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Automotive DDR SDRAM

MT46V32M8 – 8 Meg x 8 x 4 banks

MT46V16M16 – 4 Meg x 16 x 4 banks

Features

- $V_{DD} = 2.5V \pm 0.2V$, $V_{DDQ} = 2.5V \pm 0.2V$
 $V_{DD} = 2.6V \pm 0.1V$, $V_{DDQ} = 2.6V \pm 0.1V$ (DDR400)¹
- Bidirectional data strobe (DQS) transmitted/received with data, that is, 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 (BL): 2, 4, or 8
- Auto refresh
 - 64ms, 8192-cycle (AIT)
 - 16ms, 8192-cycle (AAT)
- Self refresh (not available on AAT devices)
- Longer-lead TSOP for improved reliability (OCPL)
- 2.5V I/O (SSTL_2-compatible)
- Concurrent auto precharge option supported
- ^tRAS lockout supported (^tRAP = ^tRCD)
- AEC-Q100
- PPAP submission
- 8D response time

Options

- Configuration
 - 32 Meg x 8 (8 Meg x 8 x 4 banks) 32M8
 - 16 Meg x 16 (4 Meg x 16 x 4 banks) 16M16
- Plastic package – OCPL
 - 66-pin TSOP TG
 - 66-pin TSOP (Pb-free) P
- Plastic package
 - 60-ball FBGA (8mm x 12.5mm) CV
 - 60-ball FBGA (8mm x 12.5mm) (Pb-free) CY
- Timing – cycle time
 - 5ns @ CL = 3 (DDR400) -5B
- Self refresh
 - Standard None
 - Low-power self refresh L
- Temperature rating
 - Industrial (–40°C to +85°C) AIT
 - Automotive (–40°C to +105°C) AAT
- Revision
 - x8, x16 :M

Notes: 1. DDR400 devices operating at \leq DDR333 conditions can use $V_{DD}/V_{DDQ} = 2.5V \pm 0.2V$.
2. Not all options listed can be combined to define an offered product. Use the Part Catalog Search on www.micron.com for product offerings and availability.

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
-6	133	167	n/a	2.1ns	±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

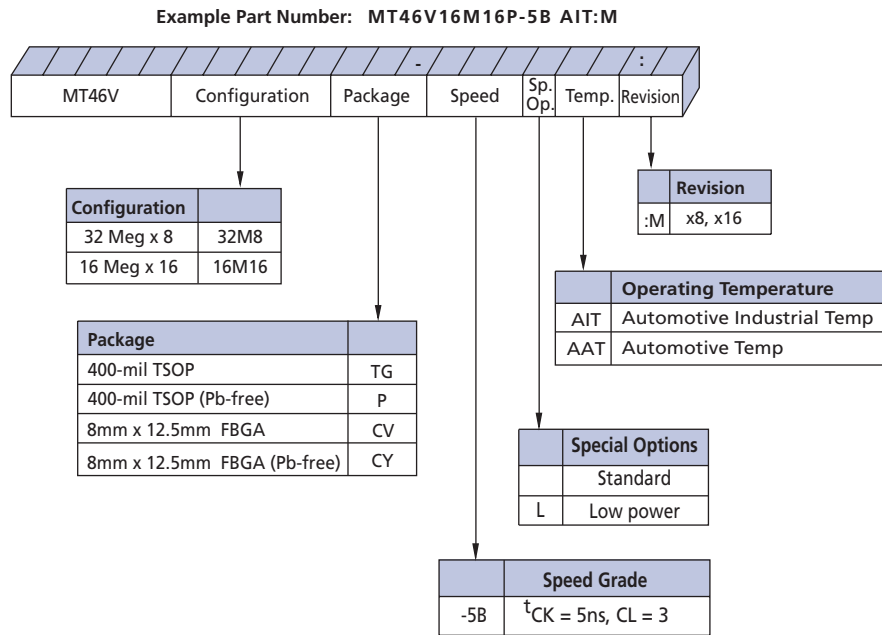
Parameter	32 Meg x 8	16 Meg x 16
Configuration	8 Meg x 8 x 4 banks	4 Meg x 16 x 4 banks
Refresh count	8K	8K
Row address	8K (A[12:0])	8K (A[12:0])
Bank address	4 (BA[1:0])	4 (BA[1:0])
Column address	1K (A[9:0])	512 (A[8:0])

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)
-5B¹	Yes	Yes	Yes	Yes	Yes	Yes
-6	-	Yes	Yes	Yes	Yes	Yes
-6T	-	Yes	Yes	Yes	Yes	Yes
-75E	-	-	Yes	Yes	Yes	Yes
-75Z	-	-	-	Yes	Yes	Yes
-75	-	-	-	-	Yes	Yes
	-5B	-6/-6T	-75E	-75Z	-75	-75

Notes: 1. The -5B device is backward compatible with all slower speed grades. The voltage range of -5B device operating at slower speed grades is $V_{DD} = V_{DDQ} = 2.5V \pm 0.2V$.

Figure 1: 256Mb DDR SDRAM Part Numbers



FBGA Part Marking System

Due to space limitations, FBGA-packaged components have an abbreviated part marking that is different from the part number. For a quick conversion of an FBGA code, see the FBGA Part Marking Decoder on Micron’s Web site: www.micron.com.

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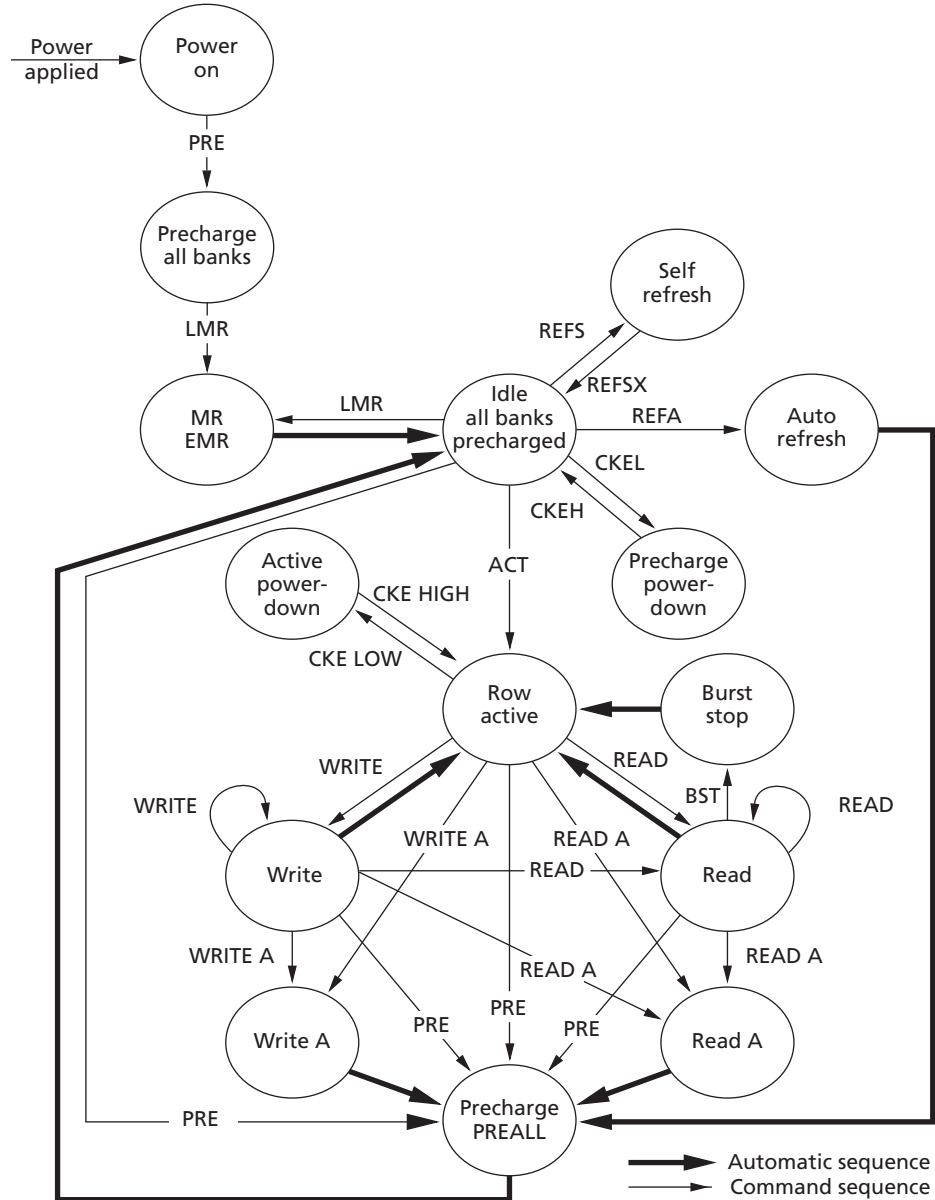
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State Diagram

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 $2n$ -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 $2n$ -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 (DQ[7:0]) DM refers to LDM and DQS refers to LDQS. For the upper byte (DQ[15:8]) 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.

Automotive Industrial Temperature

The automotive temperature (AIT) option, Ambient and case temperatures cannot be less than -40°C or greater than 85°C

Automotive Temperature

The automotive temperature (AAT) option adheres to the following specifications:

- 16ms refresh rate
- Self refresh not supported
- Ambient and case temperatures cannot be less than -40°C or greater than 105°C

Functional Block Diagrams

The 256Mb DDR SDRAM is a high-speed CMOS, dynamic random-access memory containing 268,435,456 bits. It is internally configured as a 4-bank DRAM.

Figure 3: 32 Meg x 8 Functional Block Diagram

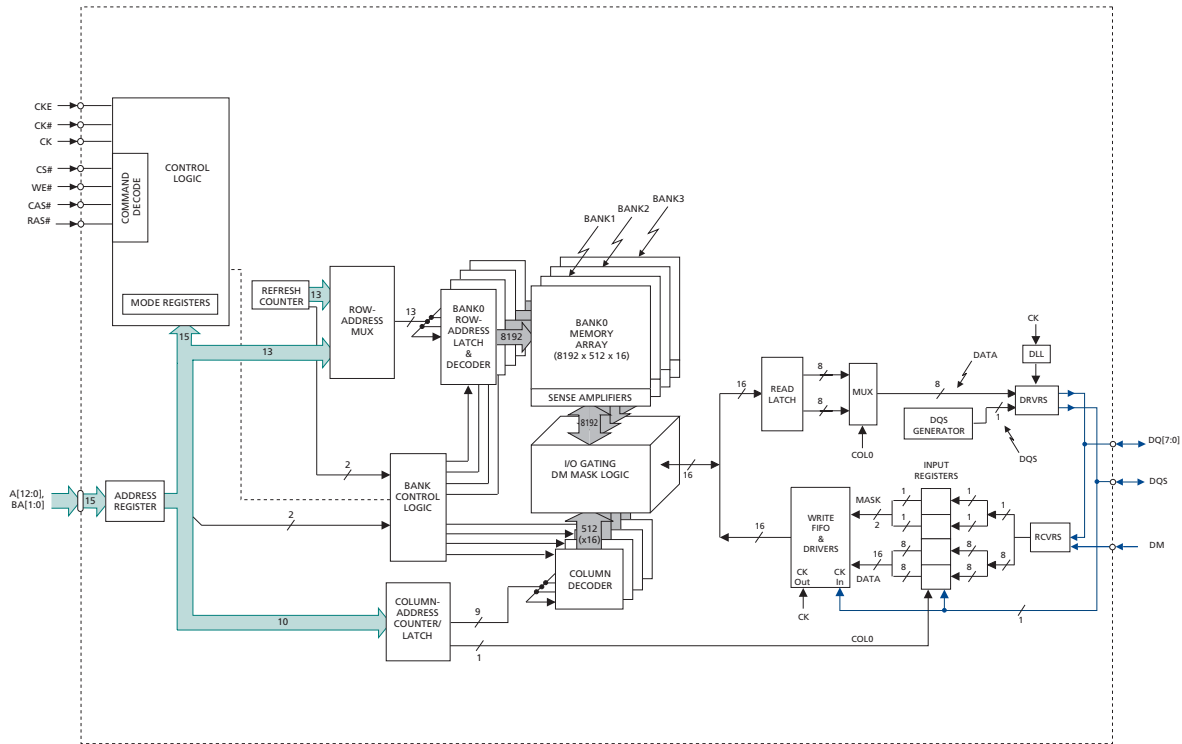
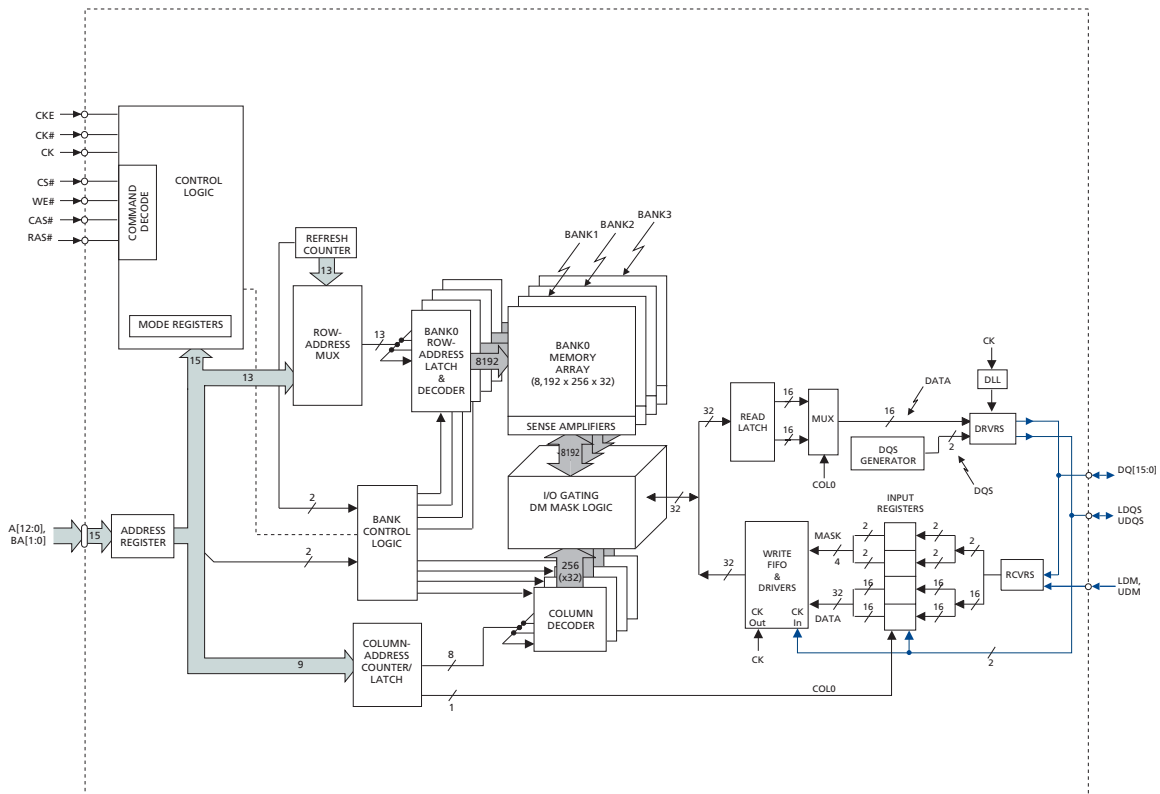


Figure 4: 16 Meg x 16 Functional Block Diagram



Pin and Ball Assignments and Descriptions

Figure 5: 66-Pin TSOP Pin Assignments (Top View)

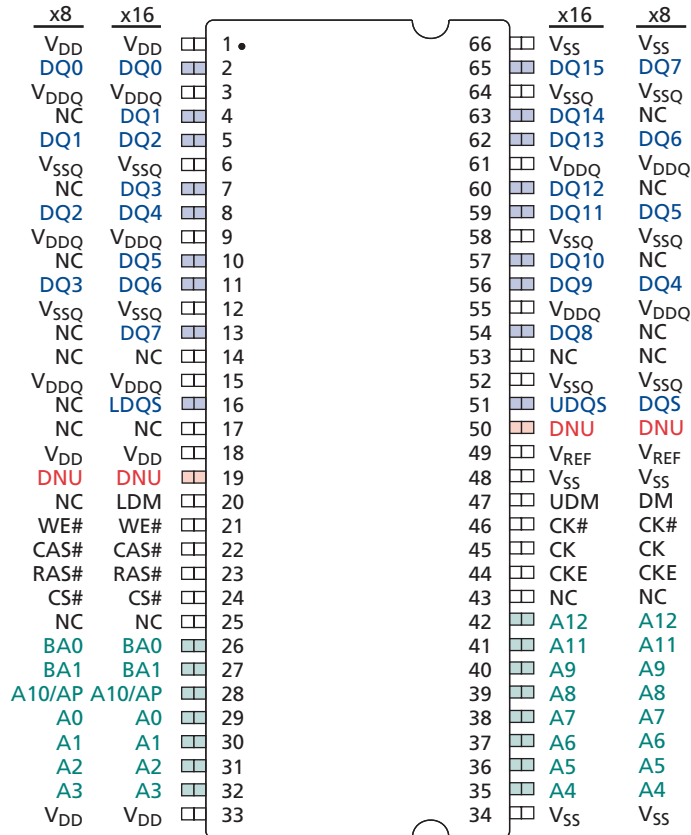


Figure 6: 60-Ball FBGA Ball Assignments (Top View)

x8 (Top View)

1	2	3	4	5	6	7	8	9
V _{SSQ}	DQ7	V _{SS}	●	A	●	V _{DD}	DQ0	V _{DDQ}
NC	V _{DDQ}	DQ6	●	B	●	DQ1	V _{SSQ}	NC
NC	V _{SSQ}	DQ5	●	C	●	DQ2	V _{DDQ}	NC
NC	V _{DDQ}	DQ4	●	D	●	DQ3	V _{SSQ}	NC
NC	V _{SSQ}	DQS	●	E	●	NC	V _{DDQ}	NC
V _{REF}	V _{SS}	DM	●	F	●	NC	V _{DD}	DNU
	CK	CK#	●	G	●	WE#	CAS#	
	A12	CKE	●	H	●	RAS#	CS#	
	A11	A9	●	J	●	BA1	BA0	
	A8	A7	●	K	●	A0	A10	
	A6	A5	●	L	●	A2	A1	
	A4	V _{SS}	●	M	●	V _{DD}	A3	

x16 (Top View)

1	2	3	4	5	6	7	8	9
V _{SSQ}	DQ15	V _{SS}	●	A	●	V _{DD}	DQ0	V _{DDQ}
DQ14	V _{DDQ}	DQ13	●	B	●	DQ2	V _{SSQ}	DQ1
DQ12	V _{SSQ}	DQ11	●	C	●	DQ4	V _{DDQ}	DQ3
DQ10	V _{DDQ}	DQ9	●	D	●	DQ6	V _{SSQ}	DQ5
DQ8	V _{SSQ}	UDQS	●	E	●	LDQS	V _{DDQ}	DQ7
V _{REF}	V _{SS}	UDM	●	F	●	LDM	V _{DD}	DNU
	CK	CK#	●	G	●	WE#	CAS#	
	A12	CKE	●	H	●	RAS#	CS#	
	A11	A9	●	J	●	BA1	BA0	
	A8	A7	●	K	●	A0	A10	
	A6	A5	●	L	●	A2	A1	
	A4	V _{SS}	●	M	●	V _{DD}	A3	

Table 4: Pin and Ball Descriptions

FBGA Numbers	TSOP Numbers	Symbol	Type	Description
K7, L8, L7, M8, M2, L3, L2, K3, K2, J3, K8, J2, H2	29, 30, 31, 32, 35, 36, 37, 38, 39, 40, 28, 41, 42	A0, A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12	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 BA[1:0]) or all banks (A10 HIGH). The address inputs also provide the op-code during a LOAD MODE REGISTER command.
J8, J7	26, 27	BA0, BA1	Input	Bank address inputs: BA[1:0] define to which bank an ACTIVE, READ, WRITE, or PRECHARGE command is being applied. BA[1:0] also define which mode register (mode register or extended mode register) is loaded during the LOAD MODE REGISTER (LMR) command.
G2, G3	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 the negative edge of CK#. Output data (DQ and DQS) is referenced to the crossings of CK and CK#.
H3	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 a SSTL_2 input only.
H8	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.
F3, F7, F3	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 DQ[7:0] and UDM is DM for DQ[15:8]. Pin 20 is a NC on x8.
H7, G8, G7	23, 22, 21	RAS#, CAS#, WE#	Input	Command inputs: RAS#, CAS#, and WE# (along with CS#) define the command being entered.
A8, B9, B7, C9, C7, D9, D7, E9, E1, D3, D1, C3, C1, B3, B1, A2	2, 4, 5, 7, 8, 10, 11, 13, 54, 56, 57, 59, 60, 62, 63, 65	DQ[2:0], DQ[5:3], DQ[8:6], DQ[11:9], DQ[14:12], DQ15	I/O	Data input/output: Data bus for x16.
A8, B7, C7, D7, D3, C3, B3, A2	2, 5, 8, 11, 56, 59, 62, 65	DQ[2:0], DQ[5:3], DQ[7:6]	I/O	Data input/output: Data bus for x8.

Table 4: Pin and Ball Descriptions (continued)

FBGA Numbers	TSOP Numbers	Symbol	Type	Description
E3 E7 E3	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 DQ[7:0] and UDQS is DQS for DQ[15:8]. Pin 16 (E7) is NC on x8.
F8, M7, A7	1, 18, 33	V _{DD}	Supply	Power supply.
B2, D2, C8, E8, A9	3, 9, 15, 55, 61	V _{DDQ}	Supply	DQ power supply: Isolated on the die for improved noise immunity.
A3, F2, M3	34, 48, 66	V _{SS}	Supply	Ground.
A1, C2, E2, B8, D8	6, 12, 52, 58, 64	V _{SSQ}	Supply	DQ ground: Isolated on the die for improved noise immunity.
F1	49	V _{REF}	Supply	SSTL_2 reference voltage.
–	14, 17, 25, 43, 53	NC	–	No connect for x16: These pins should be left unconnected.
B1, B9, C1, C9, D1, D9, E1, E7, E9, F7	4, 7, 10, 13, 14, 16, 17, 20, 25, 43, 53, 54, 57, 60, 63	NC	–	No connect for x8: These pins should be left unconnected.
F9	19, 50	DNU	–	Do not use: Must float to minimize noise on V _{REF}

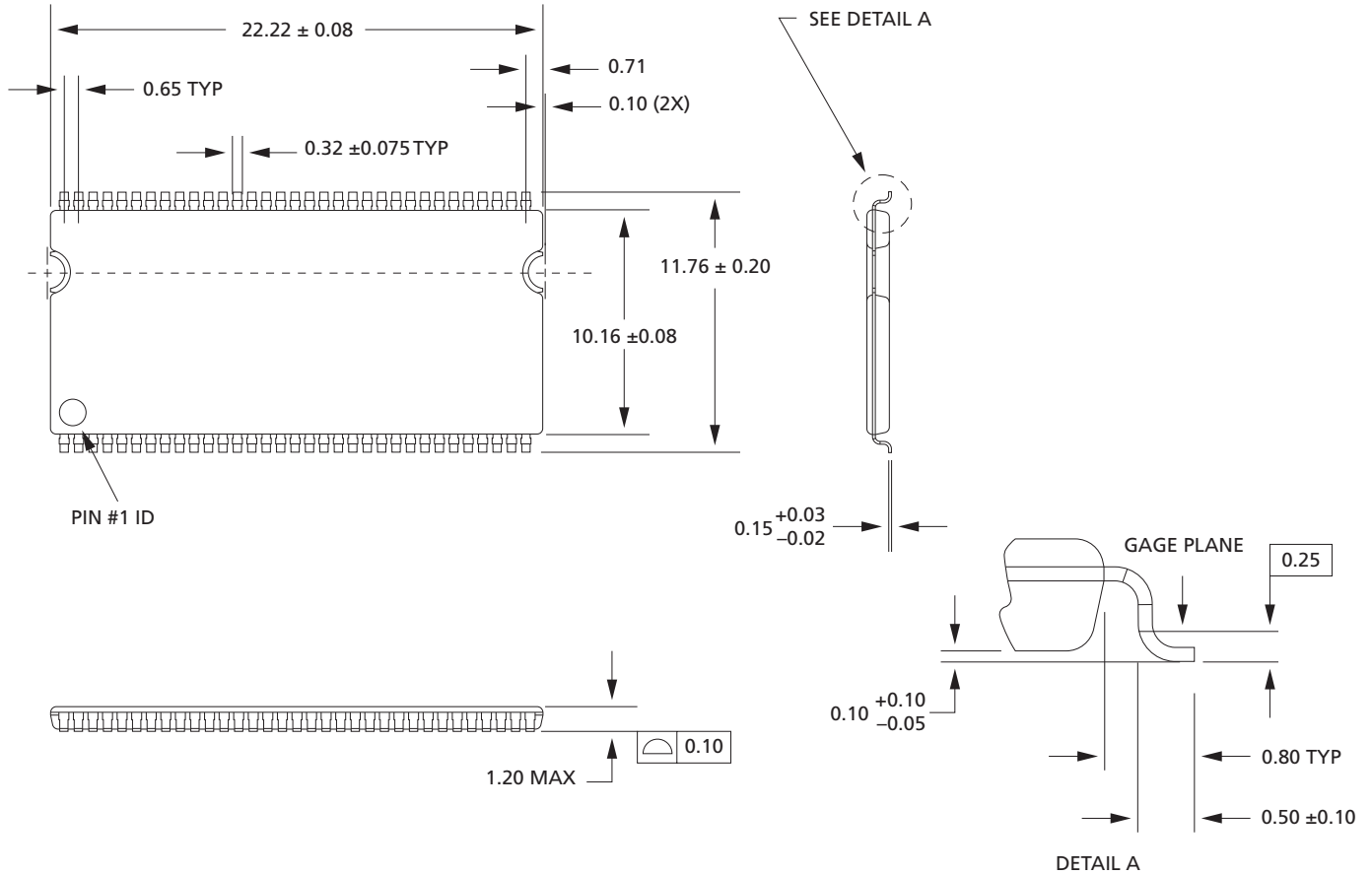
Table 5: Reserved NC Pin Descriptions

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

TSOP Numbers	Symbol	Type	Description
17	A13	Input	Address input A13 for 1Gb devices.

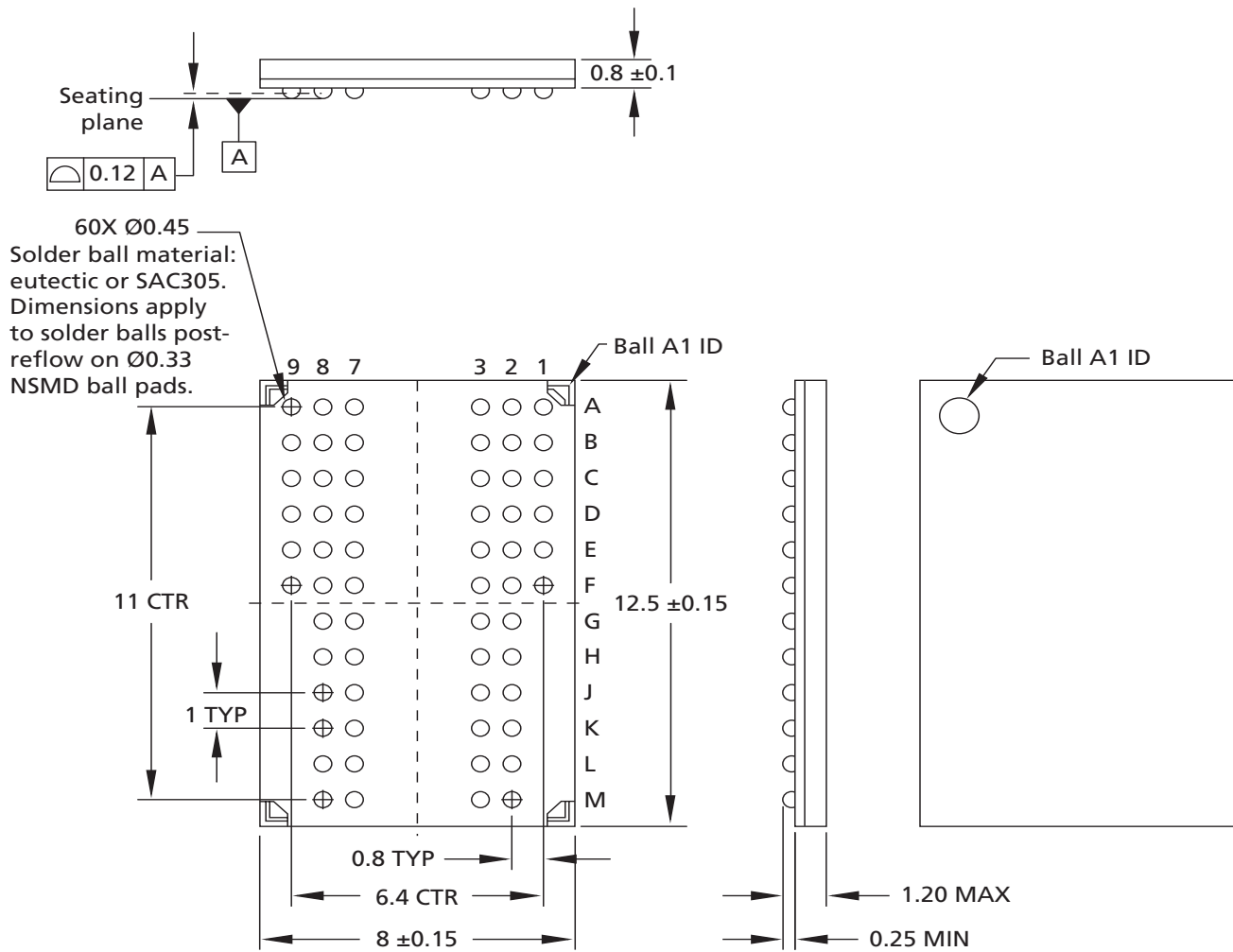
Package Dimensions

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



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

Figure 8: 60-Ball FBGA (8mm x 12.5mm)



- Notes:
1. All dimensions are in millimeters.
 2. Topside part marking decoder can be found on Micron's Web site.

Electrical Specifications – I_{DD}

Table 6: I_{DD} Specifications and Conditions (x8, x16: -5B)

V_{DDQ} = 2.6V ±0.1V, V_{DD} = 2.6V ±0.1V (-5B); 0°C ≤ T_A ≤ +70°C; Notes: 1–5, 11, 13, 15, 47; Notes appear on pages 34–39; See also Table 7 on page 17

Parameter/Condition	Symbol	-5B	-6/6T	Units	Notes	
Operating one-bank precharge current: ^t RC = ^t RC (MIN); ^t CK = ^t CK (MIN); DQ, DM, and DQS inputs changing once per clock cycle; Address and control inputs changing once every two clock cycles	I _{DD0}	75	65	mA	23, 48	
Operating one-bank active-read-precharge current: Burst = 4; ^t RC = ^t RC (MIN); ^t CK = ^t CK (MIN); I _{OUT} = 0mA; Address and control inputs changing once per clock cycle	I _{DD1}	85	75	mA	23, 48	
Precharge power-down standby current: All banks idle; Power-down mode; ^t CK = ^t CK (MIN); CKE = LOW	I _{DD2P}	4	4	mA	24, 33	
Idle standby current: CS# = HIGH; All banks are idle; ^t CK = ^t CK (MIN); CKE = HIGH; Address and other control inputs changing once per clock cycle; V _{IN} = V _{REF} for DQ, DQS, and DM	I _{DD2F}	23	23	mA	51	
Active power-down standby current: One bank active; Power-down mode; ^t CK = ^t CK (MIN); CKE = LOW	I _{DD3P}	14	14	mA	24, 33	
Active standby current: CS# = HIGH; CKE = HIGH; One bank active; ^t RC = ^t RAS (MAX); ^t CK = ^t CK (MIN); DQ, DM, and DQS inputs changing twice per clock cycle; Address and other control inputs changing once per clock cycle	I _{DD3N}	30	30	mA	23	
Operating burst read current: Burst = 2; Continuous burst reads; One bank active; Address and control inputs changing once per clock cycle; ^t CK = ^t CK (MIN); I _{OUT} = 0mA	I _{DD4R}	105	95	mA	23, 48	
Operating burst write current: Burst = 2; Continuous burst writes; One bank active; Address and control inputs changing once per clock cycle; ^t CK = ^t CK (MIN); DQ, DM, and DQS inputs changing twice per clock cycle	I _{DD4W}	105	95	mA	23	
Auto refresh burst current:	^t REFC = ^t RFC (MIN)	I _{DD5}	115	105	mA	50
	^t REFC = 7.8μs (AIT)	I _{DD5A}	6	6	mA	28, 50
	^t REFC = 1.95μs (AAT)	I _{DD5A}	9	9	mA	28, 50
Self refresh current: CKE ≤ 0.2V (Not supported for AAT)	Standard	I _{DD6}	4	4	mA	12
	Low power (L)	I _{DD6A}	2	2	mA	12
Operating bank interleave read current: Four-bank interleaving READs (burst = 4) with auto precharge; ^t RC = minimum ^t RC allowed; ^t CK = ^t CK (MIN); Address and control inputs change only during ACTIVE, READ, or WRITE commands	I _{DD7}	175	175	mA	23, 49	

Electrical Specifications – DC and AC

Stresses greater than those listed in Table 7 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 7: Absolute Maximum Ratings

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

Table 8: DC Electrical Characteristics and Operating Conditions (-5B)

Notes: 1–5 and 17 apply to the entire table; Notes appear on page 34; $V_{DDQ} = 2.6V \pm 0.1V$, $V_{DD} = 2.6V \pm 0.1V$

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}	$0.49 \times V_{DDQ}$	$0.51 \times V_{DDQ}$	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 $0V \leq V_{IN} \leq V_{DD}$, V_{REF} pin $0V \leq V_{IN} \leq 1.35V$ (All other pins not under test = 0V)	I_I	-2	2	μA		
Output leakage current: (DQ are disabled; $0V \leq V_{OUT} \leq V_{DDQ}$)	I_{OZ}	-5	5	μA		
Full-drive option output levels (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	High current ($V_{OUT} = V_{DDQ} - 0.373V$, minimum V_{REF} minimum V_{TT})	I_{OHR}	-9	-	mA	39, 40
	Low current ($V_{OUT} = 0.373V$, maximum V_{REF} maximum V_{TT})	I_{OLR}	9	-	mA	
Ambient operating temperatures	Commercial	T_A	0	70	°C	
	Industrial (AIT)	T_A	-40	85	°C	
	Automotive (AAT)	T_A	-40	105	°C	

Table 9: DC Electrical Characteristics and Operating Conditions (-6, -6T, -75E, -75Z, -75)

 Notes: 1–5, 17 apply to the entire table; Notes appear on page 34; $V_{DDQ} = 2.5V \pm 0.2V$, $V_{DD} = 2.5V \pm 0.2V$

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}	$0.49 \times V_{DDQ}$	$0.51 \times V_{DDQ}$	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 $0V \leq V_{IN} \leq V_{DD}$, V_{REF} pin $0V \leq V_{IN} \leq 1.35V$ (All other pins not under test = 0V)	I_I	-2	2	μA		
Output leakage current: (DQ are disabled; $0V \leq V_{OUT} \leq V_{DDQ}$)	I_{OZ}	-5	5	μA		
Full-drive option output levels (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 (Design Revision F and K only):	High current ($V_{OUT} = V_{DDQ} - 0.373V$, minimum V_{REF} minimum V_{TT})	I_{OHR}	-9	-	mA	39, 40
	Low current ($V_{OUT} = 0.373V$, maximum V_{REF} maximum V_{TT})	I_{OLR}	9	-	mA	
Ambient operating temperatures	Commercial	T_A	0	70	$^{\circ}C$	
	Industrial (AIT)	T_A	-40	85	$^{\circ}C$	
	Automotive (AAT)	T_A	-40	105	$^{\circ}C$	

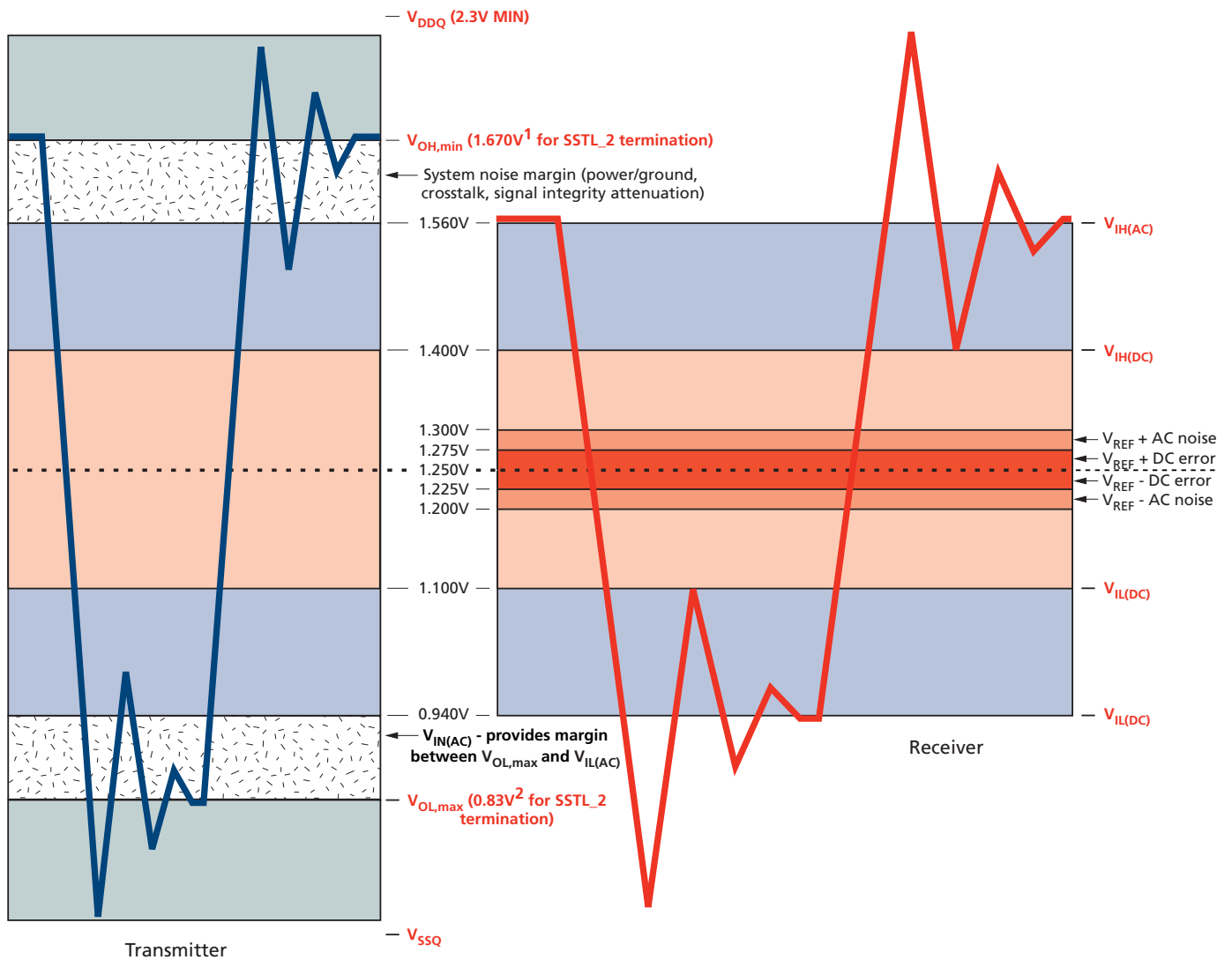
Table 10: AC Input Operating Conditions

Notes: 1–5, 17 apply to the entire table; Notes appear on page 34;

 $0^{\circ}C \leq T_A \leq 70^{\circ}C$; $V_{DDQ} = 2.5V \pm 0.2V$, $V_{DD} = 2.5V \pm 0.2V$ ($V_{DDQ} = 2.6V \pm 0.1V$, $V_{DD} = 2.6V \pm 0.1V$ for -5B)

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	$V_{REF(AC)}$	$0.49 \times V_{DDQ}$	$0.51 \times V_{DDQ}$	V	7

Figure 9: Input Voltage Waveform



- Notes:
1. $V_{OH,min}$ with test load is 1.927V.
 2. $V_{OL,max}$ with test load is 0.373V.
 3. Numbers in diagram reflect nominal values utilizing circuit below for all devices other than -5B.

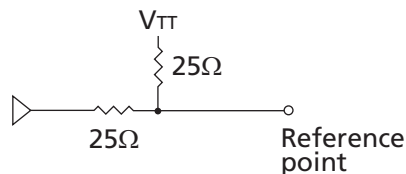


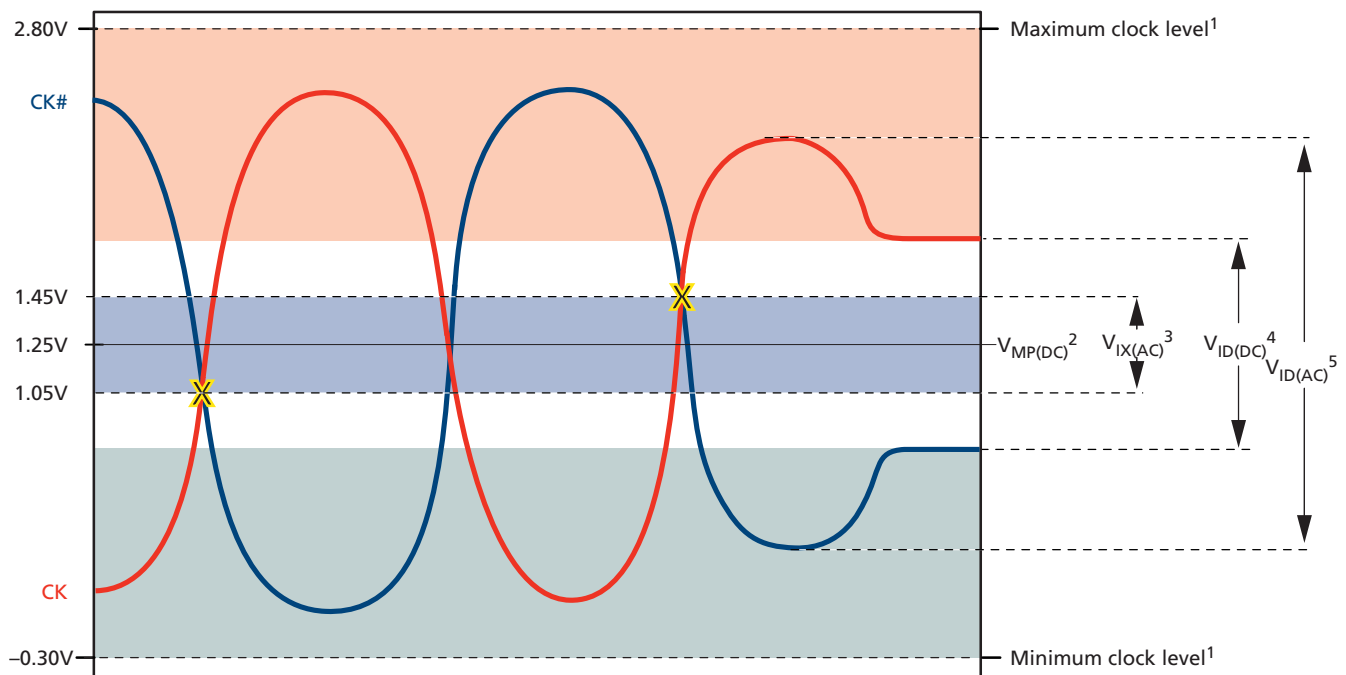
Table 11: Clock Input Operating Conditions

Notes: 1–5, 16, 17, 31 apply to the entire table; Notes appear on page 34;

$0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$; $V_{DDQ} = 2.5\text{V} \pm 0.2\text{V}$, $V_{DD} = 2.5\text{V} \pm 0.2\text{V}$ ($V_{DDQ} = 2.6\text{V} \pm 0.1\text{V}$, $V_{DD} = 2.6\text{V} \pm 0.1\text{V}$ for -5B)

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#	$V_{IX(AC)}$	$0.5 \times V_{DDQ} - 0.2$	$0.5 \times V_{DDQ} + 0.2$	V	10

Figure 10: SSTL_2 Clock Input



- Notes:
1. CK or CK# may not be more positive than $V_{DDQ} + 0.3\text{V}$ or more negative than $V_{SS} - 0.3\text{V}$.
 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 12: Capacitance (x8 TSOP)

Note: 14 applies to the entire table; Notes appear on page 34

Parameter	Symbol	Min	Max	Units	Notes
Delta input/output capacitance: DQ[7:0] (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: DQ, 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 13: Capacitance (x8 FBGA)

Note: 14 applies to the entire table; Notes appear on page 34

Parameter	Symbol	Min	Max	Units	Notes
Delta input/output capacitance: DQ, 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: DQ, 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 14: Capacitance (x16 TSOP)

Note: 14 applies to the entire table; Notes appear on page 34

Parameter	Symbol	Min	Max	Units	Notes
Delta input/output capacitance: DQ[7:0], LDQS, LDM	DC _{IO_L}	–	0.50	pF	25
Delta input/output capacitance: DQ[15:8], UDQS, UDM	DC _{IO_U}	–	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 15: Capacitance (x16 FBGA)

Note: 14 applies to the entire table; Notes appear on page 34

Parameter	Symbol	Min	Max	Units	Notes
Delta input/output capacitance: DQ[7:0], LDQS, LDM	DC _{IO_L}	–	0.50	pF	25
Delta input/output capacitance: DQ[15:8], UDQS, UDM	DC _{IO_U}	–	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 16: Electrical Characteristics and Recommended AC Operating Conditions (-5B)

Notes 1–6, 16–18, 34 apply to the entire table; Notes appear on page 34;
 $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$; $V_{\text{DDQ}} = 2.6\text{V} \pm 0.1\text{V}$, $V_{\text{DD}} = 2.6\text{V} \pm 0.1\text{V}$

AC Characteristics		-5B		Units	Notes	
Parameter	Symbol	Min	Max			
Access window of DQ from CK/CK#	t^{AC}	-0.70	0.70	ns		
CK high-level width	t^{CH}	0.45	0.55	t^{CK}	31	
Clock cycle time	CL = 3	$t^{\text{CK}}(3)$	5	7.5	ns	52
	CL = 2.5	$t^{\text{CK}}(2.5)$	6	13	ns	46, 52
	CL = 2	$t^{\text{CK}}(2)$	7.5	13	ns	46, 52
CK low-level width	t^{CL}	0.45	0.55	t^{CK}	31	
DQ and DM input hold time relative to DQS	t^{DH}	0.40	–	ns	27, 32	
DQ and DM input pulse width (for each input)	t^{DIPW}	1.75	–	ns	32	
Access window of DQS from CK/CK#	t^{DQSCk}	-0.60	0.60	ns		
DQS input high pulse width	t^{DQSH}	0.35	–	t^{CK}		
DQS input low pulse width	t^{DQSL}	0.35	–	t^{CK}		
DQS–DQ skew, DQS to last DQ valid, per group, per access	t^{DQSQ}	–	0.40	ns	26, 27	
WRITE command to first DQS latching transition	t^{DQSS}	0.72	1.28	t^{CK}		
DQ and DM input setup time relative to DQS	t^{DS}	0.40	–	ns	27, 32	
DQS falling edge from CK rising – hold time	t^{DSH}	0.2	–	t^{CK}		
DQS falling edge to CK rising – setup time	t^{DSS}	0.2	–	t^{CK}		
Half-clock period	t^{HP}	$t^{\text{CH}}, t^{\text{CL}}$	–	ns	35	
Data-out High-Z window from CK/CK#	t^{HZ}	–	0.70	ns	19, 43	
Address and control input hold time (slew rate ≥ 0.5 V/ns)	t^{IH}_{F}	0.60	–	ns	15	
Address and control input pulse width (for each input)	t^{IPW}	2.2	–	ns		
Address and control input setup time (slew rate ≥ 0.5 V/ns)	t^{IS}_{F}	0.60	–	ns	15	
Data-out Low-Z window from CK/CK#	t^{LZ}	-0.70	–	ns	19, 43	
LOAD MODE REGISTER command cycle time	t^{MRD}	10	–	ns		
DQ–DQS hold, DQS to first DQ to go non-valid, per access	t^{QH}	$t^{\text{HP}} - t^{\text{QHS}}$	–	ns	26, 27	
Data hold skew factor	t^{QHS}	–	0.50	ns		
ACTIVE-to-READ with auto precharge command	t^{RAP}	15	–	ns		
ACTIVE-to-PRECHARGE command	t^{RAS}	40	70,000	ns	36	
ACTIVE-to-ACTIVE/AUTO REFRESH command period	t^{RC}	55	–	ns	55	
ACTIVE-to-READ or WRITE delay	t^{RCD}	15	–	ns		
REFRESH-to-REFRESH command interval (Industrial)	$t^{\text{REFC}}_{\text{AIT}}$	–	70.3	μs	24	
REFRESH-to-REFRESH command interval (Automotive)	$t^{\text{REFC}}_{\text{AAT}}$	–	17.55	μs	24	
Average periodic refresh interval (Industrial)	$t^{\text{REFI}}_{\text{AIT}}$	–	7.8	μs	24	
Average periodic refresh interval (Automotive)	$t^{\text{REFI}}_{\text{AAT}}$	–	1.95	μs	24	
AUTO REFRESH command period	t^{RFC}	70	–	ns	50	
PRECHARGE command period	t^{RP}	15	–	ns		
DQS read preamble	t^{RPRE}	0.9	1.1	t^{CK}	44	
DQS read postamble	t^{RPST}	0.4	0.6	t^{CK}	44	
ACTIVE bank a to ACTIVE bank b command	t^{RRD}	10	–	ns		
Terminating voltage delay to V_{DD}	t^{VTD}	0	–	ns		
DQS write preamble	t^{WPRE}	0.25	–	t^{CK}		
DQS write preamble setup time	t^{WPRES}	0	–	ns	21, 22	
DQS write postamble	t^{WPST}	0.4	0.6	t^{CK}	20	

Table 16: Electrical Characteristics and Recommended AC Operating Conditions (-5B) (continued)

Notes 1–6, 16–18, 34 apply to the entire table; Notes appear on page 34;
 $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$; $V_{\text{DDQ}} = 2.6\text{V} \pm 0.1\text{V}$, $V_{\text{DD}} = 2.6\text{V} \pm 0.1\text{V}$

AC Characteristics		-5B		Units	Notes
Parameter	Symbol	Min	Max		
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	t_{XSNR}	70	–	ns	
Exit SELF REFRESH-to-READ command	t_{XSRD}	200	–	t_{CK}	
Data valid output window	n/a	$t_{\text{QH}} - t_{\text{DQSQ}}$		ns	26

Table 17: Electrical Characteristics and Recommended AC Operating Conditions (-6)

Notes: 1–6, 16–18, 34 apply to the entire table; Notes appear on page 34;

 $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$; $V_{\text{DDQ}} = 2.5\text{V} \pm 0.2\text{V}$, $V_{\text{DD}} = 2.5\text{V} \pm 0.2\text{V}$

AC Characteristics		-6 (FBGA)		Units	Notes	
Parameter	Symbol	Min	Max			
Access window of DQ from CK/CK#	t^{AC}	-0.70	0.70	ns		
CK high-level width	t^{CH}	0.45	0.55	t^{CK}	31	
Clock cycle time	CL = 2.5	$t^{\text{CK}}(2.5)$	6	13	ns	46, 52
	CL = 2	$t^{\text{CK}}(2)$	7.5	13	ns	46, 52
CK low-level width	t^{CL}	0.45	0.55	t^{CK}	31	
DQ and DM input hold time relative to DQS	t^{DH}	0.45	–	ns	27, 32	
DQ and DM input pulse width (for each input)	t^{DIPW}	1.75	–	ns	32	
Access window of DQS from CK/CK#	t^{DQSCK}	-0.6	0.6	ns		
DQS input high pulse width	t^{DQSH}	0.35	–	t^{CK}		
DQS input low pulse width	t^{DQSL}	0.35	–	t^{CK}		
DQS–DQ skew, DQS to last DQ valid, per group, per access	t^{DQSQ}	–	0.4	ns	26, 27	
WRITE command to first DQS latching transition	t^{DQSS}	0.75	1.25	t^{CK}		
DQ and DM input setup time relative to DQS	t^{DS}	0.45	–	ns	27, 32	
DQS falling edge from CK rising - hold time	t^{DSH}	0.2	–	t^{CK}		
DQS falling edge to CK rising - setup time	t^{DSS}	0.2	–	t^{CK}		
Half-clock period	t^{HP}	t^{CH} , t^{CL}	–	ns	35	
Data-out High-Z window from CK/CK#	t^{HZ}	–	0.7	ns	19, 43	
Address and control input hold time (fast slew rate)	t^{IH_F}	0.75	–	ns		
Address and control input hold time (slow slew rate)	t^{IH_S}	0.8	–	ns	15	
Address and control input pulse width (for each input)	t^{IPW}	2.2	–	ns		
Address and control input setup time (fast slew rate)	t^{IS_F}	0.75	–	ns		
Address and control input setup time (slow slew rate)	t^{IS_S}	0.8	–	ns	15	
Data-out Low-Z window from CK/CK#	t^{LZ}	-0.7	–	ns	19, 43	
LOAD MODE REGISTER command cycle time	t^{MRD}	12	–	ns		
DQ–DQS hold, DQS to first DQ to go non-valid, per access	t^{QH}	$t^{\text{HP}} - t^{\text{QHS}}$	–	ns	26, 27	
Data hold skew factor	t^{QHS}	–	0.50	ns		
ACTIVE-to-READ with auto precharge command	t^{RAP}	15	–	ns		
ACTIVE-to-PRECHARGE command	t^{RAS}	42	70,000	ns	36, 54	
ACTIVE-to-ACTIVE/AUTO REFRESH command period	t^{RC}	60	–	ns	55	
ACTIVE-to-READ or WRITE delay	t^{RCD}	15	–	ns		
REFRESH-to-REFRESH command interval (Industrial)	$t^{\text{REFC}}_{\text{AIT}}$	–	70.3	μs	24	
REFRESH-to-REFRESH command interval (Automotive)	$t^{\text{REFC}}_{\text{AAT}}$	–	17.55	μs	24	
Average periodic refresh interval (Industrial)	$t^{\text{REFI}}_{\text{AIT}}$	–	7.8	μs	24	
Average periodic refresh interval (Automotive)	$t^{\text{REFI}}_{\text{AAT}}$	–	1.95	μs	24	
AUTO REFRESH command period	t^{RFC}	72	–	ns	50	
PRECHARGE command period	t^{RP}	15	–	ns		
DQS read preamble	t^{RPRE}	0.9	1.1	t^{CK}	44	
DQS read postamble	t^{RPST}	0.4	0.6	t^{CK}	44	
ACTIVE bank a to ACTIVE bank b command	t^{RRD}	12	–	ns		
Terminating voltage delay to V_{SS}	t^{VTD}	0	–	ns		
DQS write preamble	t^{WPRE}	0.25	–	t^{CK}		



Table 17: Electrical Characteristics and Recommended AC Operating Conditions (-6) (continued)

Notes: 1–6, 16–18, 34 apply to the entire table; Notes appear on page 34;
 $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$; $V_{\text{DDQ}} = 2.5\text{V} \pm 0.2\text{V}$, $V_{\text{DD}} = 2.5\text{V} \pm 0.2\text{V}$

AC Characteristics		-6 (FBGA)		Units	Notes
Parameter	Symbol	Min	Max		
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}	1	–	t^{CK}	
Exit SELF REFRESH-to-non-READ command	t^{XSNR}	75	–	ns	
Exit SELF REFRESH-to-READ command	t^{XSRD}	200	–	t^{CK}	
Data valid output window	–	$t^{\text{QH}} - t^{\text{DQSQ}}$		ns	26