

# DDR4 SDRAM UDIMM

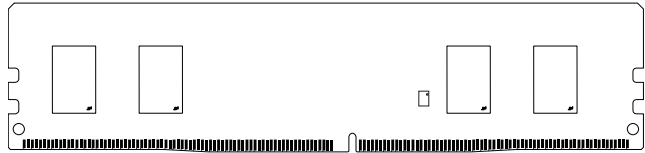
## MTA4ATF51264AZ – 4GB

### Features

- DDR4 functionality and operations supported as defined in the component data sheet
- 288-pin, unbuffered dual in-line memory module (UDIMM)
- Fast data transfer rates: PC4-3200, PC4-2666, or PC4-2400
- 4GB (512 Meg x 64)
- $V_{DD} = 1.20V$  (NOM)
- $V_{PP} = 2.5V$  (NOM)
- $V_{DDSPD} = 2.5V$  (NOM)
- Nominal and dynamic on-die termination (ODT) for data, strobe, and mask signals
- Low-power auto self refresh (LPASR)
- Data bus inversion (DBI) for data bus
- On-die  $V_{REFDQ}$  generation and calibration
- Single-rank
- On-board I<sup>2</sup>C serial presence-detect (SPD) EEPROM
- 8 internal banks; 2 groups of 4 banks each
- Fixed burst chop (BC) of 4 and burst length (BL) of 8 via the mode register set (MRS)
- Selectable BC4 or BL8 on-the-fly (OTF)
- Gold edge contacts
- Halogen-free
- Fly-by topology
- Terminated control command and address bus

**Figure 1: 288-Pin UDIMM (MO-309 R/C C)**

Module height: 31.25mm (1.23in)



### Options

- Operating temperature
  - Commercial ( $0^{\circ}C \leq T_{OPER} \leq 95^{\circ}C$ )
- Package
  - 288-pin DIMM (halogen-free)
- Frequency/CAS latency
  - 0.62ns @ CL = 22 (DDR4-3200)
  - 0.75ns @ CL = 19 (DDR4-2666)
  - 0.83ns @ CL = 17 (DDR4-2400)

### Marking

None  
Z  
-3G2  
-2G6  
-2G3

**Table 1: Key Timing Parameters**

Speed Grade	PC4-	Data Rate (MT/s)									$t_{RCD}$ (ns)	$t_{RP}$ (ns)	$t_{RC}$ (ns)
		CL =											
		24	22	21	20 \ 19	18 \ 17	16 \ 15	14 \ 13	12 \ 11	10 \ 9			
-3G2	3200	3200, 2933	3200, 2933	2933	2666 \ 2666	2400 \ 2400	2133 \ 2133	1866 \ 1866	1600 \ 1600	1333 \ -	13.75	13.75	45.75
-2G9	2933	-	2933	2933	2666 \ 2666	2400 \ 2400	2133 \ 2133	1866 \ 1866	1600 \ 1600	1333 \ -	14.32 (13.75) <sup>1</sup>	14.32 (13.75) <sup>1</sup>	46.32 (45.75) <sup>1</sup>
-2G6	2666	-	-	-	2666 \ 2666	2400 \ 2400	2133 \ 2133	1866 \ 1866	1600 \ 1600	1333 \ -	14.25 (13.75) <sup>1</sup>	14.25 (13.75) <sup>1</sup>	46.25 (45.75) <sup>1</sup>
-2G3	2400	-	-	-	-	2400 \ 2400	2133 \ 2133	1866 \ 1866	1600 \ 1600	1333 \ -	14.16 (13.75) <sup>1</sup>	14.16 (13.75) <sup>1</sup>	46.16 (45.75) <sup>1</sup>

**Table 1: Key Timing Parameters (Continued)**

Speed Grade	PC4-	Data Rate (MT/s)									<sup>t</sup> RCD (ns)	<sup>t</sup> RP (ns)	<sup>t</sup> RC (ns)
		CL =											
		24	22	21	20 \ 19	18 \ 17	16 \ 15	14 \ 13	12 \ 11	10 \ 9			
-2G1	2133	-	-	-	-	-	2133 \ 2133	1866 \ 1866	1600 \ 1600	1333 \ 1333	14.06 (13.5) <sup>1</sup>	14.06 (13.5) <sup>1</sup>	47.06 (46.5) <sup>1</sup>

Note: 1. Down-bin timing, refer to component data sheet Speed Bin Tables for details.

**Table 2: Addressing**

Parameter	4GB
Row address	64K A[15:0]
Column address	1K A[9:0]
Device bank group address	2 BG0
Device bank address per group	4 BA[1:0]
Device configuration	8Gb (512 Meg x 16), 8 banks
Module rank address	CS0_n

**Table 3: Part Numbers and Timing Parameters – 4GB Modules**

Base device: MT40A512M16,<sup>1</sup> 8Gb DDR4 SDRAM

Part Number <sup>2</sup>	Module Density	Configuration	Module Bandwidth	Memory Clock/Data Rate	Clock Cycles (CL- <sup>t</sup> RCD- <sup>t</sup> RP)
MTA4ATF51264AZ-3G2__	4GB	512 Meg x 64	25.6 GB/s	0.62ns/3200 MT/s	22-22-22
MTA4ATF51264AZ-2G6__	4GB	512 Meg x 64	21.3 GB/s	0.75ns/2666 MT/s	19-19-19
MTA4ATF51264AZ-2G3__	4GB	512 Meg x 64	19.2 GB/s	0.83ns/2400 MT/s	17-17-17

- Notes: 1. The data sheet for the base device can be found on [micron.com](http://micron.com).  
 2. All part numbers end with a two-place code (not shown) that designates component and PCB revisions. Consult factory for current revision codes. Example: [MTA4ATF51264AZ-3G2J1](#).

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## Pin Assignments

The pin assignment table below is a comprehensive list of all possible pin assignments for DDR4 UDIMM modules. See Functional Block Diagram for pins specific to this module.

**Table 4: Pin Assignments**

288-Pin DDR4 UDIMM Front								288-Pin DDR4 UDIMM Back							
Pin	Symbol	Pin	Symbol	Pin	Symbol	Pin	Symbol	Pin	Symbol	Pin	Symbol	Pin	Symbol	Pin	Symbol
1	NC	37	V <sub>SS</sub>	73	V <sub>DD</sub>	109	V <sub>SS</sub>	145	NC	181	DQ29	217	V <sub>DD</sub>	253	DQ41
2	V <sub>SS</sub>	38	DQ24	74	CK0_t	110	DM5_n/ DBI5_n, NC	146	V <sub>REFCA</sub>	182	V <sub>SS</sub>	218	CK1_t	254	V <sub>SS</sub>
3	DQ4	39	V <sub>SS</sub>	75	CK0_c	111	NC	147	V <sub>SS</sub>	183	DQ25	219	CK1_c	255	DQS5_c
4	V <sub>SS</sub>	40	DM3_n/ DBI3_n, NC	76	V <sub>DD</sub>	112	V <sub>SS</sub>	148	DQ5	184	V <sub>SS</sub>	220	V <sub>DD</sub>	256	DQS5_t
5	DQ0	41	NC	77	V <sub>TT</sub>	113	DQ46	149	V <sub>SS</sub>	185	DQS3_c	221	V <sub>TT</sub>	257	V <sub>SS</sub>
6	V <sub>SS</sub>	42	V <sub>SS</sub>	78	EVENT_n, NF	114	V <sub>SS</sub>	150	DQ1	186	DQS3_t	222	PARITY	258	DQ47
7	DM0_n/ DBI0_n, NC	43	DQ30	79	A0	115	DQ42	151	V <sub>SS</sub>	187	V <sub>SS</sub>	223	V <sub>DD</sub>	259	V <sub>SS</sub>
8	NC	44	V <sub>SS</sub>	80	V <sub>DD</sub>	116	V <sub>SS</sub>	152	DQS0_c	188	DQ31	224	BA1	260	DQ43
9	V <sub>SS</sub>	45	DQ26	81	BA0	117	DQ52	153	DQS0_t	189	V <sub>SS</sub>	225	A10_AP	261	V <sub>SS</sub>
10	DQ6	46	V <sub>SS</sub>	82	RAS_n/ A16	118	V <sub>SS</sub>	154	V <sub>SS</sub>	190	DQ27	226	V <sub>DD</sub>	262	DQ53
11	V <sub>SS</sub>	47	CB4/ NC	83	V <sub>DD</sub>	119	DQ48	155	DQ7	191	V <sub>SS</sub>	227	NC	263	V <sub>SS</sub>
12	DQ2	48	V <sub>SS</sub>	84	CS0_n	120	V <sub>SS</sub>	156	V <sub>SS</sub>	192	CB5, NC	228	WE_n/ A14	264	DQ49
13	V <sub>SS</sub>	49	CB0/ NC	85	V <sub>DD</sub>	121	DM6_n/ DBI6_n, NC	157	DQ3	193	V <sub>SS</sub>	229	V <sub>DD</sub>	265	V <sub>SS</sub>
14	DQ12	50	V <sub>SS</sub>	86	CAS_n/ A15	122	NC	158	V <sub>SS</sub>	194	CB1, NC	230	NC	266	DQS6_c
15	V <sub>SS</sub>	51	DM8_n/ DBI8_n, NC	87	ODT0	123	V <sub>SS</sub>	159	DQ13	195	V <sub>SS</sub>	231	V <sub>DD</sub>	267	DQS6_t
16	DQ8	52	NC	88	V <sub>DD</sub>	124	DQ54	160	V <sub>SS</sub>	196	DQS8_c	232	A13	268	V <sub>SS</sub>
17	V <sub>SS</sub>	53	V <sub>SS</sub>	89	CS1_n, NC	125	V <sub>SS</sub>	161	DQ9	197	DQS8_t	233	V <sub>DD</sub>	269	DQ55
18	DMI_n/ DBI1_n, NC	54	CB6/ DBI8_n, NC	90	V <sub>DD</sub>	126	DQ50	162	V <sub>SS</sub>	198	V <sub>SS</sub>	234	NC	270	V <sub>SS</sub>
19	NC	55	V <sub>SS</sub>	91	ODT1, NC	127	V <sub>SS</sub>	163	DQS1_c	199	CB7, NC	235	NC	271	DQ51
20	V <sub>SS</sub>	56	CB2/ NC	92	V <sub>DD</sub>	128	DQ60	164	DQS1_t	200	V <sub>SS</sub>	236	V <sub>DD</sub>	272	V <sub>SS</sub>
21	DQ14	57	V <sub>SS</sub>	93	NC	129	V <sub>SS</sub>	165	V <sub>SS</sub>	201	CB3, NC	237	NC	273	DQ61
22	V <sub>SS</sub>	58	RESET_n	94	V <sub>SS</sub>	130	DQ56	166	DQ15	202	V <sub>SS</sub>	238	SA2	274	V <sub>SS</sub>
23	DQ10	59	V <sub>DD</sub>	95	DQ36	131	V <sub>SS</sub>	167	V <sub>SS</sub>	203	CKE1, NC	239	V <sub>SS</sub>	275	DQ57



## 4GB (x64, SR) 288-Pin DDR4 UDIMM Pin Assignments

**Table 4: Pin Assignments (Continued)**

288-Pin DDR4 UDIMM Front								288-Pin DDR4 UDIMM Back							
Pin	Symbol	Pin	Symbol	Pin	Symbol	Pin	Symbol	Pin	Symbol	Pin	Symbol	Pin	Symbol	Pin	Symbol
24	V <sub>SS</sub>	60	CKE0	96	V <sub>SS</sub>	132	DM7_n/ DBI7_n, NC	168	DQ11	204	V <sub>DD</sub>	240	DQ37	276	V <sub>SS</sub>
25	DQ20	61	V <sub>DD</sub>	97	DQ32	133	NC	169	V <sub>SS</sub>	205	NC	241	V <sub>SS</sub>	277	DQS7_c
26	V <sub>SS</sub>	62	ACT_n	98	V <sub>SS</sub>	134	V <sub>SS</sub>	170	DQ21	206	V <sub>DD</sub>	242	DQ33	278	DQS7_t
27	DQ16	63	BG0	99	DM4_n/ DBI4_n, NC	135	DQ62	171	V <sub>SS</sub>	207	BG1	243	V <sub>SS</sub>	279	V <sub>SS</sub>
28	V <sub>SS</sub>	64	V <sub>DD</sub>	100	NC	136	V <sub>SS</sub>	172	DQ17	208	ALERT_n	244	DQS4_c	280	DQ63
29	DM2_n/ DBI2_n, NC	65	A12/BC_n	101	V <sub>SS</sub>	137	DQ58	173	V <sub>SS</sub>	209	V <sub>DD</sub>	245	DQS4_t	281	V <sub>SS</sub>
30	NC	66	A9	102	DQ38	138	V <sub>SS</sub>	174	DQS2_c	210	A11	246	V <sub>SS</sub>	282	DQ59
31	V <sub>SS</sub>	67	V <sub>DD</sub>	103	V <sub>SS</sub>	139	SA0	175	DQS2_t	211	A7	247	DQ39	283	V <sub>SS</sub>
32	DQ22	68	A8	104	DQ34	140	SA1	176	V <sub>SS</sub>	212	V <sub>DD</sub>	248	V <sub>SS</sub>	284	V <sub>DDSPD</sub>
33	V <sub>SS</sub>	69	A6	105	V <sub>SS</sub>	141	SCL	177	DQ23	213	A5	249	DQ35	285	SDA
34	DQ18	70	V <sub>DD</sub>	106	DQ44	142	V <sub>PP</sub>	178	V <sub>SS</sub>	214	A4	250	V <sub>SS</sub>	286	V <sub>PP</sub>
35	V <sub>SS</sub>	71	A3	107	V <sub>SS</sub>	143	V <sub>PP</sub>	179	DQ19	215	V <sub>DD</sub>	251	DQ45	287	V <sub>PP</sub>
36	DQ28	72	A1	108	DQ40	144	NC	180	V <sub>SS</sub>	216	A2	252	V <sub>SS</sub>	288	V <sub>PP</sub>

## Pin Descriptions

The pin description table below is a comprehensive list of all possible pins for DDR4 modules. All pins listed may not be supported on this module. See Functional Block Diagram for pins specific to this module.

**Table 5: Pin Descriptions**

Symbol	Type	Description
Ax	Input	<b>Address inputs:</b> Provide the row address for ACTIVATE commands and the column address for READ/WRITE commands in order to select one location out of the memory array in the respective bank (A10/AP, A12/BC_n, WE_n/A14, CAS_n/A15, and RAS_n/A16 have additional functions; see individual entries in this table). The address inputs also provide the op-code during the MODE REGISTER SET command. A17 is only defined for x4 SDRAM.
A10/AP	Input	<b>Auto precharge:</b> A10 is sampled during READ and WRITE commands to determine whether an auto precharge should be performed on the accessed bank after a READ or WRITE operation (HIGH = auto precharge; LOW = no auto precharge). 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 the bank group and bank addresses.
A12/BC_n	Input	<b>Burst chop:</b> 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 in the DDR4 component data sheet.
ACT_n	Input	<b>Command input:</b> ACT_n defines the ACTIVATE command being entered along with CS_n. The input into RAS_n/A16, CAS_n/A15, and WE_n/A14 are considered as row address A16, A15, and A14. See Command Truth Table.
BAx	Input	<b>Bank address inputs:</b> Define the bank (with a bank group) to which an ACTIVATE, READ, WRITE, or PRECHARGE command is being applied. Also determine which mode register is to be accessed during a MODE REGISTER SET command.
BGx	Input	<b>Bank group address inputs:</b> Define the bank group to which a REFRESH, ACTIVATE, READ, WRITE, or PRECHARGE command is being applied. Also determine which mode register is to be accessed during a MODE REGISTER SET command. BG[1:0] are used in the x4 and x8 configurations. x16-based SDRAM only has BG0.
C0, C1, C2 (RDIMM/LRDIMM only)	Input	<b>Chip ID:</b> These inputs are used only when devices are stacked; that is, 2H, 4H, and 8H stacks for x4 and x8 configurations using through-silicon vias (TSVs). These pins are not used in the x16 configuration. Some DDR4 modules support a traditional DDP package, which uses CS1_n, CKE1, and ODT1 to control the second die. All other stack configurations, such as a 4H or 8H, are assumed to be single-load (master/slave) type configurations where C0, C1, and C2 are used as chip ID selects in conjunction with a single CS_n, CKE, and ODT. Chip ID is considered part of the command code.
CKx_t CKx_c	Input	<b>Clock:</b> Differential clock inputs. All address, command, and control input signals are sampled on the crossing of the positive edge of CK_t and the negative edge of CK_c.
CKEx	Input	<b>Clock enable:</b> CKE HIGH activates and CKE LOW deactivates the internal clock signals, device input buffers, and output drivers. Taking CKE LOW provides PRECHARGE POWER-DOWN and SELF REFRESH operations (all banks idle), or active power-down (row active in any bank). CKE is asynchronous for self refresh exit. After V <sub>REFCA</sub> has become stable during the power-on and initialization sequence, it 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, RESET_n, and CKE) are disabled during power-down. Input buffers (excluding CKE and RESET_n) are disabled during self refresh.
CSx_n	Input	<b>Chip select:</b> All commands are masked when CS_n is registered HIGH. CS_n provides external rank selection on systems with multiple ranks. CS_n is considered part of the command code (CS2_n and CS3_n are not used on UDIMMs).

**Table 5: Pin Descriptions (Continued)**

Symbol	Type	Description
ODTx	Input	<b>On-die termination:</b> ODT (registered HIGH) enables termination resistance internal to the DDR4 SDRAM. When enabled, ODT ( $R_{TT}$ ) is applied only to each DQ, DQS <sub>t</sub> , DQS <sub>c</sub> , DM <sub>n</sub> /DBI <sub>n</sub> /TDQS <sub>t</sub> , and TDQS <sub>c</sub> signal for x4 and x8 configurations (when the TDQS function is enabled via the mode register). For the x16 configuration, $R_{TT}$ is applied to each DQ, DQSU <sub>t</sub> , DQSU <sub>c</sub> , DQSL <sub>t</sub> , DQSL <sub>c</sub> , UDM <sub>n</sub> , and LDM <sub>n</sub> signal. The ODT pin will be ignored if the mode registers are programmed to disable $R_{TT}$ .
PARITY	Input	<b>Parity for command and address:</b> This function can be enabled or disabled via the mode register. When enabled in MR5, the DRAM calculates parity with ACT <sub>n</sub> , RAS <sub>n</sub> /A16, CAS <sub>n</sub> /A15, WE <sub>n</sub> /A14, BG[1:0], BA[1:0], A[16:0]. Input parity should be maintained at the rising edge of the clock and at the same time as command and address with CS <sub>n</sub> LOW.
RAS <sub>n</sub> /A16 CAS <sub>n</sub> /A15 WE <sub>n</sub> /A14	Input	<b>Command inputs:</b> RAS <sub>n</sub> /A16, CAS <sub>n</sub> /A15, and WE <sub>n</sub> /A14 (along with CS <sub>n</sub> ) define the command and/or address being entered and have multiple functions. For example, for activation with ACT <sub>n</sub> LOW, these are addresses like A16, A15, and A14, but for a non-activation command with ACT <sub>n</sub> HIGH, these are command pins for READ, WRITE, and other commands defined in Command Truth Table.
RESET <sub>n</sub>	CMOS Input	<b>Active LOW asynchronous reset:</b> Reset is active when RESET <sub>n</sub> is LOW and inactive when RESET <sub>n</sub> is HIGH. RESET <sub>n</sub> must be HIGH during normal operation.
SAX	Input	<b>Serial address inputs:</b> Used to configure the temperature sensor/SPD EEPROM address range on the I <sup>2</sup> C bus.
SCL	Input	<b>Serial clock for temperature sensor/SPD EEPROM:</b> Used to synchronize communication to and from the temperature sensor/SPD EEPROM on the I <sup>2</sup> C bus.
DQx, CBx	I/O	<b>Data input/output and check bit input/output:</b> Bidirectional data bus. DQ represents DQ[3:0], DQ[7:0], and DQ[15:0] for the x4, x8, and x16 configurations, respectively. If cyclic redundancy checksum (CRC) is enabled via the mode register, the CRC code is added at the end of the data burst. Any one or all of DQ0, DQ1, DQ2, or DQ3 may be used for monitoring of internal $V_{REF}$ level during test via mode register setting MR[4] A[4] = HIGH; training times change when enabled.
DM <sub>n</sub> /DBI <sub>n</sub> / TDQS <sub>t</sub> (DMU <sub>n</sub> , DBIU <sub>n</sub> ), (DML <sub>n</sub> / DBII <sub>n</sub> )	I/O	<b>Input data mask and data bus inversion:</b> DM <sub>n</sub> is an input mask signal for write data. Input data is masked when DM <sub>n</sub> is sampled LOW coincident with that input data during a write access. DM <sub>n</sub> is sampled on both edges of DQS. DM is multiplexed with the DBI function by the mode register A10, A11, and A12 settings in MR5. For a x8 device, the function of DM or TDQS is enabled by the mode register A11 setting in MR1. DBI <sub>n</sub> is an input/output identifying whether to store/output the true or inverted data. If DBI <sub>n</sub> is LOW, the data will be stored/output after inversion inside the DDR4 device and not inverted if DBI <sub>n</sub> is HIGH. TDQS is only supported in x8 SDRAM configurations (TDQS is not valid for UDIMMs).
SDA	I/O	<b>Serial Data:</b> Bidirectional signal used to transfer data in or out of the EEPROM or EEPROM/TS combo device.
DQS <sub>t</sub> DQS <sub>c</sub> DQSU <sub>t</sub> DQSU <sub>c</sub> DQSL <sub>t</sub> DQSL <sub>c</sub>	I/O	<b>Data strobe:</b> Output with read data, input with write data. Edge-aligned with read data, centered-aligned with write data. For x16 configurations, DQSL corresponds to the data on DQ[7:0], and DQSU corresponds to the data on DQ[15:8]. For the x4 and x8 configurations, DQS corresponds to the data on DQ[3:0] and DQ[7:0], respectively. DDR4 SDRAM supports a differential data strobe only and does not support a single-ended data strobe.
ALERT <sub>n</sub>	Output	<b>Alert output:</b> Possesses functions such as CRC error flag and command and address parity error flag as output signal. If a CRC error occurs, ALERT <sub>n</sub> goes LOW for the period time interval and returns HIGH. If an error occurs during a command address parity check, ALERT <sub>n</sub> goes LOW until the on-going DRAM internal recovery transaction is complete. During connectivity test mode, this pin functions as an input. Use of this signal is system-dependent. If not connected as signal, ALERT <sub>n</sub> pin must be connected to $V_{DD}$ on DIMMs.
EVENT <sub>n</sub>	Output	<b>Temperature event:</b> The EVENT <sub>n</sub> pin is asserted by the temperature sensor when critical temperature thresholds have been exceeded. This pin has no function (NF) on modules without temperature sensors.

**Table 5: Pin Descriptions (Continued)**

Symbol	Type	Description
TDQS_t TDQS_c (x8 DRAM-based RDIMM only)	Output	<b>Termination data strobe:</b> When enabled via the mode register, the DRAM device enables the same $R_{TT}$ termination resistance on TDQS_t and TDQS_c that is applied to DQS_t and DQS_c. When the TDQS function is disabled via the mode register, the DM/TDQS_t pin provides the data mask (DM) function, and the TDQS_c pin is not used. The TDQS function must be disabled in the mode register for both the x4 and x16 configurations. The DM function is supported only in x8 and x16 configurations. DM, DBI, and TDQS are a shared pin and are enabled/disabled by mode register settings. For more information about TDQS, see the DDR4 DRAM component data sheet (TDQS_t and TDQS_c are not valid for UDIMMs).
$V_{DD}$	Supply	<b>Module power supply:</b> 1.2V (TYP).
$V_{PP}$	Supply	<b>DRAM activating power supply:</b> 2.5V $-0.125V$ / $+0.250V$ .
$V_{REFCA}$	Supply	Reference voltage for control, command, and address pins.
$V_{SS}$	Supply	Ground.
$V_{TT}$	Supply	Power supply for termination of address, command, and control $V_{DD}/2$ .
$V_{DDSPD}$	Supply	Power supply used to power the I <sup>2</sup> C bus for SPD.
RFU	–	Reserved for future use.
NC	–	<b>No connect:</b> No internal electrical connection is present.
NF	–	<b>No function:</b> May have internal connection present, but has no function.



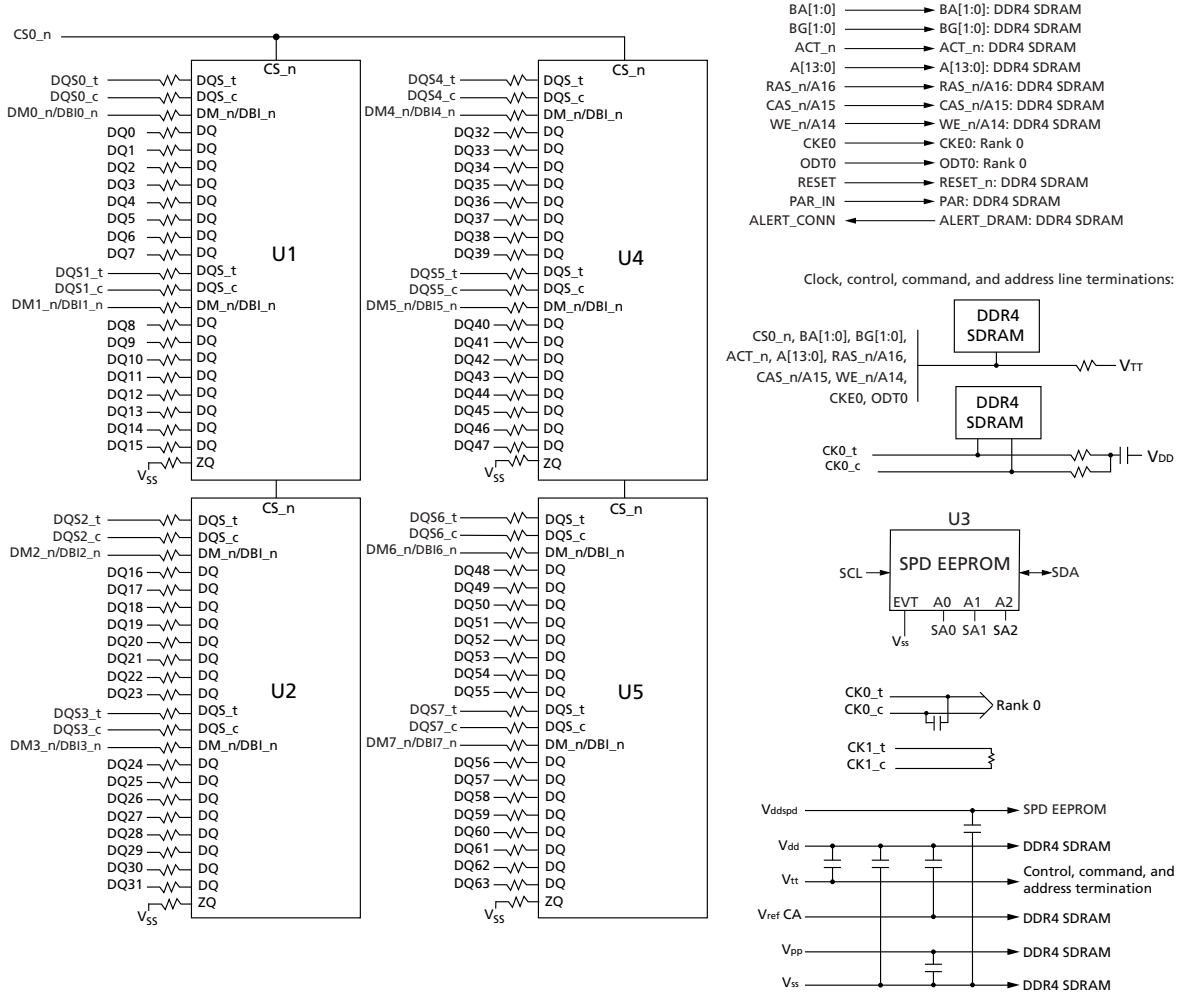
## DQ Map

Table 6: Component-to-Module DQ Map

Component Reference Number	Component DQ	Module DQ	Module Pin Number	Component Reference Number	Component DQ	Module DQ	Module Pin Number
U1	00	3	157	U2	00	19	179
	01	1	150		01	17	172
	02	2	12		02	18	34
	03	0	5		03	16	27
	04	7	155		04	23	177
	05	5	148		05	21	170
	06	6	10		06	22	32
	07	4	3		07	20	25
	08	11	168		08	27	190
	09	8	16		09	24	38
	10	10	23		10	26	45
	11	9	161		11	25	183
	12	14	21		12	30	43
	13	13	159		13	29	181
	14	15	166		14	31	188
	15	12	14	15	28	36	
U4	00	35	249	U5	00	51	271
	01	33	242		01	49	264
	02	34	104		02	50	126
	03	32	97		03	48	119
	04	39	247		04	55	269
	05	37	240		05	53	262
	06	38	102		06	54	124
	07	36	95		07	52	117
	08	43	260		08	59	282
	09	40	108		09	56	130
	10	42	115		10	58	137
	11	41	253		11	57	275
	12	46	113		12	62	135
	13	45	251		13	61	273
	14	47	257		14	63	280
	15	44	106	15	60	128	

## Functional Block Diagram

Figure 2: Functional Block Diagram



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

## General Description

High-speed DDR4 SDRAM modules use DDR4 SDRAM devices with two or four internal memory bank groups. DDR4 SDRAM modules utilizing 4- and 8-bit-wide DDR4 SDRAM devices have four internal bank groups consisting of four memory banks each, providing a total of 16 banks. 16-bit-wide DDR4 SDRAM devices have two internal bank groups consisting of four memory banks each, providing a total of eight banks. DDR4 SDRAM modules benefit from DDR4 SDRAM's use of an  $8n$ -prefetch architecture with an interface designed to transfer two data words per clock cycle at the I/O pins. A single READ or WRITE operation for the DDR4 SDRAM effectively consists of a single  $8n$ -bit-wide, four-clock data transfer at the internal DRAM core and eight corresponding  $n$ -bit-wide, one-half-clock-cycle data transfers at the I/O pins.

DDR4 modules use two sets of differential signals: DQS\_t and DQS\_c to capture data and CK\_t and CK\_c to capture commands, addresses, and control signals. Differential clocks and data strobes ensure exceptional noise immunity for these signals and provide precise crossing points to capture input signals.

## Fly-By Topology

DDR4 modules use faster clock speeds than earlier DDR technologies, making signal quality more important than ever. For improved signal quality, the clock, control, command, and address buses have been routed in a fly-by topology, where each clock, control, command, and address pin on each DRAM is connected to a single trace and terminated (rather than a tree structure, where the termination is off the module near the connector). Inherent to fly-by topology, the timing skew between the clock and DQS signals can be easily accounted for by using the write-leveling feature of DDR4.

## Module Manufacturing Location

Micron Technology manufactures modules at sites world-wide. Customers may receive modules from any of the following manufacturing locations:

**Table 7: DRAM Module Manufacturing Locations**

Manufacturing Site Location	Country of Origin Specified on Label
Boise, USA	USA
Aguadilla, Puerto Rico	Puerto Rico
Xian, China	China
Singapore	Singapore

## Address Mapping to DRAM

### Address Mirroring

To achieve optimum routing of the address bus on DDR4 multi rank modules, the address bus will be wired as shown in the table below, or mirrored. For quad rank modules, ranks 1 and 3 are mirrored and ranks 0 and 2 are non-mirrored. Highlighted address pins have no secondary functions allowing for normal operation when cross-wired. Data is still read from the same address it was written. However, Load Mode operations require a specific address. This requires the controller to accommodate for a rank that is "mirrored." Systems may reference DDR4 SPD to determine if the module has mirroring implemented or not. See the JEDEC DDR4 SPD specification for more details.

**Table 8: Address Mirroring**

Edge Connector Pin	DRAM Pin, Non-mirrored	DRAM Pin, Mirrored
A0	A0	A0
A1	A1	A1
A2	A2	A2
A3	A3	A4
A4	A4	A3
A5	A5	A6
A6	A6	A5
A7	A7	A8
A8	A8	A7
A9	A9	A9
A10	A10	A10
A11	A11	A13
A13	A13	A11
A12	A12	A12
A14	A14	A14
A15	A15	A15
A16	A16	A16
A17	A17	A17
BA0	BA0	BA1
BA1	BA1	BA0
BG0	BG0	BG1
BG1	BG1	BG0

## SPD EEPROM Operation

DDR4 SDRAM modules incorporate serial presence detect (SPD). The SPD data is stored in a 512-byte JEDEC JC-42.4-compliant EEPROM that is segregated into four 128-byte, write-protectable blocks. The SPD content is aligned with these blocks as shown in the table below.

Block	Range		Description
0	0–127	000h–07Fh	Configuration and DRAM parameters
1	128–255	080h–0FFh	Module-specific parameters
2	256–319	100h–13Fh	Reserved; all bytes coded as 00h
	320–383	140h–17Fh	Manufacturing information
3	384–511	180h–1FFh	End-user programmable

The first 384 bytes are programmed by Micron to comply with JEDEC standard JC-45, "Appendix X: Serial Presence Detect (SPD) for DDR4 SDRAM Modules." The remaining 128 bytes of storage are available for use by the customer.

The EEPROM resides on a two-wire I<sup>2</sup>C serial interface and is not integrated with the memory bus in any way. It operates as a slave device in the I<sup>2</sup>C bus protocol, with all operations synchronized by the serial clock. Transfer rates of up to 1 MHz are achievable at 2.5V (NOM).

Micron implements reversible software write protection on DDR4 SDRAM-based modules. This prevents the lower 384 bytes (bytes 0–383) from being inadvertently programmed or corrupted. The upper 128 bytes remain available for customer use and unprotected.

## Electrical Specifications

Stresses greater than those listed may cause permanent damage to the module. This is a stress rating only, and functional operation of the module at these or any other conditions outside those indicated in each device's data sheet is not implied. Exposure to absolute maximum rating conditions for extended periods may adversely affect reliability.

**Table 9: Absolute Maximum Ratings**

Symbol	Parameter	Min	Max	Units	Notes
$V_{DD}$	$V_{DD}$ supply voltage relative to $V_{SS}$	-0.4	1.5	V	1
$V_{DDQ}$	$V_{DDQ}$ supply voltage relative to $V_{SS}$	-0.4	1.5	V	1
$V_{PP}$	Voltage on $V_{PP}$ pin relative to $V_{SS}$	-0.4	3.0	V	2
$V_{IN}, V_{OUT}$	Voltage on any pin relative to $V_{SS}$	-0.4	1.5	V	

**Table 10: Operating Conditions**

Symbol	Parameter	Min	Nom	Max	Units	Notes
$V_{DD}$	$V_{DD}$ supply voltage	1.14	1.2	1.26	V	1
$V_{PP}$	DRAM activating power supply	2.375	2.5	2.75	V	2
$V_{REFCA(DC)}$	Input reference voltage command/address bus	$0.49 \times V_{DD}$	$0.5 \times V_{DD}$	$0.51 \times V_{DD}$	V	3
$I_{VTT}$	Termination reference current from $V_{TT}$	-750	-	750	mA	
$V_{TT}$	Termination reference voltage (DC) – command/address bus	$0.49 \times V_{DD} - 20\text{mV}$	$0.5 \times V_{DD}$	$0.51 \times V_{DD} + 20\text{mV}$	V	4
$I_{IN}$	Input leakage current; any input excluding ZQ; $0V < V_{IN} < 1.1V$	-2.0	-	2.0	$\mu\text{A}$	5
$I_{ZQ}$	Input leakage current; ZQ	-50.0	-	10.0	$\mu\text{A}$	5, 6
$I_{OZpd}$	Output leakage current; $V_{OUT} = V_{DD}$ ; DQ is disabled	-	-	10.0	$\mu\text{A}$	
$I_{OZpu}$	Output leakage current; $V_{OUT} = V_{SS}$ ; DQ is disabled; ODT is disabled with ODT input HIGH	-50.0	-	-	$\mu\text{A}$	
$I_{VREFCA}$	$V_{REFCA}$ leakage; $V_{REFCA} = V_{DD}/2$ (after DRAM is initialized)	-2.0	-	2.0	$\mu\text{A}$	5

- Notes:
- $V_{DDQ}$  tracks with  $V_{DD}$ ;  $V_{DDQ}$  and  $V_{DD}$  are tied together.
  - $V_{PP}$  must be greater than or equal to  $V_{DD}$  at all times.
  - $V_{REFCA}$  must not be greater than  $0.6 \times V_{DD}$ . When  $V_{DD}$  is less than 500mV,  $V_{REF}$  may be less than or equal to 300mV.
  - $V_{TT}$  termination voltages in excess of the specification limit adversely affect the voltage margins of command and address signals and reduce timing margins.
  - Multiply by the number of DRAM die on the module.
  - Tied to ground. Not connected to edge connector.

**Table 11: Thermal Characteristics**

Symbol	Parameter/Condition	Value	Units	Notes
T <sub>C</sub>	Commercial operating case temperature	0 to 85	°C	1, 2, 3
T <sub>C</sub>		>85 to 95	°C	1, 2, 3, 4
T <sub>OPER</sub>	Normal operating temperature range	0 to 85	°C	5, 7
T <sub>OPER</sub>	Extended temperature operating range (optional)	>85 to 95	°C	5, 7
T <sub>STG</sub>	Non-operating storage temperature	-55 to 100	°C	6
RH <sub>STG</sub>	Non-operating Storage Relative Humidity (non-condensing)	5 to 95	%	
NA	Change Rate of Storage Temperature	20	°C/hour	

- Notes:
1. Maximum operating case temperature; T<sub>C</sub> is measured in the center of the package.
  2. A thermal solution must be designed to ensure the DRAM device does not exceed the maximum T<sub>C</sub> during operation.
  3. Device functionality is not guaranteed if the DRAM device exceeds the maximum T<sub>C</sub> during operation.
  4. If T<sub>C</sub> exceeds 85°C, the DRAM must be refreshed externally at 2X refresh, which is a 3.9μs interval refresh rate.
  5. The refresh rate must double when 85°C < T<sub>OPER</sub> ≤ 95°C.
  6. Storage temperature is defined as the temperature of the top/center of the DRAM and does not reflect the storage temperatures of shipping trays.
  7. For additional information, refer to technical note TN-00-08: "Thermal Applications" available at [micron.com](http://micron.com).

## DRAM Operating Conditions

Recommended AC operating conditions are given in the DDR4 component data sheets. Component specifications are available at [micron.com](http://micron.com). Module speed grades correlate with component speed grades, as shown below.

**Table 12: Module and Component Speed Grades**

DDR4 components may exceed the listed module speed grades; module may not be available in all listed speed grades

Module Speed Grade	Component Speed Grade
-3G2	-062E
-2G9	-068
-2G6	-075
-2G3	-083
-2G1	-093E

## Design Considerations

### Simulations

Micron memory modules are designed to optimize signal integrity through carefully designed terminations, controlled board impedances, routing topologies, trace length matching, and decoupling. However, good signal integrity starts at the system level. Micron encourages designers to simulate the signal characteristics of the system's memory bus to ensure adequate signal integrity of the entire memory system.

### Power

Operating voltages are specified at the edge connector of the module, not at the DRAM. Designers must account for any system voltage drops at anticipated power levels to ensure the required supply voltage is maintained.

### $I_{DD}$ , $I_{PP}$ and $I_{DDQ}$ Specifications

$I_{DD}$  and  $I_{PP}$  values are only for the DDR4 SDRAM, and calculated from values in the supporting component data sheet.  $I_{PP}$  and  $I_{DDQ}$  currents are not included in  $I_{DD}$  currents.  $I_{DD}$  and  $I_{DDQ}$  currents are not included in  $I_{PP}$  currents. Micron does not specify  $I_{DDQ}$  currents. In DRAM module application,  $I_{DDQ}$  cannot be measured separately because  $V_{DD}$  and  $V_{DDQ}$  use a merged-power layer in the module PCB.



## I<sub>DD</sub> Specifications

**Table 13: DDR4 I<sub>DD</sub> Specifications and Conditions – 4GB (Die Revision B)**

Values are for the MT40A512M16 DDR4 SDRAM only and are computed from values specified in the 8Gb (512 Meg x 16) component data sheet

Parameter	Symbol	2666	2400	Units
One bank ACTIVATE-PRECHARGE current	I <sub>DD0</sub>	340	320	mA
One bank ACTIVATE-PRECHARGE, Word Line Boost, I <sub>pp</sub> current	I <sub>pp0</sub>	16	16	mA
One bank ACTIVATE-READ-PRECHARGE current	I <sub>DD1</sub>	420	400	mA
Precharge standby current	I <sub>DD2N</sub>	140	136	mA
Precharge standby ODT current	I <sub>DD2NT</sub>	300	300	mA
Precharge power-down current	I <sub>DD2P</sub>	100	100	mA
Precharge quiet standby current	I <sub>DD2Q</sub>	120	120	mA
Active standby current	I <sub>DD3N</sub>	200	188	mA
Active standby I <sub>pp</sub> current	I <sub>pp3N</sub>	12	12	mA
Active power-down current	I <sub>DD3P</sub>	172	164	mA
Burst read current	I <sub>DD4R</sub>	1052	972	mA
Burst write current	I <sub>DD4W</sub>	976	912	mA
Burst refresh current (1x REF)	I <sub>DD5R</sub>	244	236	mA
Burst refresh I <sub>pp</sub> current (1x REF)	I <sub>pp5R</sub>	20	20	mA
Self refresh current: Normal temperature range (0°C to 85°C)	I <sub>DD6N</sub>	120	120	mA
Self refresh current: Extended temperature range (0°C to 95°C)	I <sub>DD6E</sub>	140	140	mA
Self refresh current: Reduced temperature range (0°C to 45°C)	I <sub>DD6R</sub>	80	80	mA
Auto self refresh current (25°C)	I <sub>DD6A</sub>	34.4	34.4	mA
Auto self refresh current (45°C)	I <sub>DD6A</sub>	80	80	mA
Auto self refresh current (75°C)	I <sub>DD6A</sub>	120	120	mA
Auto self refresh I <sub>pp</sub> current	I <sub>pp6X</sub>	20	20	mA
Bank interleave read current	I <sub>DD7</sub>	1036	996	mA
Bank interleave read I <sub>pp</sub> current	I <sub>pp7</sub>	60	60	mA
Maximum power-down current	I <sub>DD8</sub>	100	100	mA

**Table 14: DDR4 I<sub>DD</sub> Specifications and Conditions – 4GB (Die Revision D)**

Values are for the MT40A512M16 DDR4 SDRAM only and are computed from values specified in the 8Gb (512 Meg x 16) component data sheet

Parameter	Symbol	2666	2400	Units
One bank ACTIVATE-PRECHARGE current	I <sub>DD0</sub>	340	320	mA
One bank ACTIVATE-PRECHARGE, Word Line Boost, I <sub>PP</sub> current	I <sub>PP0</sub>	16	16	mA
One bank ACTIVATE-READ-PRECHARGE current	I <sub>DD1</sub>	420	400	mA
Precharge standby current	I <sub>DD2N</sub>	140	136	mA
Precharge standby ODT current	I <sub>DD2NT</sub>	300	300	mA
Precharge power-down current	I <sub>DD2P</sub>	100	100	mA
Precharge quiet standby current	I <sub>DD2Q</sub>	120	120	mA
Active standby current	I <sub>DD3N</sub>	220	208	mA
Active standby I <sub>PP</sub> current	I <sub>PP3N</sub>	12	12	mA
Active power-down current	I <sub>DD3P</sub>	172	164	mA
Burst read current	I <sub>DD4R</sub>	1052	972	mA
Burst write current	I <sub>DD4W</sub>	1020	960	mA
Burst refresh current (1x REF)	I <sub>DD5R</sub>	268	256	mA
Burst refresh I <sub>PP</sub> current (1x REF)	I <sub>PP5R</sub>	20	20	mA
Self refresh current: Normal temperature range (0°C to 85°C)	I <sub>DD6N</sub>	124	124	mA
Self refresh current: Extended temperature range (0°C to 95°C)	I <sub>DD6E</sub>	144	144	mA
Self refresh current: Reduced temperature range (0°C to 45°C)	I <sub>DD6R</sub>	84	84	mA
Auto self refresh current (25°C)	I <sub>DD6A</sub>	34.4	34.4	mA
Auto self refresh current (45°C)	I <sub>DD6A</sub>	84	84	mA
Auto self refresh current (75°C)	I <sub>DD6A</sub>	124	124	mA
Auto self refresh I <sub>PP</sub> current	I <sub>PP6X</sub>	20	20	mA
Bank interleave read current	I <sub>DD7</sub>	1036	996	mA
Bank interleave read I <sub>PP</sub> current	I <sub>PP7</sub>	80	80	mA
Maximum power-down current	I <sub>DD8</sub>	100	100	mA

**Table 15: DDR4 I<sub>DD</sub> Specifications and Conditions – 4GB (Die Revision H)**

Values are for the MT40A512M16 DDR4 SDRAM only and are computed from values specified in the 8Gb (512 Meg x 16) component data sheet

Parameter	Symbol	2666	2400	Units
One bank ACTIVATE-PRECHARGE current	I <sub>DD0</sub>	320	300	mA
One bank ACTIVATE-PRECHARGE, Word Line Boost, I <sub>PP</sub> current	I <sub>PP0</sub>	20	20	mA
One bank ACTIVATE-READ-PRECHARGE current	I <sub>DD1</sub>	428	400	mA
Precharge standby current	I <sub>DD2N</sub>	168	156	mA
Precharge standby ODT current	I <sub>DD2NT</sub>	200	188	mA
Precharge power-down current	I <sub>DD2P</sub>	108	108	mA
Precharge quiet standby current	I <sub>DD2Q</sub>	144	136	mA
Active standby current	I <sub>DD3N</sub>	200	188	mA
Active standby I <sub>PP</sub> current	I <sub>PP3N</sub>	18	18	mA
Active power-down current	I <sub>DD3P</sub>	160	148	mA
Burst read current	I <sub>DD4R</sub>	1248	1036	mA
Burst write current	I <sub>DD4W</sub>	1436	1192	mA
Burst refresh current (1x REF)	I <sub>DD5R</sub>	208	196	mA
Burst refresh I <sub>PP</sub> current (1x REF)	I <sub>PP5R</sub>	22	22	mA
Self refresh current: Normal temperature range (0°C to 85°C)	I <sub>DD6N</sub>	144	144	mA
Self refresh current: Extended temperature range (0°C to 95°C)	I <sub>DD6E</sub>	200	200	mA
Self refresh current: Reduced temperature range (0°C to 45°C)	I <sub>DD6R</sub>	104	104	mA
Auto self refresh current (25°C)	I <sub>DD6A</sub>	60	60	mA
Auto self refresh current (45°C)	I <sub>DD6A</sub>	104	104	mA
Auto self refresh current (75°C)	I <sub>DD6A</sub>	144	144	mA
Auto self refresh I <sub>PP</sub> current	I <sub>PP6X</sub>	20	20	mA
Bank interleave read current	I <sub>DD7</sub>	1284	1244	mA
Bank interleave read I <sub>PP</sub> current	I <sub>PP7</sub>	88	88	mA
Maximum power-down current	I <sub>DD8</sub>	84	84	mA

**Table 16: DDR4 I<sub>DD</sub> Specifications and Conditions – 4GB (Die Revision E)**

Values are for the MT40A512M16 DDR4 SDRAM only and are computed from values specified in the 8Gb (512 Meg x 16) component data sheet

Parameter	Symbol	3200	2666	2400	Units
One bank ACTIVATE-PRECHARGE current	I <sub>DD0</sub>	216	200	192	mA
One bank ACTIVATE-PRECHARGE, Word Line Boost, I <sub>PP</sub> current	I <sub>PP0</sub>	16	16	16	mA
One bank ACTIVATE-READ-PRECHARGE current	I <sub>DD1</sub>	320	304	296	mA
Precharge standby current	I <sub>DD2N</sub>	132	124	120	mA
Precharge standby ODT current	I <sub>DD2NT</sub>	220	196	184	mA
Precharge power-down current	I <sub>DD2P</sub>	88	88	88	mA
Precharge quiet standby current	I <sub>DD2Q</sub>	104	104	104	mA
Active standby current	I <sub>DD3N</sub>	176	160	152	mA
Active standby I <sub>PP</sub> current	I <sub>PP3N</sub>	12	12	12	mA
Active power-down current	I <sub>DD3P</sub>	136	128	124	mA
Burst read current	I <sub>DD4R</sub>	1248	1092	1012	mA
Burst write current	I <sub>DD4W</sub>	1000	864	796	mA
Burst refresh current (1x REF)	I <sub>DD5R</sub>	200	192	188	mA
Burst refresh I <sub>PP</sub> current (1x REF)	I <sub>PP5R</sub>	20	20	20	mA
Self refresh current: Normal temperature range (0°C to 85°C)	I <sub>DD6N</sub>	136	136	136	mA
Self refresh current: Extended temperature range (0°C to 95°C)	I <sub>DD6E</sub>	232	232	232	mA
Self refresh current: Reduced temperature range (0°C to 45°C)	I <sub>DD6R</sub>	84	84	84	mA
Auto self refresh current (25°C)	I <sub>DD6A</sub>	34.4	34.4	34.4	mA
Auto self refresh current (45°C)	I <sub>DD6A</sub>	84	84	84	mA
Auto self refresh current (75°C)	I <sub>DD6A</sub>	124	124	124	mA
Auto self refresh current (95°C)	I <sub>DD6A</sub>	232	232	232	mA
Auto self refresh I <sub>PP</sub> current	I <sub>PP6X</sub>	20	20	20	mA
Bank interleave read current	I <sub>DD7</sub>	1080	1008	972	mA
Bank interleave read I <sub>PP</sub> current	I <sub>PP7</sub>	72	72	72	mA
Maximum power-down current	I <sub>DD8</sub>	72	72	72	mA

**Table 17: DDR4 I<sub>DD</sub> Specifications and Conditions – 4GB (Die Revision J)**

Values are for the MT40A512M16 DDR4 SDRAM only and are computed from values specified in the 8Gb (512 Meg x 16) component data sheet

Parameter	Symbol	3200	2666	Units
One bank ACTIVATE-PRECHARGE current	I <sub>DD0</sub>	208	192	mA
One bank ACTIVATE-PRECHARGE, Word Line Boost, I <sub>PP</sub> current	I <sub>PP0</sub>	16	16	mA
One bank ACTIVATE-READ-PRECHARGE current	I <sub>DD1</sub>	304	288	mA
Precharge standby current	I <sub>DD2N</sub>	124	120	mA
Precharge standby ODT current	I <sub>DD2NT</sub>	212	188	mA
Precharge power-down current	I <sub>DD2P</sub>	88	88	mA
Precharge quiet standby current	I <sub>DD2Q</sub>	104	104	mA
Active standby current	I <sub>DD3N</sub>	176	160	mA
Active standby I <sub>PP</sub> current	I <sub>PP3N</sub>	12	12	mA
Active power-down current	I <sub>DD3P</sub>	136	128	mA
Burst read current	I <sub>DD4R</sub>	1184	1040	mA
Burst write current	I <sub>DD4W</sub>	952	820	mA
Burst refresh current (1x REF)	I <sub>DD5R</sub>	188	180	mA
Burst refresh I <sub>PP</sub> current (1x REF)	I <sub>PP5R</sub>	20	20	mA
Self refresh current: Normal temperature range (0°C to 85°C)	I <sub>DD6N</sub>	128	128	mA
Self refresh current: Extended temperature range (0°C to 95°C)	I <sub>DD6E</sub>	220	220	mA
Self refresh current: Reduced temperature range (0°C to 45°C)	I <sub>DD6R</sub>	80	80	mA
Auto self refresh current (25°C)	I <sub>DD6A</sub>	32.8	32.8	mA
Auto self refresh current (45°C)	I <sub>DD6A</sub>	80	80	mA
Auto self refresh current (75°C)	I <sub>DD6A</sub>	120	120	mA
Auto self refresh current (95°C)	I <sub>DD6A</sub>	220	220	mA
Auto self refresh I <sub>PP</sub> current	I <sub>PP6X</sub>	20	20	mA
Bank interleave read current	I <sub>DD7</sub>	1028	960	mA
Bank interleave read I <sub>PP</sub> current	I <sub>PP7</sub>	60	60	mA
Maximum power-down current	I <sub>DD8</sub>	72	72	mA

## SPD EEPROM Operating Conditions

For the latest SPD data, refer to Micron's SPD page: [micron.com/spd](http://micron.com/spd).

**Table 18: SPD EEPROM DC Operating Conditions**

Parameter/Condition	Symbol	Min	Nom	Max	Units
Supply voltage	$V_{DDSPD}$	–	2.5	–	V
Input low voltage: logic 0; all inputs	$V_{IL}$	–0.5	–	$V_{DDSPD} \times 0.3$	V
Input high voltage: logic 1; all inputs	$V_{IH}$	$V_{DDSPD} \times 0.7$	–	$V_{DDSPD} + 0.5$	V
Output low voltage: 3mA sink current $V_{DDSPD} > 2V$	$V_{OL}$	–	–	0.4	V
Input leakage current: (SCL, SDA) $V_{IN} = V_{DDSPD}$ or $V_{SSSPD}$	$I_{LI}$	–	–	$\pm 5$	$\mu A$
Output leakage current: $V_{OUT} = V_{DDSPD}$ or $V_{SSSPD}$ , SDA in High-Z	$I_{LO}$	–	–	$\pm 5$	$\mu A$

- Notes:
1. Table is provided as a general reference. Consult JEDEC JC-42.4 EE1004 and TSE2004 device specifications for complete details.
  2. All voltages referenced to  $V_{DDSPD}$ .

**Table 19: SPD EEPROM AC Operating Conditions**

Parameter/Condition	Symbol	Min	Max	Units
Clock frequency	$t_{SCL}$	10	1000	kHz
Clock pulse width HIGH time	$t_{HIGH}$	260	–	ns
Clock pulse width LOW time	$t_{LOW}$	500	–	ns
Detect clock LOW timeout	$t_{TIMEOUT}$	25	35	ms
SDA rise time	$t_R$	–	120	ns
SDA fall time	$t_F$	–	120	ns
Data-in setup time	$t_{SU:DAT}$	50	–	ns
Data-in hold time	$t_{HD:DI}$	0	–	ns
Data out hold time	$t_{HD:DAT}$	0	350	ns
Start condition setup time	$t_{SU:STA}$	260	–	ns
Start condition hold time	$t_{HD:STA}$	260	–	ns
Stop condition setup time	$t_{SU:STO}$	260	–	ns
Time the bus must be free before a new transition can start	$t_{BUF}$	500	–	ns
Write time	$t_W$	–	5	ms
Warm power cycle time off	$t_{POFF}$	1	–	ms
Time from power on to first command	$t_{INIT}$	10	–	ms

- Note:
1. Table is provided as a general reference. Consult JEDEC JC-42.4 EE1004 and TSE2004 device specifications for complete details.

