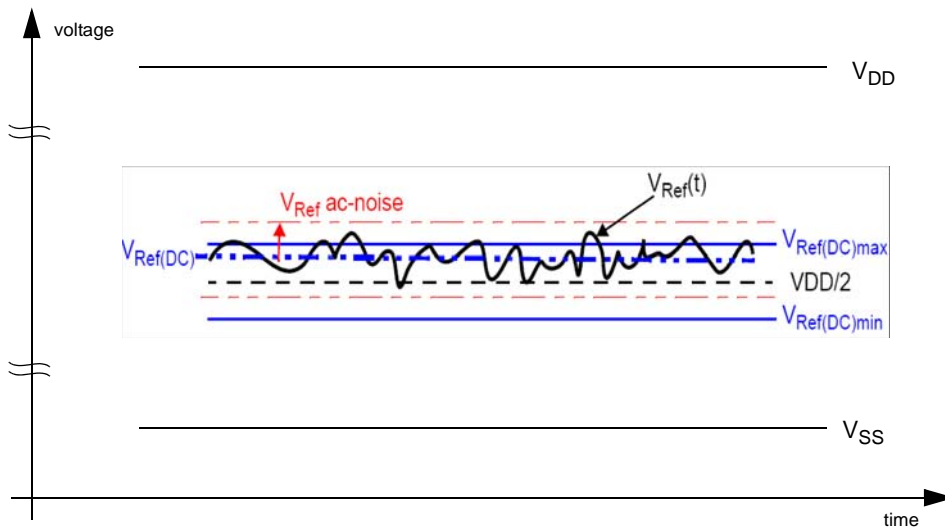


Illustration of $V_{REF}(DC)$ tolerance and V_{REF} AC-noise limits

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} .

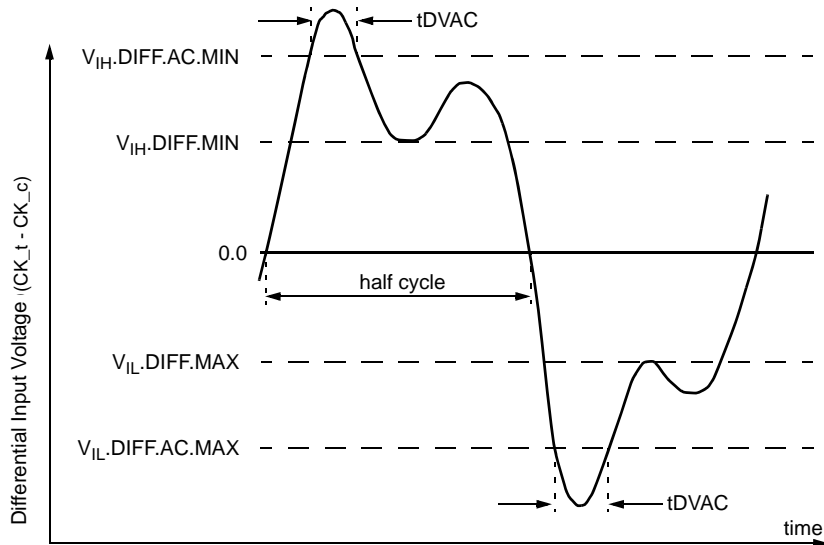
" V_{REF} " shall be understood as $V_{REF}(DC)$, as defined in Figure above.

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

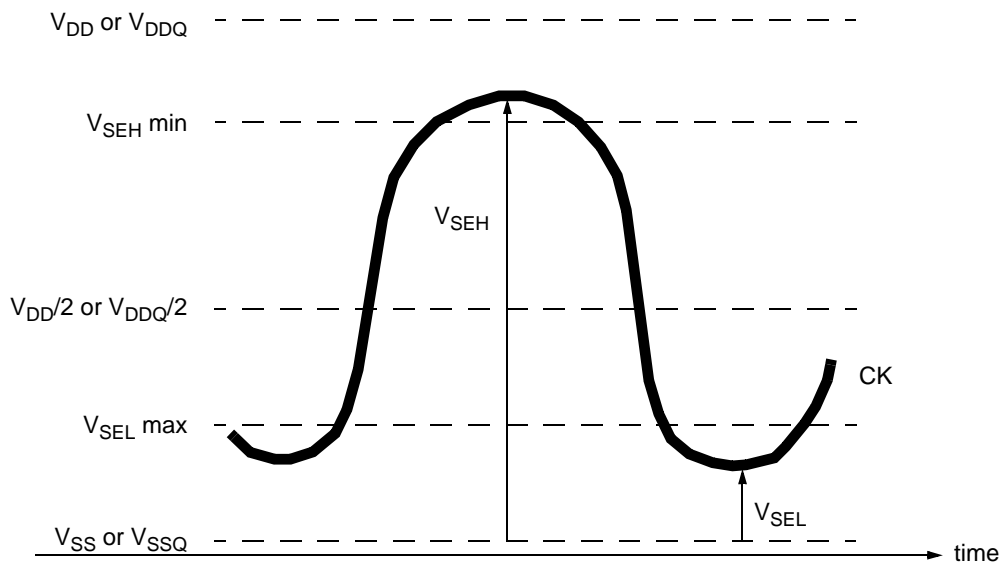
Slew Rate [V/ns]	tDVAC [ps] @ $ V_{IH/Ldiff}(AC) = 200mV$		tDVAC [ps] @ $ V_{IH/Ldiff}(AC) = TBDmV$	
	min	max	min	max
> 4.0	120	-	TBD	-
4.0	115	-	TBD	-
3.0	110	-	TBD	-
2.0	105	-	TBD	-
1.8	100	-	TBD	-
1.6	95	-	TBD	-
1.4	90	-	TBD	-
1.2	85	-	TBD	-
1.0	80	-	TBD	-
< 1.0	80	-	TBD	-

Single-ended requirements for differential signals

Each individual component of a differential signal (CK_t, CK_c) has also to comply with certain requirements for single-ended signals.

CK_t and CK_c have to approximately reach V_{SEH}min / V_{SEL}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_t and CK_c



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_{SEL}max, V_{SEH}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 _{SEH}	Single-ended high-level for CK_t, CK_c	(VDD/2) +0.100	NOTE3	TBD	NOTE3	V	1, 2
V _{SEL}	Single-ended low-level for CK_t, CK_c	NOTE3	(VDD/2)- 0.100	NOTE3	TBD	V	1, 2

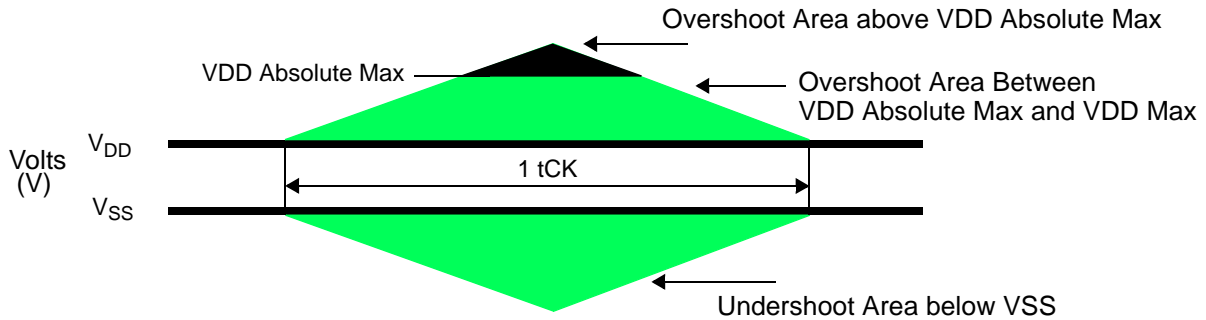
NOTE :

1. For CK_t - CK_c use V_{IH,CA}/V_{IL,CA}(AC) of ADD/CMD;
2. V_{IH}(AC)/V_{IL}(AC) for ADD/CMD is based on V_{REFCA};
3. These values are not defined, however the single-ended 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.

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)						

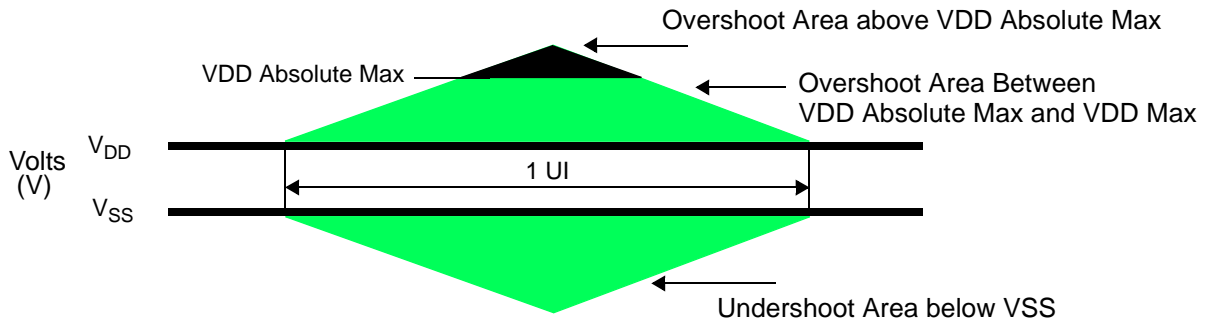


Address,Command and Control Overshoot and Undershoot Definition

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)						



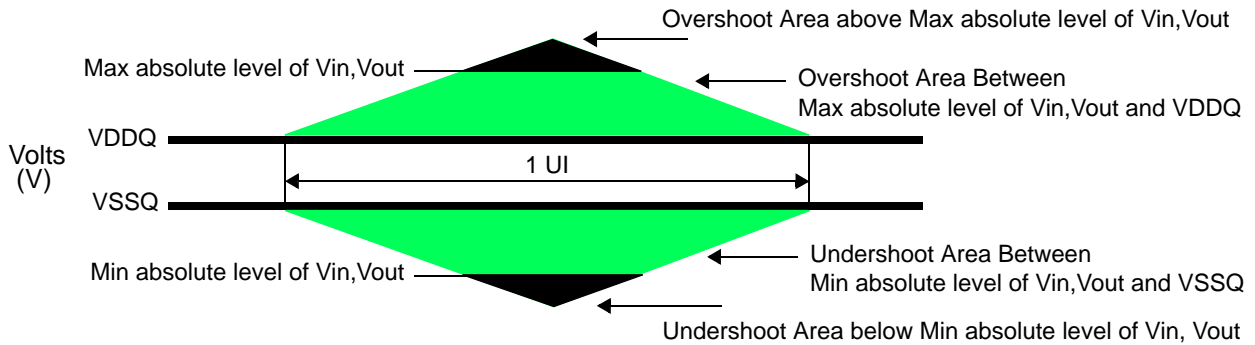
Clock Overshoot and Undershoot Definition

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

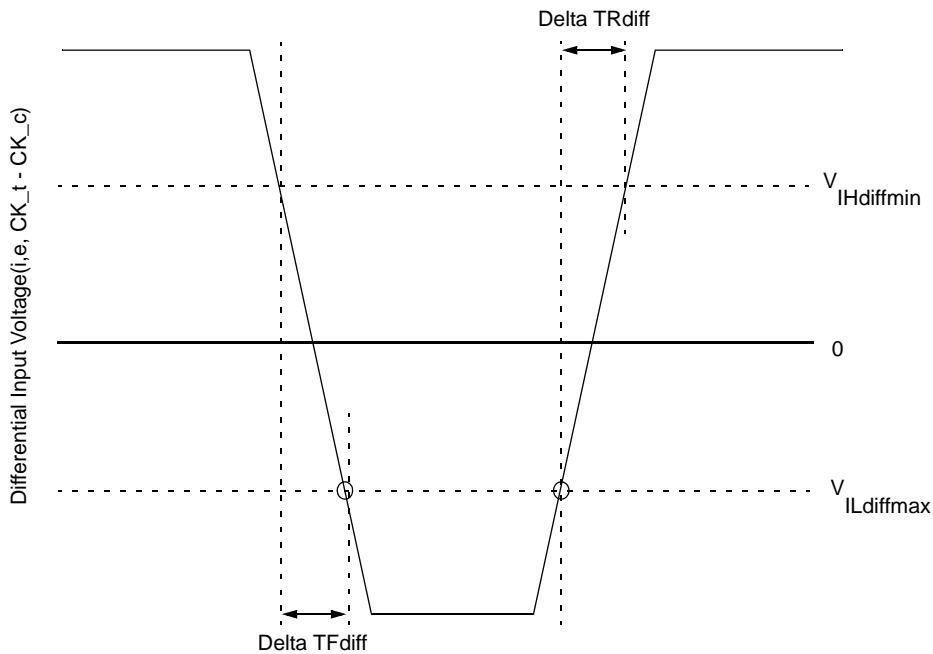
Slew Rate Definitions

Slew Rate Definitions for Differential Input Signals (CK)

Input slew rate for differential signals (CK_t, CK_c) are defined and measured as shown in Table and Figure below.

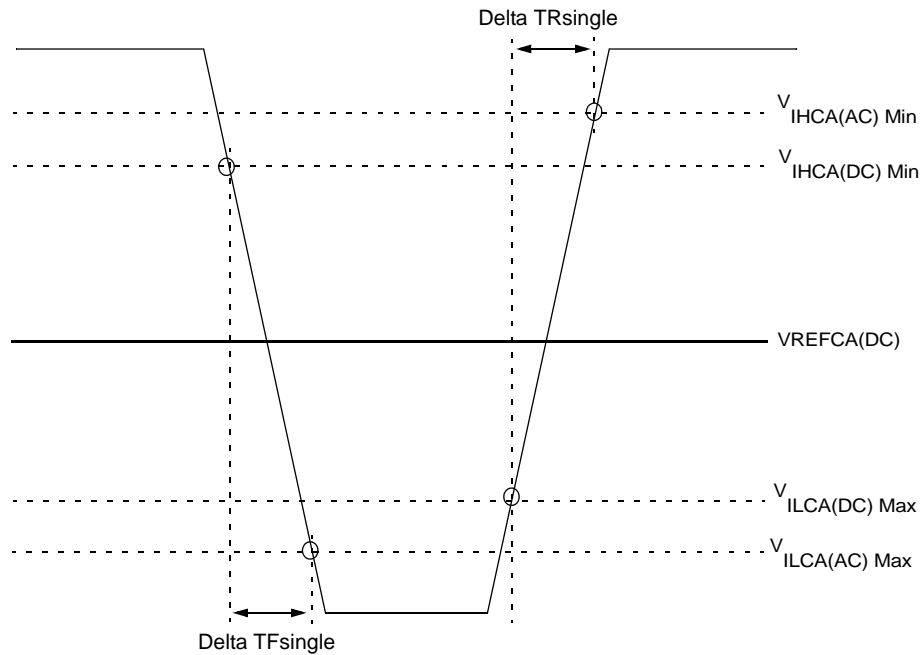
Differential Input Slew Rate Definition

Description			Defined by
	from	to	
Differential input slew rate for rising edge(CK_t - CK_c)	$V_{ILdiffmax}$	$V_{IHdiffmin}$	$[V_{IHdiffmin} - V_{ILdiffmax}] / \Delta TRdiff$
Differential input slew rate for falling edge(CK_t - CK_c)	$V_{IHdiffmin}$	$V_{ILdiffmax}$	$[V_{IHdiffmin} - V_{ILdiffmax}] / \Delta TFdiff$
NOTE: The differential signal (i.e.,CK_t - CK_c) must be linear between these thresholds.			



Differential Input Slew Rate Definition for CK_t, CK_c

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



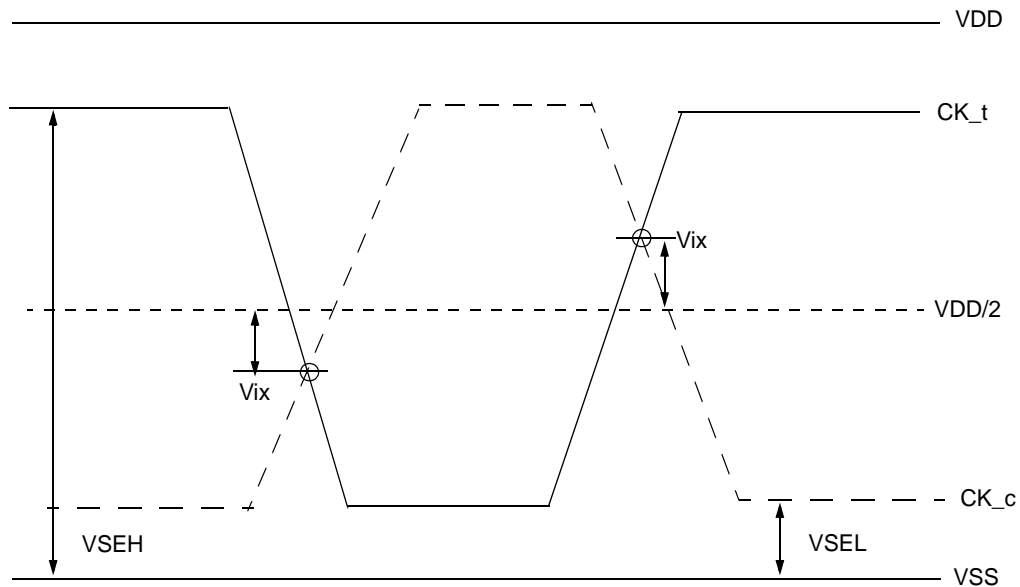
Single-ended Input Slew Rate definition for CMD and ADD

NOTE :

1. Single-ended input slew rate for rising edge = $\{ V_{IHCA(AC)Min} - V_{ILCA(DC)Max} \} / \Delta T_{Rsingle}$
2. Single-ended input slew rate for falling edge = $\{ V_{IHCA(DC)Min} - V_{ILCA(AC)Max} \} / \Delta T_{Fsingle}$
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

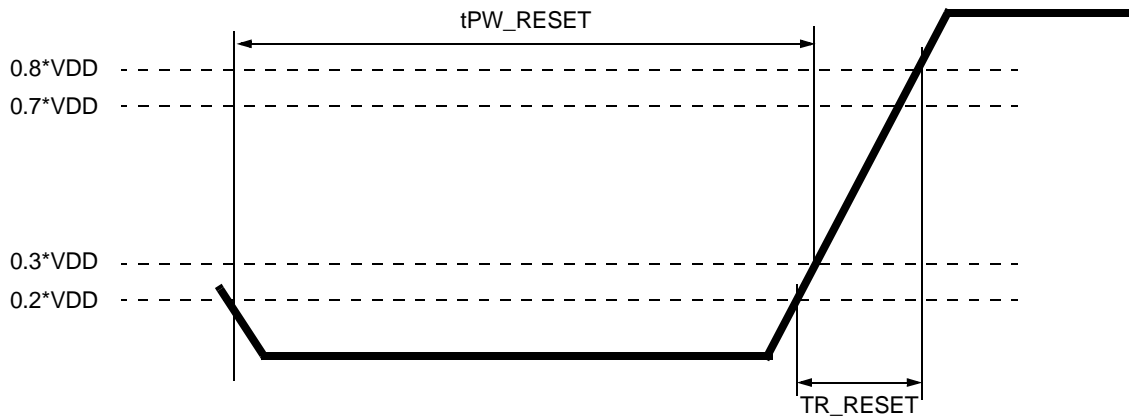
CMOS rail to rail Input Levels for RESET_n

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 :

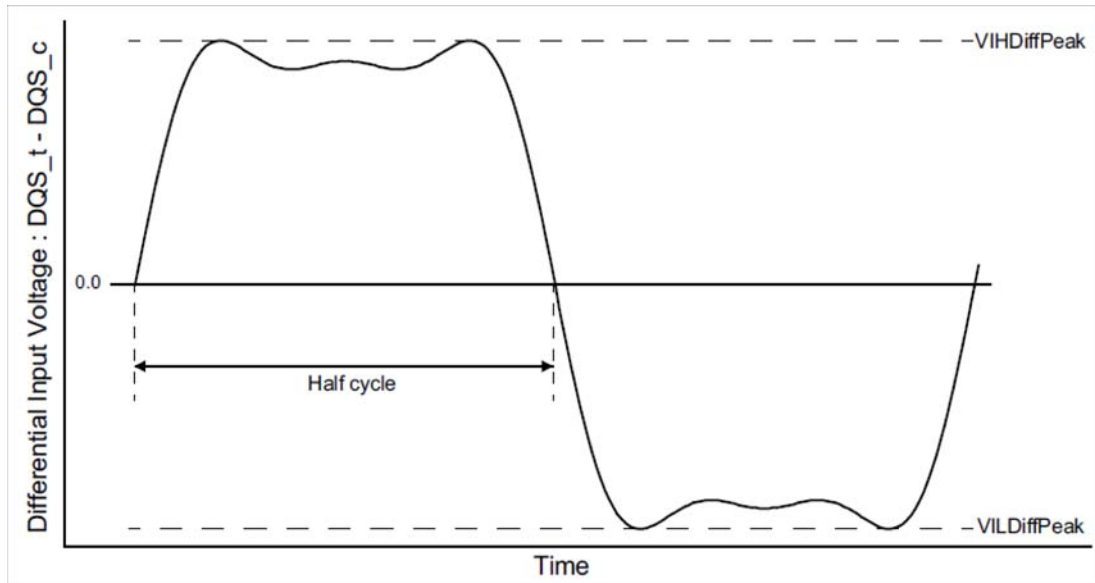
1. After RESET_n is registered LOW, RESET_n level shall be maintained below VIL(DC)_RESET during tPW_RESET, otherwise, SDRAM may not be reset.
2. Once RESET_n is registered HIGH, RESET_n level must be maintained above VIH(DC)_RESET, otherwise, SDRAM operation will not be guaranteed until it is reset 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

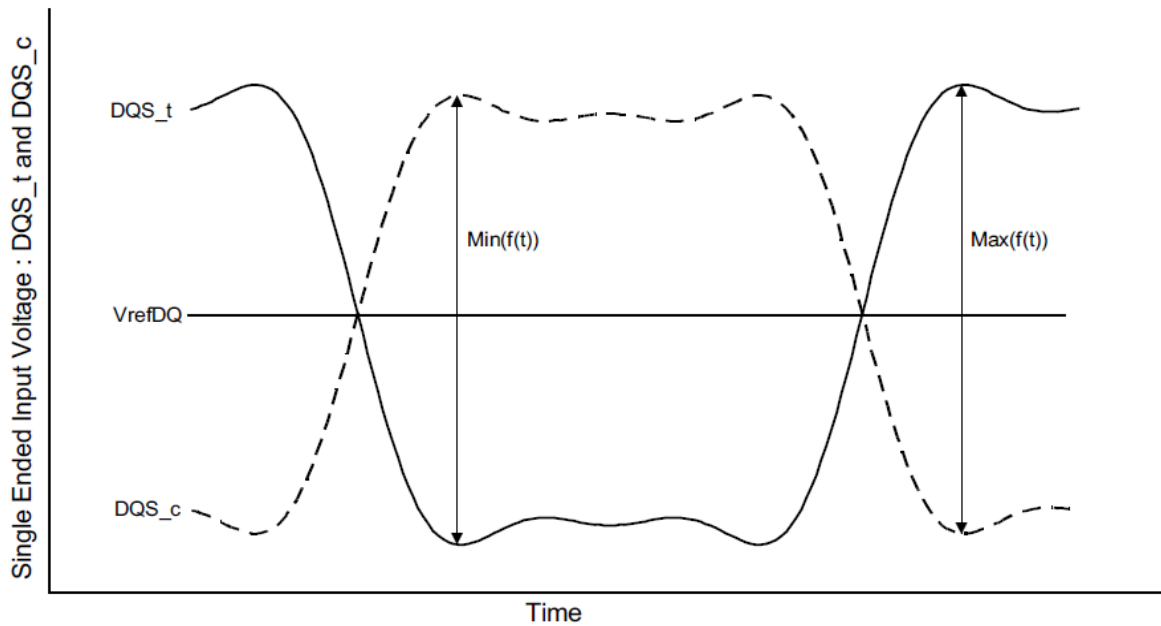
The peak voltage of Differential DQS signals are calculated in a following equation.

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

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

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

The $\text{Max}(f(t))$ or $\text{Min}(f(t))$ used to determine the midpoint which to reference the $\pm 35\%$ window of the exempt non-monotonic signaling shall be the smallest peak voltage observed in all ui's.



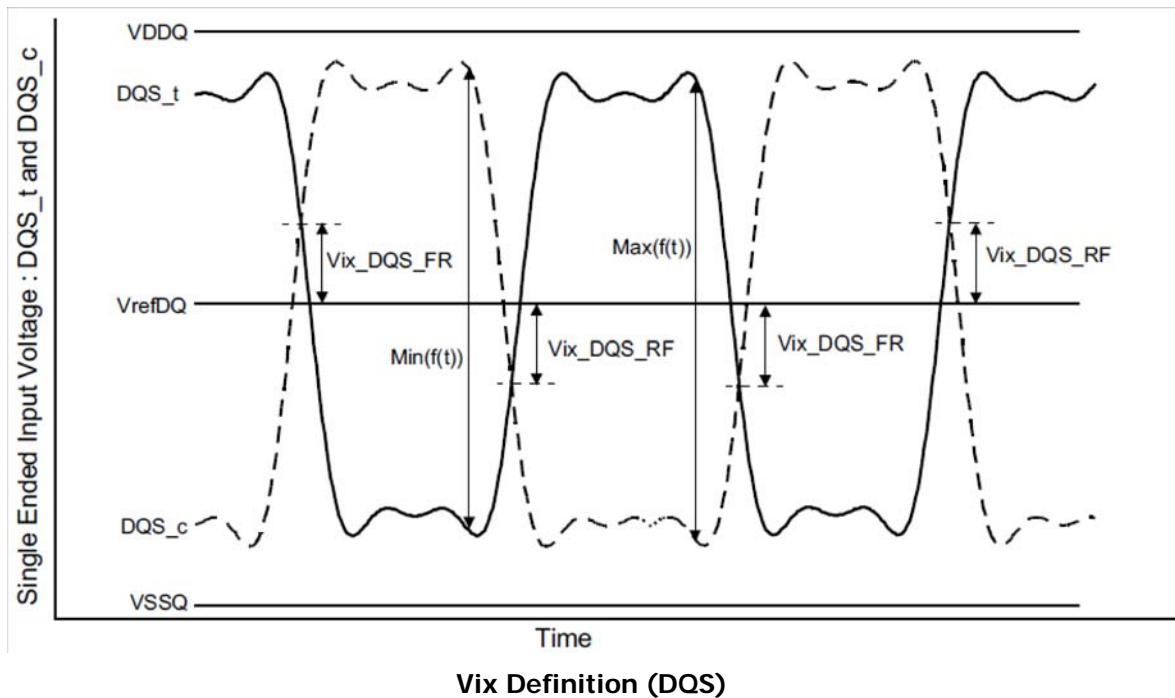
Definition of differential DQS Peak Voltage and range of exempt non-monotonic signaling

Differential Input Cross Point Voltage

To achieve tight RxMask input requirements as well as output skew parameters with respect to strobe, the cross point voltage of differential input signals (DQS_t, DQS_c) must meet the requirements in Table below. The differential input cross point voltage VIX_{DQS} (VIX_{DQS_FR} and VIX_{DQS_RF}) is measured from the actual cross point of DQS_t, DQS_c relative to the VDQSmid for the DQS_t and DQS_c signals.

VDQSmid is the midpoint of the minimum levels achieved by the transitioning DQS_t and DQS_c signals, and noted by VDQS_{trans}. VDQS_{trans} is the difference between the lowest horizontal tangent above VDQSmid of the transitioning DQS signals and the highest horizontal tangent below VDQSmid of the transitioning DQS signals.

A non-monotonic transitioning signal's ledge is exempt or not used in determination of a horizontal tangent provided the said ledge occurs within +/- 30% of the midpoint of either VID_{DIFF}. Peak Voltage (DQS_t rising) or VIL_{DIFF}. Peak Voltage (DQS_c rising), refer to Future Definition of differential DQS Peak Voltage and range of exempt non-monotonic signaling. A secondary horizontal tangent resulting from a ring-back transition is also exempt in determination of a horizontal tangent. That is, a falling transition's horizontal tangent is derived from its negative slope to zero slope transition (point A in Figure below) and a ring-back's horizontal tangent derived from its positive slope to zero slope transition (point B in Figure below) is not a valid horizontal tangent; and a rising transition's horizontal tangent is derived from its positive slope to zero slope transition (point C in Figure below) and a ring-back's horizontal tangent derived from its negative slope to zero slope transition (point D in Figure below) is not a valid horizontal tangent.



Cross point voltage for differential input signals

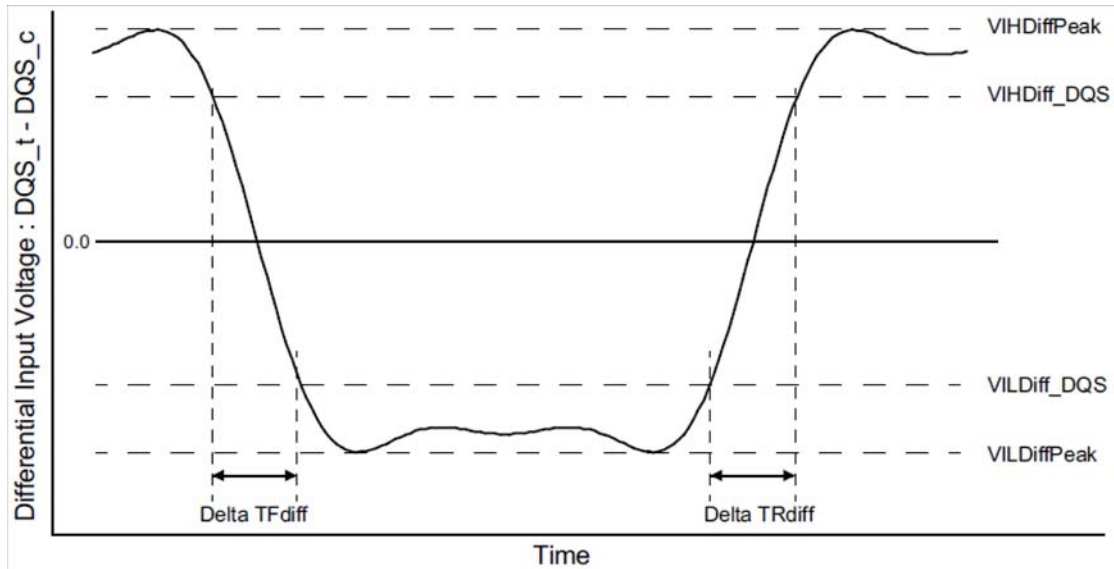
Symbol	Parameter	DDR4-1600,1866,2133,2400		DDR4-2666,2933,3200		Unit	Note
		Min	Max	Min	Max		
Vix_DOS_ratio	DQS_t and DQS_c crossing relative to the midpoint of the DQS_t and DQS_c signal swings	-	25	TBD	TBD	%	1,2

NOTE :

1. Vix_DQS_Ratio is DQS VIX crossing (Vix_DQS_FR or Vix_DQS_RF) divided by VDQS_trans. VDQS_trans is the difference between the lowest horizontal tangent above VDQSmid of the transitioning DQS signals and the highest horizontal tangent below VDQSmid of the transitioning DQS signals.
2. VDQSmid will be similar to the VREFDQ internal setting value obtained during Vref Training if the DQS and DQs drivers and paths are matched.

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	-	130	-	TBD	TBD	mV	
VILDiff_DQS	Differential Input Low	-	-136	-	-130	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 _{diff}	Differential Input Slew Rate	3	18	3	18	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 50Ω 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 50Ω to $V_{TT} = V_{DDQ}$ at each of the differential outputs.

Single-ended Output Slew Rate

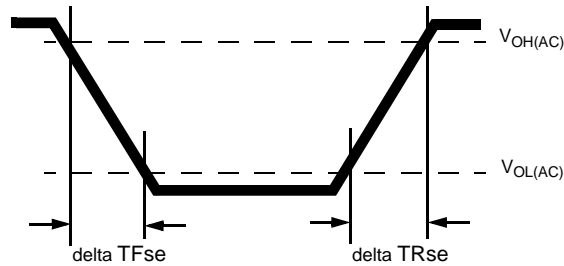
With the reference load for timing measurements, output slew rate for falling and rising edges is defined and measured between $V_{OL(AC)}$ and $V_{OH(AC)}$ for single ended signals as shown in Table and Figure below.

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

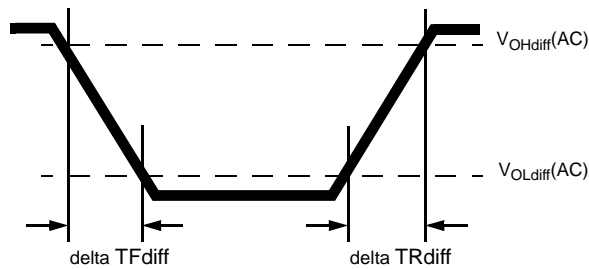
With the reference load for timing measurements, output slew rate for falling and rising edges is defined and measured between VOLdiff(AC) and VOHdiff(AC) for differential signals as shown in Table and Figure below.

Differential output slew rate definition

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

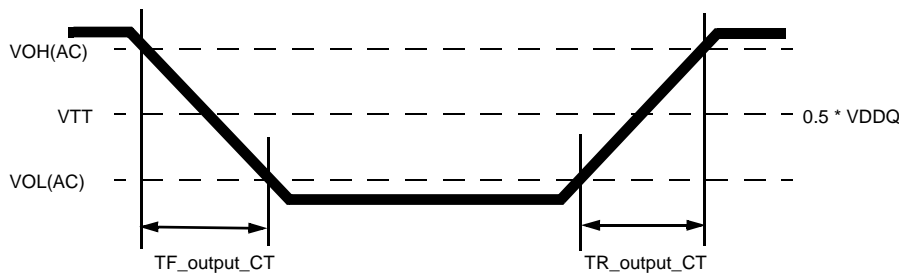
Following output parameters will be applied for DDR4 SDRAM Output Signal during Connectivity Test Mode.

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 :

- The effective test load is 50Ω 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) ^{5,10}	18.00	ns	10	
Internal read command to first data with read DBI enabled	tAA_DBI		tAA(min) + 2nCK	tAA(max) + 2nCK	ns	10	
ACT to internal read or write delay time	tRCD		13.75 (13.50) ^{5,10}	-	ns	10	
PRE command period	tRP		13.75 (13.50) ^{5,10}	-	ns	10	
ACT to PRE command period	tRAS		35	9 x tREFI	ns	10	
ACT to ACT or REF command period	tRC		48.75 (48.50) ^{5,10}	-	ns	10	
	Normal	Read DBI					
CWL = 9	CL = 9	CL = 11	tCK(AVG)	1.5	1.6	ns	1,2,3,4,9,12
	CL = 10	CL = 12	tCK(AVG)	Reserved		ns	1,2,3,4,9
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	11,12	
Supported CL Settings with read DBI			11,13,14		nCK	11	
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 ¹² (13.50) ^{5,10}	18.00	ns	10	
Internal read command to first data with read DBI enabled	tAA_DBI		tAA(min) + 2nCK	tAA(max) + 2nCK	ns	10	
ACT to internal read or write delay time	tRCD		13.92 (13.50) ^{5,10}	-	ns	10	
PRE command period	tRP		13.92 (13.50) ^{5,10}	-	ns	10	
ACT to PRE command period	tRAS		34	9 x tREFI	ns	10	
ACT to ACT or REF command period	tRC		47.92 (47.50) ^{5,10}	-	ns	10	
	Normal	Read DBI					
CWL = 9	CL = 9	CL = 11	tCK(AVG)	1.5	1.6	ns	1,2,3,4,9,10
	CL = 10	CL = 12	tCK(AVG)	Reserved		ns	1,2,3,4,9
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
	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	11,12	
Supported CL Settings with read DBI			11,13,14,15,16		nCK	12	
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 ¹² (13.50) ^{5,10}	18.00	ns	10	
Internal read command to first data with read DBI enabled		tAA_DBI	tAA(min)+3nCK	tAA(max)+3nCK	ns	10	
ACT to internal read or write delay time		tRCD	14.06 (13.50) ^{5,10}	-	ns	10	
PRE command period		tRP	14.06 (13.50) ^{5,10}	-	ns	10	
ACT to PRE command period		tRAS	33	9 x tREFI	ns	10	
ACT to ACT or REF command period		tRC	47.06 (46.50) ^{5,10}	-	ns	10	
	Normal	Read DBI					
CWL = 9	CL = 9	CL = 11	tCK(AVG)	1.5	1.6	ns	1,2,3,4,9,12
	CL = 10	CL = 12	tCK(AVG)	Reserved		ns	1,2,3,9
CWL = 9,11	CL = 11	CL = 13	tCK(AVG)	1.25	<1.5	ns	1,2,3,4,7
	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
	CL = 14	CL = 16	tCK(AVG)	1.071	<1.25	ns	1,2,3,7
CWL = 11,14	CL = 14	CL = 17	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 15	CL = 18	tCK(AVG)	0.937	<1.071	ns	1,2,3,4
	CL = 16	CL = 19	tCK(AVG)	0.937	<1.071	ns	1,2,3
Supported CL Settings			9,11,12,13,14,15,16		nCK	11,12	
Supported CL Settings with read DBI			11,13,14,15,16,18,19		nCK		
Supported CWL Settings			9,10,11,12,14		nCK		

DDR4-2400 Speed Bins and Operations

Speed Bin			DDR4-2400T		Unit	NOTE	
CL-nRCD-nRP			17-17-17				
Parameter	Symbol		min	max			
Internal read command to first data	tAA		14.16 (13.75) ^{5,10}	18.00	ns	10	
Internal read command to first data with read DBI enabled	tAA_DBI		tAA(min)+3nCK	tAA(max)+3nCK	ns	10	
ACT to internal read or write delay time	tRCD		14.16 (13.75) ^{5,10}	-	ns	10	
PRE command period	tRP		14.16 (13.75) ^{5,10}	-	ns	10	
ACT to PRE command period	tRAS		32	9 x tREFI	ns	10	
ACT to ACT or REF command period	tRC		46.16 (45.75) ^{5,10}	-	ns	10	
	Normal	Read DBI					
CWL = 9	CL = 9	CL = 11	tCK(AVG)	Reserved		ns	1,2,3,4,9
	CL = 10	CL = 12	tCK(AVG)	1.5	1.6	ns	1,2,3,4,9
CWL = 9,11	CL = 10	CL = 12	tCK(AVG)	Reserved		ns	4
	CL = 11	CL = 13	tCK(AVG)	1.25	<1.5	ns	1,2,3,4,8
	CL = 12	CL = 14	tCK(AVG)	1.25	<1.5	ns	1,2,3,8
CWL = 10,12	CL = 12	CL = 14	tCK(AVG)	Reserved		ns	4
	CL = 13	CL = 15	tCK(AVG)	1.071	<1.25	ns	1,2,3,4,8
	CL = 14	CL = 16	tCK(AVG)	1.071	<1.25	ns	1,2,3,8
CWL = 11,14	CL = 14	CL = 17	tCK(AVG)	Reserved		ns	4
	CL = 15	CL = 18	tCK(AVG)	0.937	<1.071	ns	1,2,3,4,8
	CL = 16	CL = 19	tCK(AVG)	0.937	<1.071	ns	1,2,3,8
CWL = 12,16	CL = 15	CL = 18	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 16	CL = 19	tCK(AVG)	Reserved		ns	1,2,3,4
	CL = 17	CL = 20	tCK(AVG)	0.833	<0.937	ns	
	CL = 18	CL = 21	tCK(AVG)	0.833	<0.937	ns	1,2,3
Supported CL Settings			10,11,12,13,14,15,16,17,18		nCK	11	
Supported CL Settings with read DBI			12,14,16,18,19,20,21		nCK		
Supported CWL Settings			9,10,11,12,14,16		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. Any DDR4-2400 speed bin also supports functional operation at lower frequencies as shown in the table which are not subject to Production Tests but verified by Design/Characterization.
9. DDR4-1600 AC timing apply if DRAM operates at lower than 1600 MT/s data rate.
10. Parameters apply from tCK(avg)min to tCK(avg)max at all standard JEDEC clock period values as stated in the Speed Bin Tables.
11. CL number in parentheses, it means that these numbers are optional.
12. DDR4 SDRAM supports CL=9 as long as a system meets tAA(min).
13. Each speed bin lists the timing requirements that need to be supported in order for a given DRAM to be JEDEC compliant. JEDEC compliance does not require support for all speed bins within a given speed. JEDEC compliance requires meeting the parameters for a least one of the listed speed bins.

IDD and IDDQ Specification Parameters and Test Conditions

IDD, IPP and IDDQ Measurement Conditions

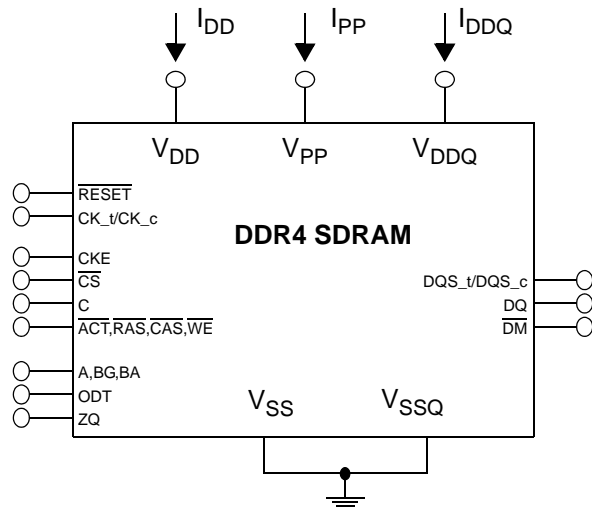
In this chapter, IDD, IPP and IDDQ measurement conditions such as test load and patterns are defined. Figure shows the setup and test load for IDD, IPP and IDDQ measurements.

- 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_B (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

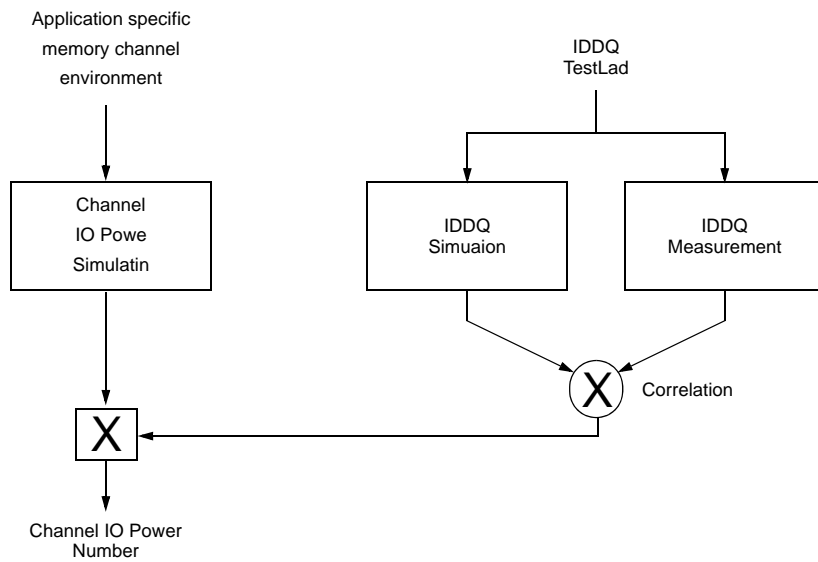


Figure 2 - Correlation from simulated Channel IO Power to actual Channel IO Power supported by IDDQ Measurement

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		0.937		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	Operating One Bank Active-Precharge Current (AL=0) CKE: High; External clock: On; tCK, nRC, nRAS, CL: see Table 1; BL: 8 ¹ ; 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 ² ; ODT Signal: stable at 0; Pattern Details: see Table 3
IDD0A	Operating One Bank Active-Precharge Current (AL=CL-1) AL = CL-1, Other conditions: see IDD0
IPP0	Operating One Bank Active-Precharge IPP Current Same condition with IDD0
IDD1	Operating One Bank Active-Read-Precharge Current (AL=0) CKE: High; External clock: On; tCK, nRC, nRAS, nRCD, CL: see Table 1; BL: 8 ¹ ; 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 ² ; ODT Signal: stable at 0; Pattern Details: see Table 4
IDD1A	Operating One Bank Active-Read-Precharge Current (AL=CL-1) AL = CL-1, Other conditions: see IDD1
IPP1	Operating One Bank Active-Read-Precharge IPP Current Same condition with IDD1
IDD2N	Precharge Standby Current (AL=0) CKE: High; External clock: On; tCK, CL: see Table 1; BL: 8 ¹ ; 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 ² ; ODT Signal: stable at 0; Pattern Details: see Table 5
IDD2NA	Precharge Standby Current (AL=CL-1) AL = CL-1, Other conditions: see IDD2N
IPP2N	Precharge Standby IPP Current Same condition with IDD2N
IDD2NT	Precharge Standby ODT Current CKE: High; External clock: On; tCK, CL: see Table 1; BL: 8 ¹ ; 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 ² ; ODT Signal: toggling according to Table 6; Pattern Details: see Table 6
IDDQ2NT (Optional)	Precharge Standby ODT IDDQ Current Same definition like for IDD2NT, however measuring IDDQ current instead of IDD current
IDD2NL	Precharge Standby Current with CAL enabled Same definition like for IDD2N, CAL enabled ³
IDD2NG	Precharge Standby Current with Gear Down mode enabled Same definition like for IDD2N, Gear Down mode enabled ³
IDD2ND	Precharge Standby Current with DLL disabled Same definition like for IDD2N, DLL disabled ³

IDD2N_par	Precharge Standby Current with CA parity enabled Same definition like for IDD2N, CA parity enabled ³
IDD2P	Precharge Power-Down Current CKE: Low; External clock: On; tCK, CL: see Table 1; BL: 8¹; 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 Registers²; ODT Signal: stable at 0
IPP2P	Precharge Power-Down IPP Current Same condition with IDD2P
IDD2Q	Precharge Quiet Standby Current CKE: High; External clock: On; tCK, CL: see Table 1; BL: 8 ¹ ; 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 ² ; ODT Signal: stable at 0
IDD3N	Active Standby Current CKE: High; External clock: On; tCK, CL: see Table 1; BL: 8 ¹ ; 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 ² ; ODT Signal: stable at 0; Pattern Details: see Table 5
IDD3NA	Active Standby Current (AL=CL-1) AL = CL-1, Other conditions: see IDD3N
IPP3N	Active Standby IPP Current Same condition with IDD3N
IDD3P	Active Power-Down Current CKE: Low; External clock: On; tCK, CL: see Table 1; BL: 8 ¹ ; 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 ² ; ODT Signal: stable at 0
IPP3P	Active Power-Down IPP Current Same condition with IDD3P
IDD4R	Operating Burst Read Current CKE: High; External clock: On; tCK, CL: see Table 1; BL: 8 ² ; 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 ² ; ODT Signal: stable at 0; Pattern Details: see Table 7
IDD4RA	Operating Burst Read Current (AL=CL-1) AL = CL-1, Other conditions: see IDD4R
IDD4RB	Operating Burst Read Current with Read DBI Read DBI enabled ³ , Other conditions: see IDD4R
IPP4R	Operating Burst Read IPP Current Same condition with IDD4R
IDDQ4R (Optional)	Operating Burst Read IDDQ Current Same definition like for IDD4R, however measuring IDDQ current instead of IDD current
IDDQ4RB (Optional)	Operating Burst Read IDDQ Current with Read DBI Same definition like for IDD4RB, however measuring IDDQ current instead of IDD current

IDD4W	Operating Burst Write Current CKE: High; External clock: On; tCK, CL: see Table 1; BL: 8 ¹ ; AL: 0; CS_n: High between WR; Command, Address, Bank Group Address, Bank Address Inputs : partially toggling according to Table 8; Data IO : seamless write data burst with different data between one burst and the next one according to Table 8; DM_n : stable at 1; Bank Activity : all banks open, WR commands cycling through banks: 0,0,1,1,2,2,... (see Table 8); Output Buffer and RTT : Enabled in Mode Registers ² ; ODT Signal : stable at HIGH; Pattern Details : see Table 8
IDD4WA	Operating Burst Write Current (AL=CL-1) AL = CL-1, Other conditions: see IDD4W
IDD4WB	Operating Burst Write Current with Write DBI Write DBI enabled ³ , Other conditions: see IDD4W
IDD4WC	Operating Burst Write Current with Write CRC Write CRC enabled ³ , Other conditions: see IDD4W
IDD4W_par	Operating Burst Write Current with CA Parity CA Parity enabled ³ , Other conditions: see IDD4W
IPP4W	Operating Burst Write IPP Current Same condition with IDD4W
IDD5B	Burst Refresh Current (1X REF) CKE: High; External clock: On; tCK, CL, nRFC: see Table 1; BL: 8 ¹ ; AL: 0; CS_n: High between REF; Command, Address, Bank Group Address, Bank Address Inputs : partially toggling according to Table 9; Data IO : VDDQ; DM_n : stable at 1; Bank Activity : REF command every nRFC (see Table 9); Output Buffer and RTT : Enabled in Mode Registers ² ; ODT Signal : stable at 0; Pattern Details : see Table 9
IPP5B	Burst Refresh Write IPP Current (1X REF) Same condition with IDD5B
IDD5F2	Burst Refresh Current (2X REF) tRFC=tRFC_x2, Other conditions: see IDD5B
IPP5F2	Burst Refresh Write IPP Current (2X REF) Same condition with IDD5F2
IDD5F4	Burst Refresh Current (4X REF) tRFC=tRFC_x4, Other conditions: see IDD5B
IPP5F4	Burst Refresh Write IPP Current (4X REF) Same condition with IDD5F4
IDD6N	Self Refresh Current: Normal Temperature Range T _{CASE} : 0 - 85°C; Low Power Array Self Refresh (LP ASR) : Normal ⁴ ; CKE: Low; External clock : Off; CK_t and CK_c#: LOW; CL: see Table 1; BL: 8 ¹ ; AL: 0; CS_n#: Command, Address, Bank Group Address, Bank Address, Data IO : High; DM_n : stable at 1; Bank Activity : Self-Refresh operation; Output Buffer and RTT : Enabled in Mode Registers ² ; ODT Signal : MID-LEVEL
IPP6N	Self Refresh IPP Current: Normal Temperature Range Same condition with IDD6N
IDD6E	Self-Refresh Current: Extended Temperature Range ⁵⁾ T _{CASE} : 0 - 95°C; Low Power Array Self Refresh (LP ASR) : Extended ⁴ ; CKE: Low; External clock : Off; CK_t and CK_c#: LOW; CL: see Table 1; BL: 8 ¹ ; AL: 0; CS_n, Command, Address, Bank Group Address, Bank Address, Data IO : High; DM_n : stable at 1; Bank Activity : Extended Temperature Self-Refresh operation; Output Buffer and RTT : Enabled in Mode Registers ² ; ODT Signal : MID-LEVEL
IPP6E	Self Refresh IPP Current: Extended Temperature Range Same condition with IDD6E

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

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 Pattern¹

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] ³	BG[1:0] ²	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data ⁴			
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 ²	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, IDD1A and IPP1 Measurement-Loop Pattern^{a)}

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] ³	BG[1:0] ²	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data ⁴			
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 ^b	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 ^b	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] ² = 0, BA[1:0] = 2 instead																			
		3	3*nRC	repeat Sub-Loop 1, 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 1, 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																			
		8	7*nRC	repeat Sub-Loop 1, use BG[1:0] ² = 1, BA[1:0] = 0 instead																			
		9	9*nRC	repeat Sub-Loop 1, use BG[1:0] ² = 2, BA[1:0] = 0 instead																			
		10	10*nRC	repeat Sub-Loop 0, use BG[1:0] ² = 3, BA[1:0] = 1 instead																			
		11	11*nRC	repeat Sub-Loop 1, use BG[1:0] ² = 2, BA[1:0] = 2 instead																			
		12	12*nRC	repeat Sub-Loop 0, use BG[1:0] ² = 3, BA[1:0] = 3 instead																			
		13	13*nRC	repeat Sub-Loop 1, use BG[1:0] ² = 2, BA[1:0] = 1 instead																			
		14	14*nRC	repeat Sub-Loop 0, use BG[1:0] ² = 3, BA[1:0] = 2 instead																			
15	15*nRC	repeat Sub-Loop 1, use BG[1:0] ² = 2, BA[1:0] = 3 instead																					
16	16*nRC	repeat Sub-Loop 0, use BG[1:0] ² = 3, BA[1:0] = 0 instead																					

For x4 and x8 only

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 Pattern¹

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] ³	BG[1:0] ²	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data ⁴		
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 ²	3	0	0	0	7	F	0	0	0
			3	D#, D#	1	1	1	1	1	1	0	0	3 ²	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 Pattern¹

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] ³	BG[1:0] ²	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data ⁴		
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 ²	3	0	0	0	7	F	0	0	-
			3	D#, D#	1	1	1	1	1	1	0	0	3 ²	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 Pattern¹

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] ³	BG[1:0] ²	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data ⁴			
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 ²	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 ²	3	0	0	0	7	F	0	0	-
		2	8-11	repeat Sub-Loop 0, use BG[1:0] ² = 0, BA[1:0] = 2 instead																			
		3	12-15	repeat Sub-Loop 1, 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 1, 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 1, 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 1, 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 1, 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 1, 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 1, use BG[1:0] ² = 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 Pattern¹

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] ³	BG[1:0] ²	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data ⁴			
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	0	-	
			2,3	D#, D#	1	1	1	1	1	1	0	3 ²	3	0	0	0	7	F	0	0	0	-	
		1	4	WR	0	1	1	0	1	1	0	1	1	0	0	0	7	F	0	0	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	1	0	0	0	0	0	0	0	0	0	0	0	-
				6,7	D#, D#	1	1	1	1	1	1	0	3 ²	3	0	0	0	7	F	0	0	0	-
		2	8-11	repeat Sub-Loop 0, use BG[1:0] ² = 0, BA[1:0] = 2 instead																			
		3	12-15	repeat Sub-Loop 1, 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 1, 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 1, 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 1, 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 1, 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 1, 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 1, use BG[1:0] ² = 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 Pattern¹

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] ^c	BG[1:0] ^b	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data ^d		
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	0	-
		3,4	D#, D#	1	1	1	1	1	1	1	0	3 ²	3	0	0	0	0	7	F	0	0	-
		5	WR	0	1	1	0	1	1	1	0	1	1	0	0	0	0	7	F	0	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	0	-
		8,9	D#, D#	1	1	1	1	1	1	1	0	3 ²	3	0	0	0	0	7	F	0	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 Pattern¹

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] ³	BG[1:0] ²	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data ⁴			
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	-
				3	D#, D#	1	1	1	1	1	0	0	3 ²	3	0	0	0	7	F	0	0	-	
				4	D#, D#	1	1	1	1	1	0	0	3 ²	3	0	0	0	7	F	0	0	-	
				4-7	repeat pattern 1...4, use BG[1:0] ² = 1, BA[1:0] = 1 instead																		
				8-11	repeat pattern 1...4, use BG[1:0] ² = 0, BA[1:0] = 2 instead																		
				12-15	repeat pattern 1...4, use BG[1:0] ² = 1, BA[1:0] = 3 instead																		
				16-19	repeat pattern 1...4, use BG[1:0] ² = 0, BA[1:0] = 1 instead																		
				20-23	repeat pattern 1...4, use BG[1:0] ² = 1, BA[1:0] = 2 instead																		
				24-27	repeat pattern 1...4, use BG[1:0] ² = 0, BA[1:0] = 3 instead																		
				28-31	repeat pattern 1...4, use BG[1:0] ² = 1, BA[1:0] = 0 instead																		
				32-35	repeat pattern 1...4, use BG[1:0] ² = 2, BA[1:0] = 0 instead																		
				36-39	repeat pattern 1...4, use BG[1:0] ² = 3, BA[1:0] = 1 instead																		
				40-43	repeat pattern 1...4, use BG[1:0] ² = 2, BA[1:0] = 2 instead																		
				44-47	repeat pattern 1...4, use BG[1:0] ² = 3, BA[1:0] = 3 instead																		
				48-51	repeat pattern 1...4, use BG[1:0] ² = 2, BA[1:0] = 1 instead																		
				52-55	repeat pattern 1...4, use BG[1:0] ² = 3, BA[1:0] = 2 instead																		
				56-59	repeat pattern 1...4, use BG[1:0] ² = 2, BA[1:0] = 3 instead																		
				60-63	repeat pattern 1...4, use BG[1:0] ² = 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 Pattern¹

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] ³	BG[1:0] ²	BA[1:0]	A12/BC_n	A[17,13,11]	A[10]/AP	A[9:7]	A[6:3]	A[2:0]	Data ⁴		
toggling	Static High	0	0	ACT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-		
		1	RDA	0	1	1	0	1	0	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 ²	3	3	0	0	0	7	F	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	0	1	1	0	0	1	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] ² = 0, BA[1:0] = 2 instead																		
		3	3*nRRD	repeat Sub-Loop 1, use BG[1:0] ² = 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] ² = 0, BA[1:0] = 1 instead																		
		6	nFAW + nRRD	repeat Sub-Loop 1, use BG[1:0] ² = 1, BA[1:0] = 2 instead																		
		7	nFAW + 2*nRRD	repeat Sub-Loop 0, use BG[1:0] ² = 0, BA[1:0] = 3 instead																		
		8	nFAW + 3*nRRD	repeat Sub-Loop 1, use BG[1:0] ² = 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] ² = 2, BA[1:0] = 0 instead																		
		11	2*nFAW + nRRD	repeat Sub-Loop 1, use BG[1:0] ² = 3, BA[1:0] = 1 instead																		
		12	2*nFAW + 2*nRRD	repeat Sub-Loop 0, use BG[1:0] ² = 2, BA[1:0] = 2 instead																		
		13	2*nFAW + 3*nRRD	repeat Sub-Loop 1, use BG[1:0] ² = 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] ² = 2, BA[1:0] = 1 instead																				
16	3*nFAW + nRRD	repeat Sub-Loop 1, use BG[1:0] ² = 3, BA[1:0] = 2 instead																				
17	3*nFAW + 2*nRRD	repeat Sub-Loop 0, use BG[1:0] ² = 2, BA[1:0] = 3 instead																				
18	3*nFAW + 3*nRRD	repeat Sub-Loop 1, use BG[1:0] ² = 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 (Tcase: 0 to 95°C)

2GB, 256M x 64 SO-DIMM: HMA425S6AFR6N

Symbol	2133		2400		unit	note
	IDD	IPP	IDD	IPP		
IDD0	164	12	176	12	mA	
IDD0A	164	12	180	12	mA	
IDD1	224	10	236	10	mA	
IDD1A	224	10	240	10	mA	
IDD2N	68	3	72	3	mA	
IDD2NA	76	3	84	3	mA	
IDD2NT	64	3	68	3	mA	
IDD2NL	68	3	76	3	mA	
IDD2NG	52	3	56	3	mA	
IDD2ND	72	3	76	3	mA	
IDD2NP	84	3	92	3	mA	
IDD2P	48	3	52	3	mA	
IDD2Q	68	3	72	3	mA	
IDD3N	136	5	148	5	mA	
IDD3NA	140	5	152	5	mA	
IDD3P	112	5	120	5	mA	
IDD4R	586	5	656	5	mA	
IDD4RA	597	5	668	5	mA	
IDD4RB	590	5	660	5	mA	
IDD4W	626	5	701	5	mA	
IDD4WA	643	5	720	5	mA	
IDD4WB	626	5	701	5	mA	
IDD4WC	559	5	626	5	mA	
IDD4WP	688	5	791	5	mA	
IDD5B	728	138	728	138	mA	
IDD5F2	800	141	800	142	mA	
IDD5F4	600	102	600	103	mA	
IDD6N	48	16	48	16	mA	
IDD6E	64	10	64	10	mA	
IDD6R	32	8	32	8	mA	
IDD6A	88	5	88	5	mA	
IDD7	724	57	752	57	mA	
IDD8	28	9	28	9	mA	

4GB, 512M x 64 SO-DIMM: HMA451S6AFR8N

Symbol	2133		2400		unit	note
	IDD	IPP	IDD	IPP		
IDD0	219	13	232	14	mA	
IDD0A	219	14	234	14	mA	
IDD1	264	11	282	11	mA	
IDD1A	267	11	286	11	mA	
IDD2N	109	5	117	5	mA	
IDD2NA	154	6	169	6	mA	
IDD2NT	142	5	156	5	mA	
IDD2NL	73	5	80	5	mA	
IDD2NG	113	5	122	5	mA	
IDD2ND	103	5	109	5	mA	
IDD2NP	109	5	117	5	mA	
IDD2P	72	5	79	5	mA	
IDD2Q	106	5	114	5	mA	
IDD3N	197	7	213	7	mA	
IDD3NA	197	7	213	7	mA	
IDD3P	144	7	156	7	mA	
IDD4R	663	7	742	7	mA	
IDD4RA	679	7	760	7	mA	
IDD4RB	667	7	747	7	mA	
IDD4W	712	7	798	7	mA	
IDD4WA	732	7	820	7	mA	
IDD4WB	712	7	798	7	mA	
IDD4WC	632	7	708	7	mA	
IDD4WP	712	7	798	7	mA	
IDD5B	1457	254	1457	254	mA	
IDD5F2	1597	282	1597	284	mA	
IDD5F4	1202	203	1202	205	mA	
IDD6N	77	13	77	13	mA	
IDD6E	97	15	97	15	mA	
IDD6R	61	10	61	10	mA	
IDD6A	107	20	107	20	mA	
IDD7	963	77	991	77	mA	
IDD8	30	14	30	14	mA	

4GB, 512M x 72 SO-DIMM: HMA451S7AFR8N

Symbol	2133		2400		unit	note
	IDD	IPP	IDD	IPP		
IDD0	261	15	274	16	mA	
IDD0A	264	15	276	16	mA	
IDD1	317	12	329	13	mA	
IDD1A	321	12	336	13	mA	
IDD2N	132	6	143	6	mA	
IDD2NA	190	7	199	7	mA	
IDD2NT	175	6	188	6	mA	
IDD2NL	90	6	93	6	mA	
IDD2NG	137	6	146	6	mA	
IDD2ND	123	6	133	6	mA	
IDD2NP	132	6	143	6	mA	
IDD2P	89	6	93	6	mA	
IDD2Q	128	6	131	6	mA	
IDD3N	239	8	255	8	mA	
IDD3NA	240	8	255	8	mA	
IDD3P	176	8	182	8	mA	
IDD4R	835	8	909	8	mA	
IDD4RA	855	8	932	8	mA	
IDD4RB	841	8	916	8	mA	
IDD4W	898	8	986	8	mA	
IDD4WA	922	8	1013	8	mA	
IDD4WB	898	8	986	8	mA	
IDD4WC	796	8	867	8	mA	
IDD4WP	898	8	986	8	mA	
IDD5B	1639	286	1639	286	mA	
IDD5F2	1797	317	1797	320	mA	
IDD5F4	1352	229	1352	231	mA	
IDD6N	86	15	86	15	mA	
IDD6E	109	16	109	16	mA	
IDD6R	68	11	68	11	mA	
IDD6A	120	22	120	22	mA	
IDD7	1115	87	1159	87	mA	
IDD8	34	16	34	16	mA	

8GB, 1G x 64 SO-DIMM: HMA41GS6AFR8N

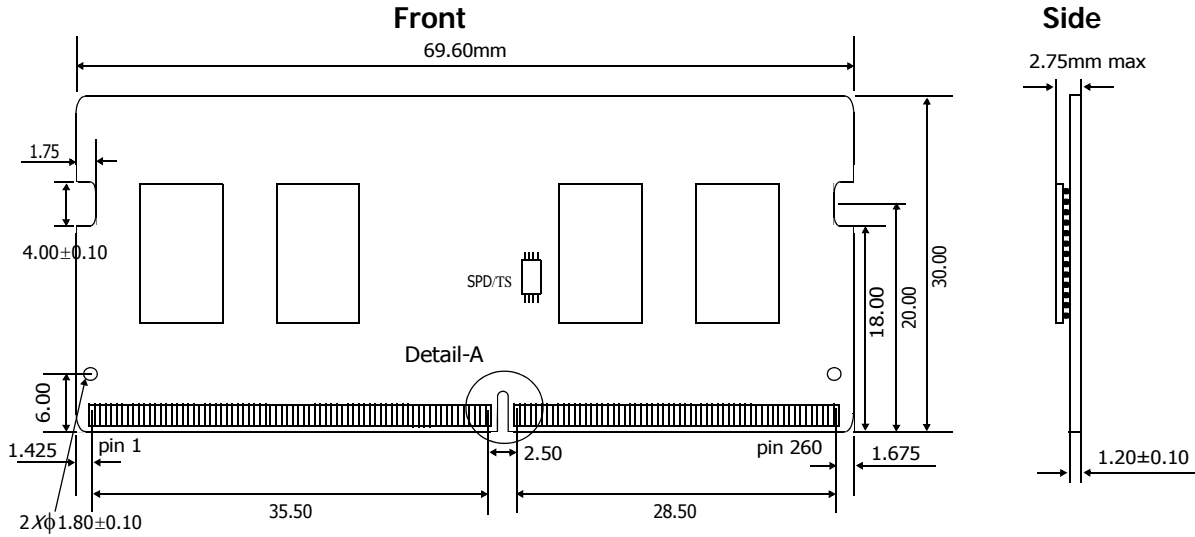
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	IDD	IPP	IDD	IPP		
IDD0	329	19	350	19	mA	
IDD0A	373	19	403	20	mA	
IDD1	373	16	399	17	mA	
IDD1A	421	17	455	17	mA	
IDD2N	219	11	234	11	mA	
IDD2NA	307	12	338	12	mA	
IDD2NT	283	11	312	11	mA	
IDD2NL	146	11	160	11	mA	
IDD2NG	226	11	244	11	mA	
IDD2ND	206	11	218	11	mA	
IDD2NP	219	11	234	11	mA	
IDD2P	143	11	158	11	mA	
IDD2Q	212	11	227	11	mA	
IDD3N	394	14	426	14	mA	
IDD3NA	395	14	426	14	mA	
IDD3P	289	14	312	15	mA	
IDD4R	772	12	859	12	mA	
IDD4RA	832	13	929	13	mA	
IDD4RB	777	12	864	12	mA	
IDD4W	822	12	915	13	mA	
IDD4WA	886	13	989	13	mA	
IDD4WB	822	12	915	12	mA	
IDD4WC	741	12	825	12	mA	
IDD4WP	822	12	915	13	mA	
IDD5B	1566	259	1574	259	mA	
IDD5F2	1707	287	1715	290	mA	
IDD5F4	1311	209	1319	211	mA	
IDD6N	153	26	153	26	mA	
IDD6E	193	29	193	29	mA	
IDD6R	122	19	122	19	mA	
IDD6A	213	40	213	40	mA	
IDD7	1072	83	1109	83	mA	
IDD8	60	28	60	28	mA	

8GB, 1G x 72 SO-DIMM: HMA1GS7AFR8N

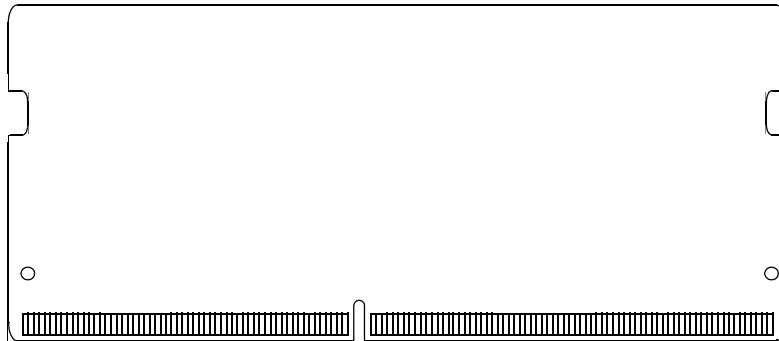
Symbol	2133		2400		unit	note
	IDD	IPP	IDD	IPP		
IDD0	370	21	393	22	mA	
IDD0A	419	22	454	23	mA	
IDD1	420	18	449	19	mA	
IDD1A	473	19	512	19	mA	
IDD2N	246	12	264	12	mA	
IDD2NA	346	13	380	13	mA	
IDD2NT	319	12	351	12	mA	
IDD2NL	165	12	180	12	mA	
IDD2NG	254	12	274	12	mA	
IDD2ND	231	12	245	12	mA	
IDD2NP	246	12	264	12	mA	
IDD2P	161	12	177	12	mA	
IDD2Q	239	12	256	12	mA	
IDD3N	443	16	479	16	mA	
IDD3NA	444	16	479	16	mA	
IDD3P	325	16	351	16	mA	
IDD4R	869	14	967	14	mA	
IDD4RA	936	15	1045	15	mA	
IDD4RB	874	14	972	14	mA	
IDD4W	925	14	1029	14	mA	
IDD4WA	996	15	1112	15	mA	
IDD4WB	925	14	1030	14	mA	
IDD4WC	834	14	928	14	mA	
IDD4WP	925	14	1030	14	mA	
IDD5B	1762	292	1770	292	mA	
IDD5F2	1920	323	1929	326	mA	
IDD5F4	1475	235	1484	237	mA	
IDD6N	172	30	172	30	mA	
IDD6E	217	33	217	33	mA	
IDD6R	137	22	137	22	mA	
IDD6A	240	45	240	45	mA	
IDD7	1206	93	1247	93	mA	
IDD8	68	32	68	32	mA	

Module Dimensions

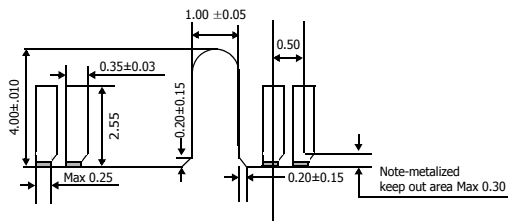
256Mx64 - HMA425S6AFR6N



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Detail - A

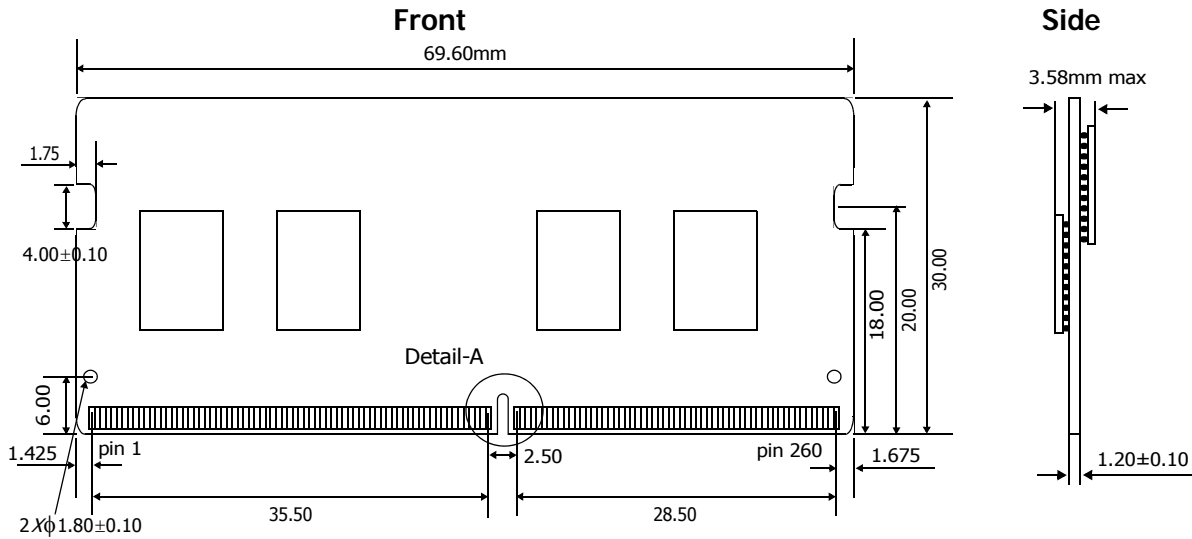


Note:

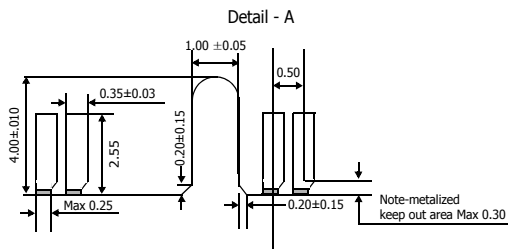
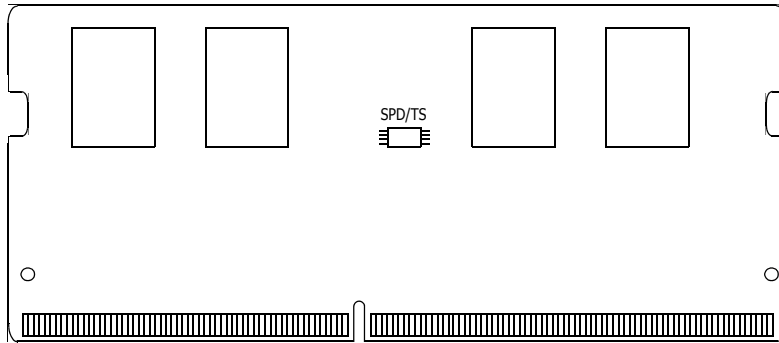
1. ±0.13 tolerance on all dimensions unless otherwise stated.

Units: millimeters

512Mx64 - HMA451S6AFR8N-TF



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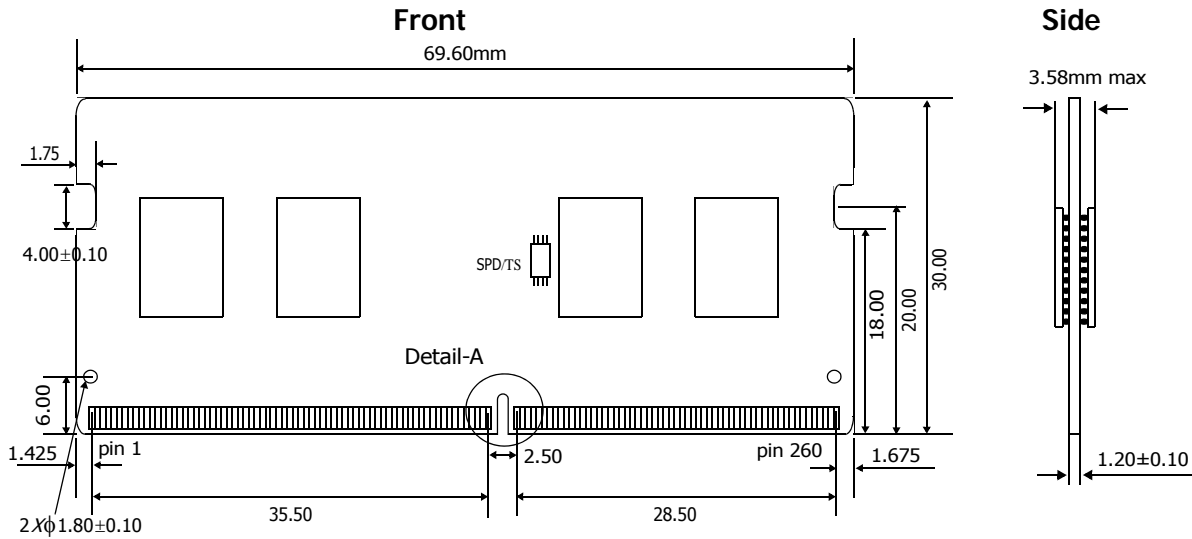


Note:

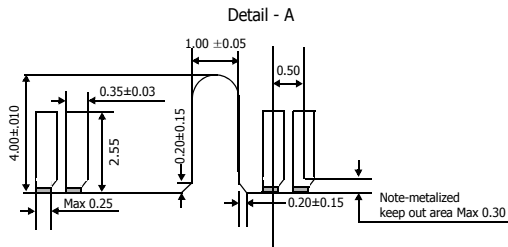
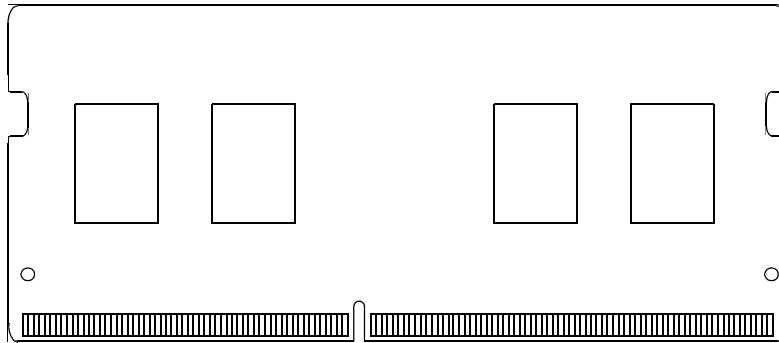
1. ±0.13 tolerance on all dimensions unless otherwise stated.

Units: millimeters

512Mx64 - HMA451S6AFR8N-UH



Back

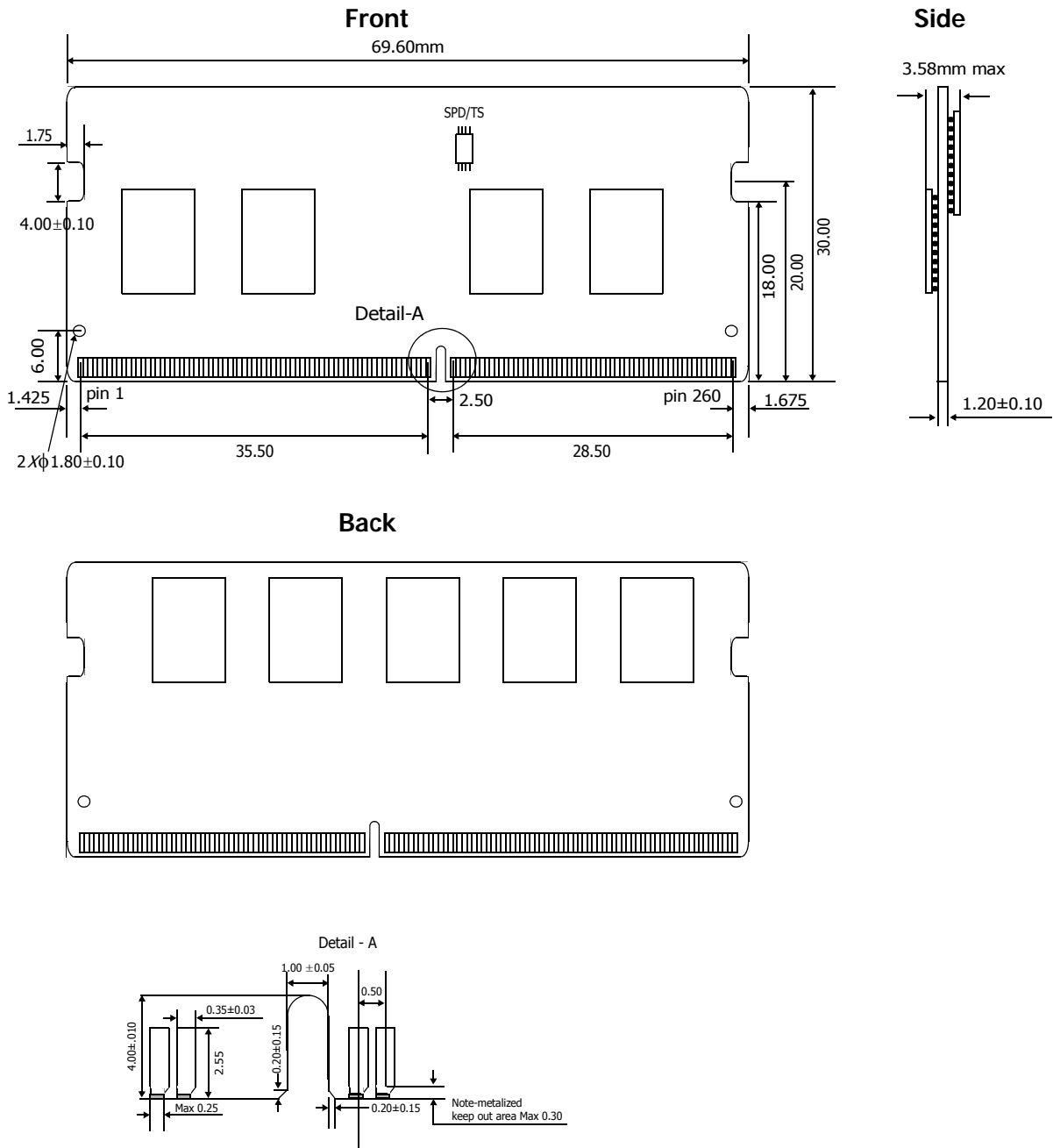


Note:

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

Units: millimeters

512Mx72 - HMA451S7AFR8N-TF

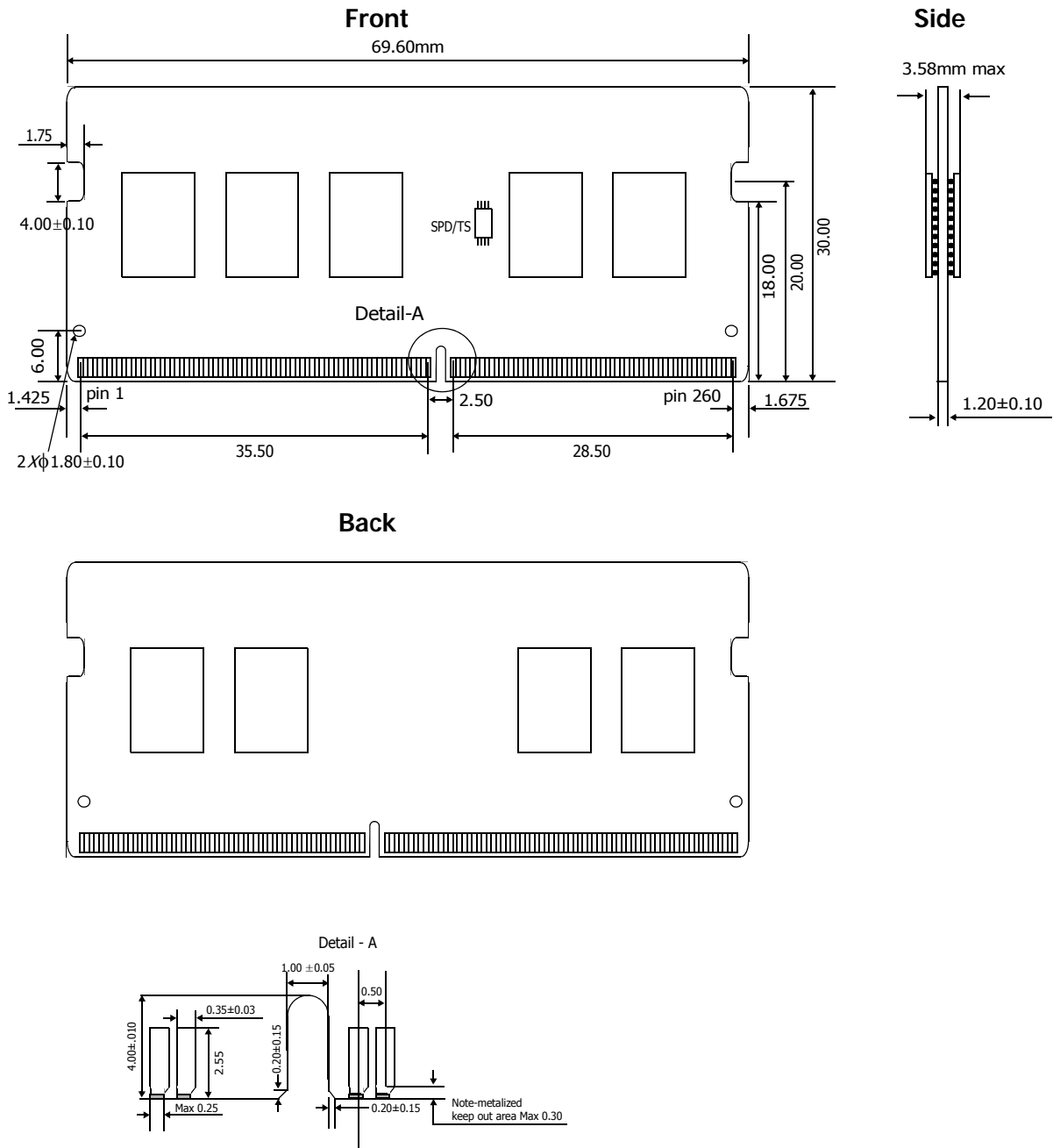


Note:

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

Units: millimeters

512Mx72 - HMA451S7AFR8N-UH

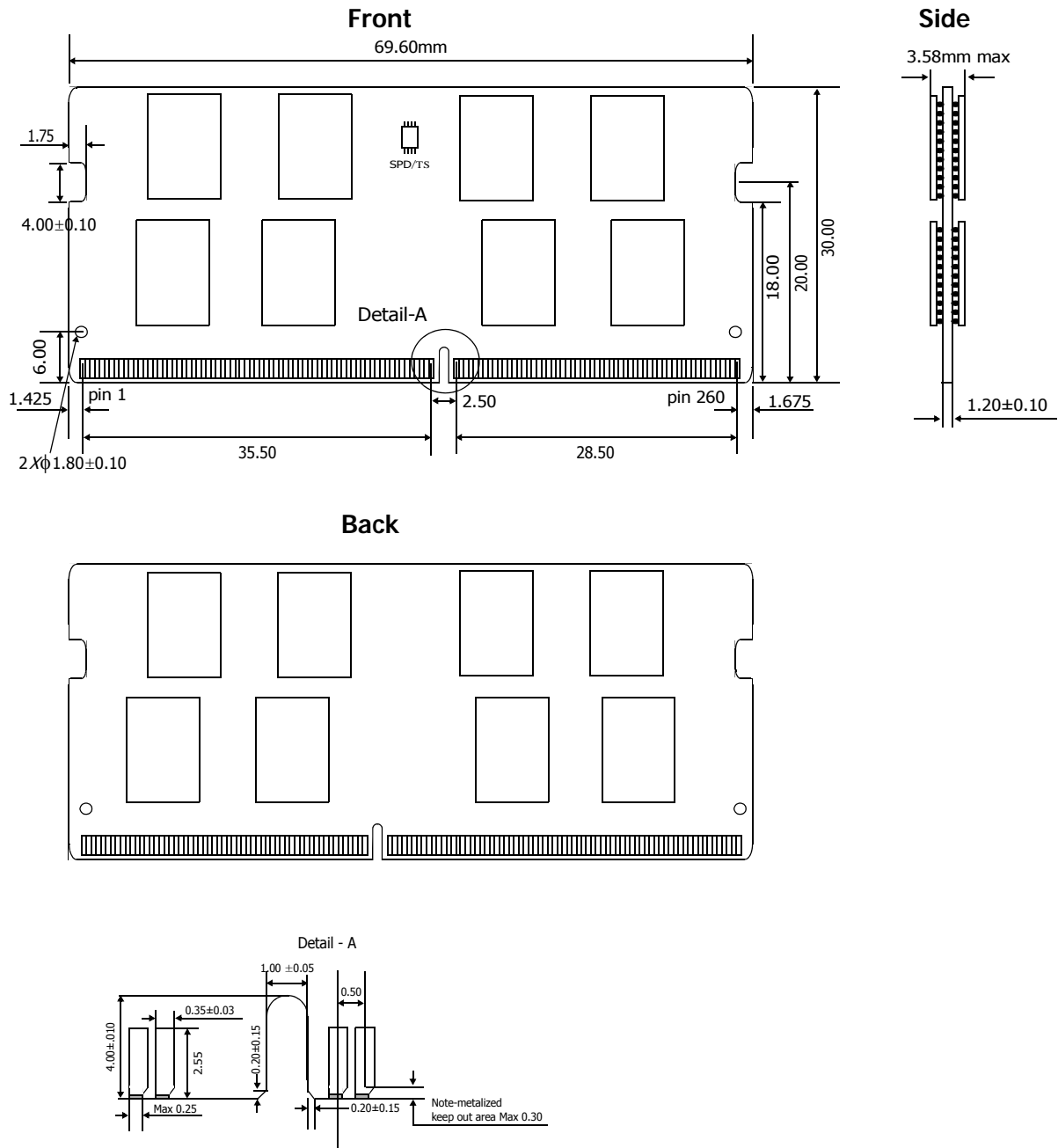


Note:

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

Units: millimeters

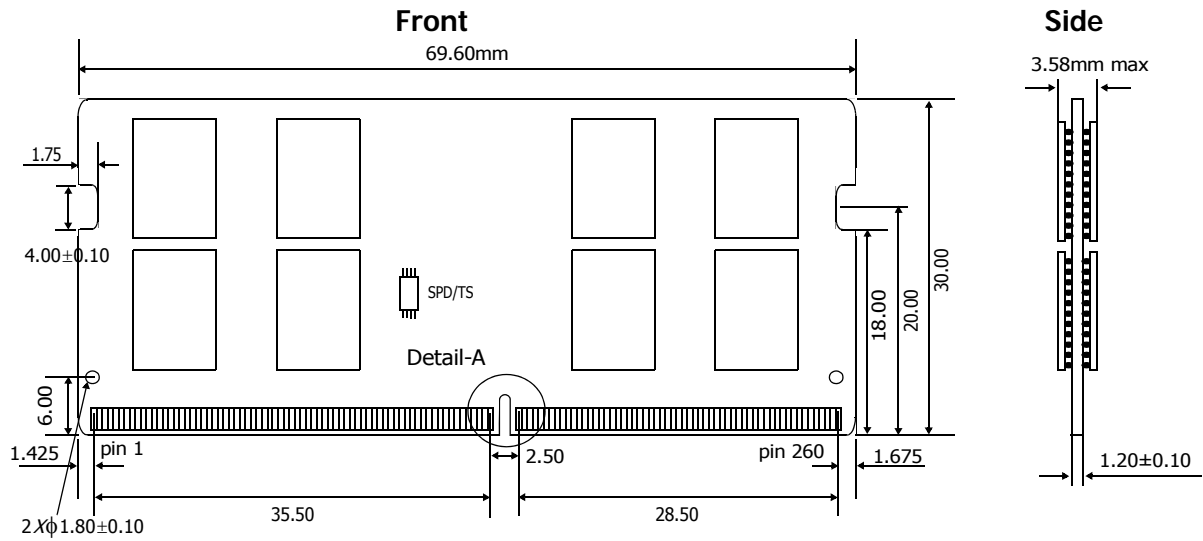
1Gx64 - HMA41GS6AFR8N-TF



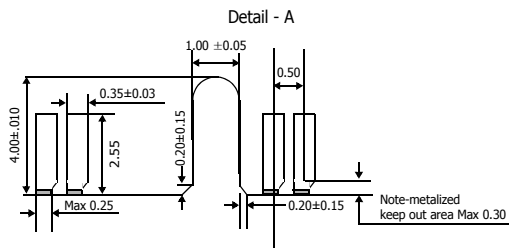
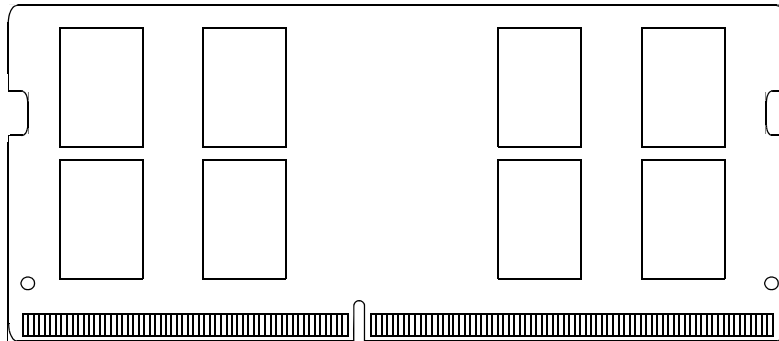
Note:
 1. ±0.13 tolerance on all dimensions unless otherwise stated.

Units: millimeters

1Gx64 - HMA41GS6AFR8N-UH



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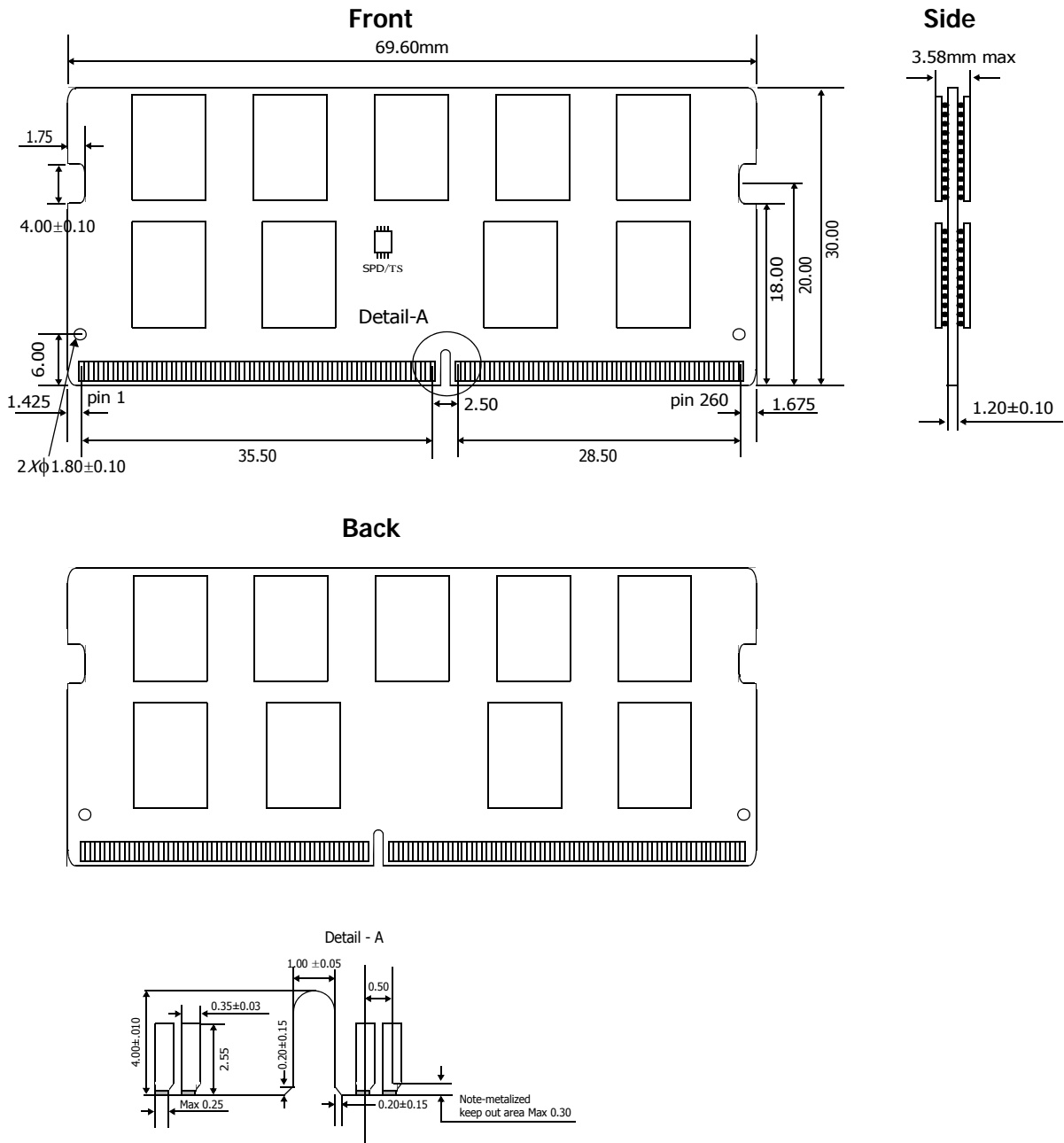


Note:

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

Units: millimeters

1Gx72 - HMA41GS7AFR8N-TF

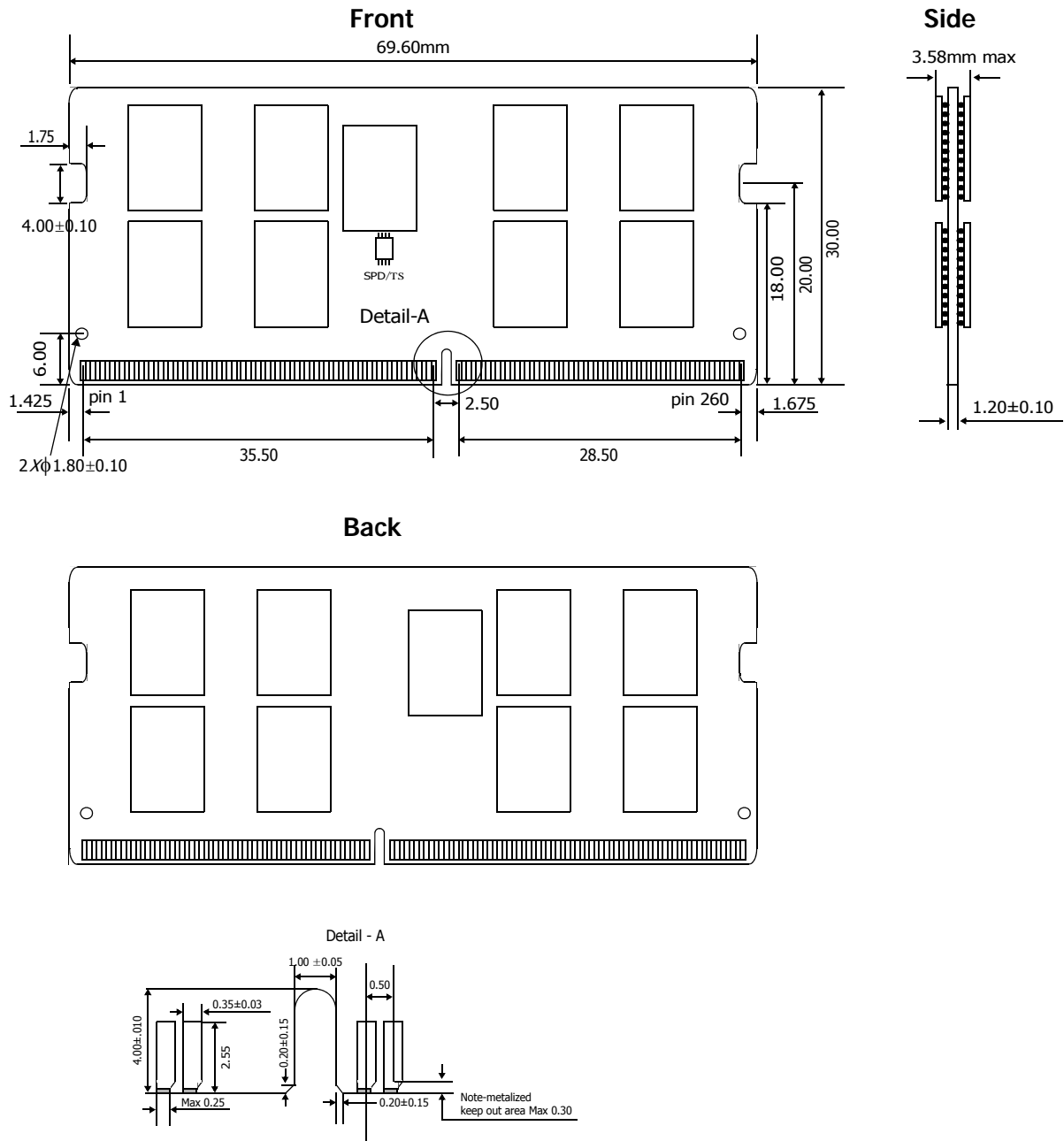


Note:

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

Units: millimeters

1Gx72 - HMA41GS7AFR8N-UH



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

Units: millimeters