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Double Data Rate (DDR) SDRAM

MT46V32M4 – 8 Meg x 4 x 4 Banks
MT46V16M8 – 4 Meg x 8 x 4 Banks
MT46V8M16 – 2 Meg x 16 x 4 Banks

Features

- V_{DD} = +2.5V ±0.2V, V_{DDQ} = +2.5V ±0.2V
- V_{DD} = +2.6V ±0.1V, V_{DDQ} = +2.6V ±0.1V (DDR400)
- Bidirectional data strobe (DQS) transmitted/ received with data, i.e., source-synchronous data capture (x16 has two – one per byte)
- Internal, pipelined double-data-rate (DDR) architecture; two data accesses per clock cycle
- Differential clock inputs (CK and CK#)
- Commands entered on each positive CK edge
- DQS edge-aligned with data for READs; center-aligned with data for WRITEs
- DLL to align DQ and DQS transitions with CK
- Four internal banks for concurrent operation
- Data mask (DM) for masking write data (x16 has two – one per byte)
- Programmable burst lengths: 2, 4, or 8
- Auto refresh and self refresh modes
- Longer lead TSOP for improved reliability (OCPL)
- 2.5V I/O (SSTL_2 compatible)
- Concurrent auto precharge option is supported
- ^{t}RAS lockout supported (^{t}RAP = ^{t}RCD)

Options — Marking

- Configuration
  - 32 Meg x 4 (8 Meg x 4 x 4 banks) — 32M4
  - 16 Meg x 8 (4 Meg x 8 x 4 banks) — 16M8
  - 8 Meg x 16 (2 Meg x 16 x 4 banks) — 8M16
- Plastic package – OCPL
  - 66-pin TSOP — TG
  - 66-pin TSOP (Pb-free) — P
- Timing – cycle time
  - 5ns @ CL = 3 (DDR400) — -5B
  - 6ns @ CL = 2.5 (DDR333) (TSOP only) — -6T
  - 7.5ns @ CL = 2 (DDR266)[1] — -75E
  - 7.5ns @ CL = 2 (DDR266A) — -75Z
  - 7.5ns @ CL = 2.5 (DDR266B) — -75
- Self refresh
  - Standard — None
  - Low-power self refresh — L
- Temperature rating
  - Commercial (0°C to 70°C) — None
  - Industrial (–40°C to +85°C) — IT
- Revision — :D

Notes: 1. Not recommended for new designs

Table 1: Key Timing Parameters

CL = CAS (READ) latency; MIN clock rate with 50% duty cycle at CL = 2 (-75E, -75Z), CL = 2.5 (-6, -6T, -75), and CL = 3 (-5B)

Speed Grade	Clock Rate (MHz)			Data Out Window	Access Window	DQS–DQ Skew
	CL = 2	CL = 2.5	CL = 3			
-5B	133	167	200	1.6ns	±0.70ns	+0.40ns
-6T	133	167	n/a	2.0ns	±0.70ns	+0.45ns
-75E/-75Z	133	133	n/a	2.5ns	±0.75ns	+0.50ns
-75	100	133	n/a	2.5ns	±0.75ns	+0.50ns

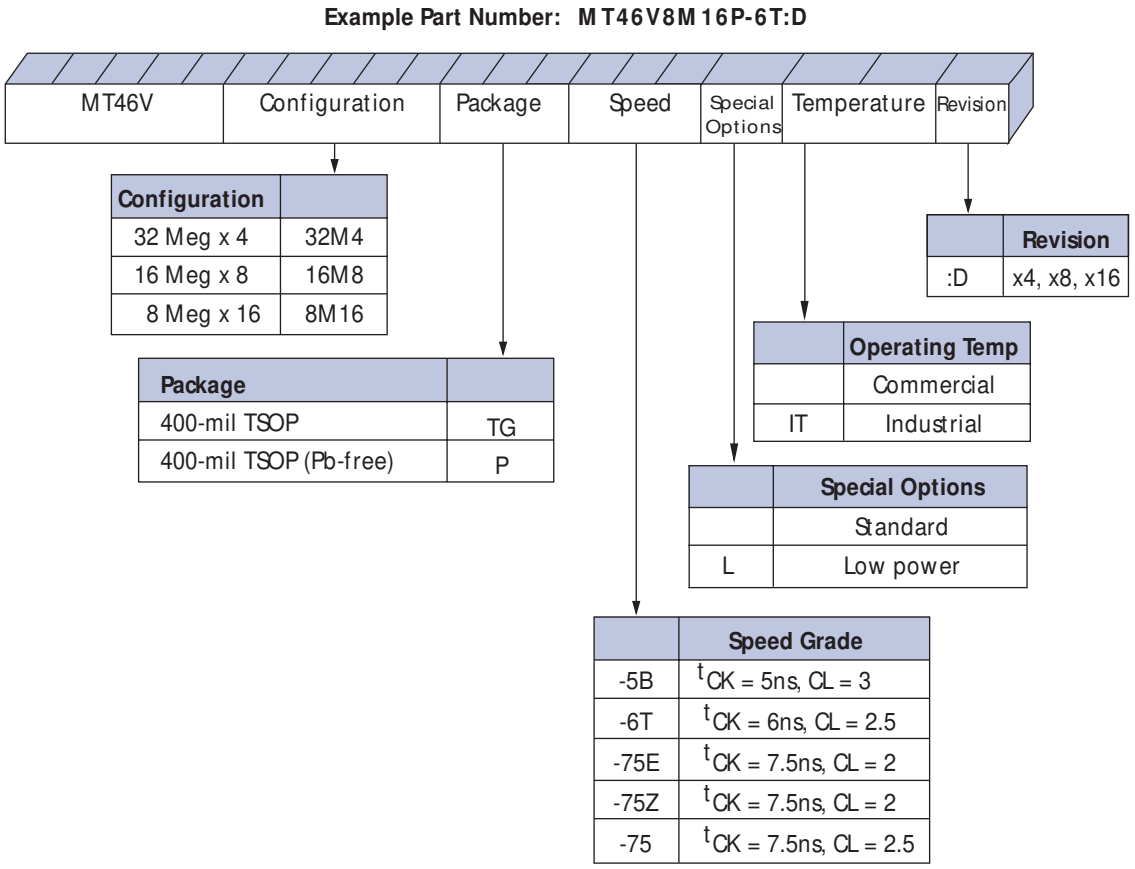
Table 2: Addressing

Parameter	32 Meg x 4	16 Meg x 8	8 Meg x 16
Configuration	8 Meg x 4 x 4 banks	4 Meg x 8 x 4 banks	2 Meg x 16 x 4 banks
Refresh count	4K	4K	4K
Row address	4K (A0–A11)	4K (A0–A11)	4K (A0–A11)
Bank address	4 (BA0, BA1)	4 (BA0, BA1)	4 (BA0, BA1)
Column address	2K (A0–A9, A11)	1K (A0–A9)	512 (A0–A8)

Table 3: Speed Grade Compatibility

Marking	PC3200 (3-3-3)	PC2700 (2.5-3-3)	PC2100 (2-2-2)	PC2100 (2-3-3)	PC2100 (2.5-3-3)	PC1600 (2-2-2)
-5B	Yes	Yes	Yes	Yes	Yes	Yes
-6T	–	Yes	Yes	Yes	Yes	Yes
-75E	–	–	Yes	Yes	Yes	Yes
-75Z	–	–	–	Yes	Yes	Yes
-75	–	–	–	–	Yes	Yes
	-5B	**-6T**	**-75E**	**-75Z**	**-75**	**-75**

Figure 1: 128Mb DDR SDRAM Part Numbers

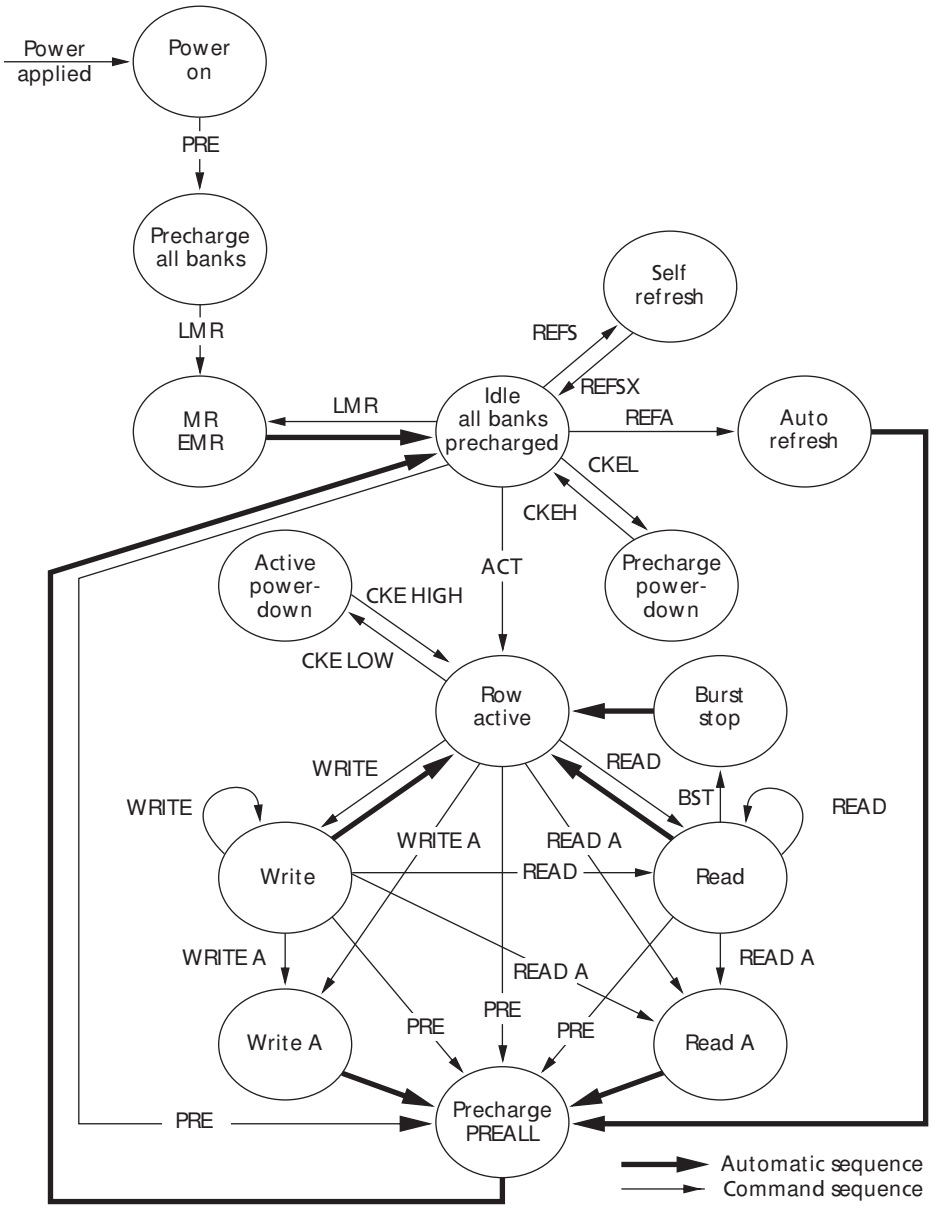


Note: Not all speeds and configurations are available in all packages.

Table of Contents

State Diagram

Figure 2: Simplified State Diagram



ACT = ACTIVE
BST = BURST TERMINATE
CKEH = Exit power down
CKEL = Enter power down
EMR = Extended mode register
LMR = LOAD MODE REGISTER
MR = Mode register
PRE = PRECHARGE
PREALL = PRECHARGE all banks
READ A = READ with auto precharge
REFA = AUTO REFRESH
REFS = Enter self refresh
REFSX = Exit self refresh
WRITE A = WRITE with auto precharge

Note: This diagram represents operations within a single bank only and does not capture concurrent operations in other banks.

Functional Description

The DDR SDRAM uses a double data rate architecture to achieve high-speed operation. The double data rate architecture is essentially a 2*n*-prefetch architecture with an interface designed to transfer two data words per clock cycle at the I/O pins. A single read or write access for the DDR SDRAM effectively consists of a single 2*n*-bit wide, one-clock-cycle data transfer at the internal DRAM core and two corresponding *n*-bit wide, one-half-clock-cycle data transfers at the I/O pins.

A bidirectional data strobe (DQS) is transmitted externally, along with data, for use in data capture at the receiver. DQS is a strobe transmitted by the DDR SDRAM during READs and by the memory controller during WRITEs. DQS is edge-aligned with data for READs and center-aligned with data for WRITEs. The x16 offering has two data strobes, one for the lower byte and one for the upper byte.

The DDR SDRAM operates from a differential clock (CK and CK#); the crossing of CK going HIGH and CK# going LOW will be referred to as the positive edge of CK. Commands (address and control signals) are registered at every positive edge of CK. Input data is registered on both edges of DQS, and output data is referenced to both edges of DQS, as well as to both edges of CK.

Read and write accesses to the DDR SDRAM are burst oriented; accesses start at a selected location and continue for a programmed number of locations in a programmed sequence. Accesses begin with the registration of an ACTIVE command, which may then be followed by a READ or WRITE command. The address bits registered coincident with the ACTIVE command are used to select the bank and row to be accessed. The address bits registered coincident with the READ or WRITE command are used to select the bank and the starting column location for the burst access.

The DDR SDRAM provides for programmable READ or WRITE burst lengths of 2, 4, or 8 locations. An AUTO PRECHARGE function may be enabled to provide a self-timed row precharge that is initiated at the end of the burst access.

As with standard SDR SDRAMs, the pipelined, multibank architecture of DDR SDRAMs allows for concurrent operation, thereby providing high effective bandwidth by hiding row precharge and activation time.

An auto refresh mode is provided, along with a power-saving power-down mode. All inputs are compatible with the JEDEC standard for SSTL_2. All full-drive option outputs are SSTL_2, Class II compatible.

General Notes

- The functionality and the timing specifications discussed in this data sheet are for the DLL-enabled mode of operation.
- Throughout the data sheet, the various figures and text refer to DQs as “DQ.” The DQ term is to be interpreted as any and all DQ collectively, unless specifically stated otherwise. Additionally, the x16 is divided into two bytes, the lower byte and upper byte. For the lower byte (DQ0–DQ7) DM refers to LDM and DQS refers to LDQS. For the upper byte (DQ8–DQ15) DM refers to UDM and DQS refers to UDQS.
- Complete functionality is described throughout the document and any page or diagram may have been simplified to convey a topic and may not be inclusive of all requirements.
- Any specific requirement takes precedence over a general statement.

Functional Block Diagrams

The 128Mb DDR SDRAM is a high-speed CMOS, dynamic random-access memory containing 134,217,728 bits. It is internally configured as a 4-bank DRAM.

Figure 3: 32 Meg x 4 Functional Block Diagram

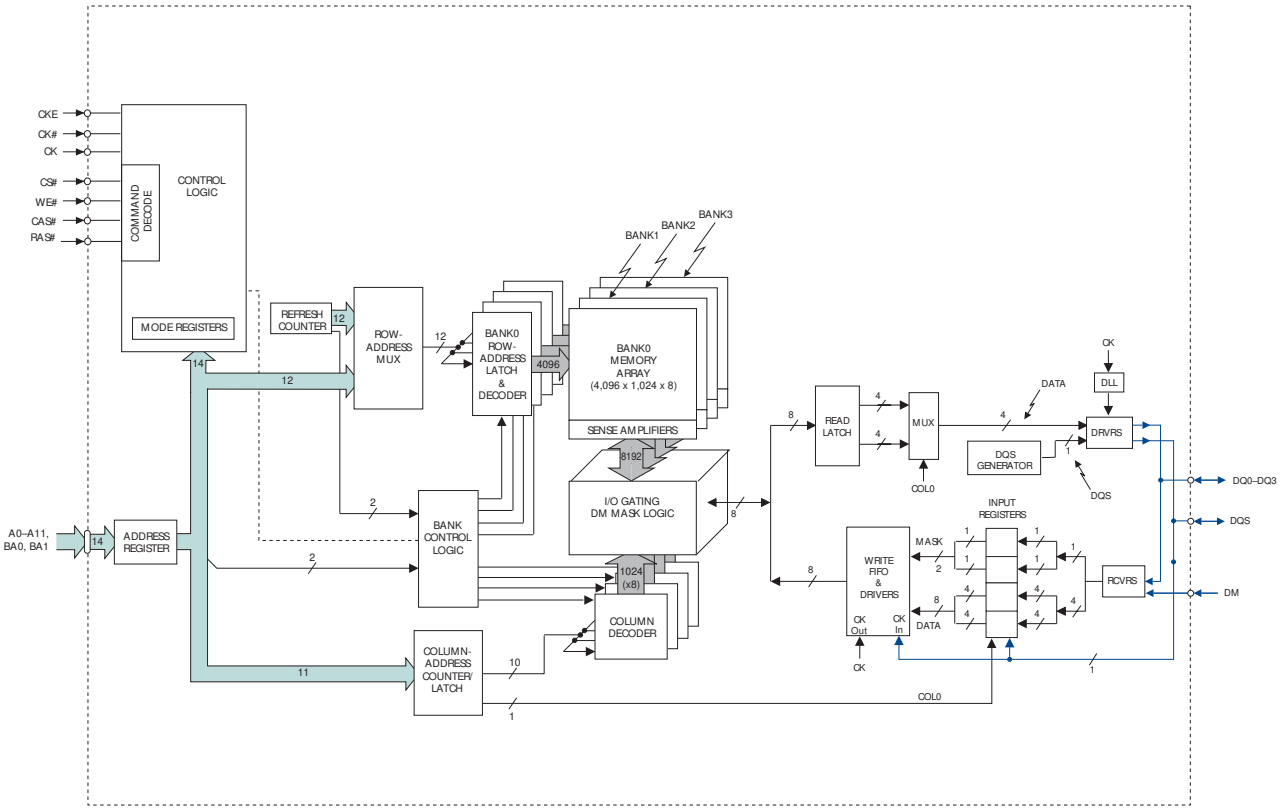


Figure 4: 16 Meg x 8 Functional Block Diagram

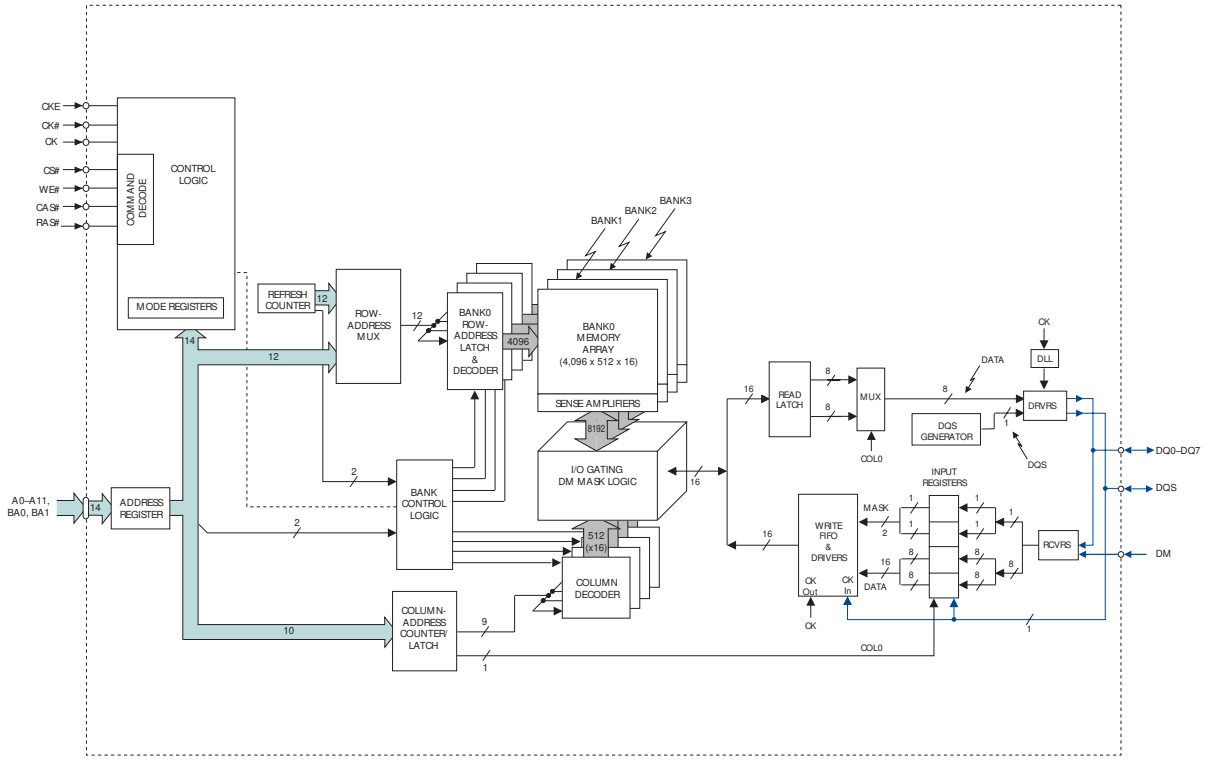
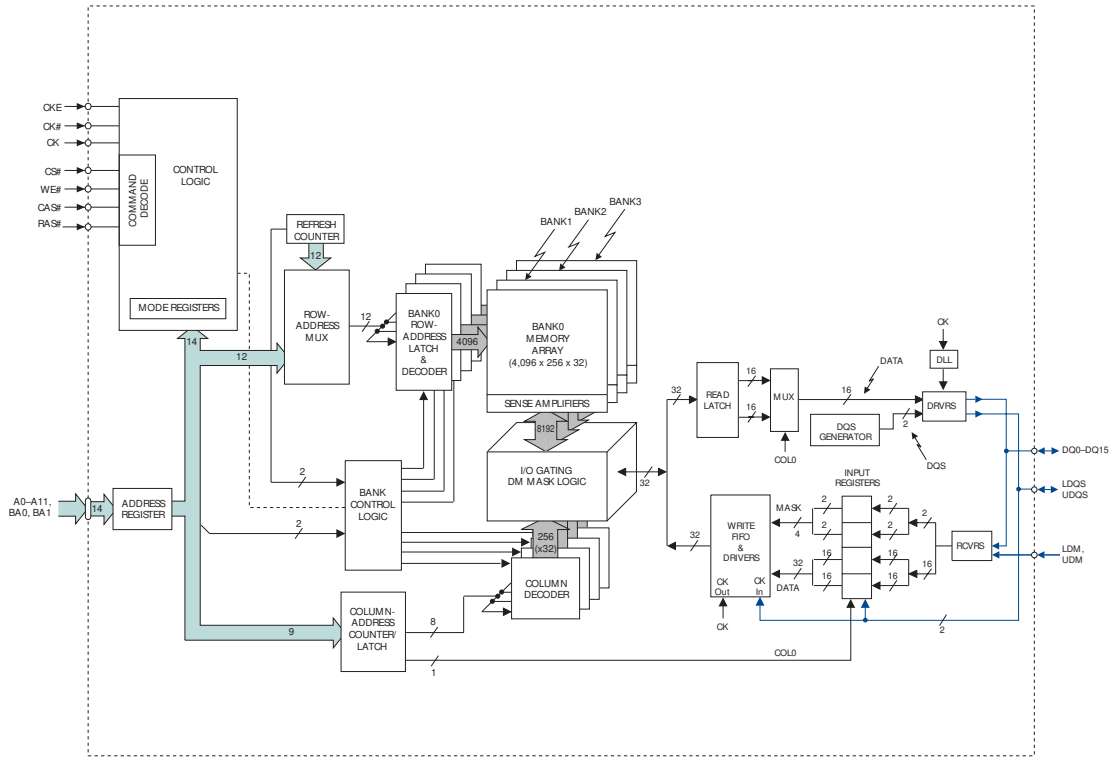


Figure 5: 8 Meg x 16 Functional Block Diagram



Pin Assignments and Descriptions

Figure 6: 66-Pin TSOP Pin Assignment (Top View)

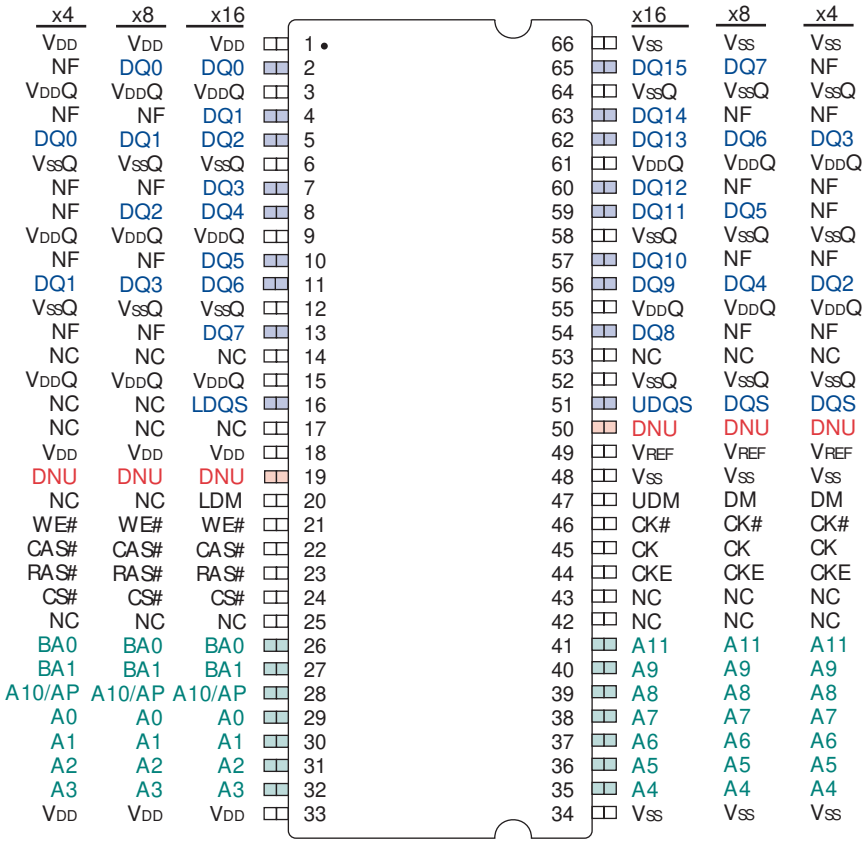


Table 4: Pin Descriptions

TSOP Numbers	Symbol	Type	Description
29, 30, 31 32, 35, 36, 37, 38, 39, 40, 28, 41	A0, A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11	Input	**Address inputs:** Provide the row address for ACTIVE commands, and the column address and auto precharge bit (A10) for READ/WRITE commands, to select one location out of the memory array in the respective bank. A10 sampled during a PRECHARGE command determines whether the PRECHARGE applies to one bank (A10 LOW, bank selected by BA0, BA1) or all banks (A10 HIGH). The address inputs also provide the op-code during a LOAD MODE REGISTER command.
26, 27	BA0, BA1	Input	**Bank address inputs:** BA0 and BA1 define to which bank an ACTIVE, READ, WRITE, or PRECHARGE command is being applied. BA0 and BA1 also define which mode register (mode register or extended mode register) is loaded during the LOAD MODE REGISTER command.
45, 46	CK, CK#	Input	**Clock:** CK and CK# are differential clock inputs. All address and control input signals are sampled on the crossing of the positive edge of CK and negative edge of CK#. Output data (DQ and DQS) is referenced to the crossings of CK and CK#.
44	CKE	Input	**Clock enable:** CKE HIGH activates and CKE LOW deactivates the internal clock, 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 synchronous for POWER-DOWN entry and exit, and for SELF REFRESH entry. CKE is asynchronous for SELF REFRESH exit and for disabling the outputs. CKE must be maintained HIGH throughout read and write accesses. Input buffers (excluding CK, CK#, and CKE) are disabled during POWER-DOWN. Input buffers (excluding CKE) are disabled during SELF REFRESH. CKE is an SSTL_2 input but will detect an LVCMOS LOW level after V_{DD} is applied and until CKE is first brought HIGH, after which it becomes an SSTL_2 input only.
24	CS#	Input	**Chip select:** CS# enables (registered LOW) and disables (registered HIGH) the command decoder. All commands are masked when CS# is registered HIGH. CS# provides for external bank selection on systems with multiple banks. CS# is considered part of the command code.
47 20 47	DM LDM UDM	Input	**Input data mask:** DM is an input mask signal for write data. Input data is masked when DM is sampled HIGH along with that input data during a write access. DM is sampled on both edges of DQS. Although DM pins are input-only, the DM loading is designed to match that of DQ and DQS pins. For the x16, LDM is DM for DQ0–DQ7 and UDM is DM for DQ8–DQ15. Pin 20 is a NC on x4 and x8.
23, 22, 21	RAS#, CAS#, WE#	Input	**Command inputs:** RAS#, CAS#, and WE# (along with CS#) define the command being entered.
2, 4, 5, 7, 8, 10, 11, 13, 54, 56, 57, 59, 60, 62, 63, 65	DQ0–DQ3 DQ4–DQ7 DQ8–DQ11 DQ12–DQ15	I/O	**Data input/output:** Data bus for x16.
2, 5, 8, 11, 56, 59, 62, 65	DQ0–DQ3 DQ4–DQ7	I/O	**Data input/output:** Data bus for x8.
5, 11, 56, 62	DQ0–DQ3	I/O	**Data input/output:** Data bus for x4.
51 16 51	DQS LDQS UDQS	I/O	**Data strobe:** Output with read data, input with write data. DQS is edge-aligned with read data, centered in write data. It is used to capture data. For the x16, LDQS is DQS for DQ0–DQ7 and UDQS is DQS for DQ8–DQ15. Pin 16 is NC on x4 and x8.
1, 18, 33	V_{DD}	Supply	Power supply.
3, 9, 15, 55, 61	$V_{DD}Q$	Supply	**DQ power supply:** Isolated on the die for improved noise immunity.

Table 4: Pin Descriptions (continued)

TSOP Numbers	Symbol	Type	Description
34, 48, 66	V_{SS}	Supply	Ground.
6, 12, 52, 58, 64	V_{SSQ}	Supply	**DQ ground:** Isolated on the die for improved noise immunity.
49	V_{REF}	Supply	SSTL_2 reference voltage.
14, 17, 25, 42, 43, 53	NC	–	**No connect for x16:** These pins should be left unconnected.
14, 16, 17, 20, 25, 42, 43, 53	NC	–	**No connect for x8:** These pins should be left unconnected.
14, 16, 17, 20, 25, 42, 43, 53	NC	–	**No connect for x4:** These pins should be left unconnected.
4, 7, 10, 13, 54, 57, 60, 63	NF	–	**No function for x8:** These pins should be left unconnected.
2, 4, 7, 8, 10, 13, 54, 57, 59, 60, 63, 65	NF	–	**No function for x4:** These pins should be left unconnected.
19, 50	DNU	–	**Do not use:** Must float to minimize noise on V_{REF}.

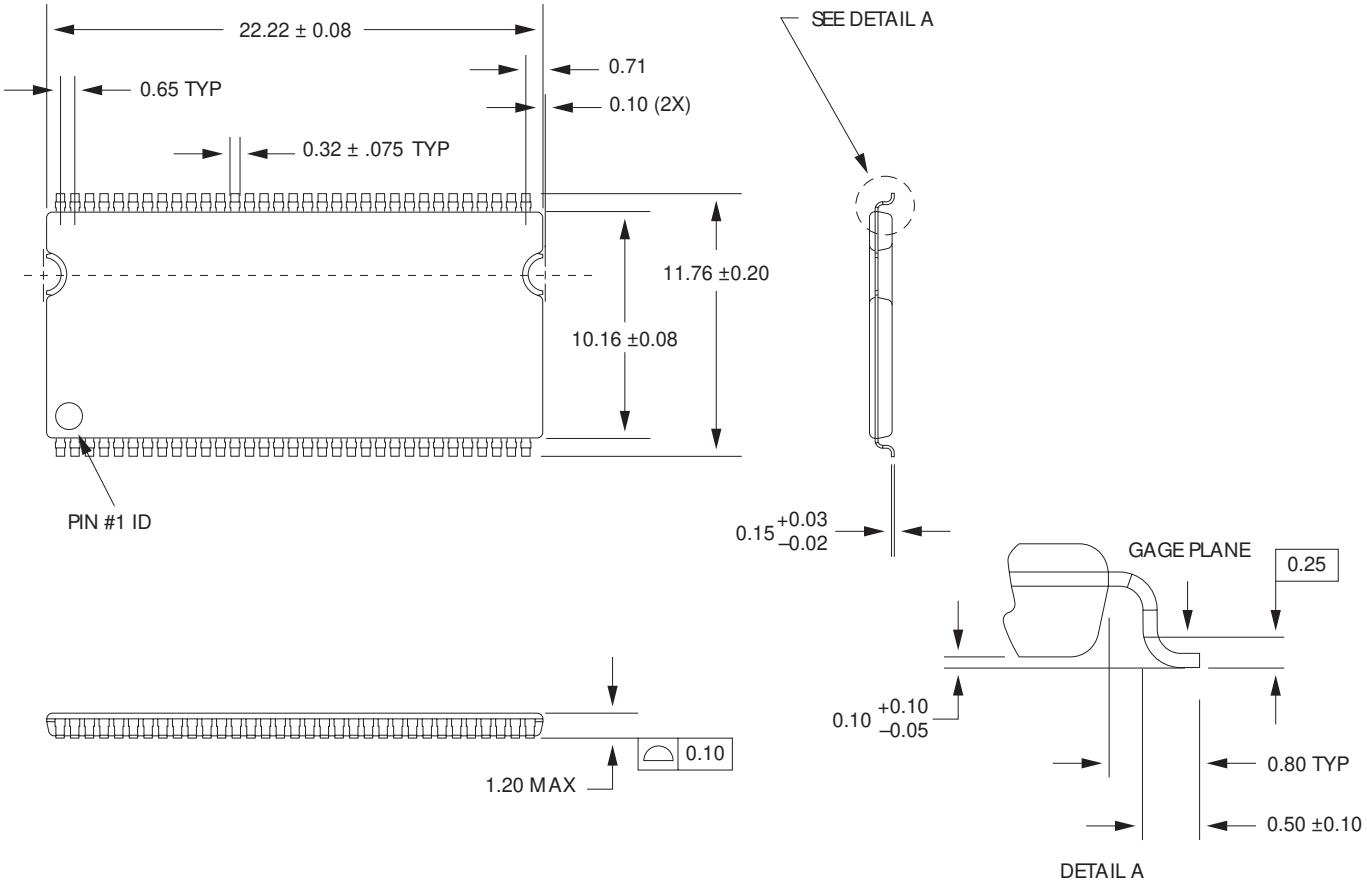
Table 5: Reserved NC Pin Descriptions

NC pins not listed may also be reserved for other uses; this table defines NC pins of importance

TSOP Numbers	Symbol	Type	Description
42, 17	A12, A13	Input	Address inputs A12 and A13 for 256Mb, 512Mb, and 1Gb devices.

Package Dimensions

Figure 7: 66-Pin Plastic TSOP (400 mil)



Notes:
1. All dimensions are in millimeters.
2. Package width and length do not include mold protrusion; allowable mold protrusion is 0.25mm per side.

Electrical Specifications – IDD

Table 6: IDD Specifications and Conditions (x4, x8; -5B, -6T, -75E, -75Z, -75)

VDDQ = +2.6V ±0.1V, VDD = +2.6V ±0.1V (-5B); VDDQ = +2.5V ±0.2V, VDD = +2.5V ±0.2V (-6T, -75E, -75Z, -75); 0°C ≤ T_A ≤ +70°C; Notes: 1–5, 11, 13, 15, 47; Notes appear on pages 26–31; See also Table 8 on page 14

Parameter/Condition		Symbol	-5B	-6T	-75E	-75Z/-75	Units	Notes
Operating one-bank active-precharge current: $^tRC = ^tRC$ (MIN); $^tCK = ^tCK$ (MIN); DQ, DM, and DQS inputs changing once per clock cycle; Address and control inputs changing once every two clock cycles		IDD0	115	125	110	105	mA	23, 48
Operating one-bank active-read-precharge current: Burst = 2; $^tRC = ^tRC$ (MIN); $^tCK = ^tCK$ (MIN); IOUT = 0mA; Address and control inputs changing once per clock cycle		IDD1	135	135	120	120	mA	23, 48
Precharge power-down standby current: All banks idle; Power-down mode; $^tCK = ^tCK$ (MIN); CKE = (LOW)		IDD2P	3	3	3	3	mA	24, 33
Idle standby current: CS# = HIGH; All banks are idle; $^tCK = ^tCK$ (MIN); CKE = HIGH; Address and other control inputs changing once per clock cycle. VIN = VREF for DQ, DQS, and DM		IDD2F	50	45	45	40	mA	51
Active power-down standby current: One bank active; Power-down mode; $^tCK = ^tCK$ (MIN); CKE = LOW		IDD3P	30	25	25	25	mA	24, 33
Active standby current: CS# = HIGH; CKE = HIGH; One bank active; $^tRC = ^tRAS$ (MAX); $^tCK = ^tCK$ (MIN); DQ, DM, and DQS inputs changing twice per clock cycle; Address and other control inputs changing once per clock cycle		IDD3N	50	50	50	45	mA	23
Operating burst read current: Burst = 2; Continuous burst reads; One bank active; Address and control inputs changing once per clock cycle; $^tCK = ^tCK$ (MIN); IOUT = 0mA		IDD4R	165	145	130	130	mA	23, 48
Operating burst write current: Burst = 2; Continuous burst writes; One bank active; Address and control inputs changing once per clock cycle; $^tCK = ^tCK$ (MIN); DQ, DM, and DQS inputs changing twice per clock cycle		IDD4W	165	145	130	130	mA	23
Auto refresh burst current:	$^tRFC = ^tRFC$ (MIN)	IDD5	240	265	220	220	mA	50
	^tRFC = 15.6µs	IDD5A	6	5	5	5	mA	28, 50
Self refresh current: CKE ≤ 0.2V	Standard	IDD6	4	4	4	4	mA	12
	Low power (L)	IDD6A	1.3	1.3	1.3	1.3	mA	12
Operating bank interleave read current: Four bank interleaving READs (Burst = 4) with auto precharge; ^tRC = minimum ^tRC allowed; $^tCK = ^tCK$ (MIN); Address and control inputs change only during ACTIVE, READ, or WRITE commands		IDD7	355	355	330	325	mA	23, 49

Table 7: IDD Specifications and Conditions (x16; -5B, -6T, -75E -75Z -75)

VDDQ = +2.6V ±0.1V, VDD = +2.6V ±0.1V (-5B); VDDQ = +2.5V ±0.2V, VDD = +2.5V ±0.2V (-6T, -75E, -75Z, -75); 0°C ≤ T_A ≤ +70°C; Notes: 1–5, 11, 13, 15, 47; Notes appear on pages 26–31; See also Table 8 on page 14

Parameter/Condition		Symbol	-5B	-6T	-75E	-75Z/-75	Units	Notes
Operating one-bank active-precharge current: $^tRC = ^tRC$ (MIN); $^tCK = ^tCK$ (MIN); DQ, DM, and DQS inputs changing once per clock cycle; Address and control inputs changing once every two clock cycles		IDD0	125	125	115	110	mA	23, 48
Operating one-bank active-read-precharge current: Burst = 2; $^tRC = ^tRC$ (MIN); $^tCK = ^tCK$ (MIN); IOUT = 0mA; Address and control inputs changing once per clock cycle		IDD1	135	135	135	125	mA	23, 48
Precharge power-down standby current: All banks idle; Power-down mode; $^tCK = ^tCK$ (MIN); CKE = (LOW)		IDD2P	3	3	3	3	mA	24, 33
Idle standby current: CS# = HIGH; All banks are idle; $^tCK = ^tCK$ (MIN); CKE = HIGH; Address and other control inputs changing once per clock cycle. VIN = VREF for DQ, DQS, and DM		IDD2F	50	45	45	40	mA	51
Active power-down standby current: One bank active; Power-down mode; $^tCK = ^tCK$ (MIN); CKE = LOW		IDD3P	30	25	25	25	mA	24, 33
Active standby current: CS# = HIGH; CKE = HIGH; One bank active; $^tRC = ^tRAS$ (MAX); $^tCK = ^tCK$ (MIN); DQ, DM, and DQS inputs changing twice per clock cycle; Address and other control inputs changing once per clock cycle		IDD3N	50	50	50	45	mA	23
Operating burst read current: Burst = 2; Continuous burst reads; One bank active; Address and control inputs changing once per clock cycle; $^tCK = ^tCK$ (MIN); IOUT = 0mA		IDD4R	185	165	140	140	mA	23, 48
Operating burst write current: Burst = 2; Continuous burst writes; One bank active; Address and control inputs changing once per clock cycle; $^tCK = ^tCK$ (MIN); DQ, DM, and DQS inputs changing twice per clock cycle		IDD4W	185	165	140	140	mA	23
Auto refresh burst current:	$^tRFC = ^tRFC$ (MIN)	IDD5	265	265	250	250	mA	50
	^tRFC = 15.6µs	IDD5A	10	5	5	5	mA	28, 50
Self refresh current: CKE ≤ 0.2V	Standard	IDD6	4	4	4	4	mA	12
	Low power (L)	IDD6A	1.3	1.3	1.3	1.3	mA	12
Operating bank interleave read current: Four bank interleaving READs (Burst = 4) with auto precharge; ^tRC = minimum ^tRC allowed; $^tCK = ^tCK$ (MIN); Address and control inputs change only during ACTIVE, READ, or WRITE commands		IDD7	385	385	375	375	mA	23, 49

Table 8: IDD Test Cycle Times
Values reflect number of clock cycles for each test

IDD Test	Speed Grade	Clock Cycle Time	tRRD	tRCD	tRAS	tRP	tRC	tRFC	tREFI	CL
IDD0	–75/75Z	7.5ns	n/a	n/a	6	3	9	n/a	n/a	n/a
	–75E	7.5ns	n/a	n/a	6	2	8	n/a	n/a	n/a
	–6T	6ns	n/a	n/a	7	3	10	n/a	n/a	n/a
	–5B	5ns	n/a	n/a	8	3	11	n/a	n/a	n/a
IDD1	–75	7.5ns	n/a	n/a	6	3	9	n/a	n/a	2.5
	–75Z	7.5ns	n/a	n/a	6	3	9	n/a	n/a	2
	–75E	7.5ns	n/a	n/a	6	2	8	n/a	n/a	2
	–6T	6ns	n/a	n/a	7	3	10	n/a	n/a	2.5
	–5B	5ns	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3
IDD4R	–75	7.5ns	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2.5
	–75Z	7.5ns	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2
	–75E	7.5ns	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2
	–6T	6ns	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2.5
	–5B	5ns	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3
IDD4W	–75	7.5ns	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	–75Z	7.5ns	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	–75E	7.5ns	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	–6T	6ns	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	–5B	5ns	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IDD5	–75/75Z	7.5ns	n/a	n/a	n/a	n/a	n/a	10	10	n/a
	–75E	7.5ns	n/a	n/a	n/a	n/a	n/a	9	9	n/a
	–6T	6ns	n/a	n/a	n/a	n/a	n/a	12	12	n/a
	–5B	5ns	n/a	n/a	n/a	n/a	n/a	14	14	n/a
IDD5A	–75/75Z	7.5ns	n/a	n/a	n/a	n/a	n/a	10	1,030	n/a
	–75E	7.5ns	n/a	n/a	n/a	n/a	n/a	9	1,031	n/a
	–6T	6ns	n/a	n/a	n/a	n/a	n/a	12	1,288	n/a
	–5B	5ns	n/a	n/a	n/a	n/a	n/a	14	1,564	n/a
IDD7	–75	7.5ns	2	3	n/a	3	10	n/a	n/a	2.5
	–75Z	7.5ns	2	3	n/a	3	10	n/a	n/a	2
	–75E	7.5ns	2	3	n/a	2	8	n/a	n/a	2
	–6T	6ns	2	3	n/a	3	10	n/a	n/a	2.5
	–5B	5ns	2	3	n/a	3	11	n/a	n/a	3

Electrical Specifications – DC and AC

Stresses greater than those listed in Table 9 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.

Table 9: Absolute Maximum Ratings

Parameter	Absolute Maximum Value
V_{DD} supply voltage relative to V_{SS}	–1V to +3.6V
V_{DDQ} supply voltage relative to V_{SS}	–1V to +3.6V
V_{REF} and inputs voltage relative to V_{SS}	–1V to +3.6V
I/O pins voltage relative to V_{SS}	–0.5V to V_{DDQ} +0.5V
Storage temperature (plastic)	–55°C to +150°C
Short circuit output current	50mA

Table 10: DC Electrical Characteristics and Operating Conditions (-5B)
Notes: 1–5 and 17 apply to entire table; Notes appear on pages 26–32;
V_{DDQ} = +2.6V ±0.1V, V_{DD} = +2.6V ±0.1V

Parameter/Condition		Symbol	Min	Max	Units	Notes
Supply voltage		V_{DD}	+2.5	+2.7	V	37, 42
I/O supply voltage		V_{DDQ}	+2.5	+2.7	V	37, 42, 45
I/O reference voltage		V_{REF}	0.49 × V_{DDQ}	0.51 × V_{DDQ}	V	7, 45
I/O termination voltage (system)		V_{TT}	V_{REF} - 0.04	V_{REF} + 0.04	V	8, 45
Input high (logic 1) voltage		$V_{IH(DC)}$	V_{REF} + 0.15	V_{DD} + 0.3	V	29
Input low (logic 0) voltage		$V_{IL(DC)}$	–0.3	V_{REF} - 0.15	V	29
Input leakage current: Any input 0V ≤ V_{IN} ≤ V_{DD}, V_{REF} pin 0V ≤ V_{IN} ≤ 1.35V (All other pins not under test = 0V)		I_I	–2	+2	µA	
Output leakage current: (DQs are disabled; 0V ≤ V_{OUT} ≤ V_{DDQ})		I_{OZ}	–5	+5	µA	
Full-drive option output levels: (x4, x8, x16)	High current (V_{OUT} = V_{DDQ} - 0.373V, minimum V_{REF}, minimum V_{TT})	I_{OH}	–16.8	–	mA	38, 40
	Low current (V_{OUT} = 0.373V, maximum V_{REF}, maximum V_{TT})	I_{OL}	+16.8	–	mA	
Reduced-drive option output levels: (x16 only)	High current (V_{OUT} = V_{DDQ} - 0.373V, minimum V_{REF}, minimum V_{TT})	I_{OHR}	–9	–	mA	39, 40
	Low current (V_{OUT} = 0.763V, maximum V_{REF}, maximum V_{TT})	I_{OLR}	+9	–	mA	
Ambient operating temperatures	Commercial	T_A	0	+70	°C	
	Industrial	T_A	–40	+85	°C	

Table 11: DC Electrical Characteristics and Operating Conditions (-6, -6T, -75E, -75Z, -75)

Notes: 1–5, 17 apply to entire table; Notes appear on pages 26–32; V_{DDQ} = +2.5V ±0.2V, V_{DD} = +2.5V ±0.2V

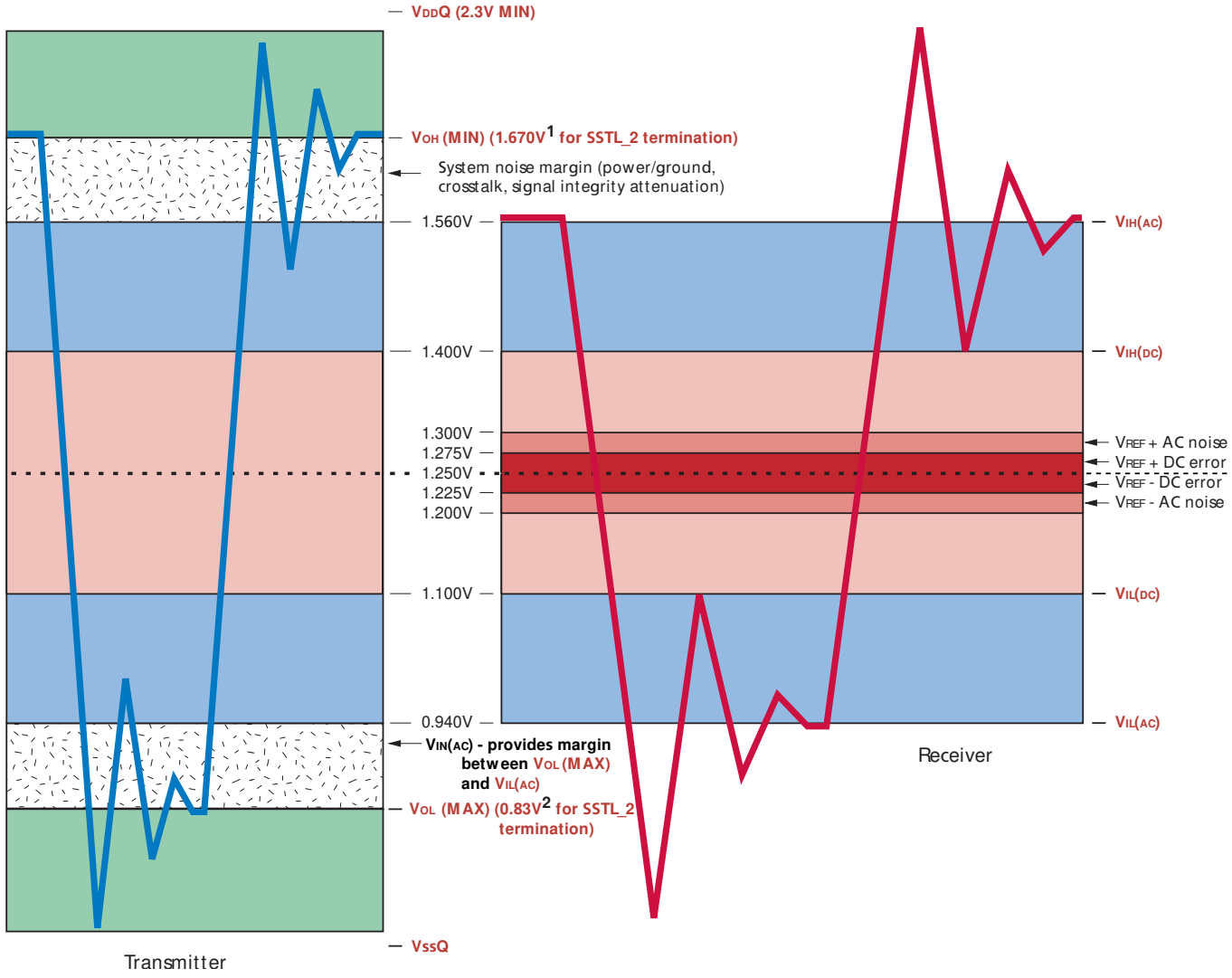
Parameter/Condition		Symbol	Min	Max	Units	Notes
Supply voltage		V_{DD}	+2.3	+2.7	V	37, 42
I/O supply voltage		V_{DDQ}	+2.3	+2.7	V	37, 42, 45
I/O reference voltage		V_{REF}	0.49 x V_{DDQ}	0.51 x V_{DDQ}	V	7, 45
I/O termination voltage (system)		V_{TT}	V_{REF} - 0.04	V_{REF} + 0.04	V	8, 45
Input high (logic 1) voltage		$V_{IH(DC)}$	V_{REF} + 0.15	V_{DD} + 0.3	V	29
Input low (logic 0) voltage		$V_{IL(DC)}$	–0.3	V_{REF} - 0.15	V	29
Input leakage current: Any input 0V ≤ V_{IN} ≤ V_{DD}, V_{REF} pin 0V ≤ V_{IN} ≤ 1.35V (All other pins not under test = 0V)		I_I	–2	+2	µA	
Output leakage current: (DQs are disabled; 0V ≤ V_{OUT} ≤ V_{DDQ})		I_{OZ}	–5	+5	µA	
Full-drive option output levels: (x4, x8, x16)	High current (V_{OUT} = V_{DDQ} - 0.373V, minimum V_{REF}, minimum V_{TT})	I_{OH}	–16.8	–	mA	38, 40
	Low current (V_{OUT} = 0.373V, maximum V_{REF}, maximum V_{TT})	I_{OL}	+16.8	–	mA	
Reduced-drive option output levels: (x16 only)	High current (V_{OUT} = V_{DDQ} - 0.763V, minimum V_{REF}, minimum V_{TT})	I_{OHR}	–9	–	mA	39, 40
	Low current (V_{OUT} = 0.763V, maximum V_{REF}, maximum V_{TT})	I_{OLR}	+9	–	mA	
Ambient operating temperatures	Commercial	T_A	0	+70	°C	
	Industrial	T_A	–40	+85	°C	

Table 12: AC Input Operating Conditions

0°C ≤ T_A ≤ +70°C; V_{DDQ} = +2.5V ±0.2V, V_{DD} = +2.5V ±0.2V
(V_{DDQ} = +2.6V ±0.1V, V_{DD} = +2.6V ±0.1V for -5B)
Notes: 1–5, 15, 17 apply to entire table; Notes appear on pages 26–32

Parameter/Condition	Symbol	Min	Max	Units	Notes
Input high (logic 1) voltage	$V_{IH(AC)}$	V_{REF} + 0.310	–	V	15, 29, 41
Input low (logic 0) voltage	$V_{IL(AC)}$	–	V_{REF} - 0.310	V	15, 29, 41
I/O reference voltage	$V_{REF(AC)}$	0.49 × V_{DDQ}	0.51 × V_{DDQ}	V	7

Figure 8: Input Voltage Waveform



Notes:
1. VOH (MIN) with test load is 1.927V.
2. VOL (MAX) with test load is 0.373V.
3. Numbers in diagram reflect nominal values utilizing circuit below for all devices other than -5B.

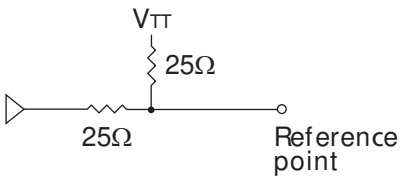
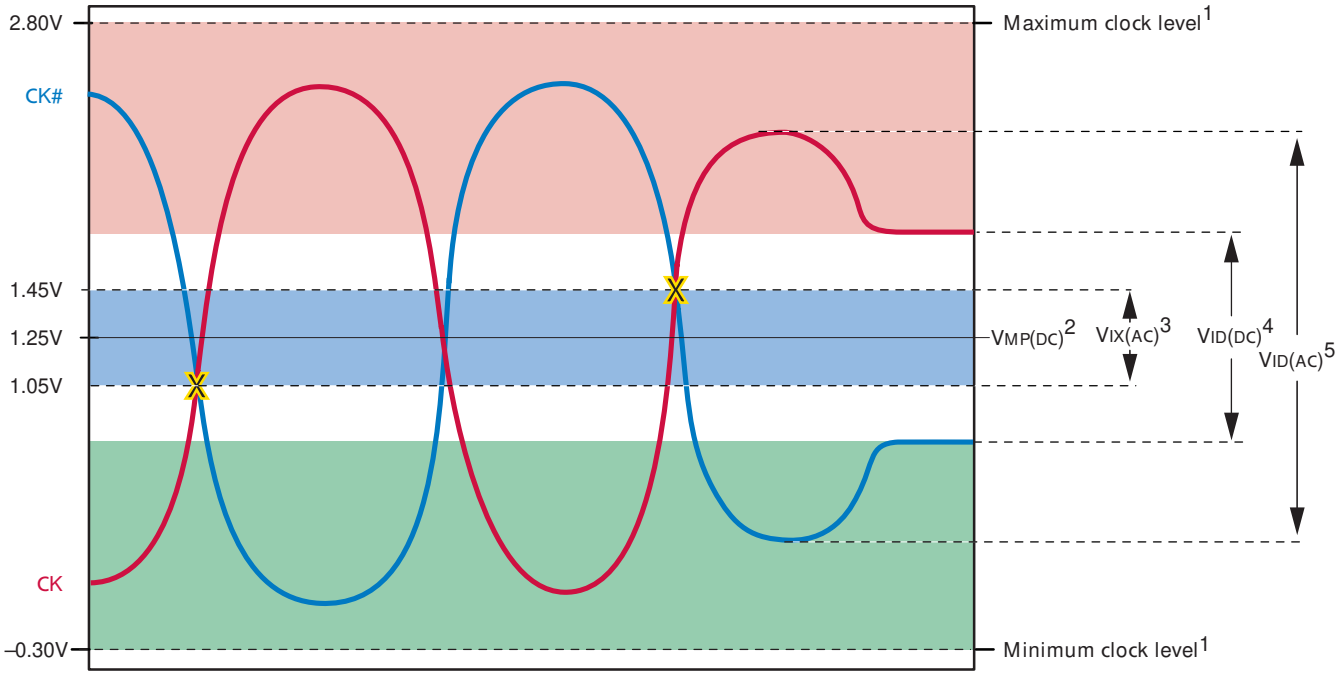


Table 13: Clock Input Operating Conditions

$0°C \le T_A \le +70°C$; V_{DDQ} = +2.5V ±0.2V, V_{DD} = +2.5V ±0.2V
(V_{DDQ} = +2.6V ±0.1V, V_{DD} = +2.6V ±0.1V for -5B)
Notes: 1–5, 16, 17, 31 apply to entire table; Notes appear on pages 26–32

Parameter/Condition	Symbol	Min	Max	Units	Notes
Clock input mid-point voltage: CK and CK#	$V_{MP(DC)}$	1.15	1.35	V	7, 10
Clock input voltage level: CK and CK#	$V_{IN(DC)}$	–0.3	V_{DDQ} + 0.3	V	7
Clock input differential voltage: CK and CK#	$V_{ID(DC)}$	0.36	V_{DDQ} + 0.6	V	7, 9
Clock input differential voltage: CK and CK#	$V_{ID(AC)}$	0.7	V_{DDQ} + 0.6	V	9
Clock input crossing point voltage: CK and CK#	$V_{IX(AC)}$	0.5 × V_{DDQ} - 0.2	0.5 × V_{DDQ} + 0.2	V	10

Figure 9: SSTL_2 Clock Input



Notes:
1. CK or CK# may not be more positive than V_{DDQ} + 0.3V or more negative than V_{SS} - 0.3V.
2. This provides a minimum of 1.15V to a maximum of 1.35V and is always half of V_{DDQ}.
3. CK and CK# must cross in this region.
4. CK and CK# must meet at least $V_{ID(DC)}$ MIN when static and is centered around $V_{MP(DC)}$.
5. CK and CK# must have a minimum 700mV peak-to-peak swing.
6. For AC operation, all DC clock requirements must also be satisfied.
7. Numbers in diagram reflect nominal values for all devices other than -5B.

Table 14: Capacitance (x4, x8 TSOP – 128Mb, 256Mb, 512Mb, 1Gb)
Note: 14 applies to entire table; Notes appear on pages 26–32

Parameter	Symbol	Min	Max	Units	Notes
Delta input/output capacitance: DQ0–DQ3 (x4), DQ0–DQ7 (x8)	DC_{IO}	–	0.50	pF	25
Delta input capacitance: Command and address	DC_{I1}	–	0.50	pF	30
Delta input capacitance: CK, CK#	DC_{I2}	–	0.25	pF	30
Input/output capacitance: DQs, DQS, DM	C_{IO}	4.0	5.0	pF	
Input capacitance: Command and address	C_{I1}	2.0	3.0	pF	
Input capacitance: CK, CK#	C_{I2}	2.0	3.0	pF	
Input capacitance: CKE	C_{I3}	2.0	3.0	pF	

Table 15: Capacitance (x4, x8 FBGA – 256Mb and 512Mb only)
Note: 14 applies to entire table; Notes appear on pages 26–32

Parameter	Symbol	Min	Max	Units	Notes
Delta input/output capacitance: DQs, DQS, DM	DC_{IO}	–	0.50	pF	25
Delta input capacitance: Command and address	DC_{I1}	–	0.50	pF	30
Delta input capacitance: CK, CK#	DC_{I2}	–	0.25	pF	30
Input/output capacitance: DQs, DQS, DM	C_{IO}	3.5	4.5	pF	
Input capacitance: Command and address	C_{I1}	1.5	2.5	pF	
Input capacitance: CK, CK#	C_{I2}	1.5	2.5	pF	
Input capacitance: CKE	C_{I3}	1.5	2.5	pF	

Table 16: Capacitance (x16 TSOP – 128Mb, 256Mb, 512Mb, 1Gb)
Note: 14 applies to entire table; Notes appear on pages 26–32

Parameter	Symbol	Min	Max	Units	Notes
Delta input/output capacitance: DQ0–DQ7, LDQS, LDM	DC_{IOL}	–	0.50	pF	25
Delta input/output capacitance: DQ8–DQ15, UDQS, UDM	DC_{IOU}	–	0.50	pF	25
Delta input capacitance: Command and address	DC_{I1}	–	0.50	pF	30
Delta input capacitance: CK, CK#	DC_{I2}	–	0.25	pF	30
Input/output capacitance: DQ, LDQS, UDQS, LDM, UDM	C_{IO}	4.0	5.0	pF	
Input capacitance: Command and address	C_{I1}	2.0	3.0	pF	
Input capacitance: CK, CK#	C_{I2}	2.0	3.0	pF	
Input capacitance: CKE	C_{I3}	2.0	3.0	pF	

Table 17: Capacitance (x16 FBGA – 256Mb and 512Mb only)
Note: 14 applies to entire table; Notes appear on pages 26–32

Parameter	Symbol	Min	Max	Units	Notes
Delta input/output capacitance: DQ0–DQ7, LDQS, LDM	DC_{IOL}	–	0.50	pF	25
Delta input/output capacitance: DQ8–DQ15, UDQS, UDM	DC_{IOU}	–	0.50	pF	25
Delta input capacitance: Command and address	DC_{I1}	–	0.50	pF	30
Delta input capacitance: CK, CK#	DC_{I2}	–	0.25	pF	30
Input/output capacitance: DQ, LDQS, UDQS, LDM, UDM	C_{IO}	3.5	4.5	pF	
Input capacitance: Command and address	C_{I1}	1.5	2.5	pF	
Input capacitance: CK, CK#	C_{I2}	1.5	2.5	pF	
Input capacitance: CKE	C_{I3}	1.5	2.5	pF	

Table 18: Electrical Characteristics & Recommended AC Operating Conditions (-5B)

Notes: 1–6, 15–18, 34 apply to entire table; Notes appear on pages 26–32;
$0°C \le T_A \le +70°C$; $V_{DD}Q$ = +2.6V ±0.1V, V_{DD} = +2.6V ±0.1V

AC Characteristics			-5B			
Parameter		**Symbol**	**Min**	**Max**	**Units**	**Notes**
Access window of DQ from CK/CK#		^tAC	–0.70	+0.70	ns	
CK high-level width		^tCH	0.45	0.55	^tCK	31
Clock cycle time	CL = 3	^tCK (3)	5	7.5	ns	52
	CL = 2.5	^tCK (2.5)	6	13	ns	46, 52
	CL = 2	^tCK (2)	7.5	13	ns	46, 52
CK low-level width		^tCL	0.45	0.55	^tCK	31
DQ and DM input hold time relative to DQS		^tDH	0.40	–	ns	27, 32
DQ and DM input pulse width (for each input)		^tDIPW	1.75	–	ns	32
Access window of DQS from CK/CK#		^tDQSCK	–0.60	+0.60	ns	
DQS input high pulse width		^tDQSH	0.35	–	^tCK	
DQS input low pulse width		^tDQSL	0.35	–	^tCK	
DQS–DQ skew, DQS to last DQ valid, per group, per access		^tDQSQ	–	0.40	ns	26, 27
WRITE command to first DQS latching transition		^tDQSS	0.72	1.28	^tCK	
DQ and DM input setup time relative to DQS		^tDS	0.40	–	ns	27, 32
DQS falling edge from CK rising – hold time		^tDSH	0.2	–	^tCK	
DQS falling edge to CK rising – setup time		^tDSS	0.2	–	^tCK	
Half-clock period		^tHP	^tCH, ^tCL	–	ns	35
Data-out High-Z window from CK/CK#		^tHZ	–	+0.70	ns	19, 43
Address and control input hold time (slew rate ≥0.5 V/ns)		^tIH_F	0.60	–	ns	15
Address and control input pulse width (for each input)		^tIPW	2.2	–	ns	
Address and control input setup time (slew rate ≥0.5 V/ns)		^tIS_F	0.60	–	ns	15
Data-out Low-Z window from CK/CK#		^tLZ	–0.70	–	ns	19, 43
LOAD MODE REGISTER command cycle time		^tMRD	10	–	ns	
DQ–DQS hold, DQS to first DQ to go non-valid, per access		^tQH	^tHP - ^tQHS	–	ns	26, 27
Data hold skew factor		^tQHS	–	0.50	ns	
ACTIVE-to-READ with auto precharge command		^tRAP	15	–	ns	
ACTIVE-to-PRECHARGE command		^tRAS	40	70,000	ns	36
ACTIVE-to-ACTIVE/AUTO REFRESH command period		^tRC	55	–	ns	
ACTIVE-to-READ or WRITE delay		^tRCD	15	–	ns	
REFRESH-to-REFRESH command interval	128Mb	^tREFC	–	140.6	µs	24
	256Mb, 512Mb, 1Gb	^tREFC	–	70.3	µs	24
AUTO REFRESH command period	128Mb, 256Mb, 512Mb	^tRFC	70	–	ns	50
	1Gb	^tRFC	120	–	ns	50
Average periodic refresh interval	128Mb	^tREFI	–	15.6	µs	24
	256Mb, 512Mb, 1Gb	^tREFI	–	7.8	µs	24
PRECHARGE command period		^tRP	15	–	ns	
DQS read preamble		^tRPRE	0.9	1.1	^tCK	44
DQS read postamble		^tRPST	0.4	0.6	^tCK	44
ACTIVE bank *a* to ACTIVE bank *b* command		^tRRD	10	–	ns	
Terminating voltage delay to V_{DD}		^tVTD	0	–	ns	
DQS write preamble		^tWPRE	0.25	–	^tCK	

Table 18: Electrical Characteristics & Recommended AC Operating Conditions (-5B) (continued)
Notes: 1–6, 15–18, 34 apply to entire table; Notes appear on pages 26–32;
0°C ≤ T_A ≤ +70°C; $V_{DD}Q$ = +2.6V ±0.1V, V_{DD} = +2.6V ±0.1V

AC Characteristics		-5B			
Parameter	Symbol	Min	Max	Units	Notes
DQS write preamble setup time	^{t}WPRES	0	–	ns	21, 22
DQS write postamble	^{t}WPST	0.4	0.6	^{t}CK	20
Write recovery time	^{t}WR	15	–	ns	
Internal WRITE-to-READ command delay	^{t}WTR	2	–	^{t}CK	
Exit SELF REFRESH-to-non-READ command (128Mb, 256Mb, 512Mb)	^{t}XSNR	70	–	ns	
Exit SELF REFRESH-to-non-READ command (1Gb)	^{t}XSNR	126	–	ns	
Exit SELF REFRESH-to-READ command	^{t}XSRD	200	–	^{t}CK	
Data valid output window (DVW)	n/a	^{t}QH - ^{t}DQSQ		ns	26

Table 19: Electrical Characteristics and Recommended AC Operating Conditions (-6, -6T, -75E)

Notes: 1–6, 15–18, 34 apply to entire table; Notes appear on pages 26–32;
$0°C \le T_A \le +70°C$; $V_{DD}Q$ = +2.5V ±0.2V, V_{DD} = +2.5V ±0.2V

AC Characteristics			-6 (FBGA)[1]		-6T (TSOP)		-75E			
Parameter		Symbol	Min	Max	Min	Max	Min	Max	Units	Notes
Access window of DQ from CK/CK#		^tAC	–0.70	+0.70	–0.70	+0.70	–0.75	+0.75	ns	
CK high-level width		^tCH	0.45	0.55	0.45	0.55	0.45	0.55	^tCK	31
Clock cycle time	CL = 2.5	^tCK (2.5)	6	13	6	13	7.5	13	ns	46, 52
	CL = 2	^tCK (2)	7.5	13	7.5	13	7.5	13	ns	46, 52
CK low-level width		^tCL	0.45	0.55	0.45	0.55	0.45	0.55	^tCK	31
DQ and DM input hold time relative to DQS		^tDH	0.45	–	0.45	–	0.5	–	ns	27, 32
DQ and DM input pulse width (for each input)		^tDIPW	1.75	–	1.75	–	1.75	–	ns	32
Access window of DQS from CK/CK#		^tDQSCK	–0.6	+0.6	–0.6	+0.6	–0.75	+0.75	ns	
DQS input high pulse width		^tDQSH	0.35	–	0.35	–	0.35	–	^tCK	
DQS input low pulse width		^tDQSL	0.35	–	0.35	–	0.35	–	^tCK	
DQS–DQ skew, DQS to last DQ valid, per group, per access		^tDQSQ	–	0.4	–	0.45	–	0.5	ns	26, 27
WRITE command to first DQS latching transition		^tDQSS	0.75	1.25	0.75	1.25	0.75	1.25	^tCK	
DQ and DM input setup time relative to DQS		^tDS	0.45	–	0.45	–	0.5	–	ns	27, 32
DQS falling edge from CK rising - hold time		^tDSH	0.2	–	0.2	–	0.2	–	^tCK	
DQS falling edge to CK rising - setup time		^tDSS	0.2	–	0.2	–	0.2	–	^tCK	
Half-clock period		^tHP	^tCH, ^tCL	–	^tCH, ^tCL	–	^tCH, ^tCL	–	ns	35
Data-out High-Z window from CK/CK#		^tHZ	–	+0.7	–	+0.7	–	+0.75	ns	19, 43
Address and control input hold time (fast slew rate)		^tIH_F	0.75	–	0.75	–	0.90	–	ns	
Address and control input hold time (slow slew rate)		^tIH_S	0.8	–	0.8	–	1	–	ns	15
Address and control input pulse width (for each input)		^tIPW	2.2	–	2.2	–	2.2	–	ns	
Address and control input setup time (fast slew rate)		^tIS_F	0.75	–	0.75	–	0.90	–	ns	
Address and control input setup time (slow slew rate)		^tIS_S	0.8	–	0.8	–	1	–	ns	15
Data-out Low-Z window from CK/CK#		^tLZ	–0.7	–	–0.7	–	–0.75	–	ns	19, 43
LOAD MODE REGISTER command cycle time		^tMRD	12	–	12	–	15	–	ns	
DQ-DQS hold, DQS to first DQ to go non-valid, per access		^tQH	^tHP - ^tQHS	–	^tHP - ^tQHS	–	^tHP - ^tQHS	–	ns	26, 27
Data hold skew factor		^tQHS	–	0.50	–	0.55	–	0.75	ns	
ACTIVE-to-READ with auto precharge command		^tRAP	15	–	15	–	15	–	ns	
ACTIVE-to-PRECHARGE command		^tRAS	42	70,000	42	70,000	40	120,000	ns	36, 54
ACTIVE-to-ACTIVE/AUTO REFRESH command period		^tRC	60	–	60	–	60	–	ns	
ACTIVE-to-READ or WRITE delay		^tRCD	15	–	15	–	15	–	ns	
REFRESH-to-REFRESH command interval	128Mb	^tREFC	–	140.6	–	140.6	–	140.6	µs	24
	256Mb, 512Mb, 1Gb	^tREFC	–	70.3	–	70.3	–	70.3	µs	24
Average periodic refresh interval	128Mb	^tREFI	–	15.6	–	15.6	–	15.6	µs	24
	256Mb, 512Mb, 1Gb	^tREFI	–	7.8	–	7.8	–	7.8	µs	24
AUTO REFRESH command period	128Mb, 256Mb, 512Mb	^tRFC	72	–	72	–	75	–	ns	50
	1Gb	^tRFC	–	–	120	–	–	–	ns	50
PRECHARGE command period		^tRP	15	–	15	–	15	–	ns	
DQS read preamble		^tRPRE	0.9	1.1	0.9	1.1	0.9	1.1	^tCK	44

Table 19: Electrical Characteristics and Recommended AC Operating Conditions (-6, -6T, -75E) (continued)

Notes: 1–6, 15–18, 34 apply to entire table; Notes appear on pages 26–32;

AC Characteristics			-6 (FBGA)[1]		-6T (TSOP)		-75E			
Parameter		Symbol	Min	Max	Min	Max	Min	Max	Units	Notes
DQS read postamble		^{t}RPST	0.4	0.6	0.4	0.6	0.4	0.6	^{t}CK	44
ACTIVE bank *a* to ACTIVE bank *b* command		^{t}RRD	12	–	12	–	15	–	ns	
Terminating voltage delay to V_{SS}		^{t}VTD	0	–	0	–	0	–	ns	
DQS write preamble		^{t}WPRE	0.25	–	0.25	–	0.25	–	^{t}CK	
DQS write preamble setup time		^{t}WPRES	0	–	0	–	0	–	ns	21, 22
DQS write postamble		^{t}WPST	0.4	0.6	0.4	0.6	0.4	0.6	^{t}CK	20
Write recovery time		^{t}WR	15	–	15	–	15	–	ns	
Internal WRITE-to-READ command delay		^{t}WTR	1	–	1	–	1	–	^{t}CK	
Exit SELF REFRESH-to-non-READ command	128Mb, 256Mb, 512Mb	^{t}XSNR	75	–	75	–	75	–	ns	
	1Gb	^{t}XSNR	–	–	126	–	–	–	ns	
Exit SELF REFRESH-to-READ command		^{t}XSRD	200	–	200	–	200	–	^{t}CK	
Data valid output window (DVW)		n/a	^{t}QH - ^{t}DQSQ		^{t}QH - ^{t}DQSQ		^{t}QH - ^{t}DQSQ		ns	26

Notes: 1. -6 (FBGA) available in 256Mb and 512Mb densities only.

Table 20: Electrical Characteristics and Recommended AC Operating Conditions (-75Z, -75)

Notes: 1–6, 15–18, 34 apply to entire table; Notes appear on pages 26–32;
$0°C \le T_A \le +70°C$; $V_{DD}Q$ = +2.5V ±0.2V, V_{DD} = +2.5V ±0.2V

AC Characteristics			-75Z		-75			
Parameter		Symbol	Min	Max	Min	Max	Units	Notes
Access window of DQ from CK/CK#		^tAC	–0.75	+0.75	–0.75	+0.75	ns	
CK high-level width		^tCH	0.45	0.55	0.45	0.55	^tCK	31
Clock cycle time	CL = 2.5	^tCK (2.5)	7.5	13	7.5	13	ns	46
	CL = 2	^tCK (2)	7.5	13	10	13	ns	46
CK low-level width		^tCL	0.45	0.55	0.45	0.55	^tCK	31
DQ and DM input hold time relative to DQS		^tDH	0.5	–	0.5	–	ns	27, 32
DQ and DM input pulse width (for each input)		^tDIPW	1.75	–	1.75	–	ns	32
Access window of DQS from CK/CK#		^tDQSCK	–0.75	+0.75	–0.75	+0.75	ns	
DQS input high pulse width		^tDQSH	0.35	–	0.35	–	^tCK	
DQS input low pulse width		^tDQSL	0.35	–	0.35	–	^tCK	
DQS–DQ skew, DQS to last DQ valid, per group, per access		^tDQSQ	–	0.5	–	0.5	ns	26, 27
WRITE command-to-first DQS latching transition		^tDQSS	0.75	1.25	0.75	1.25	^tCK	
DQ and DM input setup time relative to DQS		^tDS	0.5	–	0.5	–	ns	27, 32
DQS falling edge from CK rising – hold time		^tDSH	0.2	–	0.2	–	^tCK	
DQS falling edge to CK rising – setup time		^tDSS	0.2	–	0.2	–	^tCK	
Half-clock period		^tHP	^tCH,^tCL	–	^tCH,^tCL	–	ns	35
Data-out High-Z window from CK/CK#		^tHZ	–	+0.75	–	+0.75	ns	19, 43
Address and control input hold time (fast slew rate)		^tIH_F	0.90	–	0.90	–	ns	
Address and control input hold time (slow slew rate)		^tIH_S	1	–	1	–	ns	15
Address and control input pulse width (for each input)		^tIPW	2.2	–	2.2	–	ns	
Address and control input setup time (fast slew rate)		^tIS_F	0.90	–	0.90	–	ns	
Address and control input setup time (slow slew rate)		^tIS_S	1	–	1	–	ns	15
Data-out Low-Z window from CK/CK#		^tLZ	–0.75	–	–0.75	–	ns	19, 43
LOAD MODE REGISTER command cycle time		^tMRD	15	–	15	–	ns	
DQ–DQS hold, DQS to first DQ to go non-valid, per access		^tQH	^tHP - ^tQHS	–	^tHP - ^tQHS	–	ns	26, 27
Data hold skew factor		^tQHS	–	0.75	–	0.75	ns	
ACTIVE-to-READ with auto precharge command		^tRAP	20	–	20	–	ns	
ACTIVE-to-PRECHARGE command		^tRAS	40	120,000	40	120,000	ns	36
ACTIVE-to-ACTIVE/AUTO REFRESH command period		^tRC	65	–	65	–	ns	
ACTIVE-to-READ or WRITE delay		^tRCD	20	–	20	–	ns	
REFRESH-to-REFRESH command interval	128Mb	^tREFC	–	140.6	–	140.6	µs	24
	256Mb, 512Mb, 1Gb	^tREFC	–	70.3	–	70.3	µs	24
Average periodic refresh interval	128Mb	^tREFI	–	15.6	–	15.6	µs	24
	256Mb, 512Mb, 1Gb	^tREFI	–	7.8	–	7.8	µs	24
AUTO REFRESH command period	128Mb, 256Mb, 512Mb	^tRFC	75	–	75	–	ns	50
	1Gb	^tRFC	–	–	120	–	ns	50

Table 20: Electrical Characteristics and Recommended AC Operating Conditions (-75Z, -75) (continued)
Notes: 1–6, 15–18, 34 apply to entire table; Notes appear on pages 26–32;

AC Characteristics			-75Z		-75			
Parameter		Symbol	Min	Max	Min	Max	Units	Notes
PRECHARGE command period		^{t}RP	20	–	20	–	ns	
DQS read preamble		^{t}RPRE	0.9	1.1	0.9	1.1	^{t}CK	44
DQS read postamble		^{t}RPST	0.4	0.6	0.4	0.6	^{t}CK	44
ACTIVE bank *a* to ACTIVE bank *b* command		^{t}RRD	15	–	15	–	ns	
Terminating voltage delay to V_{DD}		^{t}VTD	0	–	0	–	ns	
DQS write preamble		^{t}WPRE	0.25	–	0.25	–	^{t}CK	
DQS write preamble setup time		^{t}WPRES	0	–	0	–	ns	21, 22
DQS write postamble		^{t}WPST	0.4	0.6	0.4	0.6	^{t}CK	20
Write recovery time		^{t}WR	15	–	15	–	ns	
Internal WRITE-to-READ command delay		^{t}WTR	1	–	1	–	^{t}CK	
Exit SELF REFRESH-to-non-READ command	128Mb, 256Mb, 512Mb	^{t}XSNR	75	–	75	–	ns	
	1Gb	^{t}XSNR	–	–	127.5	–	ns	
Exit SELF REFRESH-to-READ command		^{t}XSRD	200	–	200	–	^{t}CK	
Data valid output window (DVW)		n/a	^{t}QH - ^{t}DQSQ		^{t}QH - ^{t}DQSQ		ns	26

Table 21: Input Slew Rate Derating Values for Addresses and Commands
Note: 15 applies to entire table; 0°C ≤ T_A ≤ +70°C; V_{DDQ} = +2.5V ±0.2V, V_{DD} = +2.5V ±0.2V

Speed	Slew Rate	^{t}IS	^{t}IH	Units
-75/-75Z/-75E	0.500 V/ns	1.00	1	ns
-75/-75Z/-75E	0.400 V/ns	1.05	1	ns
-75/-75Z/-75E	0.300 V/ns	1.10	1	ns

Table 22: Input Slew Rate Derating Values for DQ, DQS, and DM
Note: 32 apply to entire table; 0°C ≤ T_A ≤ +70°C; V_{DDQ} = +2.5V ±0.2V, V_{DD} = +2.5V ±0.2V

Speed	Slew Rate	^{t}DS	^{t}DH	Units
-75/-75Z/-75E	0.500 V/ns	0.50	0.50	ns
-75/-75Z/-75E	0.400 V/ns	0.55	0.55	ns
-75/-75Z/-75E	0.300 V/ns	0.60	0.60	ns