Mobile DDR SDRAM

MT46H32M16LF – 8 Meg x 16 x 4 banks
MT46H16M32LF – 4 Meg x 32 x 4 banks

Features

- VDD/VDDQ = 1.70–1.95V
- 1.2V I/O option VDDQ = 1.14–1.30V
- Bidirectional data strobe per byte of data (DQS)
- 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
- Four internal banks for concurrent operation
- Data masks (DM) for masking write data—one mask per byte
- Programmable burst lengths (BL): 2, 4, 8, or 16
- Concurrent auto precharge option is supported
- Auto refresh and self refresh modes
- 1.8V LVCMOS-compatible inputs
- On-chip temp sensor to control self refresh rate
- Partial-array self refresh (PASR)
- Deep power-down (DPD)
- Status read register (SRR)
- Selectable output drive strength (DS)
- Clock stop capability
- 64ms refresh

Table 1: Key Timing Parameters (CL = 3)

Speed Grade	Clock Rate (MHz)	Access Time
-5	200	5.0ns
-54	185	5.0ns
-6	166	5.0ns
-75	133	6.0ns

Options	Marking
• VDD/VDDQ	
– 1.8V/1.8V	H
– 1.8V/1.2V[1]	HC
• Configuration	
– 32 Meg x 16 (8 Meg x 16 x 4 banks)	32M16
– 16 Meg x 32 (4 Meg x 32 x 4 banks)	16M32
• Row-size option	
– JEDEC-standard option	LF
– Reduced page-size option[1]	LG
• Plastic “green” package	
– 60-ball VFBGA (8 mm x 9 mm)[2]	BF
– 90-ball VFBGA (10mm x 13mm)[3]	CM
– 90-ball VFBGA (9mm x 13mm)[3]	CX
• Timing – cycle time	
– 5ns @ CL = 3	-5
– 5.4ns @ CL = 3	-54
– 6ns @ CL = 3	-6
– 7.5ns @ CL = 3	-75
• Power	
– Standard IDD2/IDD6	None
– Low-power IDD2/IDD6[1]	L
• Operating temperature range	
– Commercial (0° to +70°C)	None
– Industrial (–40°C to +85°C)	IT
• Design revision	:B

Notes: 1. Contact factory for availability.
2. Only available for x16 configuration.
3. Only available for x32 configuration.

Table 2: Configuration Addressing

Architecture	32 Meg x 16	16 Meg x 32	Reduced Page-Size Option 16 Meg x 32
Configuration	8 Meg x 16 x 4 banks	4 Meg x 32 x 4 banks	8 Meg x 32 x 4 banks
Refresh count	8K	8K	8K
Row addressing	A0–A12	A0–A12	A0–A13
Column addressing	A0–A9	A0–A8	A0–A7

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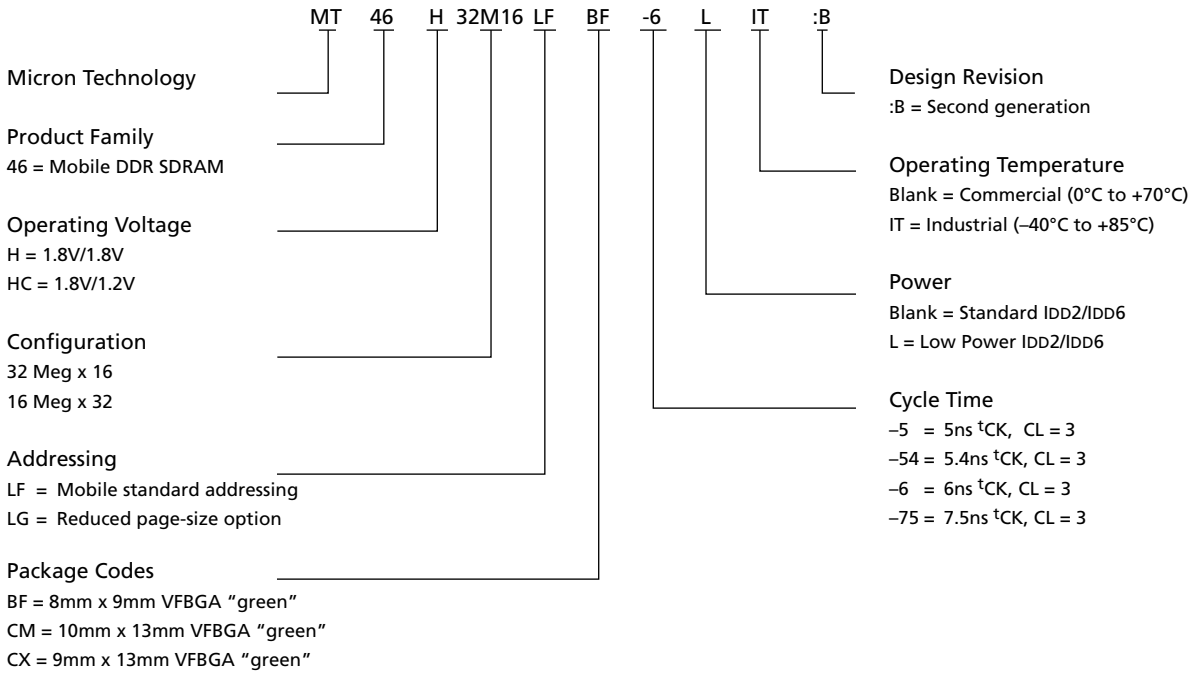
Figure 1: 512Mb Mobile DDR Part Numbering



FBGA Part Marking Decoder

Due to space limitations, FBGA-packaged components have an abbreviated part marking that is different from the part number. Micron's FBGA part marking decoder is available at www.micron.com/decoder.

General Description

The 512Mb Mobile DDR SDRAM is a high-speed CMOS, dynamic random-access memory containing 536,870,912 bits. It is internally configured as a quad-bank DRAM. Each of the x16's 134,217,728-bit banks is organized as 8,192 rows by 1,024 columns by 16 bits. Each of the x32's 134,217,728-bit banks is organized as 8,192 rows by 512 columns by 32 bits. In the reduced page-size (LG) option, each of the x32's 134,217,728-bit banks are organized as 16,384 rows by 256 columns by 32 bits.

Notes:

1. 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 the 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. The x32 is divided into four bytes. For DQ0–DQ7, DM refers to DM0 and DQS refers to DQS0. For DQ8–DQ15, DM refers to DM1 and DQS refers to DQS1. For DQ16–DQ23, DM refers to DM2 and DQS refers to DQS2, and for DQ24–DQ31, DM refers to DM3 and DQS refers to DQS3.
2. 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.
3. Any specific requirement takes precedence over a general statement.

Functional Block Diagrams

Figure 2: Functional Block Diagram (32 Meg x 16)

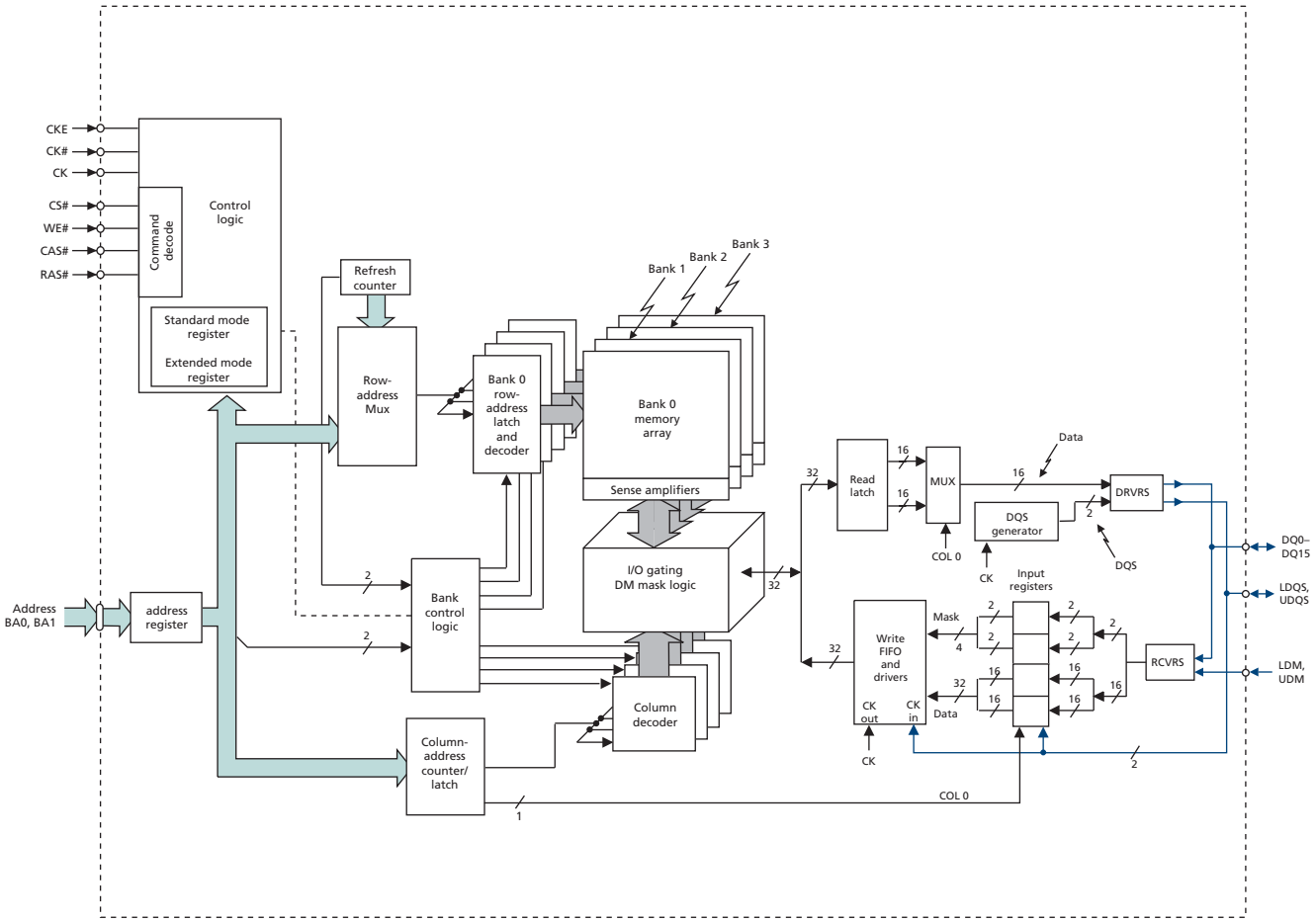
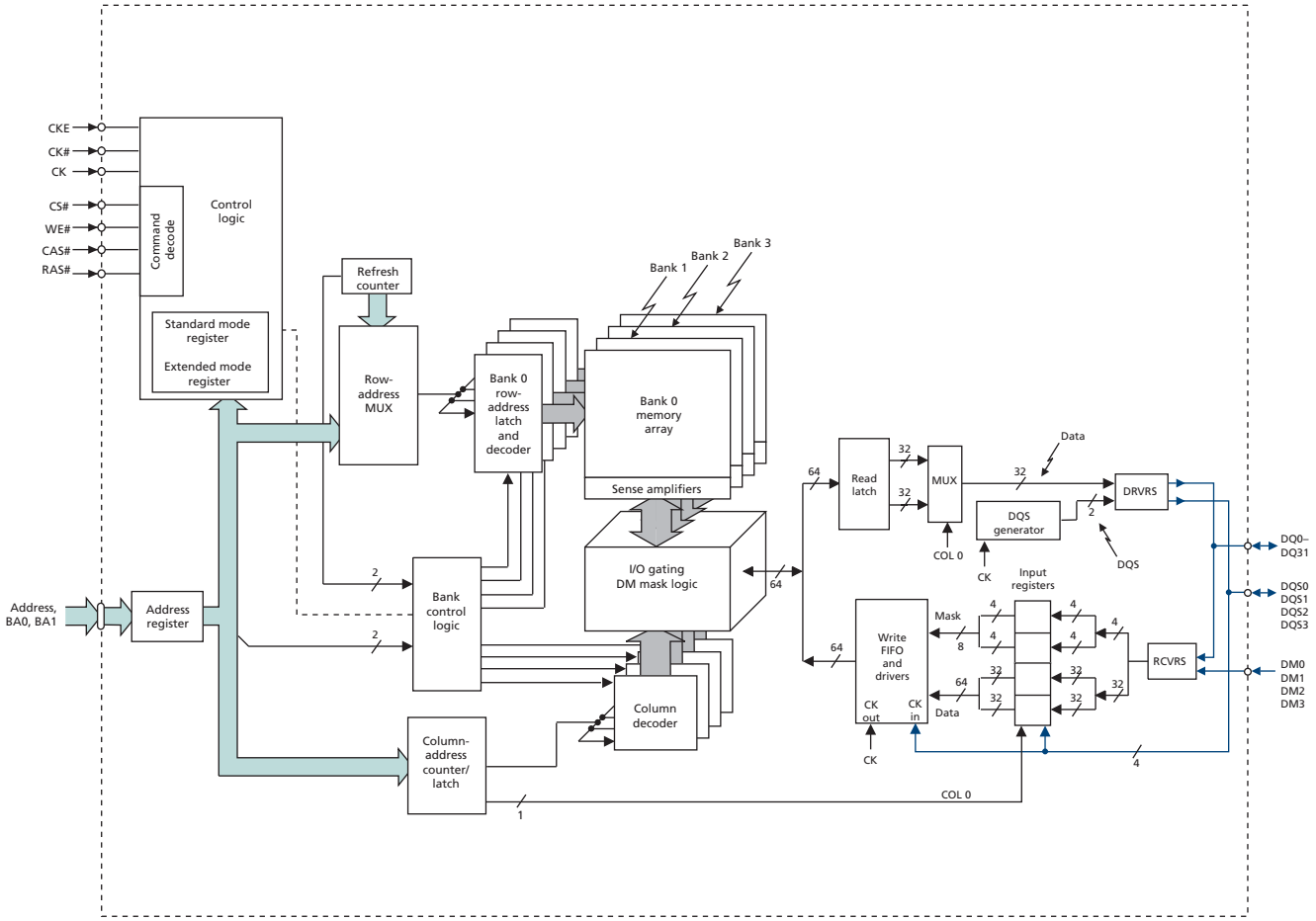
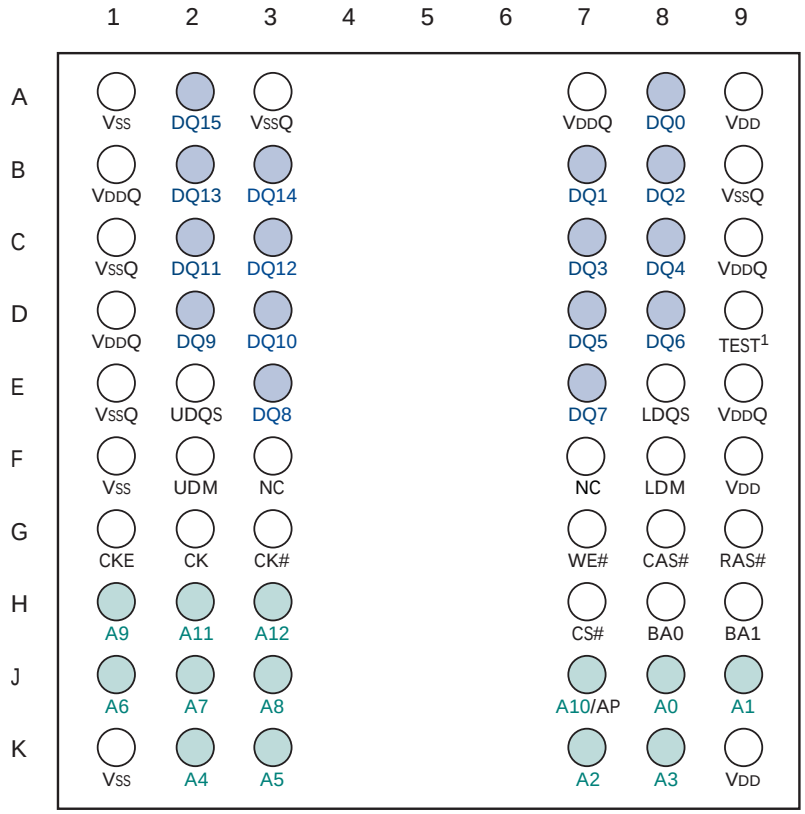


Figure 3: Functional Block Diagram (16 Meg x 32)



Ball Assignments and Descriptions

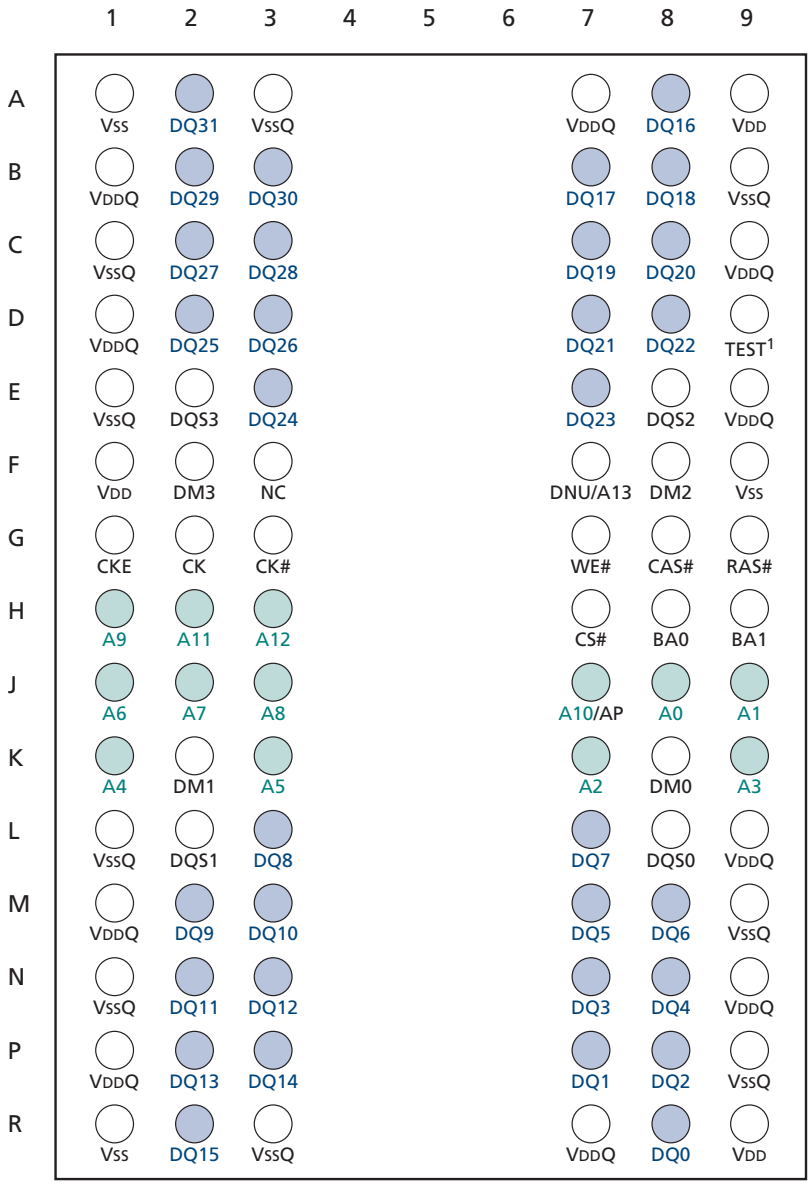
Figure 4: 60-Ball VFBGA Assignments – 8mm x 9mm (Top View)



Ball and Array

Notes: 1. D9 is a test pin that must be tied to VSS or VSSQ in normal operations.

Figure 5: 90-Ball VFBGA Ball Assignments – 10mm x 13mm and 9mm x 13mm (Top View)



Ball and Array

Notes: 1. D9 is a test pin that must be tied to VSS or VSSQ in normal operations.

Table 3: VFBGA Ball Descriptions

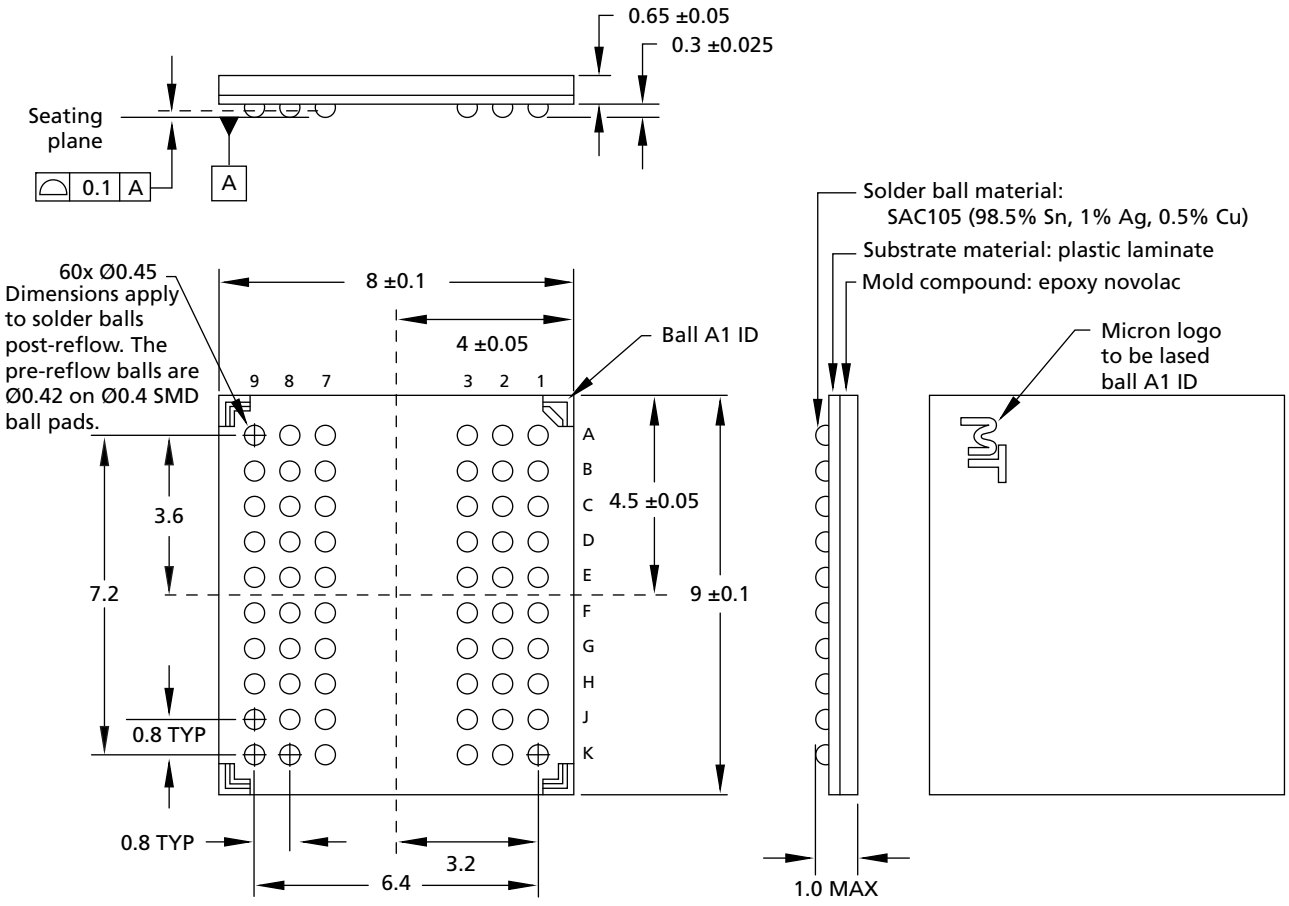
60-Ball VFBGA	90-Ball VFBGA	Symbol	Type	Description
G2, G3	G2, G3	CK, CK#	Input	Clock: CK is the system clock input. CK and CK# are differential clock inputs. All address and control input signals are sampled on the crossing of the positive edge of CK and the negative edge of CK#. Input and output data is referenced to the crossing of CK and CK# (both directions of the crossing).
G1	G1	CKE	Input	Clock enable: CKE HIGH activates, and CKE LOW deactivates, the internal clock signals, input buffers, and output drivers. Taking CKE LOW enables PRECHARGE power-down and SELF REFRESH operations (all banks idle), or ACTIVE power-down (row active in any bank). CKE is synchronous for all functions except SELF REFRESH exit. All input buffers (except CKE) are disabled during power-down and self refresh modes.
H7	H7	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.
G9, G8, G7	G9, G8, G7	RAS#, CAS#, WE#	Input	Command inputs: RAS#, CAS#, and WE# (along with CS#) define the command being entered.
F2, F8	K8, K2, F8, F2	UDM, LDM (60-ball) DM0–DM3 (90-ball)	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 balls are input-only, the DM loading is designed to match that of DQ and DQS balls.
H8, H9	H8, H9	BA0, BA1	Input	Bank address inputs: BA0 and BA1 define the bank to which an ACTIVE, READ, WRITE, or PRECHARGE command is being applied. BA0 and BA1 also determine which mode register is loaded during a LOAD MODE REGISTER command.
J8, J9, K7, K8, K2, K3, J1, J2, J3, H1, J7, H2, H3	J8, J9, K7, K9, K1, K3, J1, J2, J3, H1, J7, H2, H3	A0–A12 (60-ball) A0–A12 (90-ball)	Input	Address inputs: Provide the row address for ACTIVE commands, and the column address and auto-precharge bit (A10) for READ or WRITE commands, to select one location out of the memory array in the respective bank. During a PRECHARGE command, A10 determines whether the PRECHARGE applies to one bank (A10 LOW, bank selected by BA0 and BA1) or all banks (A10 HIGH). The address inputs also provide the op-code during a LOAD MODE REGISTER command.
A8, B7, B8, C7, C8, D7, D8, E7, E3, D2, D3, C2, C3, B2, B3, A2	R8, P7, P8, N7, N8, M7, M8, L7, L3, M2, M3, N2, N3, P2, P3, R2, A8, B7, B8, C7, C8, D7, D8, E7, E3, D2, D3, C2, C3, B2, B3, A2	DQ0–DQ15 (60-ball) DQ0–DQ31 (90-ball)	I/O	Data input/output: Data bus for x16 and x32.

Table 3: VFBGA Ball Descriptions (continued)

60-Ball VFBGA	90-Ball VFBGA	Symbol	Type	Description
E8, E2	L8, L2, E8, E2	LDQS, UDQS (60-ball) DQS0–DQS3 (90-ball)	I/O	Data strobe: Output with read data, input with write data. DQS is edge-aligned with read data, center-aligned in write data. It is used to capture data.
A7, B1, C9, D1, E9	A7, B1, C9, D1, E9, L9, M1, N9, P1, R7	$V_{DD}Q$	Supply	DQ power supply.
A3, B9, C1, E1	A3, B9, C1, E1, L1, M9, N1, P9, R3	$V_{SS}Q$	Supply	DQ ground.
A9, F9, K9	A9, F1, R9	V_{DD}	Supply	Power supply.
A1, F1, K1	A1, F9, R1	V_{SS}	Supply	Ground.
F3, F7	F3	NC	–	No connect: F3 and F7 (60-ball) and F3 (90-ball) may be left unconnected.
–	F7	A13/DNU	Input	A13 if reduced page-size option, otherwise, do not use.
D9	D9	TEST	Input	Test pin: Must be tied to V_{SS} or $V_{SS}Q$ in normal operations.

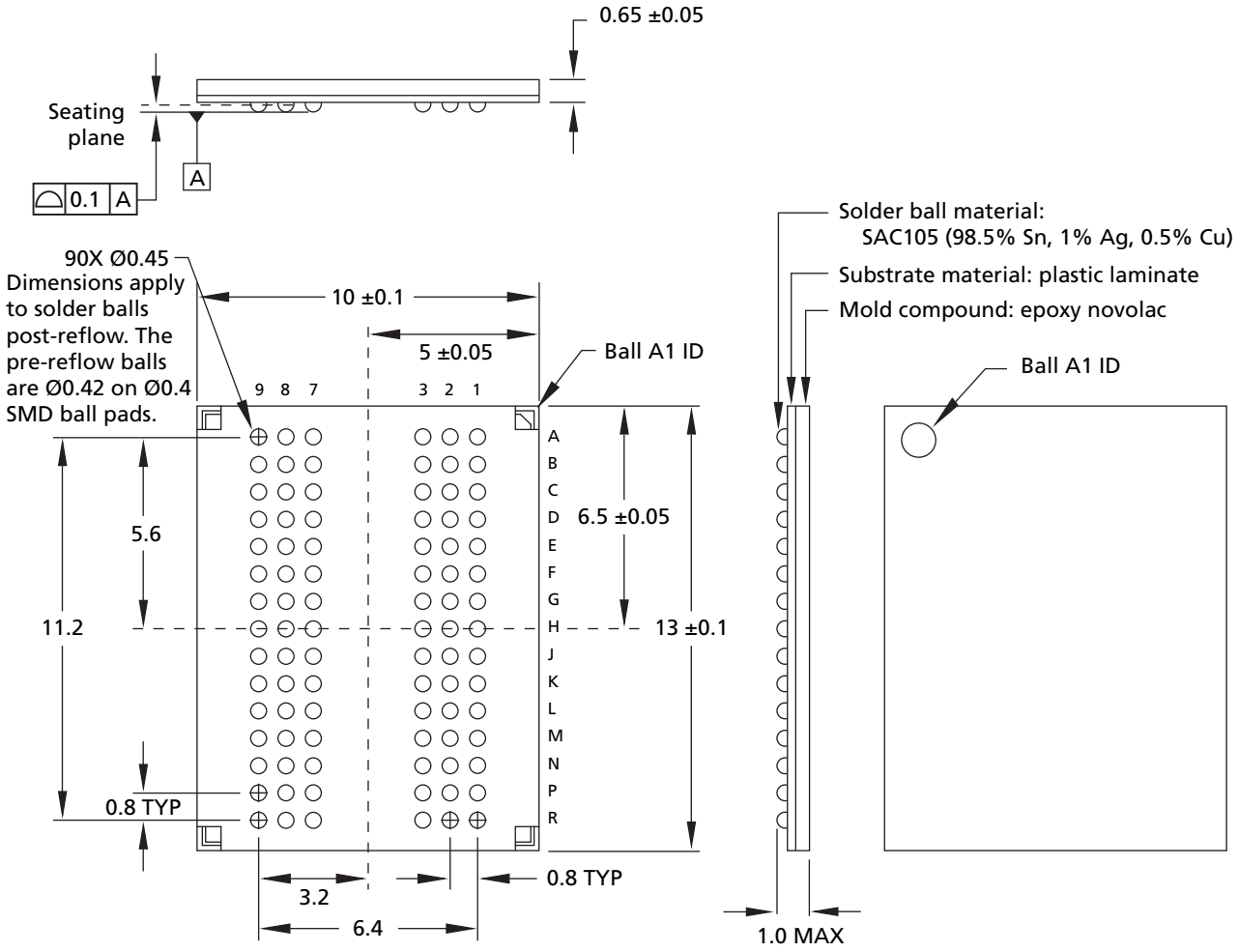
Package Dimensions

Figure 6: 60-Ball VFBGA Package



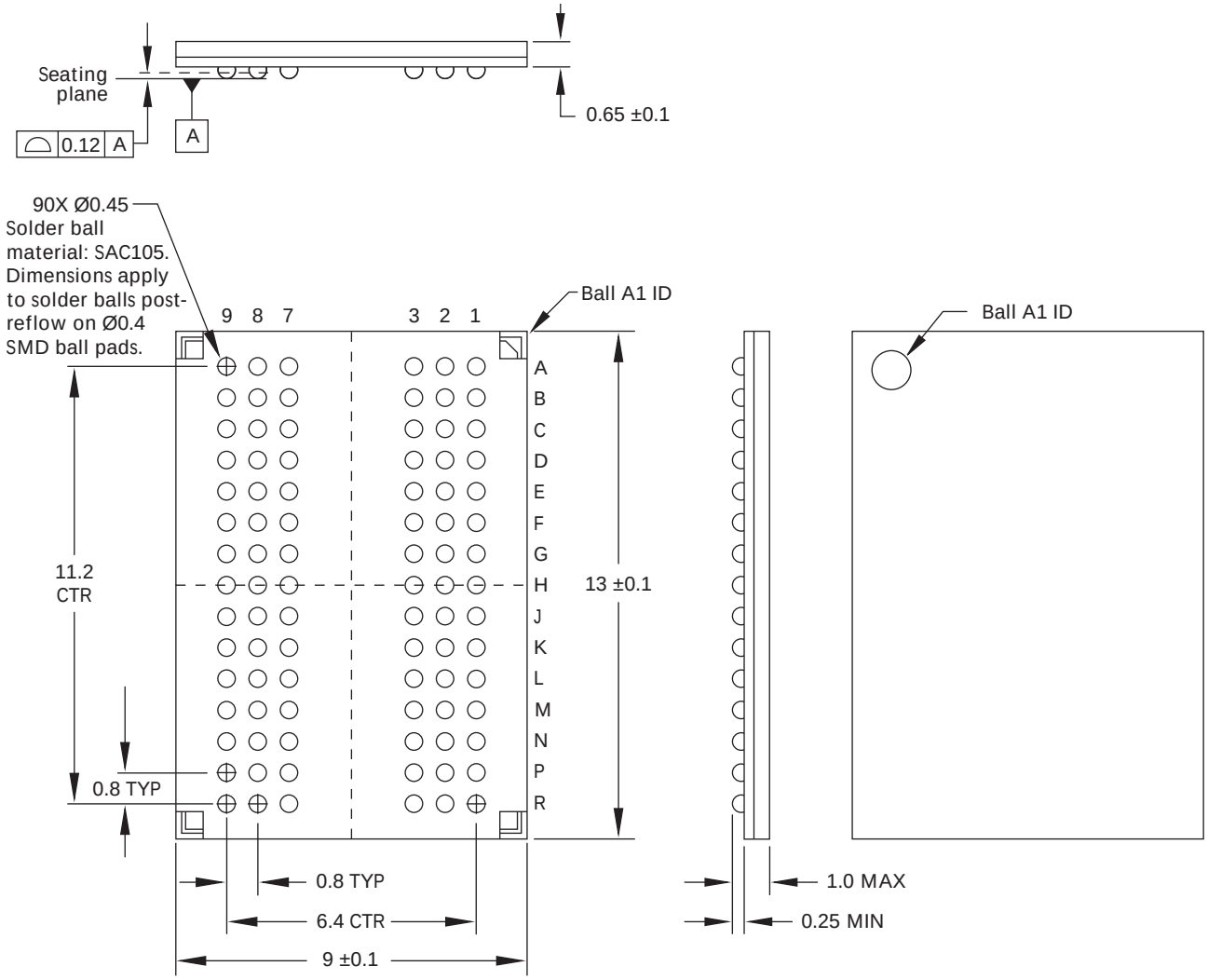
Notes: 1. All dimensions are in millimeters.

Figure 7: 90-Ball VFBGA Package (10mm x 13mm)



Notes: 1. All dimensions are in millimeters.

Figure 8: 90-Ball VFBGA Package (9mm x 13mm)



Notes: 1. All dimensions are in millimeters.

Electrical Specifications

Stresses greater than those listed in Table 4 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 4: Absolute Maximum Ratings
Note 1 applies to all parameters in this table.

Parameter	Symbol	Min	Max	Unit
V_{DD}/V_{DD}Q supply voltage relative to V_{SS}	V_{DD}/V_{DD}Q	–1.0	2.4	V
Voltage on any pin relative to V_{SS}	V_{IN}	–0.5	2.4 or (V_{DD}Q + 0.3V), whichever is less	V
Storage temperature (plastic)	T_{STG}	–55	+150	°C

Notes: 1. V_{DD} and V_{DD}Q must be within 300mV of each other at all times. V_{DD}Q must not exceed V_{DD}.

Table 5: AC/DC Electrical Characteristics and Operating Conditions
Notes: 1–5 apply to all parameters/conditions in this table; V_{DD}/V_{DD}Q = 1.70–1.95V

Parameter/Condition	Symbol	Min	Max	Unit	Notes
Supply voltage	V_{DD}	1.70	1.95	V	6, 7
I/O supply voltage	V_{DD}Q	1.70	1.95	V	6, 7
Address and command inputs					
Input voltage high	V_{IH}	0.8 × V_{DD}Q	V_{DD}Q + 0.3	V	8, 9
Input voltage low	V_{IL}	–0.3	0.2 × V_{DD}Q	V	8, 9
Clock inputs (CK, CK#)					
DC input voltage	V_{IN}	–0.3	V_{DD}Q + 0.3	V	10
DC input differential voltage	$V_{ID(DC)}$	0.4 × V_{DD}Q	V_{DD}Q + 0.6	V	10, 11
AC input differential voltage	$V_{ID(AC)}$	0.6 × V_{DD}Q	V_{DD}Q + 0.6	V	10, 11
AC differential crossing voltage	V_{IX}	0.4 × V_{DD}Q	0.6 × V_{DD}Q	V	10, 12
Data inputs					
DC input high voltage	$V_{IH(DC)}$	0.7 × V_{DD}Q	V_{DD}Q + 0.3	V	8, 9, 13
DC input low voltage	$V_{IL(DC)}$	–0.3	0.3 × V_{DD}Q	V	8, 9, 13
AC input high voltage	$V_{IH(AC)}$	0.8 × V_{DD}Q	V_{DD}Q + 0.3	V	8, 9, 13
AC input low voltage	$V_{IL(AC)}$	–0.3	0.2 × V_{DD}Q	V	8, 9, 13
Data outputs					
DC output high voltage: Logic 1 (I_{OH} = –0.1mA)	V_{OH}	0.9 × V_{DD}Q	–	V	
DC output low voltage: Logic 0 (I_{OL} = 0.1mA)	V_{OL}	–	0.1 × V_{DD}Q	V	
Leakage current					
Input leakage current Any input 0V ≤ V_{IN} ≤ V_{DD} (All other pins not under test = 0V)	I_I	–1	1	µA	

Table 5: AC/DC Electrical Characteristics and Operating Conditions (continued)
Notes: 1–5 apply to all parameters/conditions in this table; $V_{DD}/V_{DD}Q$ = 1.70–1.95V

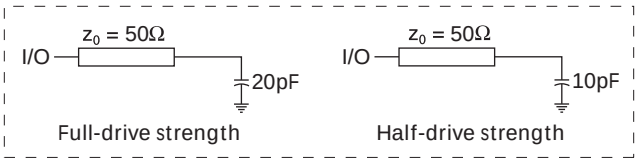
Parameter/Condition	Symbol	Min	Max	Unit	Notes
Output leakage current (DQs are disabled; 0V ≤ V_{OUT} ≤ $V_{DD}Q$)	I_{OZ}	–5	5	µA	
Operating temperature					
Commercial	T_A	0	+70	°C	
Industrial	T_A	–40	+85	°C	

Table 6: 1.2V I/O AC/DC Electrical Characteristics and Operating Conditions
Notes: 1–5 apply to all parameters/conditions in this table; $V_{DD}/V_{DD}Q$ = 1.70–1.95V

Parameter/Condition	Symbol	Min	Max	Unit	Notes
Supply voltage	V_{DD}	1.70	1.95	V	6, 7
I/O supply voltage	$V_{DD}Q$	1.14	1.30	V	6, 7
Address and command inputs					
Input voltage high	V_{IH}	0.9 × $V_{DD}Q$	$V_{DD}Q$ + 0.2	V	8, 9
Input voltage low	V_{IL}	–0.2	0.1 × $V_{DD}Q$	V	8, 9
Clock inputs (CK, CK#)					
DC input voltage	V_{IN}	–0.2	$V_{DD}Q$ + 0.2	V	10
DC input differential voltage	$V_{ID(DC)}$	0.4 × $V_{DD}Q$	$V_{DD}Q$ + 0.4	V	10, 11
AC input differential voltage	$V_{ID(AC)}$	0.6 × $V_{DD}Q$	$V_{DD}Q$ + 0.4	V	10, 11
AC differential crossing voltage	V_{IX}	0.4 × $V_{DD}Q$	0.6 × $V_{DD}Q$	V	10, 12
Data inputs					
DC input high voltage	$V_{IH(DC)}$	0.8 × $V_{DD}Q$	$V_{DD}Q$ + 0.2	V	8, 9, 13
DC input low voltage	$V_{IL(DC)}$	–0.2	0.2 × $V_{DD}Q$	V	8, 9, 13
AC input high voltage	$V_{IH(AC)}$	0.9 × $V_{DD}Q$	$V_{DD}Q$ + 0.2	V	8, 9, 13
AC input low voltage	$V_{IL(AC)}$	–0.2	0.1 × $V_{DD}Q$	V	8, 9, 13
Data outputs					
DC output high voltage: Logic 1 (I_{OH} = –0.1mA)	V_{OH}	0.9 × $V_{DD}Q$	–	V	
DC output low voltage: Logic 0 (I_{OL} = 0.1mA)	V_{OL}	–	0.1 × $V_{DD}Q$	V	
Leakage current					
Input leakage current Any input 0V ≤ V_{IN} ≤ V_{DD} (All other pins not under test = 0V)	I_I	–1	1	µA	
Output leakage current (DQs are disabled; 0V ≤ V_{OUT} ≤ $V_{DD}Q$)	I_{OZ}	–5	5	µA	
Operating temperature					
Commercial	T_A	0	+70	°C	
Industrial	T_A	–40	+85	°C	

Notes:
1. All voltages referenced to V_{SS}.
2. All parameters assume proper device initialization.
3. Tests for AC timing, I_{DD}, and electrical AC and DC characteristics may be conducted at nominal supply voltage levels, but the related specifications and device operation are guaranteed for the full voltage range specified.

4. Outputs measured with equivalent load; transmission line delay is assumed to be very small:



5. Timing and I_{DD} tests may use a V_{IL}-to-V_{IH} swing of up to 1.5V in the test environment, but input timing is still referenced to $V_{DDQ}/2$ (or to the crossing point for CK/CK#). The output timing reference voltage level is $V_{DDQ}/2$.
6. Any positive glitch must be less than 1/3 of the clock cycle and not more than +200mV or 2.0V, whichever is less. Any negative glitch must be less than 1/3 of the clock cycle and not exceed either –150mV or +1.6V, whichever is more positive.
7. V_{DD} and V_{DDQ} must track each other and V_{DDQ} must be less than or equal to V_{DD}.
8. To maintain a valid level, the transitioning edge of the input must:
   8a. Sustain a constant slew rate from the current AC level through to the target AC level, $V_{IL(AC)}$ or $V_{IH(AC)}$.
   8b. Reach at least the target AC level.
   8c. After the AC target level is reached, continue to maintain at least the target DC level, $V_{IL(DC)}$ or $V_{IH(DC)}$.
9. V_{IH} overshoot: V_{IH} (MAX) = V_{DDQ} + 1.0V for a pulse width ≤3ns and the pulse width cannot be greater than 1/3 of the cycle rate. V_{IL} undershoot: V_{IL} (MIN) = –1.0V for a pulse width ≤3ns and the pulse width cannot be greater than 1/3 of the cycle rate.
10. CK and CK# input slew rate must be ≥1 V/ns (2 V/ns if measured differentially).
11. V_{ID} is the magnitude of the difference between the input level on CK and the input level on CK#.
12. The value of V_{IX} is expected to equal $V_{DDQ}/2$ of the transmitting device and must track variations in the DC level of the same.
13. DQ and DM input slew rates must not deviate from DQS by more than 10 percent. 50ps must be added to ^{t}DS and ^{t}DH for each 100 mV/ns reduction in slew rate. If slew rate exceeds 4 V/ns, functionality is uncertain.

Table 7: Capacitance (x16, x32)

Note 1 applies to all the parameters in this table.

Parameter	Symbol	Min	Max	Unit	Notes
Input capacitance: CK, CK#	CCK	2.0	4.0	pF	
Delta input capacitance: CK, CK#	CDCK	–	0.5	pF	2
Input capacitance: command and address	CI	2.0	4.0	pF	
Delta input capacitance: command and address	CDI	–	1.0	pF	2
Input/output capacitance: DQs, DQS, DM	CIO	2.0	4.5	pF	
Delta input/output capacitance: DQs, DQS, DM	CDIO	–	1.0	pF	3

Notes:
1. This parameter is sampled. $V_{DD}/V_{DD}Q$ = 1.70–1.95V, f = 100 MHz, T_A = 25°C, $V_{OUT}(DC) = V_{DD}Q/2$, V_{OUT} (peak-to-peak) = 0.2V. DM input is grouped with I/O pins, reflecting the fact that they are matched in loading.
2. The input capacitance per pin group will not differ by more than this maximum amount for any given device.
3. The I/O capacitance per DQS and DQ byte/group will not differ by more than this maximum amount for any given device.

Table 8: IDD Specifications and Conditions (x16)

Notes: 1–5 apply to all parameters/conditions in this table; notes appear on page 19; VDD/VDDQ = 1.70–1.95V

Parameter/Condition		Symbol	Max				Unit	Notes
			-5	-54	-6	-75		
Operating 1 bank active-precharge current: ^{t}RC = ^{t}RC (MIN); ^{t}CK = ^{t}CK (MIN); CKE is HIGH; CS is HIGH between valid commands; Address inputs are switching every 2 clock cycles; Data bus inputs are stable		IDD0	70	65	60	50	mA	6
Precharge power-down standby current: All banks idle, CKE is LOW; CS is HIGH, ^{t}CK = ^{t}CK (MIN); Address and control inputs are switching; Data bus inputs are stable		IDD2P	300	300	300	300	µA	7, 8
Precharge power-down standby current: Clock stopped; All banks idle; CKE is LOW; CS is HIGH; CK = LOW, CK# = HIGH; Address and control inputs are switching; Data bus inputs are stable		IDD2PS	300	300	300	300	µA	7
Precharge nonpower-down standby current: All banks idle CKE = HIGH; CS = HIGH; ^{t}CK = ^{t}CK (MIN); Address and control inputs are switching; Data bus inputs are stable		IDD2N	15	15	15	12	mA	9
Precharge nonpower-down standby current: Clock stopped; All banks idle, CKE = HIGH; CS = HIGH; CK = LOW, CK# = HIGH; Address and control inputs are switching; Data bus inputs are stable		IDD2NS	8	8	8	8	mA	9
Active power-down standby current: 1 bank active, CKE = LOW; CS = HIGH; ^{t}CK = ^{t}CK (MIN); Address and control inputs are switching; Data bus inputs are stable		IDD3P	3	3	3	3	mA	8
Active power-down standby current: Clock stopped; 1 bank active, CKE = LOW; CS = HIGH; CK = LOW; CK# = HIGH; Address and control inputs are switching; Data bus inputs are stable		IDD3PS	2	2	2	2	mA	
Active nonpower-down standby: 1 bank active, CKE = HIGH; CS = HIGH; ^{t}CK = ^{t}CK (MIN); Address and control inputs are switching; Data bus inputs are stable		IDD3N	15	15	15	15	mA	6
Active nonpower-down standby: Clock stopped; 1 bank active, CKE = HIGH; CS = HIGH; CK = LOW; CK# = HIGH; Address and control inputs are switching; Data bus inputs are stable		IDD3NS	8	8	8	8	mA	6
Operating burst read: 1 bank active; BL = 4; ^{t}CK = ^{t}CK (MIN); Continuous READ bursts; IOUT = 0mA; Address inputs are switching every 2 clock cycles; 50% data changing each burst		IDD4R	115	110	105	90	mA	6
Operating burst write: 1 bank active; BL = 4; ^{t}CK = ^{t}CK (MIN); Continuous WRITE bursts; Address inputs are switching; 50% data changing each burst		IDD4W	115	110	105	90	mA	6
Auto refresh: Burst refresh; CKE = HIGH; Address and control inputs are switching; Data bus inputs are stable	^{t}RFC = 110ns	IDD5	105	105	100	100	mA	10
	^{t}RFC = ^{t}REFI	IDD5A	3	3	3	3	mA	10, 11
Deep power-down current: Address and control balls are stable; Data bus inputs are stable		IDD8	10				µA	7, 13

Table 9: IDD Specifications and Conditions (x32)

Notes: 1–5 apply to all parameters/conditions in this table; notes appear on page 19; VDD/VDDQ = 1.70–1.95V

Parameter/Condition		Symbol	Max				Unit	Notes
			-5	-54	-6	-75		
Operating 1 bank active-precharge current: $^{t}RC = {}^{t}RC$ (MIN); $^{t}CK = {}^{t}CK$ (MIN); CKE is HIGH; CS is HIGH between valid commands; Address inputs are switching every 2 clock cycles; Data bus inputs are stable		IDD0	70	65	60	50	mA	6
Precharge power-down standby current: All banks idle; CKE is LOW; CS is HIGH; $^{t}CK = {}^{t}CK$ (MIN); Address and control inputs are switching; Data bus inputs are stable		IDD2P	300	300	300	300	µA	7, 8
Precharge power-down standby current: Clock stopped; All banks idle; CKE is LOW; CS is HIGH, CK = LOW, CK# = HIGH; Address and control inputs are switching; Data bus inputs are stable		IDD2PS	300	300	300	300	µA	7
Precharge nonpower-down standby current: All banks idle CKE = HIGH; CS = HIGH; $^{t}CK = {}^{t}CK$ (MIN); Address and control inputs are switching; Data bus inputs are stable		IDD2N	15	15	15	12	mA	9
Precharge nonpower-down standby current: Clock stopped; All banks idle, CKE = HIGH; CS = HIGH; CK = LOW, CK# = HIGH; Address and control inputs are switching; Data bus inputs are stable		IDD2NS	8	8	8	8	mA	9
Active power-down standby current: 1 bank active, CKE = LOW; CS = HIGH; $^{t}CK = {}^{t}CK$ (MIN); Address and control inputs are switching; Data bus inputs are stable		IDD3P	3	3	3	3	mA	8
Active power-down standby current: Clock stopped; 1 bank active, CKE = LOW; CS = HIGH; CK = LOW; CK# = HIGH; Address and control inputs are switching; Data bus inputs are stable		IDD3PS	2	2	2	2	mA	
Active nonpower-down standby: 1 bank active; CKE = HIGH; CS = HIGH; $^{t}CK = {}^{t}CK$ (MIN); Address and control inputs are switching; Data bus inputs are stable		IDD3N	15	15	15	15	mA	6
Active nonpower-down standby: Clock stopped; 1 bank active, CKE = HIGH; CS = HIGH; CK = LOW; CK# = HIGH; Address and control inputs are switching; Data bus inputs are stable		IDD3NS	8	8	8	8	mA	6
Operating burst read: 1 bank active; BL = 4; CL = 3; $^{t}CK = {}^{t}CK$ (MIN); Continuous READ bursts; IOUT = 0mA; Address inputs are switching every 2 clock cycles; 50% data changing each burst		IDD4R	125	120	115	100	mA	6
Operating burst write: One bank active; BL = 4; $^{t}CK = {}^{t}CK$ (MIN); Continuous WRITE bursts; Address inputs are switching; 50% data changing each burst		IDD4W	125	120	115	100	mA	6
Auto refresh: Burst refresh; CKE = HIGH; Address and control inputs are switching; Data bus inputs are stable	^{t}RFC = 110ns	IDD5	105	105	100	100	mA	10
	$^{t}RFC = {}^{t}REFI$	IDD5A	3	3	3	3	mA	10, 11
Deep power-down current: Address and control pins are stable; Data bus inputs are stable		IDD8	10				µA	7, 13

Table 10: IDD6 Specifications and Conditions

Notes: 1–5, 7, and 12 apply to all parameters/conditions in this table; VDD/VDDQ = 1.70–1.95V

Parameter/Condition		Symbol	Low Power	Standard	Units
Self refresh CKE = LOW; tCK = tCK (MIN); Address and control inputs are stable; Data bus inputs are stable	Full array, 85°C	IDD6	500	700	µA
	Full array, 45°C		250	390	µA
	Half array, 85°C		400	520	µA
	Half array, 45°C		220	310	µA
	1/4 array, 85°C		350	430	µA
	1/4 array, 45°C		205	275	µA
	1/8 array, 85°C		350	430	µA
	1/8 array, 45°C		205	275	µA
	1/16 array, 85°C		325	375	µA
	1/16 array, 45°C		200	250	µA

Notes:
1. All voltages referenced to VSS.
2. Tests for IDD characteristics may be conducted at nominal supply voltage levels, but the related specifications and device operation are guaranteed for the full voltage range specified.
3. Timing and IDD tests may use a VIL-to-VIH swing of up to 1.5V in the test environment, but input timing is still referenced to VDDQ/2 (or to the crossing point for CK/CK#). The output timing reference voltage level is VDDQ/2.
4. IDD is dependent on output loading and cycle rates. Specified values are obtained with minimum cycle time with the outputs open.
5. IDD specifications are tested after the device is properly initialized and values are averaged at the defined cycle rate.
6. MIN (tRC or tRFC) for IDD measurements is the smallest multiple of tCK that meets the minimum absolute value for the respective parameter. tRAS (MAX) for IDD measurements is the largest multiple of tCK that meets the maximum absolute value for tRAS.
7. Measurement is taken 500ms after entering into this operating mode to allow settling time for the tester.
8. VDD must not vary more than 4 percent if CKE is not active while any bank is active.
9. IDD2N specifies DQ, DQS, and DM to be driven to a valid HIGH or LOW logic level.
10. CKE must be active (HIGH) during the entire time a REFRESH command is executed. From the time the AUTO REFRESH command is registered, CKE must be active at each rising clock edge until tRFC later.
11. This limit is a nominal value and does not result in a fail. CKE is HIGH during REFRESH command period (tRFC [MIN]) else CKE is LOW (for example, during standby).
12. Values for IDD6 85°C are guaranteed for the entire temperature range. All other IDD6 values are estimated.
13. Typical values at 25°C, not a maximum value.

Figure 9: Typical IDD6 Curves

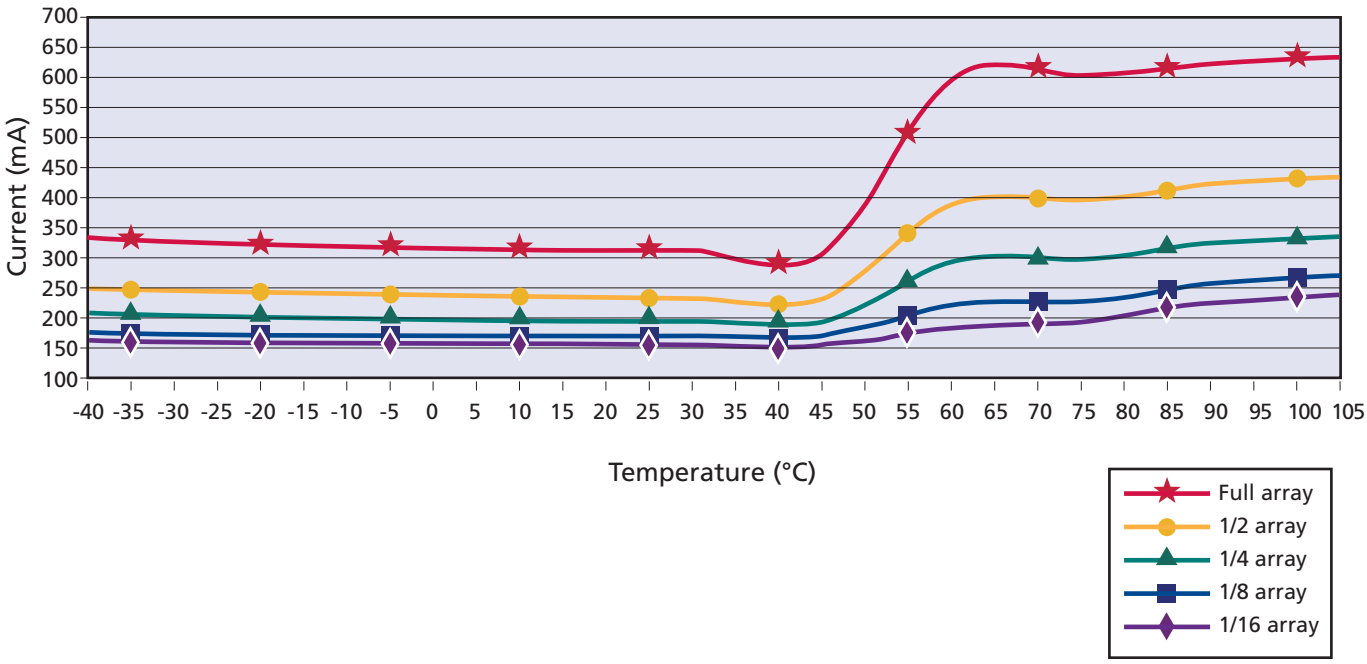


Table 11: Electrical Characteristics and Recommended AC Operating Conditions

Notes: 1–9 apply to all parameters in this table; VDD/VDDQ = 1.70–1.95V

Parameter		Symbol	-5		-54		-6		-75		Unit	Notes
			M	Max	Min	Max	Min	Max	Min	Max		
Access window of DQs from CK/CK#	CL = 3	^{t}AC	2.0	5.0	2.0	5.0	2.0	5.0	2.0	6.0	ns	
	CL = 2		2.0	6.5	2.0	6.5	2.0	6.5	2.0	6.5		
Clock cycle time	CL = 3	^{t}CK	5	–	5.4	–	6	–	7.5	–	ns	10
	CL = 2		12	–	12	–	12	–	12	–		
CK high-level width		^{t}CH	0.45	0.55	0.45	0.55	0.45	0.55	0.45	0.55	^{t}CK	
CK low-level width		^{t}CL	0.45	0.55	0.45	0.55	0.45	0.55	0.45	0.55	^{t}CK	
CKE minimum pulse width (high and low)		^{t}CKE	1	–	1	–	1	–	1	–	^{t}CK	
Auto precharge write recovery + precharge time		^{t}DAL	–	–	–	–	–	–	–	–		11
DQ and DM input hold time relative to DQS	fast slew rate	$^{t}DH_f$	0.48	–	0.54	–	0.6	–	0.8	–	ns	12, 13, 14
DQ and DM input hold time relative to DQS	slow slew rate	$^{t}DH_s$	0.58	–	0.64	–	0.7	–	0.9	–		
DQ and DM input setup time relative to DQ	fast slew rate	$^{t}DS_f$	0.48	–	0.54	–	0.6	–	0.8	–	ns	12, 13, 14
DQ and DM input setup time relative to DQS	slow slew rate	$^{t}DS_s$	0.58	–	0.64	–	0.7	–	0.9	–		
DQ and DM input pulse width (for each input)		$^{t}DIPW$	1.4	–	1.4	–	1.4	–	1.4	–	ns	15
Access window of DQS from CK/CK#	CL = 3	$^{t}DQSCK$	2.0	5.0	2.0	5.0	2.0	5.0	2.0	6.0	ns	
	CL = 2		2.0	6.5	2.0	6.5	2.0	6.5	2.0	6.5		

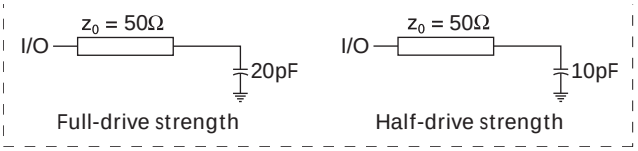
Table 11: Electrical Characteristics and Recommended AC Operating Conditions (continued)
Notes: 1–9 apply to all parameters in this table; VDD/VDDQ = 1.70–1.95V

Parameter		Symbol	-5		-54		-6		-75		Unit	Notes
			M	Max	Min	Max	Min	Max	Min	Max		
DQS input high pulse width		^{t}DQSH	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6	^{t}CK	
DQS input low pulse width		^{t}DQSL	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6	^{t}CK	
DQS–DQ skew, DQS to last DQ valid, per group, per access		^{t}DQSQ	–	0.4	–	0.45	–	0.5	–	0.6	ns	12, 16
WRITE command to first DQS latching transition		^{t}DQSS	0.75	1.25	0.75	1.25	0.75	1.25	0.75	1.25	^{t}CK	
DQS falling edge from CK rising – hold time		^{t}DSH	0.2	–	0.2	–	0.2	–	0.2	–	^{t}CK	
DQS falling edge to CK rising – setup time		^{t}DSS	0.2	–	0.2	–	0.2	–	0.2	–	^{t}CK	
Data valid output window		DVW	^{t}QH - ^{t}DQSQ		^{t}QH - ^{t}DQSQ		^{t}QH - ^{t}DQSQ		^{t}QH - ^{t}DQSQ		ns	16
Half-clock period		^{t}HP	^{t}CH, ^{t}CL	–	^{t}CH, ^{t}CL	–	^{t}CH, ^{t}CL	–	^{t}CH, ^{t}CL	–	ns	17
Data-out High-Z window from CK/CK#	CL = 3	^{t}HZ	–	5.0	–	5.0	–	5.0	–	6.0	ns	18, 19
	CL = 2		–	6.5	–	6.5	–	6.5	–	6.5		
Data-out Low-Z window from CK/CK#		^{t}LZ	1.0	–	1.0	–	1.0	–	1.0	–	ns	18
Address and control input hold time	fast slew rate	^{t}IH$_{F}$	0.9	–	1.0	–	1.1	–	1.3	–	ns	14, 20
Address and control input hold time	slow slew rate	^{t}IH$_{S}$	1.1	–	1.2	–	1.3	–	1.5	–		
Address and control input setup time	fast slew rate	^{t}IS$_{F}$	0.9	–	1.0	–	1.1	–	1.3	–	ns	14, 20
Address and control input setup time	slow slew rate	^{t}IS$_{S}$	1.1	–	1.2	–	1.3	–	1.5	–		
Address and control input pulse width		^{t}IPW	2.3	–	2.4	–	2.4	–	2.6	–	ns	15
LOAD MODE REGISTER command cycle time		^{t}MRD	2	–	2	–	2	–	2	–	^{t}CK	
DQ–DQS hold, DQS to first DQ to go non-valid, per access		^{t}QH	^{t}HP - ^{t}QHS	–	^{t}HP - ^{t}QHS	–	^{t}HP - ^{t}QHS	–	^{t}HP - ^{t}QHS	–	ns	12, 16
Data hold skew factor		^{t}QHS	–	0.5	–	0.5	–	0.65	–	0.75	ns	
ACTIVE-to-PRECHARGE command		^{t}RAS	40	70,000	42	70,000	42	70,000	45	70,000	ns	
ACTIVE-to-ACTIVE/ACTIVE-to-AUTO REFRESH command period		^{t}RC	55	–	59.4	–	60	–	67.5	–	ns	
ACTIVE-to-READ or WRITE delay		^{t}RCD	15	–	16.2	–	18	–	22.5	–	ns	
Refresh period		^{t}REF	–	64	–	64	–	64	–	64	ms	
Average periodic refresh interval		^{t}REFI	–	7.8	–	7.8	–	7.8	–	7.8	µs	22
AUTO-REFRESH command period		^{t}RFC	97.5	–	97.5	–	97.5	–	97.5	–	ns	
PRECHARGE command period		^{t}RP	15	–	16.2	–	18	–	22.5	–	ns	
DQS read preamble	CL = 3	^{t}RPRE	0.9	1.1	0.9	1.1	0.9	1.1	0.9	1.1	^{t}CK	
DQS read preamble	CL = 2	^{t}RPRE	0.5	1.1	0.5	1.1	0.5	1.1	0.5	1.1	^{t}CK	
DQS read postamble		^{t}RPST	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6	^{t}CK	
ACTIVE bank *a* to ACTIVE bank *b* command		^{t}RRD	10	–	10.8	–	12	–	15	–	ns	
Read of SRR to next valid command		^{t}SRC	CL + 1	–	CL + 1	–	CL + 1	–	CL + 1	–	^{t}CK	

Table 11: Electrical Characteristics and Recommended AC Operating Conditions (continued)
Notes: 1–9 apply to all parameters in this table; VDD/VDDQ = 1.70–1.95V

Parameter	Symbol	-5		-54		-6		-75		Unit	Notes
		M	Max	Min	Max	Min	Max	Min	Max		
SRR-to-READ	tSRR	2	–	2	–	2	–	2	–	tCK	
DQS write preamble	tWPRE	0.25	–	0.25	–	0.25	–	0.25	–	tCK	
DQS write preamble setup time	tWPRES	0	–	0	–	0	–	0	–	ns	22, 23
DQS write postamble	tWPST	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6	tCK	24
Write recovery time	tWR	15	–	15	–	15	–	15	–	ns	25
Internal WRITE-to-READ command delay	tWTR	2	–	2	–	2	–	1	–	tCK	
Exit power-down mode to first valid command	tXP	2	–	2	–	1	–	1	–	tCK	
Exit SELF REFRESH to first valid command	tXSR	120	–	120	–	120	–	120	–	ns	26

Notes:
1. All voltages referenced to VSS.
2. All parameters assume proper device initialization.
3. Tests for AC timing and electrical AC and DC characteristics may be conducted at nominal supply voltage levels, but the related specifications and device operation are guaranteed for the full voltage ranges specified.
4. The circuit shown below represents the timing reference load used in defining the relevant timing parameters of the device. It is not intended to be either a precise representation of the typical system environment or a depiction of the actual load presented by a production tester. System designers will use IBIS or other simulation tools to correlate the timing reference load to system environment. Specifications are correlated to production test conditions (generally a coaxial transmission line terminated at the tester electronics). For the half-strength driver with a nominal 10pF load, parameters tAC and tQH are expected to be in the same range. However, these parameters are not subject to production test but are estimated by design/characterization. Use of IBIS or other simulation tools for system design validation is suggested.



5. The CK/CK# input reference voltage level (for timing referenced to CK/CK#) is the point at which CK and CK# cross; the input reference voltage level for signals other than CK/CK# is VDDQ/2.
6. A CK and CK# input slew rate ≥1 V/ns (2 V/ns if measured differentially) is assumed for all parameters.
7. All AC timings assume an input slew rate of 1 V/ns.
8. CAS latency definition: with CL = 2, the first data element is valid at (tCK + tAC) after the clock at which the READ command was registered; for CL = 3, the first data element is valid at (2 × tCK + tAC) after the first clock at which the READ command was registered.
9. Timing tests may use a VIL-to-VIH swing of up to 1.5V in the test environment, but input timing is still referenced to VDDQ/2 or to the crossing point for CK/CK#. The output timing reference voltage level is VDDQ/2.
10. Clock frequency is allowed to change only during a clock stop, power-down, or self refresh mode.
11. tDAL = (tWR/tCK) + (tRP/tCK): for each term, if not already an integer, round to the next higher integer.

12. Referenced to each output group: for x16, LDQS with DQ0–DQ7; and UDQS with DQ8–DQ15. For x32, DQS0 with DQ0–DQ7; DQS1 with DQ8–DQ15; DQS2 with DQ16–DQ23; and DQS3 with DQ24–DQ31.
13. DQ and DM input slew rates must not deviate from DQS by more than 10 percent. If the DQ/DM/DQS slew rate is less than 1.0 V/ns, timing must be derated: 50ps must be added to ^{t}DS and ^{t}DH for each 100 mV/ns reduction in slew rate. If slew rate exceeds 4 V/ns, functionality is uncertain.
14. The transition time for input signals (CAS#, CKE, CS#, DM, DQ, DQS, RAS#, WE#, and addresses) are measured between V_{IL}(DC) to V_{IH}(AC) for rising input signals and V_{IH}(DC) to V_{IL}(AC) for falling input signals.
15. These parameters guarantee device timing but are not tested on each device.
16. The valid data window is derived by achieving other specifications: ^{t}HP (^{t}CK/2), ^{t}DQSQ, and ^{t}QH (^{t}HP - ^{t}QHS). The data valid window derates directly proportional with the clock duty cycle and a practical data valid window can be derived. The clock is allowed a maximum duty cycle variation of 45/55. Functionality is uncertain when operating beyond a 45/55 ratio.
17. ^{t}HP (MIN) is the lesser of ^{t}CL (MIN) and ^{t}CH (MIN) actually applied to the device CK and CK# inputs, collectively.
18. ^{t}HZ and ^{t}LZ transitions occur in the same access time windows as valid data transitions. These parameters are not referenced to a specific voltage level, but specify when the device output is no longer driving (^{t}HZ) or begins driving (^{t}LZ).
19. ^{t}HZ (MAX) will prevail over ^{t}DQSCK (MAX) + ^{t}RPST (MAX) condition.
20. Fast command/address input slew rate ≥1 V/ns. Slow command/address input slew rate ≥0.5 V/ns. If the slew rate is less than 0.5 V/ns, timing must be derated: ^{t}IS has an additional 50ps per each 100 mV/ns reduction in slew rate from the 0.5 V/ns. ^{t}IH has 0ps added, therefore, it remains constant. If the slew rate exceeds 4.5 V/ns, functionality is uncertain.
21. The refresh period equals 64ms. This equates to an average refresh rate of 7.8125µs.
22. This is not a device limit. The device will operate with a negative value, but system performance could be degraded due to bus turnaround.
23. It is recommended that DQS be valid (HIGH or LOW) on or before the WRITE command. The case shown (DQS going from High-Z to logic LOW) applies when no WRITEs were previously in progress on the bus. If a previous WRITE was in progress, DQS could be HIGH during this time, depending on ^{t}DQSS.
24. The maximum limit for this parameter is not a device limit. The device will operate with a greater value for this parameter, but system performance (bus turnaround) will degrade accordingly.
25. At least one clock cycle is required during ^{t}WR time when in auto precharge mode.
26. Clock must be toggled a minimum of two times during the ^{t}XSR period.

Table 12: Target Output Drive Characteristics (Full Strength)

Notes 1–2 apply to all values. Characteristics are specified under best and worst process variations/conditions.

Voltage (V)	Pull-Down Current (mA)		Pull-Up Current (mA)	
	Min	Max	Min	Max
0.00	0.00	0.00	0.00	0.00
0.10	2.80	18.53	–2.80	–18.53
0.20	5.60	26.80	–5.60	–26.80
0.30	8.40	32.80	–8.40	–32.80
0.40	11.20	37.05	–11.20	–37.05
0.50	14.00	40.00	–14.00	–40.00
0.60	16.80	42.50	–16.80	–42.50
0.70	19.60	44.57	–19.60	–44.57
0.80	22.40	46.50	–22.40	–46.50
0.85	23.80	47.48	–23.80	–47.48
0.90	23.80	48.50	–23.80	–48.50
0.95	23.80	49.40	–23.80	–49.40
1.00	23.80	50.05	–23.80	–50.05
1.10	23.80	51.35	–23.80	–51.35
1.20	23.80	52.65	–23.80	–52.65
1.30	23.80	53.95	–23.80	–53.95
1.40	23.80	55.25	–23.80	–55.25
1.50	23.80	56.55	–23.80	–56.55
1.60	23.80	57.85	–23.80	–57.85
1.70	23.80	59.15	–23.80	–59.15
1.80	–	60.45	–	–60.45
1.90	–	61.75	–	–61.75

Notes:
1. Based on nominal impedance of 25Ω (full strength).
2. The full variation in driver current from minimum to maximum, due to process, voltage, and temperature, will lie within the outer bounding lines of the I-V curves.

Table 13: Target Output Drive Characteristics (Three-Quarter Strength)

Notes 1–2 apply to all values. Characteristics are specified under best and worst process variations/conditions.

Voltage (V)	Pull-Down Current (mA)		Pull-Up Current (mA)	
	Min	Max	Min	Max
0.00	0.00	0.00	0.00	0.00
0.10	1.96	12.97	–1.96	–12.97
0.20	3.92	18.76	–3.92	–18.76
0.30	5.88	22.96	–5.88	–22.96
0.40	7.84	25.94	–7.84	–25.94
0.50	9.80	28.00	–9.80	–28.00
0.60	11.76	29.75	–11.76	–29.75
0.70	13.72	31.20	–13.72	–31.20
0.80	15.68	32.55	–15.68	–32.55
0.85	16.66	33.24	–16.66	–33.24
0.90	16.66	33.95	–16.66	–33.95
0.95	16.66	34.58	–16.66	–34.58
1.00	16.66	35.04	–16.66	–35.04
1.10	16.66	35.95	–16.66	–35.95
1.20	16.66	36.86	–16.66	–36.86
1.30	16.66	37.77	–16.66	–37.77
1.40	16.66	38.68	–16.66	–38.68
1.50	16.66	39.59	–16.66	–39.59
1.60	16.66	40.50	–16.66	–40.50
1.70	16.66	41.41	–16.66	–41.41
1.80	–	42.32	–	–42.32
1.90	–	43.23	–	–43.23

Notes:
1. Based on nominal impedance of 37Ω (three-quarter strength).
2. The full variation in driver current from minimum to maximum, due to process, voltage, and temperature, will lie within the outer bounding lines of the I-V curves.
3. Contact factory for availability of three-quarter drive strength.

Table 14: Target Output Drive Characteristics (One-Half Strength)

Notes 1–3 apply to all values. Characteristics are specified under best and worst process variations/conditions.

Voltage (V)	Pull-Down Current (mA)		Pull-Up Current (mA)	
	Min	Max	Min	Max
0.00	0.00	0.00	0.00	0.00
0.10	1.27	8.42	–1.27	–8.42
0.20	2.55	12.30	–2.55	–12.30
0.30	3.82	14.95	–3.82	–14.95
0.40	5.09	16.84	–5.09	–16.84
0.50	6.36	18.20	–6.36	–18.20
0.60	7.64	19.30	–7.64	–19.30
0.70	8.91	20.30	–8.91	–20.30
0.80	10.16	21.20	–10.16	–21.20
0.85	10.80	21.60	–10.80	–21.60
0.90	10.80	22.00	–10.80	–22.00
0.95	10.80	22.45	–10.80	–22.45
1.00	10.80	22.73	–10.80	–22.73
1.10	10.80	23.21	–10.80	–23.21
1.20	10.80	23.67	–10.80	–23.67
1.30	10.80	24.14	–10.80	–24.14
1.40	10.80	24.61	–10.80	–24.61
1.50	10.80	25.08	–10.80	–25.08
1.60	10.80	25.54	–10.80	–25.54
1.70	10.80	26.01	–10.80	–26.01
1.80	–	26.48	–	–26.48
1.90	–	26.95	–	–26.95

Notes:
1. Based on nominal impedance of 55Ω (one-half strength) at $V_{DDQ}/2$.
2. The full variation in driver current from minimum to maximum, due to process, voltage, and temperature, will lie within the outer bounding lines of the I-V curves.
3. The I-V curve for one-quarter drive strength is approximately 50 percent of one-half drive strength.

Table 15: 1.2V I/O Target Output Drive Characteristics (Three-Quarter Strength)

Notes 1–3 apply to all values. Characteristics are specified under best and worst process variations/conditions.

Voltage (V)	Pull-Down Current (mA)		Pull-Up Current (mA)	
	Min	Max	Min	Max
0.00	0.00	0.00	0.00	0.00
0.10	1.96	9.38	–1.96	–9.38
0.20	3.92	12.97	–3.92	–12.97
0.30	5.88	15.87	–5.88	–15.87
0.40	7.84	18.33	–7.84	–18.33
0.50	9.80	20.34	–9.80	–20.34
0.60	11.10	22.63	–11.10	–22.63
0.70	11.10	25.03	–11.10	–25.03
0.80	11.10	27.14	–11.10	–27.14
0.90	11.10	29.91	–11.10	–29.91
1.00	11.10	32.18	–11.10	–32.18
1.10	11.10	34.95	–11.10	–34.95
1.20	11.10	37.78	–11.10	–37.78
1.30		40.58		–40.58

Notes:
1. Based on nominal impedance of 37Ω (three-quarter strength).
2. The full variation in driver current from minimum to maximum, due to process, voltage, and temperature, will lie within the outer bounding lines of the I-V curves.
3. Contact factory for availability of three-quarter drive strength.

Functional Description

The Mobile 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. Single read or write access for Mobile DDR SDRAM 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.

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 Mobile 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 device has two data strobes, one for the lower byte and one for the upper byte; the x32 device has four data strobes, one per byte.

The Mobile 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 Mobile 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 is then 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 starting column location for the burst access.

The Mobile DDR SDRAM provides for programmable READ or WRITE burst lengths of 2, 4, 8, or 16. 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 DDR SDRAMs, the pipelined, multibank architecture of Mobile 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. Deep power-down mode is offered to achieve maximum power reduction by eliminating the power of the memory array. Data will not be retained after the device enters deep power-down mode.

Two self refresh features, temperature-compensated self refresh (TCSR) and partial-array self refresh (PASR), offer additional power savings. TCSR is controlled by the automatic on-chip temperature sensor. The PASR can be customized using the extended mode register settings. The two features may be combined to achieve even greater power savings.

The DLL that is typically used on standard DDR devices is not necessary on the Mobile DDR SDRAM. It has been omitted to save power.

Commands

Table 16 and Table 17 provide a quick reference of available commands. This is followed by a written description of each command. Three additional truth tables (Table 18 on page 37, Table 19 on page 38, and Table 20 on page 40) provide CKE commands and current/next state information.

Table 16: Truth Table – Commands

CKE is HIGH for all commands shown except SELF REFRESH and DEEP POWER-DOWN; all states and sequences not shown are reserved and/or illegal

Name (Function)	CS#	RAS#	CAS#	WE#	Address	Notes
DESELECT (NOP)	H	X	X	X	X	1
NO OPERATION (NOP)	L	H	H	H	X	1
ACTIVE (select bank and activate row)	L	L	H	H	Bank/row	2
READ (select bank and column, and start READ burst)	L	H	L	H	Bank/column	3
WRITE (select bank and column, and start WRITE burst)	L	H	L	L	Bank/column	3
BURST TERMINATE or DEEP POWER-DOWN (enter deep power-down mode)	L	H	H	L	X	4, 5
PRECHARGE (deactivate row in bank or banks)	L	L	H	L	Code	6
AUTO REFRESH (refresh all or single bank) or SELF REFRESH (enter self refresh mode)	L	L	L	H	X	7, 8
LOAD MODE REGISTER	L	L	L	L	Op-code	9

Notes:
1. DESELECT and NOP are functionally interchangeable.
2. BA0–BA1 provide bank address and A0–A*i* provide row address (where *i* = the most significant address bit for each configuration).
3. BA0–BA1 provide bank address; A0–A*i* provide column address (where *i* = the most significant address bit for each configuration); A10 HIGH enables the auto precharge feature (nonpersistent); A10 LOW disables the auto precharge feature.
4. Applies only to READ bursts with auto precharge disabled; this command is undefined and should not be used for READ bursts with auto precharge enabled and for WRITE bursts.
5. This command is a BURST TERMINATE if CKE is HIGH and DEEP POWER-DOWN if CKE is LOW.
6. A10 LOW: BA0–BA1 determine which bank is precharged.
   A10 HIGH: all banks are precharged and BA0–BA1 are "Don't Care."
7. This command is AUTO REFRESH if CKE is HIGH, SELF REFRESH if CKE is LOW.
8. Internal refresh counter controls row addressing; in self refresh mode all inputs and I/Os are "Don't Care" except for CKE.
9. BA0–BA1 select the standard mode register, extended mode register, or status register.

Table 17: DM Operation Truth Table

Name (Function)	DM	DQ	Notes
Write enable	L	Valid	1, 2
Write inhibit	H	X	1, 2

Notes:
1. Used to mask write data; provided coincident with the corresponding data.
2. All states and sequences not shown are reserved and/or illegal.

DESELECT

The DESELECT function (CS# HIGH) prevents new commands from being executed by the Mobile DDR SDRAM. Operations already in progress are not affected.

NO OPERATION (NOP)

The NO OPERATION (NOP) command is used to instruct the selected Mobile DDR SDRAM to perform a NOP. This prevents unwanted commands from being registered during idle or wait states. Operations already in progress are not affected.

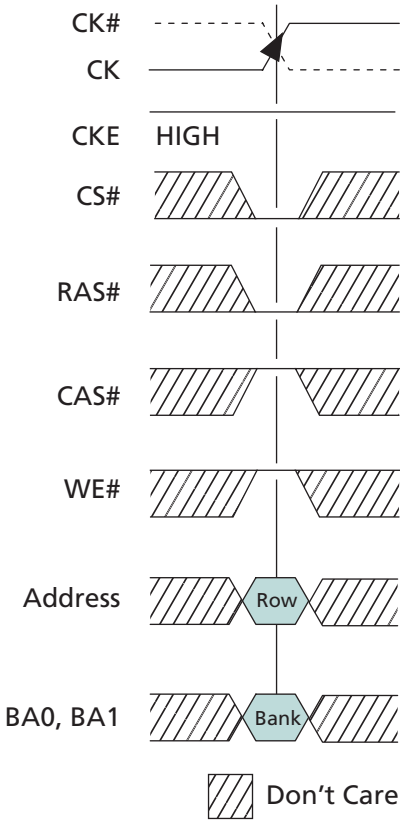
LOAD MODE REGISTER

The mode registers are loaded via inputs A0–A*n*. See mode register descriptions in "Register Definition" on page 44. The LOAD MODE REGISTER command can only be issued when all banks are idle, and a subsequent executable command cannot be issued until ^{t}MRD is met.

ACTIVE

The ACTIVE command is used to open (or activate) a row in a particular bank for a subsequent access. The values on the BA0 and BA1 inputs select the bank, and the address provided on inputs A0–A*n* selects the row. This row remains active (or open) for accesses until a PRECHARGE command is issued to that bank. A PRECHARGE command must be issued before opening a different row in the same bank.

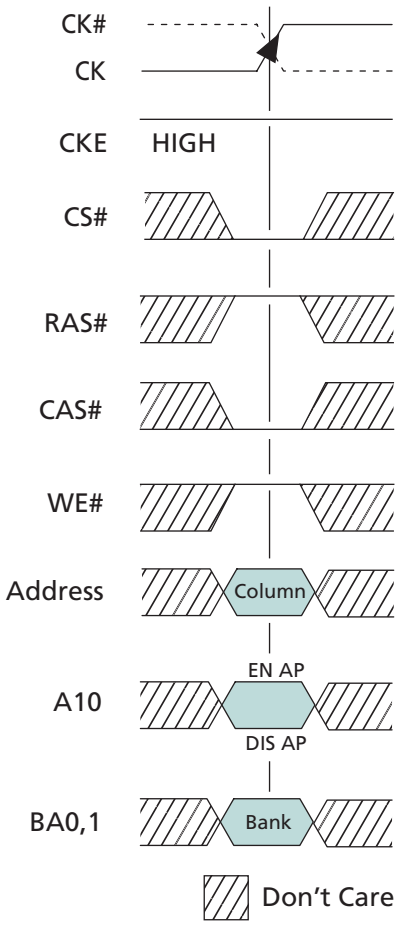
Figure 10: ACTIVE Command



READ

The READ command is used to initiate a burst read access to an active row. The values on the BA0 and BA1 inputs select the bank; the address provided on inputs A0–A*i* (where *i* = the most significant column address bit for each configuration) selects the starting column location. The value on input A10 determines whether auto precharge is used. If auto precharge is selected, the row being accessed will be precharged at the end of the READ burst; if auto precharge is not selected, the row will remain open for subsequent accesses.

Figure 11: READ Command



Notes: 1. EN AP = enable auto precharge; DIS AP = disable auto precharge.

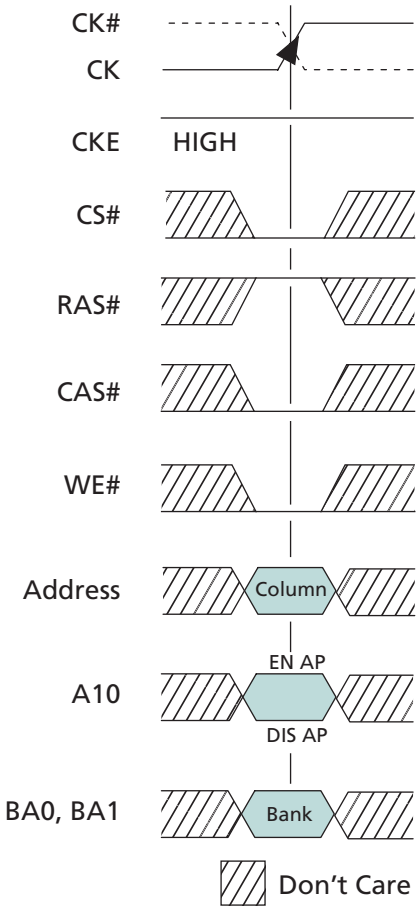
WRITE

The WRITE command is used to initiate a burst write access to an active row. The values on the BA0 and BA1 inputs select the bank; the address provided on inputs A0–A*i* (where *i* = the most significant column address bit for each configuration) selects the starting column location. The value on input A10 determines whether auto precharge is used. If auto precharge is selected, the row being accessed will be precharged at the end of the WRITE burst; if auto precharge is not selected, the row will remain open for subsequent accesses. Input data appearing on the DQs is written to the memory array subject to the DM input logic level appearing coincident with the data. If a given DM signal is regis-

tered LOW, the corresponding data will be written to memory; if the DM signal is registered HIGH, the corresponding data inputs will be ignored, and a WRITE will not be executed to that byte/column location.

If a WRITE or a READ is in progress, the entire data burst must be complete prior to stopping the clock (see the "Stopping the External Clock" section on page 83). A burst completion for WRITEs is defined when the write postamble and ^{t}WR or ^{t}WTR are satisfied.

Figure 12: WRITE Command

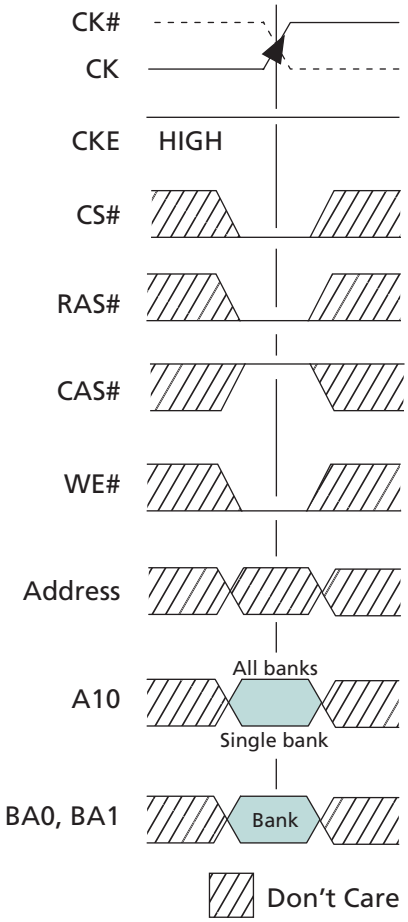


Notes: 1. EN AP = enable auto precharge; DIS AP = disable auto precharge.

PRECHARGE

The PRECHARGE command is used to deactivate the open row in a particular bank or the open row in all banks. The bank(s) will be available for a subsequent row access a specified time (^{t}RP) after the PRECHARGE command is issued. Input A10 determines whether one or all banks are to be precharged, and in the case where only one bank is to be precharged, inputs BA0 and BA1 select the bank. Otherwise, BA0 and BA1 are treated as "Don't Care." After a bank has been precharged, it is in the idle state and must be activated prior to any READ or WRITE commands being issued to that bank.

Figure 13: PRECHARGE Command



Notes: 1. If A10 is HIGH, bank address becomes "Don't Care."

BURST TERMINATE

The BURST TERMINATE command is used to truncate READ bursts with auto precharge disabled. The most recently registered READ command prior to the BURST TERMINATE command will be truncated, as described in "READs" on page 52. The open page from which the READ was terminated remains open.

AUTO REFRESH

AUTO REFRESH is used during normal operation of the Mobile DDR SDRAM and is analogous to CAS#-BEFORE-RAS# (CBR) REFRESH in FPM/EDO DRAMs. The AUTO REFRESH command is nonpersistent and must be issued each time a refresh is required.

The addressing is generated by the internal refresh controller. This makes the address bits a "Don't Care" during an AUTO REFRESH command.

To allow for improved efficiency in scheduling and switching between tasks, some flexibility in the absolute refresh interval is provided. The auto refresh period begins when the AUTO REFRESH command is registered and ends ^{t}RFC later.

SELF REFRESH

The SELF REFRESH command can be used to retain data in the Mobile DDR SDRAM, even if the rest of the system is powered down. When in the self refresh mode, the Mobile DDR SDRAM retains data without external clocking. The SELF REFRESH command is initiated like an AUTO REFRESH command, except that CKE is disabled (LOW). All command and address input signals except CKE are "Don't Care" during SELF REFRESH. See Figure 49 on page 80 for details on entering and exiting self refresh mode.

During SELF REFRESH, the device is refreshed as identified in the extended mode register (see "Partial-Array Self Refresh (PASR)" on page 48). An internal temperature sensor will adjust the refresh rate to optimize device power consumption while ensuring data integrity (see "Temperature-Compensated Self Refresh (TCSR)" on page 48).

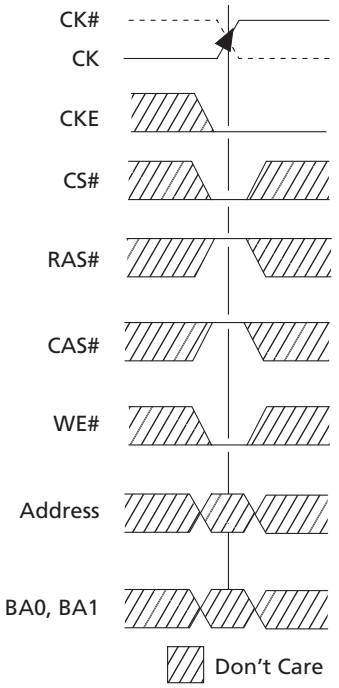
The procedure for exiting SELF REFRESH requires a sequence of commands. First, CK must be stable prior to CKE going back HIGH. Once CKE is HIGH, the Mobile DDR SDRAM must have NOP commands issued for ^{t}XSR time.

During SELF REFRESH operation, refresh intervals are scheduled internally, and may vary. These refresh intervals may be different then the specified ^{t}REFI time. For this reason, the SELF REFRESH command must not be used as a substitute for the AUTO REFRESH command.

DEEP POWER-DOWN

The DEEP POWER-DOWN (DPD) command is used to enter DPD operating mode, which achieves maximum power reduction by eliminating the power of the memory array. Data will not be retained when the device enters DPD mode. The DPD command is the same as a BURST TERMINATE command with CKE LOW.

Figure 14: DEEP POWER-DOWN Command



Operations

Table 18: Truth Table – Current State Bank *n* – Command to Bank *n*
Notes: 1–6; notes appear below and on next page

Current State	CS#	RAS#	CAS#	WE#	Command/Action	Notes
Any	H	X	X	X	DESELECT (NOP/continue previous operation)	
	L	H	H	H	NO OPERATION (NOP/continue previous operation)	
Idle	L	L	H	H	ACTIVE (select and activate row)	
	L	L	L	H	AUTO REFRESH	7
	L	L	L	L	LOAD MODE REGISTER	7
Row active	L	H	L	H	READ (select column and start READ burst)	10
	L	H	L	L	WRITE (select column and start WRITE burst)	10
	L	L	H	L	PRECHARGE (deactivate row in bank or banks)	8
Read (auto precharge disabled)	L	H	L	H	READ (select column and start new READ burst)	10
	L	H	L	L	WRITE (select column and start WRITE burst)	10, 12
	L	L	H	L	PRECHARGE (truncate READ burst, start PRECHARGE)	8
	L	H	H	L	BURST TERMINATE	9
Write (auto precharge disabled)	L	H	L	H	READ (select column and start READ burst)	10, 11
	L	H	L	L	WRITE (select column and start new WRITE burst)	10
	L	L	H	L	PRECHARGE (truncate WRITE burst, start PRECHARGE)	8, 11

Notes:

1. This table applies when CKE_{n-1} was HIGH and CKE_n is HIGH and after ^tXSR has been met (if the previous state was self refresh), after ^tXP has been met (if the previous state was power-down, or a full initialization if the previous state was deep power-down).
2. This table is bank-specific, except where noted (for example, the current state is for a specific bank and the commands shown are those allowed to be issued to that bank when in that state). Exceptions are covered in the notes below.
3. Current state definitions:

   Idle: The bank has been precharged, and ^tRP has been met.
   Row active: A row in the bank has been activated, and ^tRCD has been met. No data bursts/accesses and no register accesses are in progress.
   Read: A READ burst has been initiated with auto precharge disabled and has not yet terminated or been terminated.
   Write: A WRITE burst has been initiated with auto precharge disabled and has not yet terminated or been terminated.
4. The following states must not be interrupted by a command issued to the same bank. COMMAND INHIBIT or NOP commands, or allowable commands to the other bank, should be issued on any clock edge occurring during these states. Allowable commands to any other bank are determined by that bank's current state.

   Precharging: Starts with registration of a PRECHARGE command and ends when ^tRP is met. After ^tRP is met, the bank will be in the idle state.
   Row activating: Starts with registration of an ACTIVE command and ends when ^tRCD is met. After ^tRCD is met, the bank will be in the row active state.
   Read w/auto-precharge enabled: Starts with registration of a READ command with auto precharge enabled and ends when ^tRP has been met. After ^tRP is met, the bank will be in the idle state.
   Write w/auto-precharge enabled: Starts with registration of a WRITE command with auto precharge enabled and ends when ^tRP has been met. After ^tRP is met, the bank will be in the idle state.

5. The following states must not be interrupted by any executable command; DESELECT or NOP commands must be applied on each positive clock edge during these states.

   Refreshing: Starts with registration of an AUTO REFRESH command and ends when ^{t}RFC is met. Once ^{t}RFC is met, the DDR SDRAM will be in the all banks idle state.

   Accessing mode register: Starts with registration of a LOAD MODE REGISTER command and ends when ^{t}MRD has been met. After ^{t}MRD is met, the Mobile DDR SDRAM will be in the all banks idle state.

   Precharging all: Starts with registration of a PRECHARGE ALL command and ends when ^{t}RP is met. After ^{t}RP is met, all banks will be in the idle state.
6. All states and sequences not shown are illegal or reserved.
7. Not bank-specific; requires that all banks are idle, and bursts are not in progress.
8. May or may not be bank-specific; if multiple banks are to be precharged, each must be in a valid state for precharging.
9. Not bank-specific; BURST TERMINATE affects the most recent READ burst, regardless of bank.
10. READs or WRITEs listed in the Command/Action column include READs or WRITEs with auto precharge enabled and READs or WRITEs with auto precharge disabled.
11. Requires appropriate DM masking.
12. A WRITE command may be applied after the completion of the READ burst; otherwise, a BURST TERMINATE must be used to end the READ burst prior to asserting a WRITE command.

Table 19: Truth Table – Current State Bank *n* – Command to Bank *m*

Notes: 1–5; notes appear below and on next page

Current State	CS#	RAS#	CAS#	WE#	Command/Action	Notes
Any	H	X	X	X	DESELECT (NOP/continue previous operation)	
	L	H	H	H	NO OPERATION (NOP/continue previous operation)	
Idle	X	X	X	X	Any command allowed to bank *m*	
Row activating, active, or precharging	L	L	H	H	ACTIVE (select and activate row)	
	L	H	L	H	READ (select column and start READ burst)	
	L	H	L	L	WRITE (select column and start WRITE burst)	
	L	L	H	L	PRECHARGE	
Read (auto precharge disabled)	L	L	H	H	ACTIVE (select and activate row)	
	L	H	L	H	READ (select column and start new READ burst)	
	L	H	L	L	WRITE (select column and start WRITE burst)	7
	L	L	H	L	PRECHARGE	
Write (auto precharge disabled)	L	L	H	H	ACTIVE (select and activate row)	
	L	H	L	H	READ (select column and start READ burst)	6
	L	H	L	L	WRITE (select column and start new WRITE burst)	
	L	L	H	L	PRECHARGE	
Read (with auto precharge)	L	L	H	H	ACTIVE (select and activate row)	
	L	H	L	H	READ (select column and start new READ burst)	
	L	H	L	L	WRITE (select column and start WRITE burst)	7
	L	L	H	L	PRECHARGE	
Write (with auto precharge)	L	L	H	H	ACTIVE (select and activate row)	
	L	H	L	H	READ (select column and start READ burst)	
	L	H	L	L	WRITE (select column and start new WRITE burst)	
	L	L	H	L	PRECHARGE	

Notes:

1. This table applies when CKE_{n-1} was HIGH and CKE_n is HIGH and after ^tXSR has been met (if the previous state was self refresh), after ^tXP has been met (if the previous state was power-down, or a full initialization if the previous state was deep power-down).
2. This table describes alternate bank operation, except where noted (for example, the current state is for bank *n* and the commands shown are those allowed to be issued to bank *m*, assuming that bank *m* is in such a state that given command is allowable). Exceptions are covered in the notes below.
3. Current state definitions:

Idle:	The bank has been precharged, and ^tRP has been met.
Row active:	A row in the bank has been activated, and ^tRCD has been met. No data bursts/accesses and no register accesses are in progress.
Read:	A READ burst has been initiated and has not yet terminated or been terminated.
Write:	A WRITE burst has been initiated and has not yet terminated or been terminated.

   3a. The read with auto precharge enabled or write with auto precharge enabled states can each be broken into two parts: the access period and the precharge period. For read with auto precharge, the precharge period is defined as if the same burst was executed with auto precharge disabled and then followed with the earliest possible PRECHARGE command that still accesses all of the data in the burst. For write with auto precharge, the precharge period begins when ^tWR ends, with ^tWR measured as if auto precharge was disabled. The access period starts with registration of the command and ends where the precharge period (or ^tRP) begins.
   This device supports concurrent auto precharge such that when a read with auto precharge is enabled or a write with auto precharge is enabled, any command to other banks is allowed, as long as that command does not interrupt the read or write data transfer already in process. In either case, all other related limitations apply (for example, contention between read data and write data must be avoided).

   3b. The minimum delay from a READ or WRITE command with auto precharge disabled to a command to a different bank is summarized below.

From Command	To Command	Minimum Delay (with Concurrent Auto Precharge)
WRITE w/AP	READ or READ w/AP	[1 + (BL/2)] ^tCK + ^tWTR
	WRITE or WRITE w/AP	(BL/2) ^tCK
	PRECHARGE	1 ^tCK
	ACTIVE	1 ^tCK
READ w/AP	READ or READ w/AP	(BL/2) × ^tCK
	WRITE or WRITE w/AP	[CL + (BL/2)] ^tCK
	PRECHARGE	1 ^tCK
	ACTIVE	1 ^tCK

4. AUTO REFRESH and LOAD MODE REGISTER commands may only be issued when all banks are idle.
5. All states and sequences not shown are illegal or reserved.
6. Requires appropriate DM masking.
7. A WRITE command may be applied after the completion of the READ burst; otherwise, a BURST TERMINATE must be used to end the READ burst prior to asserting a WRITE command.

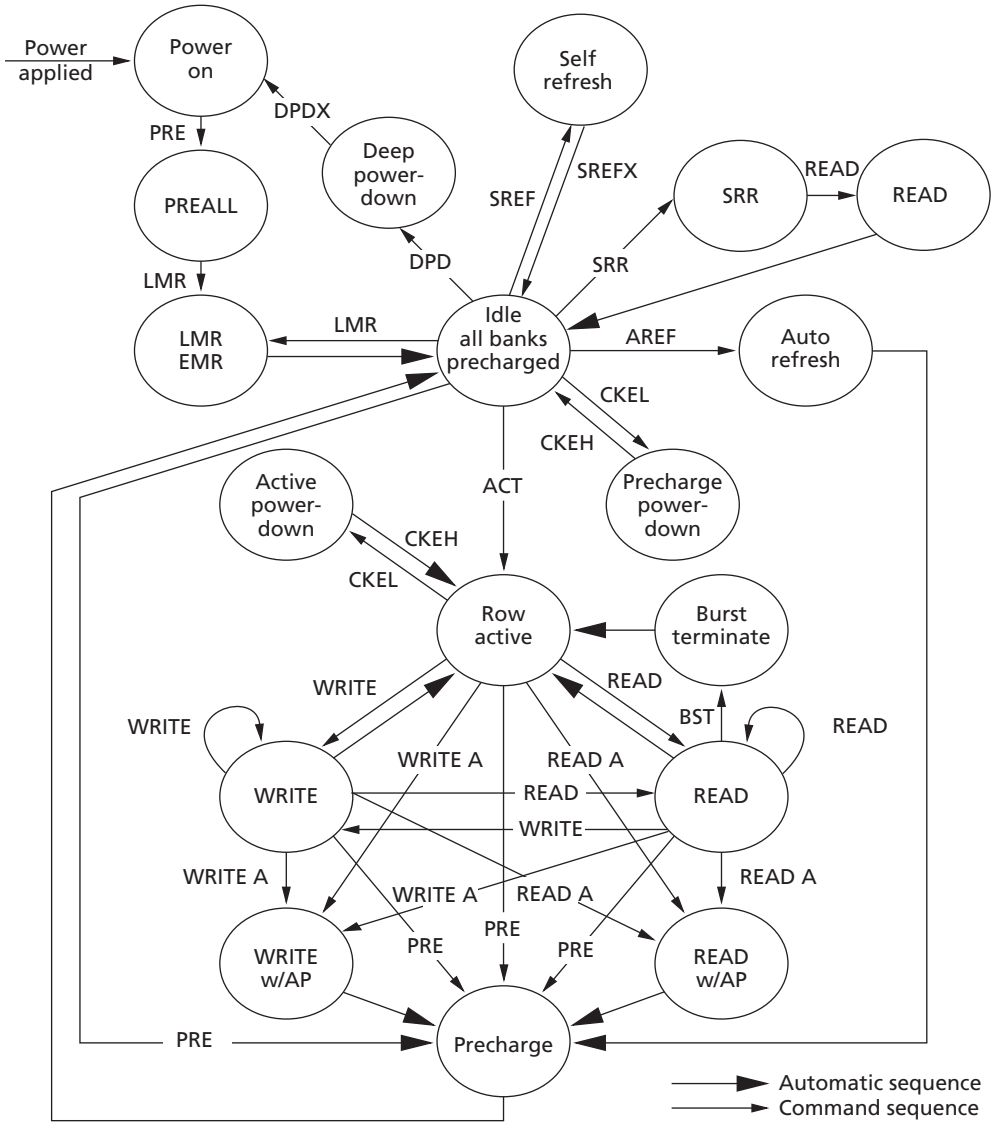
Table 20: Truth Table – CKE

Notes: 1–4

CKE_{n-1}	CKE_n	Current State	$COMMAND_n$	$ACTION_n$	Notes
L	L	Active power-down	X	Maintain active power-down	
L	L	Deep power-down	X	Maintain deep power-down	
L	L	(Precharge) power-down	X	Maintain (precharge) power-down	
L	L	Self refresh	X	Maintain self refresh	
L	H	Active power-down	DESELECT or NOP	Exit active power-down	5
L	H	Deep power-down	DESELECT or NOP	Exit deep power-down	6
L	H	(Precharge) power-down	DESELECT or NOP	Exit (precharge) power-down	
L	H	Self refresh	DESELECT or NOP	Exit self refresh	5, 7
H	L	Bank(s) active	DESELECT or NOP	Active power-down entry	
H	L	All banks idle	BURST TERMINATE	Deep power-down entry	
H	L	All banks idle	DESELECT or NOP	(Precharge) power-down entry	
H	L	All banks idle	AUTO REFRESH	Self refresh entry	
H	H		See Table 19 on page 38		
H	H		See Table 19 on page 38		

Notes:
1. CKE_n is the logic state of CKE at clock edge *n*; CKE_{n-1} was the state of CKE at the previous clock edge.
2. Current state is the state of the DDR SDRAM immediately prior to clock edge *n*.
3. $COMMAND_n$ is the command registered at clock edge *n*, and $ACTION_n$ is a result of $COMMAND_n$.
4. All states and sequences not shown are illegal or reserved.
5. DESELECT or NOP commands should be issued on any clock edges occurring during the ^tXP or ^tXSR period.
6. Upon exiting deep power-down mode, a full DRAM initialization sequence is required.
7. The clock must toggle at least two times during the ^tXSR period.

Figure 15: Mobile DRAM Simplified State Diagram



ACT = ACTIVE
AREF = AUTO REFRESH
BST = BURST TERMINATE
CKEH = Exit power-down
CKEL = Enter power-down
DPD = Enter deep power-down
DPDX = Exit deep power-down
EMR = LOAD EXTENDED MODE REGISTER
LMR = LOAD MODE REGISTER
PRE = PRECHARGE
PREALL = PRECHARGE all banks
READ = READ w/o auto precharge
READ A = READ w/ auto precharge
SREF = Enter self refresh
SREFX = Exit self refresh
SRR = STATUS REGISTER READ
WRITE = WRITE w/o auto precharge
WRITE A = WRITE w/ auto precharge

Initialization

The following sections provide detailed information covering device initialization, register definition, and device operation.

Prior to normal operation, Mobile DDR SDRAMs must be powered up and initialized in a predefined manner. Initialization procedures, other than those specified, will result in undefined operation.

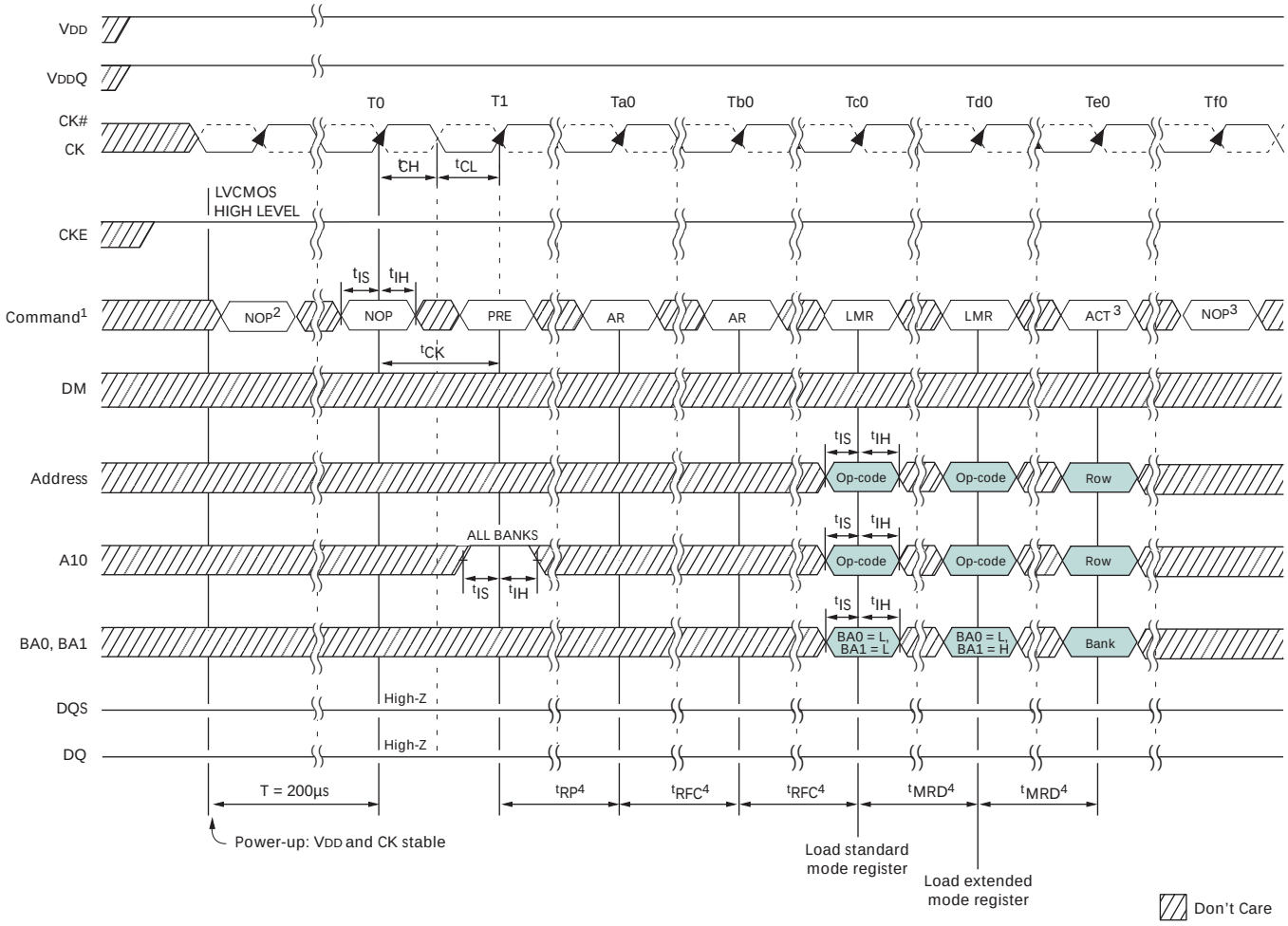
If there is an interruption to the device power, the initialization routine must be followed to ensure proper functionality of the Mobile DDR SDRAM.

To properly initialize the Mobile DDR SDRAM, this sequence must be followed:

1. The core power (V_{DD}) and I/O power ($V_{DD}Q$) must be brought up simultaneously. It is recommended that V_{DD} and $V_{DD}Q$ be from the same power source or $V_{DD}Q$ must never exceed V_{DD}. Assert and hold CKE HIGH.
2. When power supply voltages are stable and the CKE has been driven HIGH, it is safe to apply the clock.
3. When the clock is stable, a 200µs minimum delay is required by the Mobile DDR SDRAM prior to applying an executable command. During this time, NOP or DESELECT commands must be issued on the command bus.
4. Issue a PRECHARGE ALL command.
5. Issue NOP or DESELECT commands for at least ^{t}RP time.
6. Issue an AUTO REFRESH command followed by NOP or DESELECT commands for at least ^{t}RFC time. Issue a second AUTO REFRESH command followed by NOP or DESELECT commands for at least ^{t}RFC time. Two AUTO REFRESH commands must be issued. Typically, both of these commands are issued at this stage as described above.
7. Using the LOAD MODE REGISTER command, load the standard mode register as desired.
8. Issue NOP or DESELECT commands for at least ^{t}MRD time.
9. Using the LOAD MODE REGISTER command, load the extended mode register to the desired operating modes. Note that the sequence in which the standard and extended mode registers are programmed is not critical.
10. Issue NOP or DESELECT commands for at least ^{t}MRD time.

After steps 1 through 10 are completed, the Mobile DDR SDRAM has been properly initialized and is ready to receive any valid command.

Figure 16: Initialize and Load Mode Registers



Notes:
1. PRE = PRECHARGE command; LMR = LOAD MODE REGISTER command; AR = AUTO REFRESH command; ACT = ACTIVE command
2. NOP or DESELECT commands are required for at least 200µs.
3. Other valid commands are possible.
4. NOPs or DESELECTs are required during this time.

Register Definition

Mode Registers

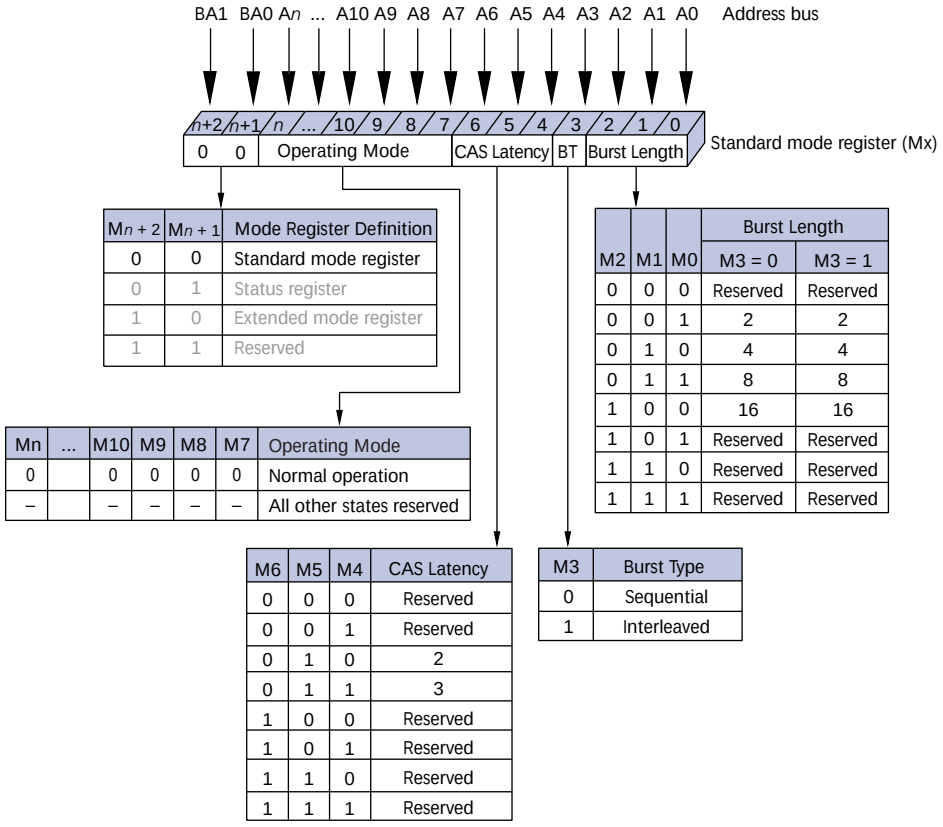
The mode registers are used to define the specific mode of operation of the Mobile DDR SDRAM. Two mode registers are used to specify the operational characteristics of the device: standard mode register and extended mode register.

Standard Mode Register

The standard mode register bit definition enables the selection of burst length, burst type, CAS latency, and operating mode, as shown in Figure 17 on page 44. Reserved states should not be used as it may result in setting the device into an unknown state or cause incompatibility with future versions of Mobile DDR SDRAMs. The standard mode register is programmed via the LOAD MODE REGISTER command (with BA0 = 0 and BA1 = 0) and will retain the stored information until it is programmed again, the device goes into deep power-down mode, or the device loses power.

Reprogramming the mode register will not alter the contents of the memory, provided it is performed correctly. The mode register must be loaded when all banks are idle and no bursts are in progress, and the controller must wait ^{t}MRD before initiating the subsequent operation. Violating any of these requirements will result in unspecified operation.

Figure 17: Standard Mode Register Definition



Mn + 2	Mn + 1	Mode Register Definition
0	0	Standard mode register
0	1	Status register
1	0	Extended mode register
1	1	Reserved

Mn	...	M10	M9	M8	M7	Operating Mode
0		0	0	0	0	Normal operation
–		–	–	–	–	All other states reserved

M2	M1	M0	Burst Length	
			M3 = 0	M3 = 1
0	0	0	Reserved	Reserved
0	0	1	2	2
0	1	0	4	4
0	1	1	8	8
1	0	0	16	16
1	0	1	Reserved	Reserved
1	1	0	Reserved	Reserved
1	1	1	Reserved	Reserved

M6	M5	M4	CAS Latency
0	0	0	Reserved
0	0	1	Reserved
0	1	0	2
0	1	1	3
1	0	0	Reserved
1	0	1	Reserved
1	1	0	Reserved
1	1	1	Reserved

M3	Burst Type
0	Sequential
1	Interleaved

Notes: 1. The integer *n* is equal to the most significant address bit.

Burst Length (BL)

Read and write accesses to the Mobile DDR SDRAM are burst oriented, with the burst length (BL) being programmable. The burst length determines the maximum number of column locations that can be accessed for a given READ or WRITE command. Burst lengths of 2, 4, 8, or 16 locations are available for both sequential and interleaved burst types.

When a READ or WRITE command is issued, a block of columns equal to the burst length is effectively selected. All accesses for that burst take place within this block, meaning that the burst will wrap when a boundary is reached. The block is uniquely selected by A1–A*i* when BL = 2, by A2–A*i* when BL = 4, by A3–A*i* when BL = 8, and by A4–Ai when BL = 16, where A*i* is the most significant column address bit for a given configuration. The remaining (least significant) address bits are used to specify the starting location within the block. The programmed burst length applies to both READ and WRITE bursts.

Burst Type

Accesses within a given burst may be programmed to be either sequential or interleaved via the standard mode register.

The ordering of accesses within a burst is determined by the burst length, the burst type, and the starting column address. See Table 21 on page 46 for details.

Table 21: Burst Definition Table

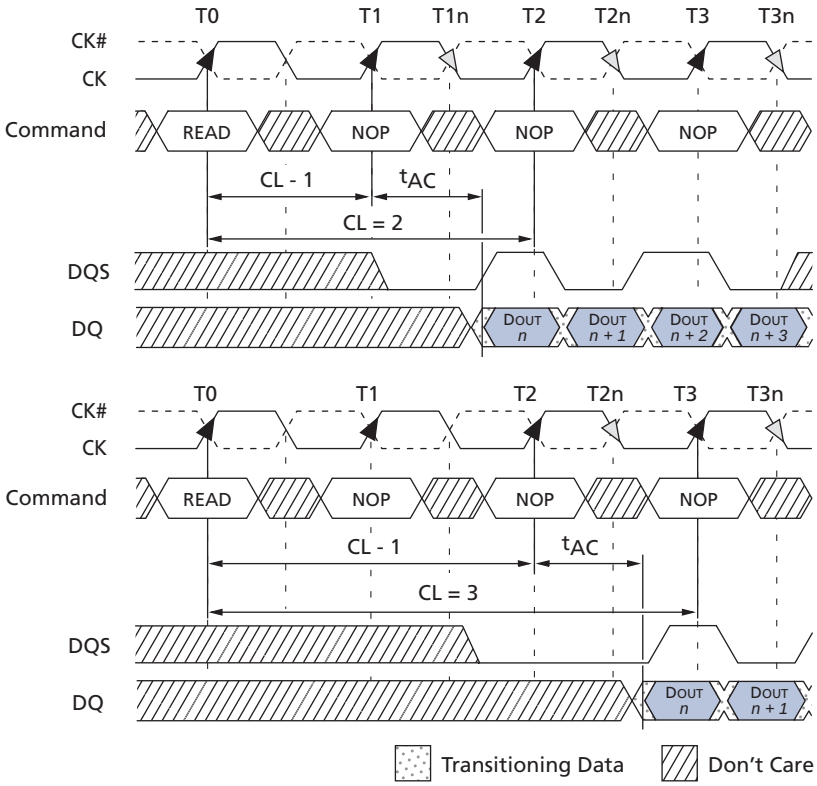
Burst Length	Starting Column Address				Order of Accesses Within a Burst	
					Type = Sequential	Type = Interleaved
2				**A0**		
				0	0-1	0-1
				1	1-0	1-0
4			**A1**	**A0**		
			0	0	0-1-2-3	0-1-2-3
			0	1	1-2-3-0	1-0-3-2
			1	0	2-3-0-1	2-3-0-1
			1	1	3-0-1-2	3-2-1-0
8		**A2**	**A1**	**A0**		
		0	0	0	0-1-2-3-4-5-6-7	0-1-2-3-4-5-6-7
		0	0	1	1-2-3-4-5-6-7-0	1-0-3-2-5-4-7-6
		0	1	0	2-3-4-5-6-7-0-1	2-3-0-1-6-7-4-5
		0	1	1	3-4-5-6-7-0-1-2	3-2-1-0-7-6-5-4
		1	0	0	4-5-6-7-0-1-2-3	4-5-6-7-0-1-2-3
		1	0	1	5-6-7-0-1-2-3-4	5-4-7-6-1-0-3-2
		1	1	0	6-7-0-1-2-3-4-5	6-7-4-5-2-3-0-1
		1	1	1	7-0-1-2-3-4-5-6	7-6-5-4-3-2-1-0
16	**A3**	**A2**	**A1**	**A0**		
	0	0	0	0	0-1-2-3-4-5-6-7-8-9-A-B-C-D-E-F	0-1-2-3-4-5-6-7-8-9-A-B-C-D-E-F
	0	0	0	1	1-2-3-4-5-6-7-8-9-A-B-C-D-E-F-0	1-0-3-2-5-4-7-6-9-8-B-A-D-C-F-E
	0	0	1	0	2-3-4-5-6-7-8-9-A-B-C-D-E-F-0-1	2-3-0-1-6-7-4-5-A-B-8-9-E-F-C-D
	0	0	1	1	3-4-5-6-7-8-9-A-B-C-D-E-F-0-1-2	3-2-1-0-7-6-5-4-B-A-9-8-F-E-D-C
	0	1	0	0	4-5-6-7-8-9-A-B-C-D-E-F-0-1-2-3	4-5-6-7-0-1-2-3-C-D-E-F-8-9-A-B
	0	1	0	1	5-6-7-8-9-A-B-C-D-E-F-0-1-2-3-4	5-4-7-6-1-0-3-2-D-C-F-E-9-8-B-A
	0	1	1	0	6-7-8-9-A-B-C-D-E-F-0-1-2-3-4-5	6-7-4-5-2-3-0-1-E-F-C-D-A-B-8-9
	0	1	1	1	7-8-9-A-B-C-D-E-F-0-1-2-3-4-5-6	7-6-5-4-3-2-1-0-F-E-D-C-B-A-9-8
	1	0	0	0	8-9-A-B-C-D-E-F-0-1-2-3-4-5-6-7	8-9-A-B-C-D-E-F-0-1-2-3-4-5-6-7
	1	0	0	1	9-A-B-C-D-E-F-0-1-2-3-4-5-6-7-8	9-8-B-A-D-C-F-E-1-0-3-2-5-4-7-6
	1	0	1	0	A-B-C-D-E-F-0-1-2-3-4-5-6-7-8-9	A-B-8-9-E-F-C-D-2-3-0-1-6-7-4-5
	1	0	1	1	B-C-D-E-F-0-1-2-3-4-5-6-7-8-9-A	B-A-9-8-F-E-D-C-3-2-1-0-7-6-5-4
	1	1	0	0	C-D-E-F-0-1-2-3-4-5-6-7-8-9-A-B	C-D-E-F-8-9-A-B-4-5-6-7-0-1-2-3
	1	1	0	1	D-E-F-0-1-2-3-4-5-6-7-8-9-A-B-C	D-C-F-E-9-8-B-A-5-4-7-6-1-0-3-2
	1	1	1	0	E-F-0-1-2-3-4-5-6-7-8-9-A-B-C-D	E-F-C-D-A-B-8-9-6-7-4-5-2-3-0-1
	1	1	1	1	F-0-1-2-3-4-5-6-7-8-9-A-B-C-D-E	F-E-D-C-B-A-9-8-7-6-5-4-3-2-1-0

CAS Latency (CL)

The CAS latency is the delay, in clock cycles, between the registration of a READ command and the availability of the first output data. The latency can be set to 2 or 3 clocks, as shown in Figure 18 on page 47.

For CL = 3, if the READ command is registered at clock edge *n*, then the data will nominally be available at (*n* + 2 clocks + ^{t}AC). For CL = 2, if the READ command is registered at clock edge *n*, then the data will be nominally be available at (*n* + 1 clock + ^{t}AC).

Figure 18: CAS Latency



Operating Mode

The normal operating mode is selected by issuing a LOAD MODE REGISTER command with bits A7–A*n* each set to zero, and bits A0–A6 set to the desired values.

All other combinations of values for A7–A*n* are reserved for future use. Reserved states should not be used because unknown operation or incompatibility with future versions may result.

Extended Mode Register

The extended mode register controls additional functions beyond those set by the mode registers. These additional functions include drive strength, TCSR, and PASR.

The extended mode register is programmed via the LOAD MODE REGISTER command with BA0 = 0 and BA1 = 1. Information in the extended mode register will be retained until it is programmed again, the device goes into deep power-down mode, or the device loses power.

Temperature-Compensated Self Refresh (TCSR)

On this version of the Mobile DDR SDRAM, a temperature sensor is implemented for automatic control of the self refresh oscillator. Programming of the TCSR bits will have no effect on the device. The self refresh oscillator will continue to refresh at the factory programmed optimal rate for the device temperature.

Partial-Array Self Refresh (PASR)

For further power savings during self refresh, the PASR feature allows the controller to select the amount of memory that will be refreshed during self refresh. The refresh options are:

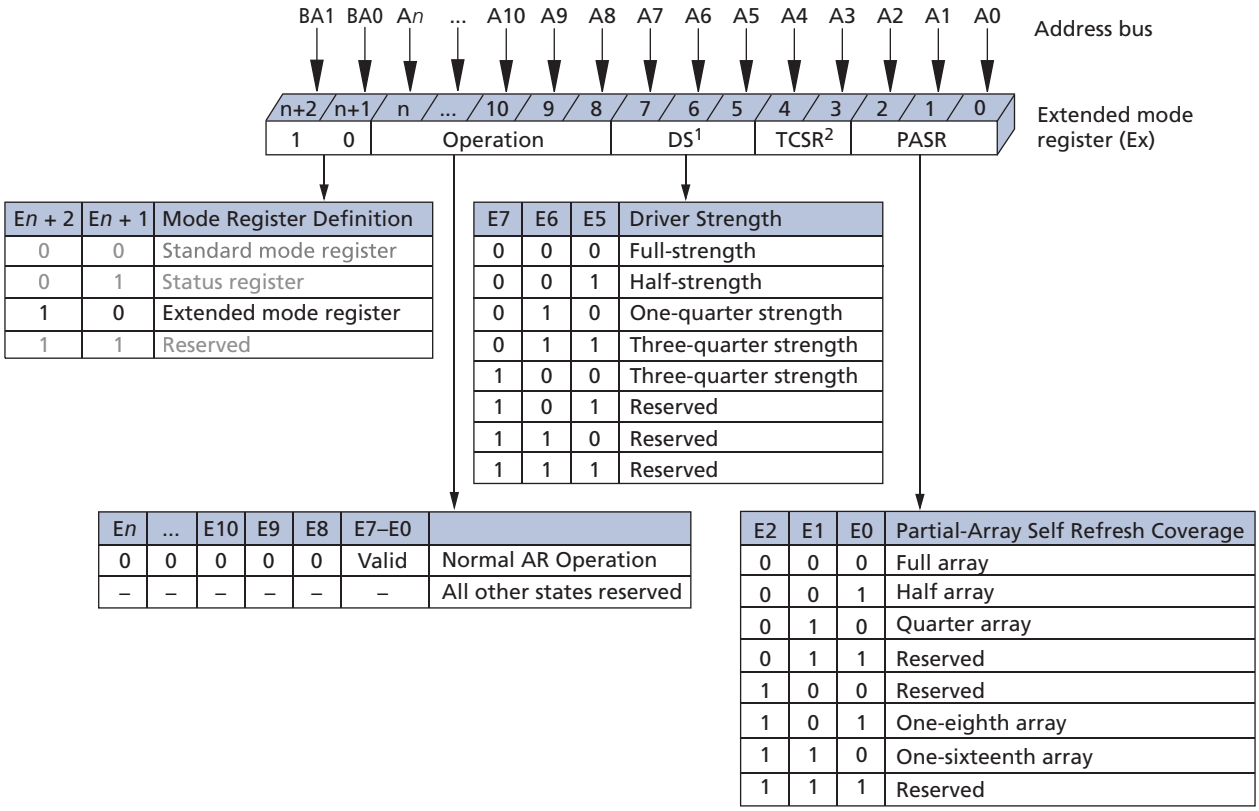
- Full array: banks 0, 1, 2, and 3
- Half array: banks 0 and 1
- Quarter array: bank 0
- Eighth array: bank 0 with row address most significant bit (MSB) = 0
- Sixteenth array: bank 0 with row address MSB = 0 and row address MSB - 1 = 0

WRITE and READ commands can still occur during standard operation, but only the selected regions of the array will be refreshed during self refresh. Data in regions that are not selected will be lost.

Output Drive Strength

Because the Mobile DDR SDRAM is designed for use in smaller systems that are typically point-to-point connections, an option to control the drive strength of the output buffers is provided. Drive strength should be selected based on the expected loading of the memory bus. There are four allowable settings for the output drivers: 25Ω, 37Ω, 55Ω, and 80Ω internal impedance. These are full, three-quarter, one-half, and one-quarter drive strengths, respectively.

Figure 19: Extended Mode Register



En + 2	En + 1	Mode Register Definition
0	0	Standard mode register
0	1	Status register
1	0	Extended mode register
1	1	Reserved

E7	E6	E5	Driver Strength
0	0	0	Full-strength
0	0	1	Half-strength
0	1	0	One-quarter strength
0	1	1	Three-quarter strength
1	0	0	Three-quarter strength
1	0	1	Reserved
1	1	0	Reserved
1	1	1	Reserved

En	...	E10	E9	E8	E7–E0	
0	0	0	0	0	Valid	Normal AR Operation
–	–	–	–	–	–	All other states reserved

E2	E1	E0	Partial-Array Self Refresh Coverage
0	0	0	Full array
0	0	1	Half array
0	1	0	Quarter array
0	1	1	Reserved
1	0	0	Reserved
1	0	1	One-eighth array
1	1	0	One-sixteenth array
1	1	1	Reserved

Notes:
1. For 1.2V I/O, only three-quarter drive strength is supported, all others are optional.
2. On-die temperature sensor is used in place of TCSR. Setting these bits will have no effect.
3. The integer *n* is equal to the most significant address bit.

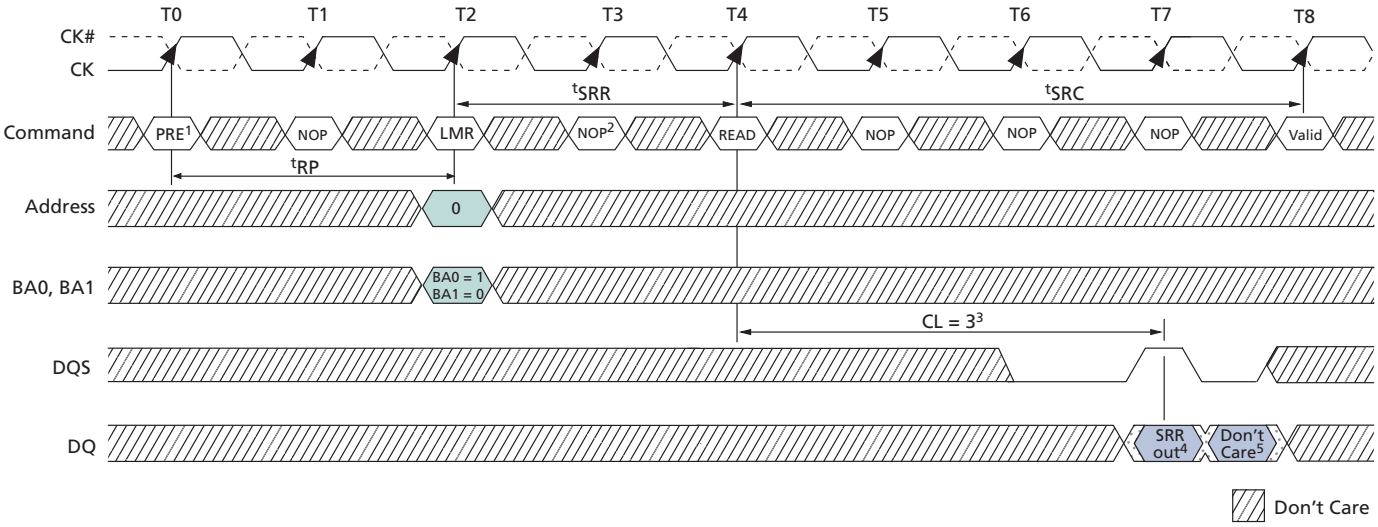
Status Read Register (SRR)

The status read register (SRR) is used to read the manufacturer ID, revision ID, refresh multiplier, width type, and density of the Mobile SDRAM as shown in Figure 21 on page 51. The SRR is read via the LOAD MODE REGISTER command with BA0 = 1 and BA1 = 0. The sequence to perform an SRR command is as follows:

1. The SDRAM must be properly initialized and in the idle or all banks precharged state.
2. Issue a LOAD MODE REGISTER command with BA[1:0] = "01."
3. Wait ^{t}SRR; only NOP or DESELECT commands are allowed during the ^{t}SRR time.
4. Issue a READ command with all address pins set to "0."
5. Subsequent commands to the SDRAM must be issued ^{t}SRC after the SRR READ command is issued; only NOPs or DESELECTS are supported during ^{t}SRC (Figure 20 on page 50).

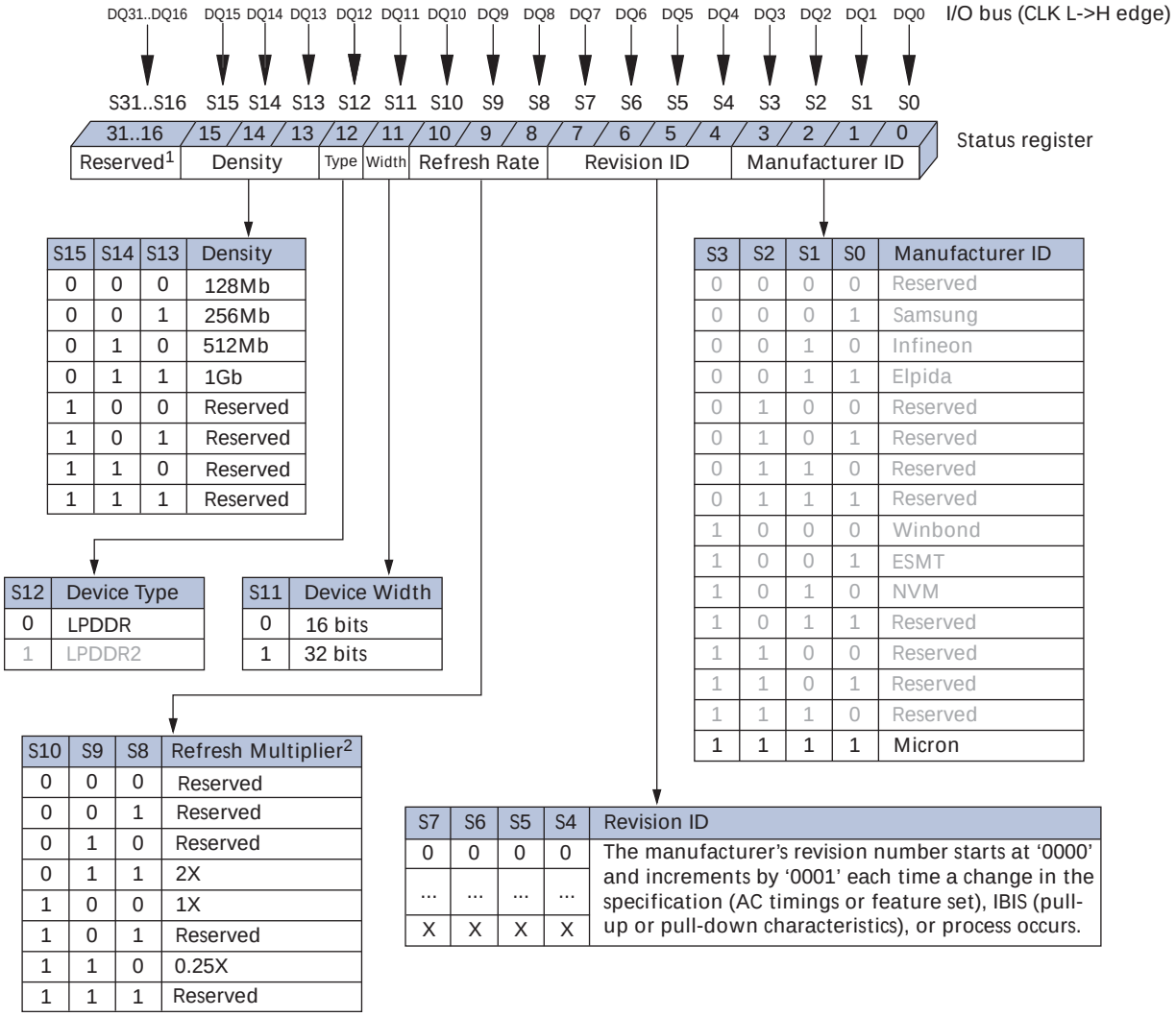
SRR output is read with a burst length of 2. SRR data is driven to the outputs on the first bit of the burst, with the output being "Don't Care" on the second bit of the burst.

Figure 20: SRR Timing



Notes:
1. All banks must be idle prior to status register read.
2. NOP or DESELECT commands are required between LMR and READ command (^{t}SRR) and between READ and next VALID command (^{t}SRC).
3. CAS latency is pre-determined by the programming of the mode register. CL = 3 is shown as an example only.
4. Burst length is fixed to 2 for SRR regardless of the value programmed by the mode register.
5. The second bit of the data-out burst is a "Don't Care."

Figure 21: Status Register Definition



S15	S14	S13	Density
0	0	0	128Mb
0	0	1	256Mb
0	1	0	512Mb
0	1	1	1Gb
1	0	0	Reserved
1	0	1	Reserved
1	1	0	Reserved
1	1	1	Reserved

S12	Device Type
0	LPDDR
1	LPDDR2

S11	Device Width
0	16 bits
1	32 bits

S10	S9	S8	Refresh Multiplier[2]
0	0	0	Reserved
0	0	1	Reserved
0	1	0	Reserved
0	1	1	2X
1	0	0	1X
1	0	1	Reserved
1	1	0	0.25X
1	1	1	Reserved

S3	S2	S1	S0	Manufacturer ID
0	0	0	0	Reserved
0	0	0	1	Samsung
0	0	1	0	Infineon
0	0	1	1	Elpida
0	1	0	0	Reserved
0	1	0	1	Reserved
0	1	1	0	Reserved
0	1	1	1	Reserved
1	0	0	0	Winbond
1	0	0	1	ESMT
1	0	1	0	NVM
1	0	1	1	Reserved
1	1	0	0	Reserved
1	1	0	1	Reserved
1	1	1	0	Reserved
1	1	1	1	Micron

S7	S6	S5	S4	Revision ID
0	0	0	0	The manufacturer's revision number starts at '0000' and increments by '0001' each time a change in the specification (AC timings or feature set), IBIS (pull-up or pull-down characteristics), or process occurs.
...	...	...	...	
X	X	X	X	

Notes:
1. Reserved bits should be set to zero (0) for future compatibility.
2. Refresh multiplier is based on the memory device's on-board temperature sensor. Required average periodic refresh interval = ^{t}REFI × multiplier.

Bank/Row Activation

Before any READ or WRITE commands can be issued to a bank within the Mobile DDR SDRAM, a row in that bank must be "opened." This is accomplished via the ACTIVE command, which selects both the bank and the row to be activated, as shown in Figure 10. After a row is opened with an ACTIVE command, a READ or WRITE command may be issued to that row, subject to the ^{t}RCD specification.

A subsequent ACTIVE command to a different row in the same bank can only be issued after the previous active row has been "closed" (precharged). The minimum time interval between successive ACTIVE commands to the same bank is defined by ^{t}RC.

A subsequent ACTIVE command to another bank can be issued while the first bank is being accessed, which results in a reduction of total row-access overhead. The minimum time interval between successive ACTIVE commands to different banks is defined by ^{t}RRD.

READs

READ burst operations are initiated with a READ command, as shown in Figure 11 on page 33. The starting column and bank addresses are provided with the READ command, and auto precharge is either enabled or disabled for that burst access. If auto precharge is enabled, the row being accessed is precharged at the completion of the burst. For the READ commands used in the following illustrations, auto precharge is disabled.

During READ bursts, the valid data-out element from the starting column address will be available following the CAS latency after the READ command. Each subsequent data-out element will be valid nominally at the next positive or negative clock edge. Figure 22 on page 53 shows general timing for each possible CAS latency setting. DQS is driven by the Mobile DDR SDRAM along with output data. The initial LOW state on DQS is known as the read preamble; the LOW state coincident with the last data-out element is known as the read postamble. The READ burst is considered complete when the read post-amble is satisfied.

Upon completion of a burst, assuming no other commands have been initiated, the DQs will go High-Z. A detailed explanation of ^{t}DQSQ (valid data-out skew), ^{t}QH (data-out window hold), and the valid data window is depicted in Figure 29 on page 60 and Figure 30 on page 61. A detailed explanation of ^{t}DQSCK (DQS transition skew to CK) and ^{t}AC (data-out transition skew to CK) is depicted in Figure 31 on page 62.

Data from any READ burst may be truncated by a READ or WRITE command to the same or alternate bank, by a BURST TERMINATE command, or by a PRECHARGE command to the same bank, provided that the auto precharge mode was not activated.

Data from any READ burst may be concatenated with or truncated with data from a subsequent READ command. In either case, a continuous flow of data can be maintained. The first data element from the new burst either follows the last element of a completed burst or the last desired data element of a longer burst which is being truncated. The new READ command should be issued *x* cycles after the first READ command, where *x* equals the number of desired data element pairs (pairs are required by the 2*n*-prefetch architecture). This is shown in Figure 23 on page 54.

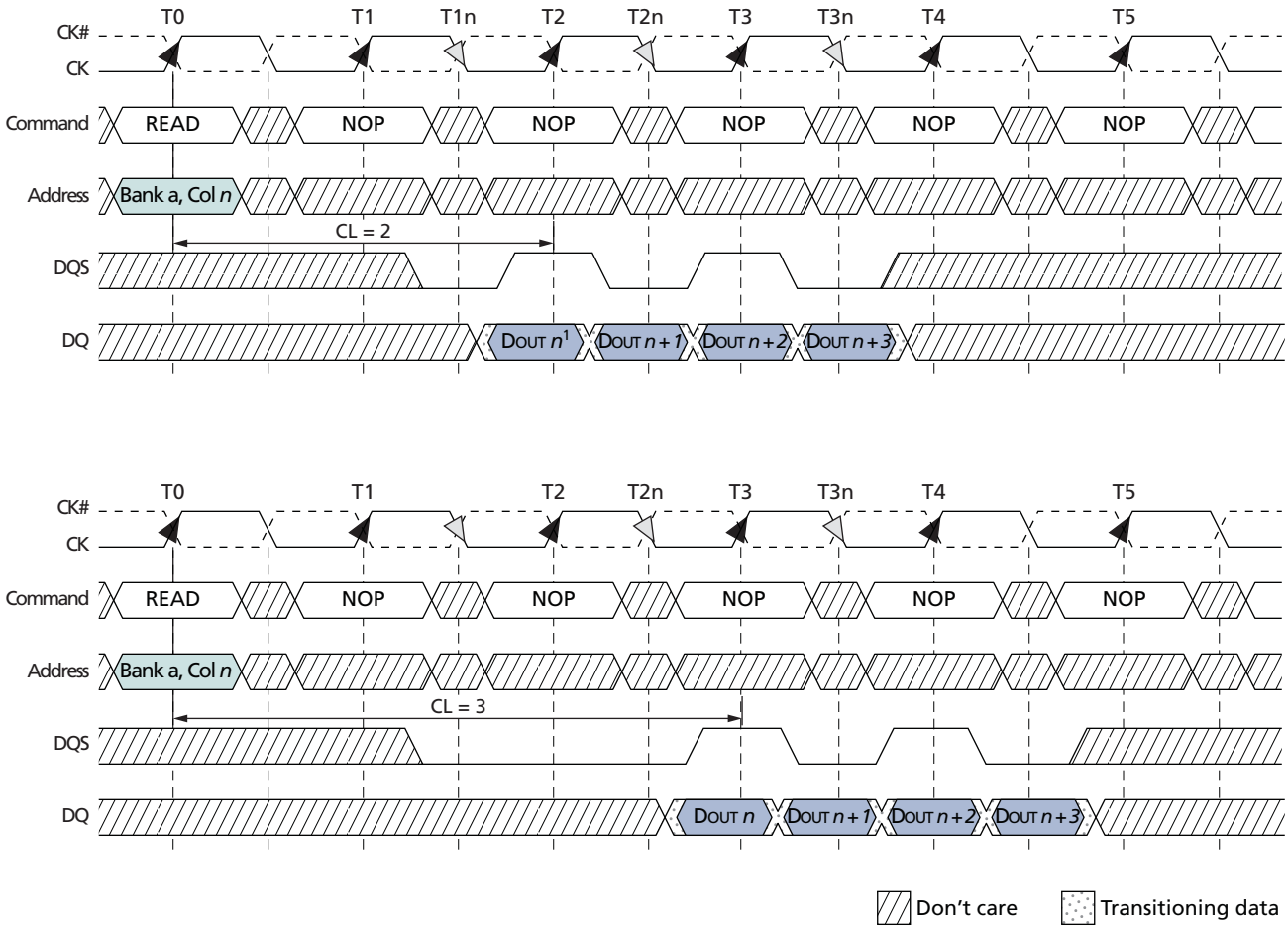
A READ command can be initiated on any clock cycle following a previous READ command. Nonconsecutive read data is shown in Figure 24 on page 55. Full-speed random read accesses within a page (or pages) can be performed as shown in Figure 25 on page 56.

Data from any READ burst may be truncated with a BURST TERMINATE command, as shown in Figure 26 on page 57. The BURST TERMINATE latency is equal to the READ (CAS) latency; for example, the BURST TERMINATE command should be issued *x* cycles after the READ command, where *x* equals the number of desired data element pairs (pairs are required by the 2*n*-prefetch architecture).

Data from any READ burst must be completed or truncated before a subsequent WRITE command can be issued. If truncation is necessary, the BURST TERMINATE command must be used, as shown in Figure 27 on page 58. A READ burst may be followed by, or truncated with, a PRECHARGE command to the same bank provided that auto precharge was not activated. The PRECHARGE command should be issued *x* cycles after

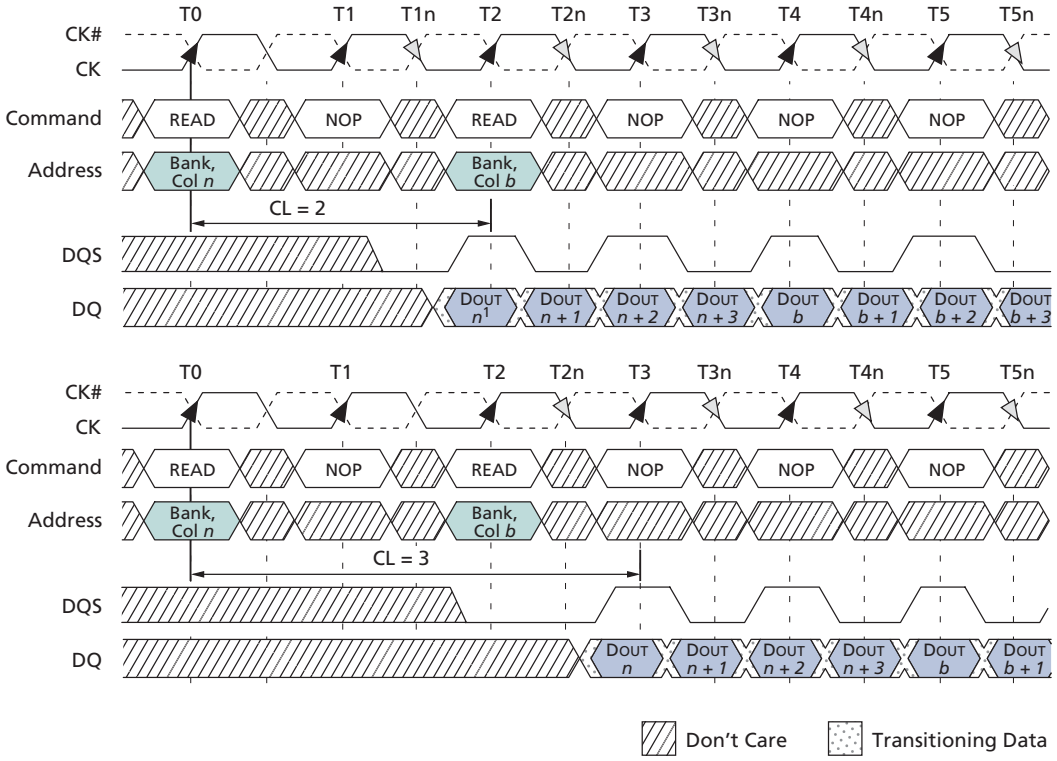
the READ command, where *x* equals the number of desired data element pairs. This is shown in Figure 28 on page 59. Following the PRECHARGE command, a subsequent command to the same bank cannot be issued until ^{t}RP is met. Part of the row precharge time is hidden during the access of the last data elements.

Figure 22: READ Burst



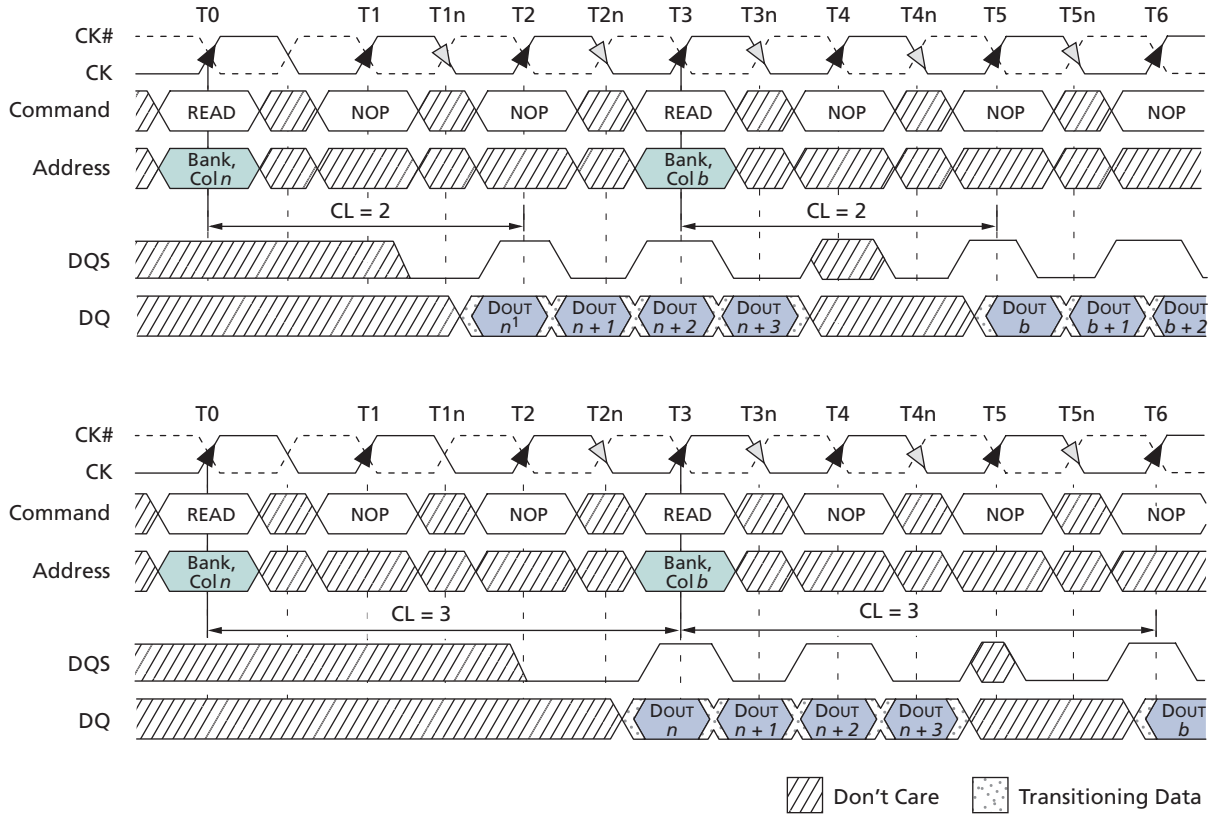
Notes:
1. DOUT *n* = data-out from column *n*.
2. BL = 4.
3. Shown with nominal ^{t}AC, ^{t}DQSCK, and ^{t}DQSQ.

Figure 23: Consecutive READ Bursts



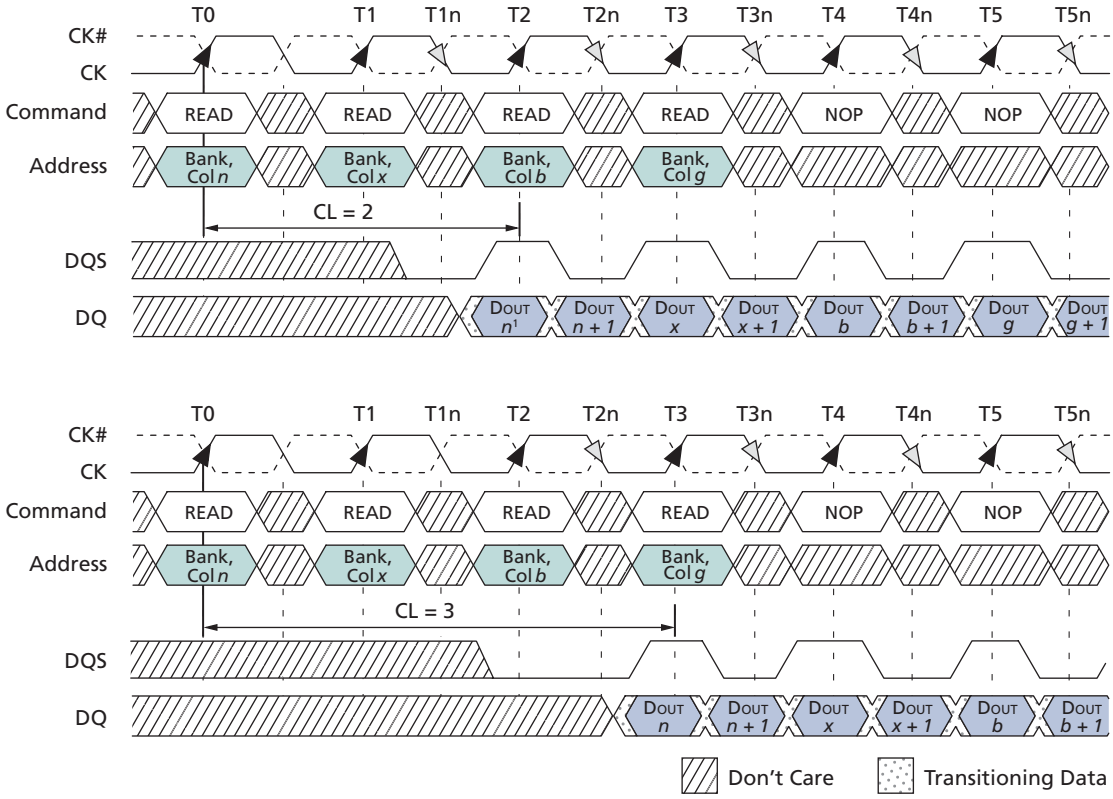
Notes:
1. DOUT *n* (or *b*) = data-out from column *n* (or column *b*).
2. BL = 4, 8, or 16 (if 4, the bursts are concatenated; if 8 or 16, the second burst interrupts the first).
3. Shown with nominal ^{t}AC, ^{t}DQSCK, and ^{t}DQSQ.
4. Example applies only when READ commands are issued to same device.

Figure 24: Nonconsecutive READ Bursts



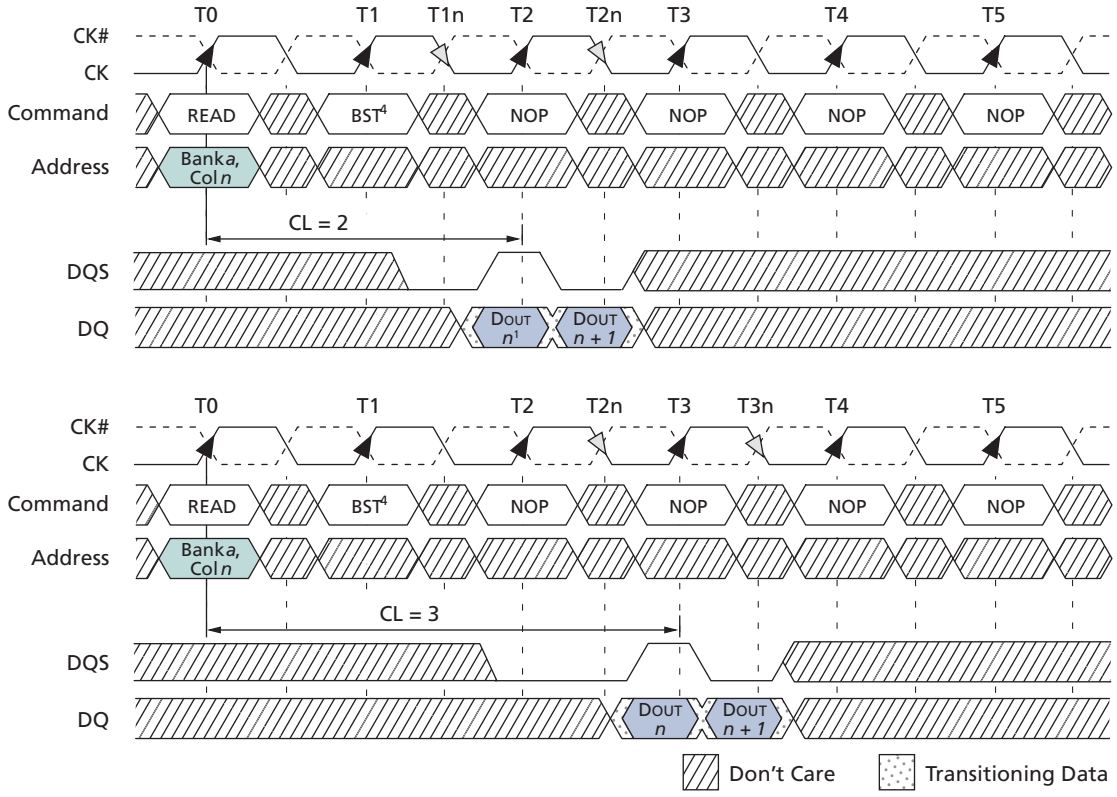
Notes:
1. DOUT *n* (or *b*) = data-out from column *n* (or column *b*).
2. BL = 4, 8, or 16 (if burst is 8 or 16, the second burst interrupts the first).
3. Shown with nominal ^{t}AC, ^{t}DQSCK, and ^{t}DQSQ.
4. Example applies when READ commands are issued to different devices or nonconsecutive READs.

Figure 25: Random READ Accesses



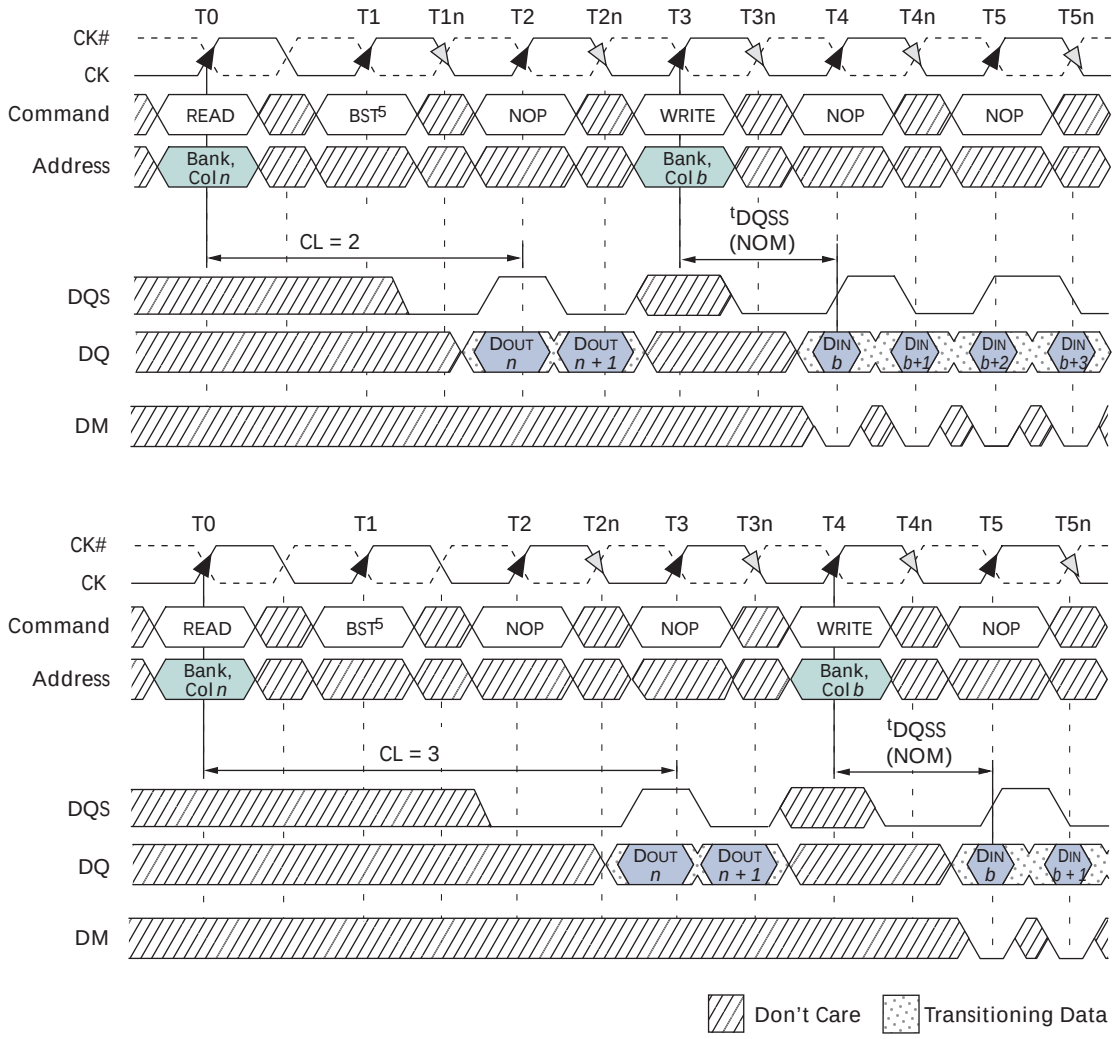
Notes:
1. DOUT *n* (or *x*, *b*, *g*) = data-out from column *n* (or column *x*, column *b*, column *g*).
2. BL = 2, 4, 8, or 16 (if 4, 8, or 16, the following burst interrupts the previous).
3. READs are to an active row in any bank.
4. Shown with nominal ^{t}AC, ^{t}DQSCK, and ^{t}DQSQ.

Figure 26: Terminating a READ Burst



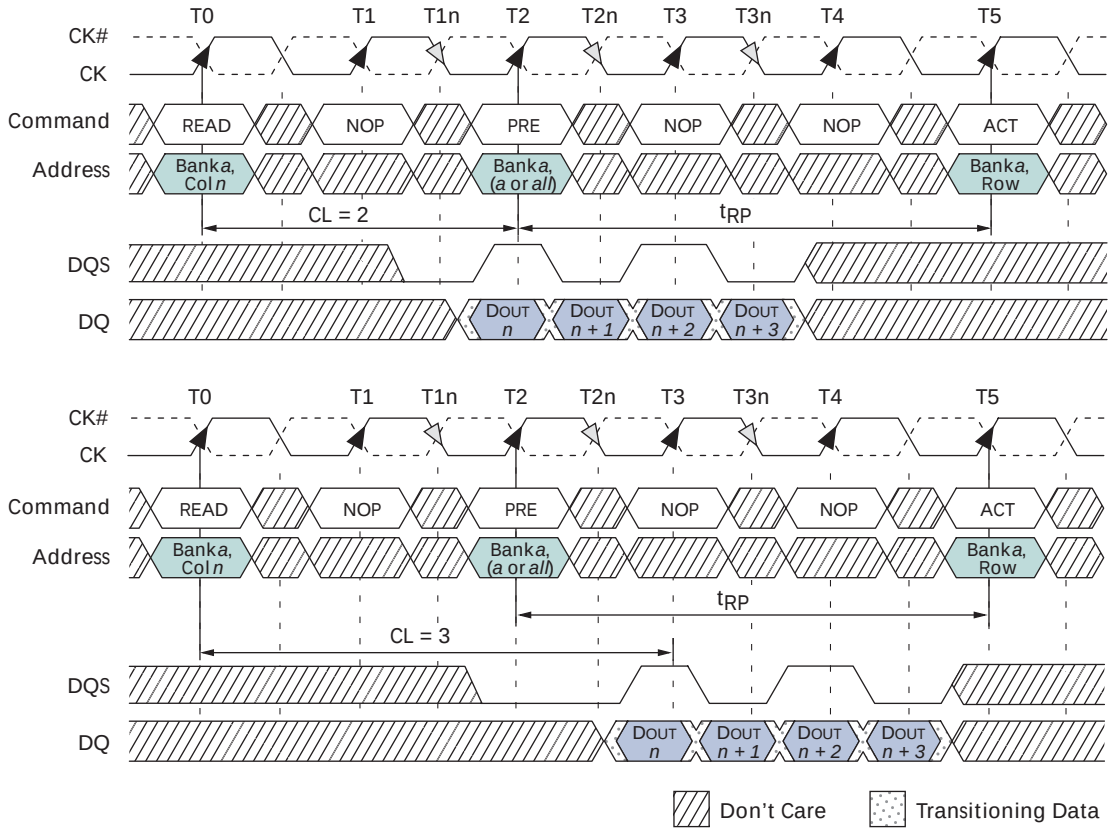
Notes:
1. Dout *n* = data-out from column *n*.
2. BL = 4, 8, or 16.
3. Shown with nominal ^{t}AC, ^{t}DQSCK, and ^{t}DQSQ.
4. BST = BURST TERMINATE command; page remains open.
5. CKE = HIGH.

Figure 27: READ-to-WRITE



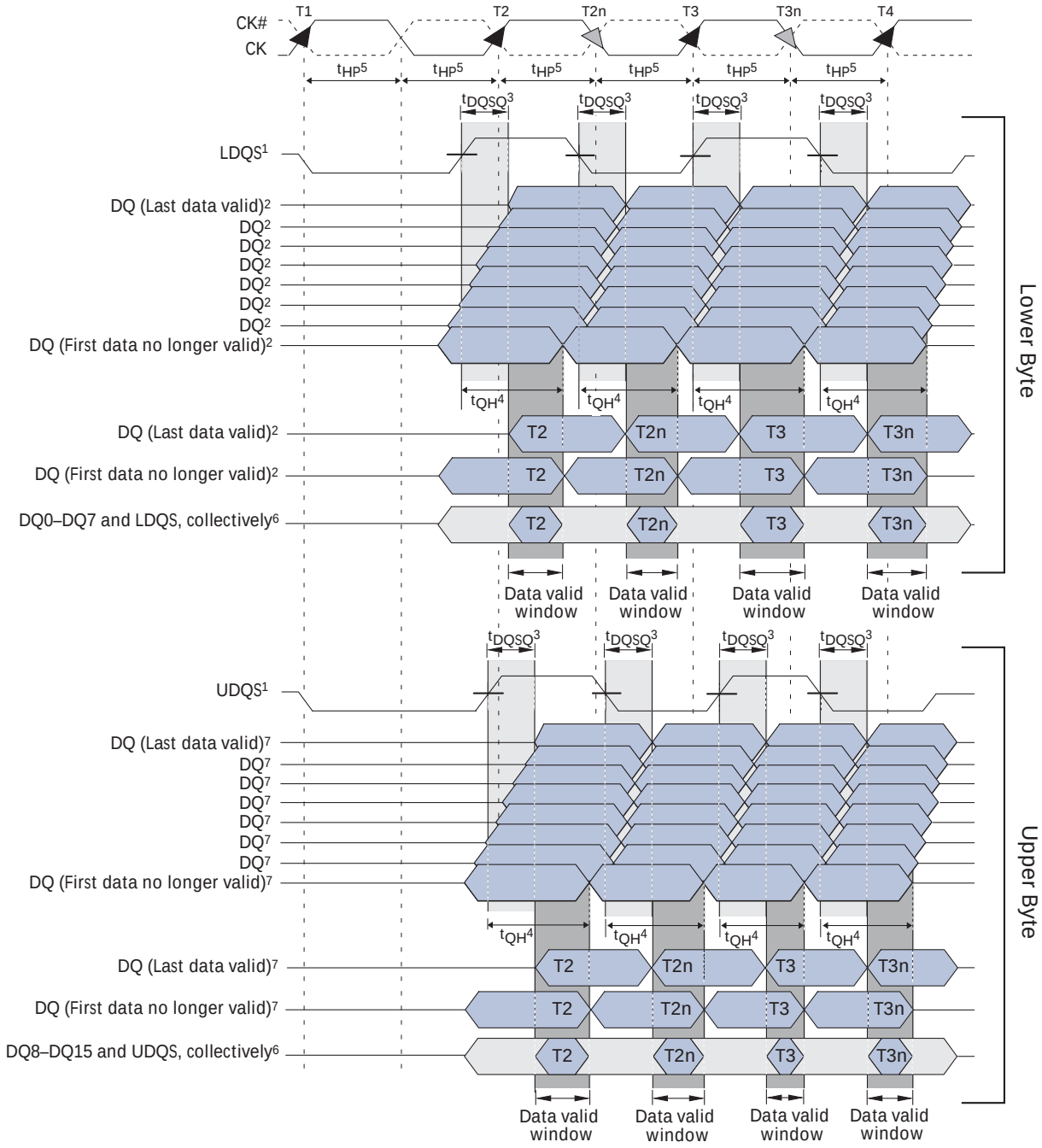
Notes:
1. DOUT *n* = data-out from column *n*.
2. DIN *b* = data-in from column *b*.
3. BL = 4 in the cases shown (applies for bursts of 8 and 16as well; if BL = 2, the BST command shown can be a NOP).
4. Shown with nominal ^{t}AC, ^{t}DQSCK, and ^{t}DQSQ.
5. BST = BURST TERMINATE command; page remains open.
6. CKE = HIGH.

Figure 28: READ-to-PRECHARGE



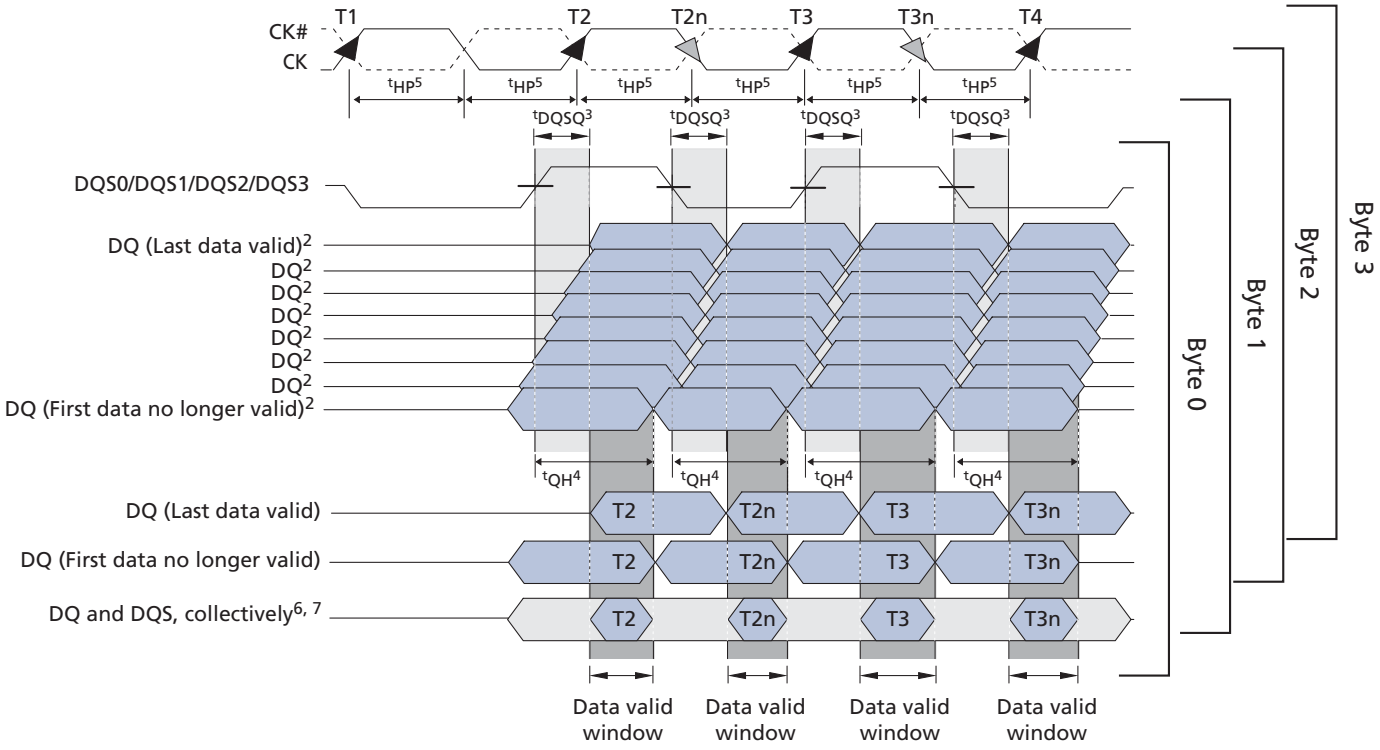
Notes:
1. DOUT *n* = data-out from column *n*.
2. BL = 4, or an interrupted burst of 8 or 16.
3. Shown with nominal ^{t}AC, ^{t}DQSCK, and ^{t}DQSQ.
4. READ-to-PRECHARGE equals 2 clocks, which allows 2 data pairs of data-out.
5. A READ command with auto precharge enabled, provided ^{t}RAS (MIN) is met, would cause a precharge to be performed at *x* number of clock cycles after the READ command, where *x* = BL/2.
6. PRE = PRECHARGE command; ACT = ACTIVE command.

Figure 29: Data Output Timing – ^{t}DQSQ, ^{t}QH, and Data Valid Window (x16)



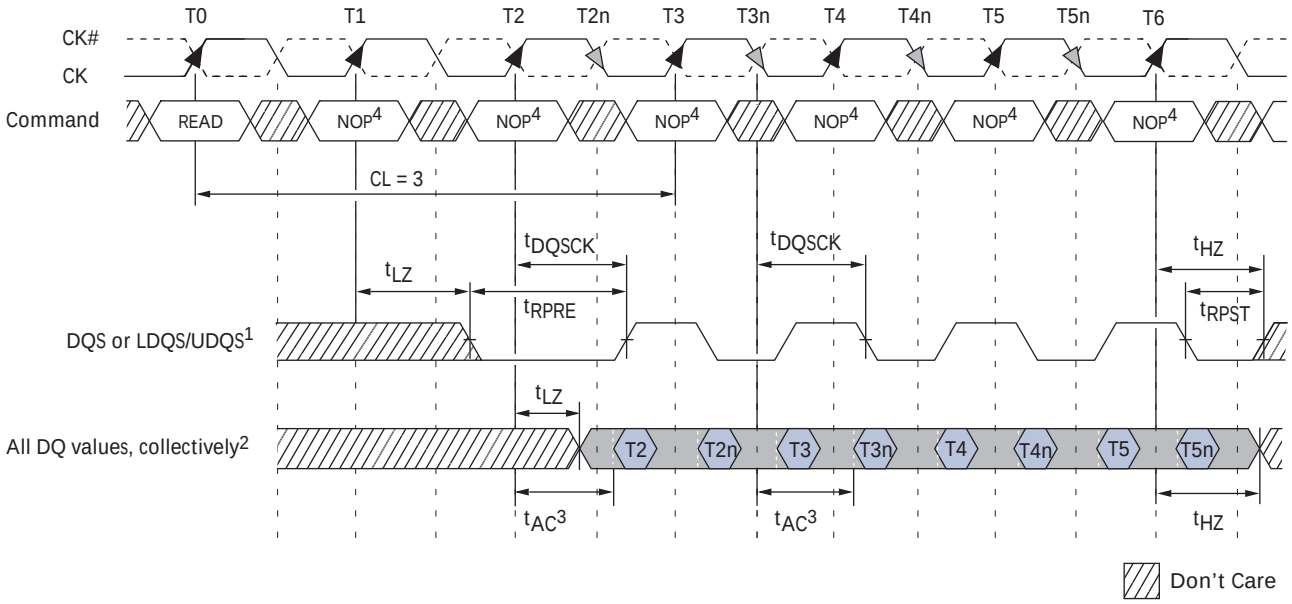
Notes:
1. DQ transitioning after DQS transitions define the ^{t}DQSQ window. LDQS defines the lower byte and UDQS defines the upper byte.
2. DQ0, DQ1, DQ2, DQ3, DQ4, DQ5, DQ6, or DQ7.
3. ^{t}DQSQ is derived at each DQS clock edge and is not cumulative over time and begins with DQS transition and ends with the last valid DQ transition.
4. ^{t}QH is derived from ^{t}HP: ^{t}QH = ^{t}HP - ^{t}QHS.
5. ^{t}HP is the lesser of ^{t}CL or ^{t}CH clock transition collectively when a bank is active.
6. The data valid window is derived for each DQS transitions and is defined as ^{t}QH - ^{t}DQSQ.
7. DQ8, DQ9, DQ10, DQ11, DQ12, DQ13, DQ14, or DQ15.

Figure 30: Data Output Timing – ^{t}DQSQ, ^{t}QH, and Data Valid Window (x32)



Notes:
1. DQ transitioning after DQS transitions define the ^{t}DQSQ window.
2. Byte 0 is DQ0...7, byte 1 is DQ8...15, byte 2 is DQ16...23, byte 3 is DQ24...31.
3. ^{t}DQSQ is derived at each DQS clock edge and is not cumulative over time and begins with DQS transition and ends with the last valid DQ transition.
4. ^{t}QH is derived from ^{t}HP: ^{t}QH = ^{t}HP - ^{t}QHS.
5. ^{t}HP is the lesser of ^{t}CL or ^{t}CH clock transition collectively when a bank is active.
6. The data valid window is derived for each DQS transition and is ^{t}QH - ^{t}DQSQ.
7. DQ0–7 and DQS0 for byte 0; DQ8–15 and DQS1 for byte 1; DQ16–23 and DQS2 for byte 2; DQ23–31 and DQS3 for byte 3.

Figure 31: Data Output Timing – ^{t}AC and ^{t}DQSCK



Notes:
1. DQ transitioning after DQS transitions define ^{t}DQSQ window.
2. All DQ must transition by ^{t}DQSQ after DQS transitions, regardless of ^{t}AC.
3. ^{t}AC is the DQ output window relative to CK and is the "long-term" component of DQ skew.
4. Commands other than NOP may be valid during this cycle.

WRITEs

WRITE bursts are initiated with a WRITE command, as shown in Figure 12 on page 34. The starting column and bank addresses are provided with the WRITE command, and auto precharge is either enabled or disabled for that access. If auto precharge is enabled, the row being accessed is precharged at the completion of the burst. For the WRITE commands used in the following illustrations, auto precharge is disabled. Basic data input timing is shown in Figure 32 on page 64 (this timing applies to all WRITE operations).

Input data appearing on the data bus is written to the memory array subject to the state of data mask DM inputs coincident with the data. If DM is registered LOW, the corresponding data will be written; if DM is registered HIGH, the corresponding data will be ignored, and the write will not be executed to that byte/column location. DM operation is illustrated in Figure 33 on page 65.

During WRITE bursts, the first valid data-in element will be registered on the first rising edge of DQS following the WRITE command, and subsequent data elements will be registered on successive edges of DQS. The LOW state on DQS between the WRITE command and the first rising edge is known as the write preamble; the LOW state on DQS following the last data-in element is known as the write postamble. The write burst is complete when the write postamble and ^{t}WR or ^{t}WTR are satisfied.

The time between the WRITE command and the first corresponding rising edge of DQS (^{t}DQSS) is specified with a relatively wide range (from 75 percent to 125 percent of one clock cycle). All of the WRITE diagrams show the nominal case, and where the two extreme cases (that is, ^{t}DQSS [MIN] and ^{t}DQSS [MAX]) might not be intuitive, they have also been included. Figure 34 on page 66 shows the nominal case and the extremes of ^{t}DQSS for a burst of 4. Upon completion of a burst, assuming no other commands have been initiated, the DQs will remain High-Z and any additional input data will be ignored.

Data for any WRITE burst may be concatenated with or truncated by a subsequent WRITE command. In either case, a continuous flow of input data can be maintained. The new WRITE command can be issued on any positive edge of clock following the previous WRITE command. The first data element from the new burst is applied after either the last element of a completed burst or the last desired data element of a longer burst that is being truncated. The new WRITE command should be issued *x* cycles after the first WRITE command, where *x* equals the number of desired data element pairs (pairs are required by the 2*n*-prefetch architecture).

Figure 35 on page 66 shows concatenated bursts of 4. An example of nonconsecutive WRITEs is shown in Figure 36 on page 67. Full-speed random write accesses within a page or pages can be performed, as shown in Figure 37 on page 67.

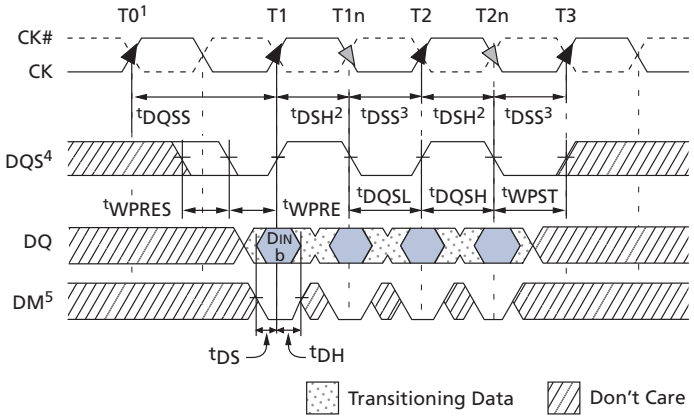
Data for any WRITE burst may be followed by a subsequent READ command. To follow a WRITE without truncating the WRITE burst, ^{t}WTR should be met, as shown in Figure 38 on page 68.

Data for any WRITE burst may be truncated by a subsequent READ command, as shown in Figure 39 on page 69. Note that only the data-in pairs that are registered prior to the ^{t}WTR period are written to the internal array, and any subsequent data-in should be masked with DM, as shown in Figure 40 on page 70.

Data for any WRITE burst may be followed by a subsequent PRECHARGE command. To follow a WRITE without truncating the WRITE burst, ^{t}WR should be met, as shown in Figure 41 on page 71.

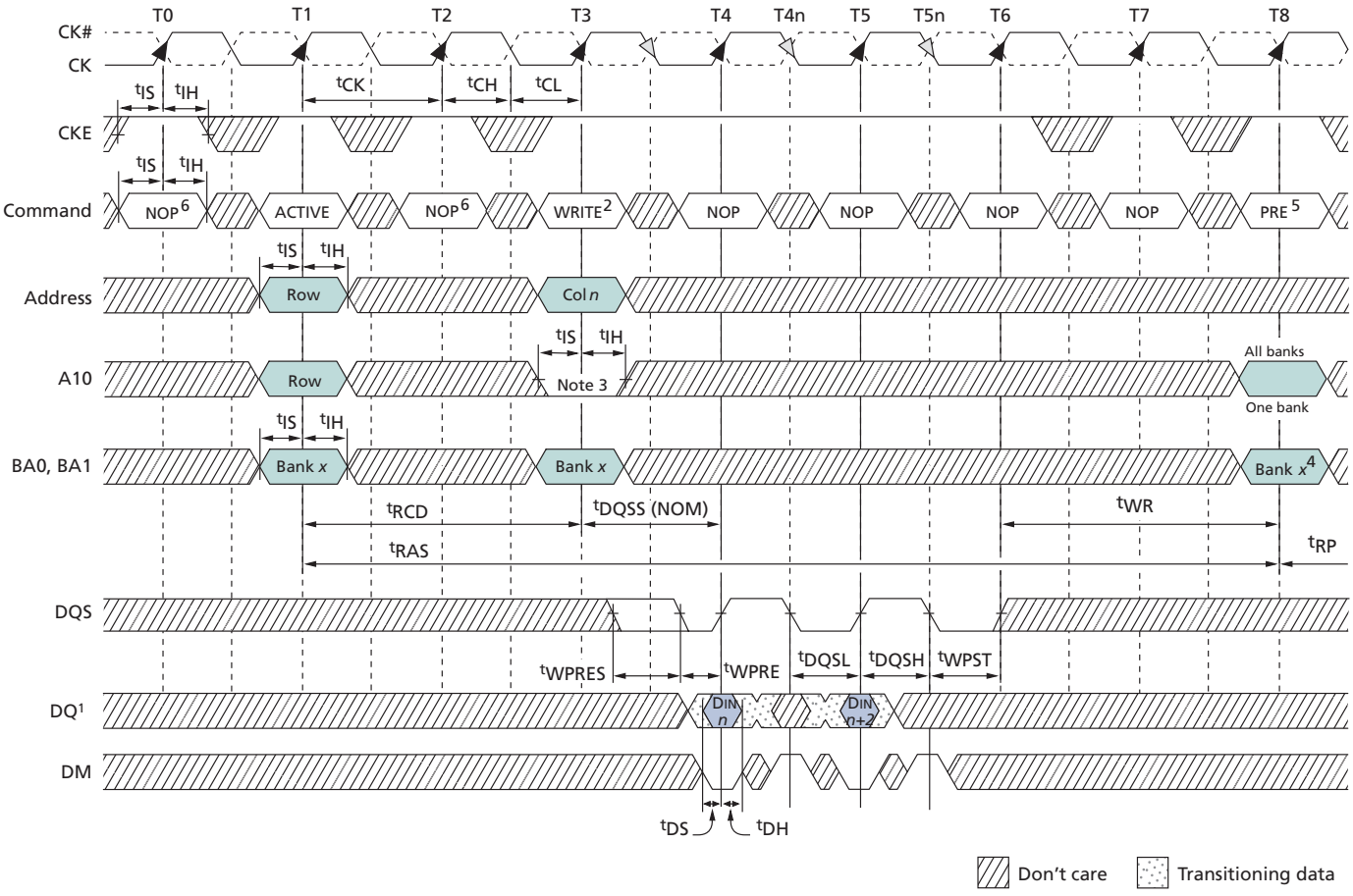
Data for any WRITE burst may be truncated by a subsequent PRECHARGE command, as shown in Figure 42 on page 72 and Figure 43 on page 73. Note that only the data-in pairs that are registered prior to the tWR period are written to the internal array, and any subsequent data-in should be masked with DM, as shown in Figure 42 and Figure 43. After the PRECHARGE command, a subsequent command to the same bank cannot be issued until tRP is met.

Figure 32: Data Input Timing



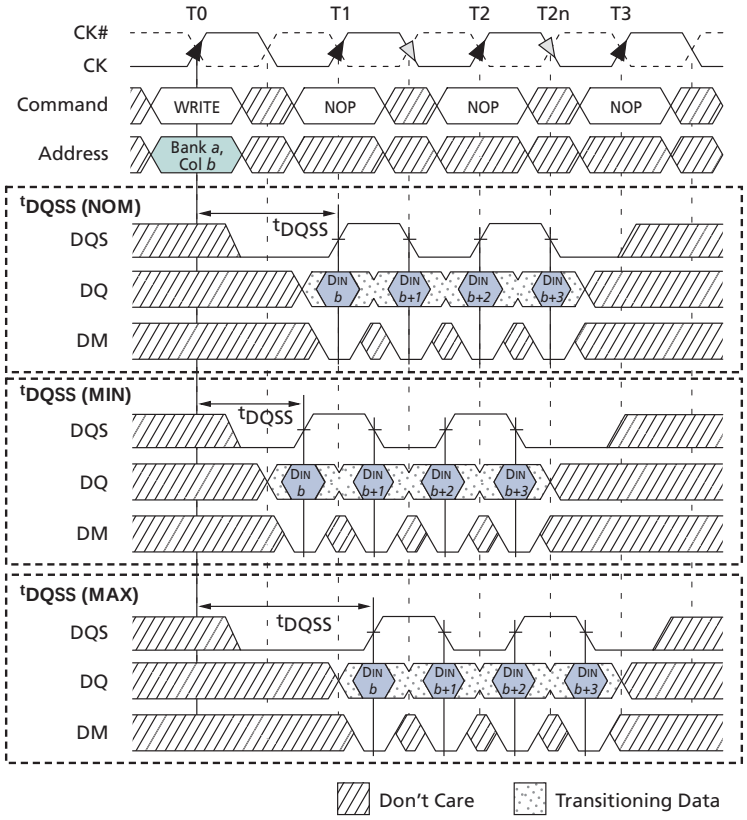
Notes:
1. WRITE command issued at T0.
2. tDSH (MIN) generally occurs during tDQSS (MIN).
3. tDSS (MIN) generally occurs during tDQSS (MAX).
4. For x16, LDQS controls the lower byte; UDQS controls the upper byte. For x32, DQS0 controls DQ[7:0], DQS1 controls DQ[15:8], DQS2 controls DQ[23:16], and DQS3 controls DQ[31:24].
5. For x16, LDM controls the lower byte; UDM controls the upper byte. For x32, DM0 controls DQ[7:0], DM1 controls DQ[15:8], DM2 controls DQ[23:16], and DM3 controls DQ[31:24].

Figure 33: Write – DM Operation



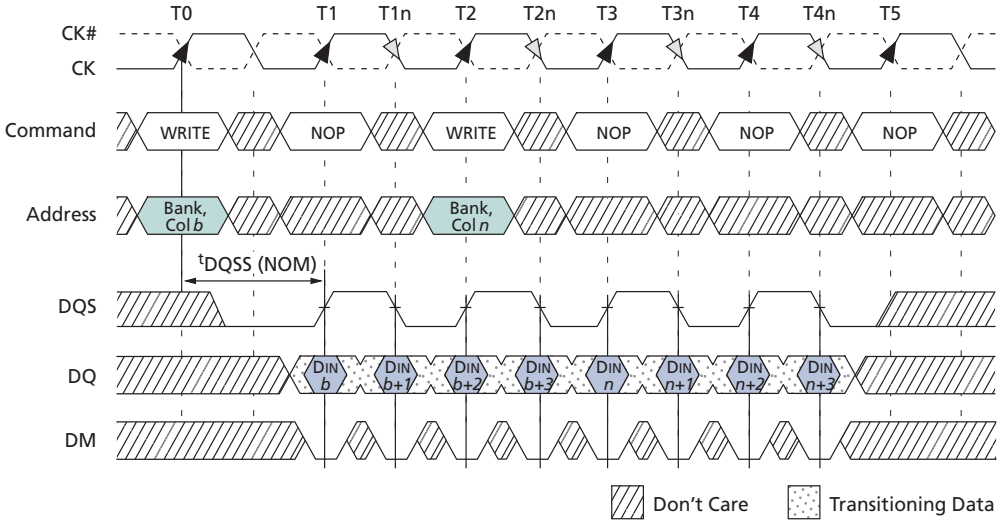
Notes:
1. DIN *n* = data-in from column *n*.
2. BL = 4 in the case shown.
3. Disable auto precharge.
4. "Don't Care" if A10 is HIGH at T8.
5. PRE = PRECHARGE.
6. NOP commands are shown for ease of illustration; other commands may be valid at these times.

Figure 34: WRITE Burst



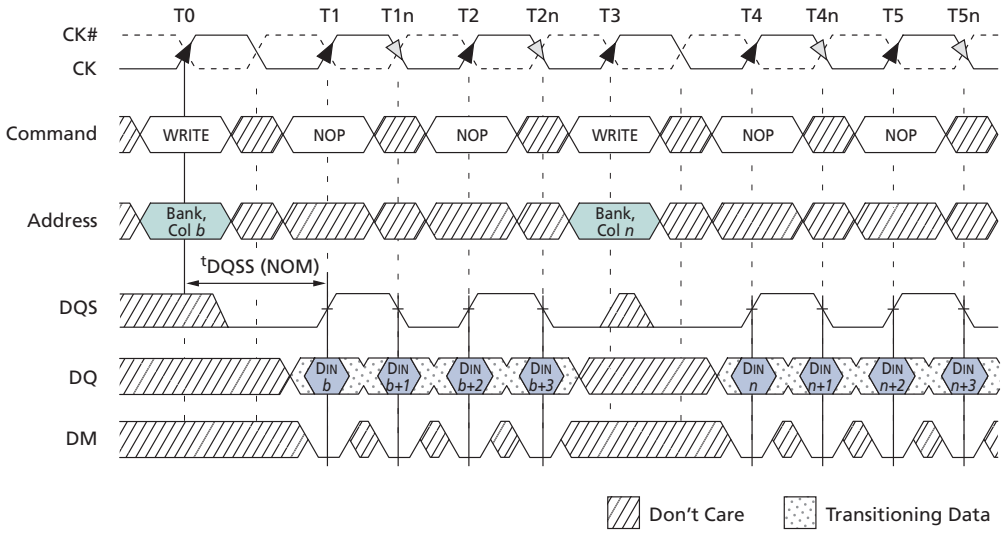
Notes:
1. DIN *b* = data-in for column *b*.
2. An uninterrupted burst of 4 is shown.
3. A10 is LOW with the WRITE command (auto precharge is disabled).

Figure 35: Consecutive WRITE-to-WRITE



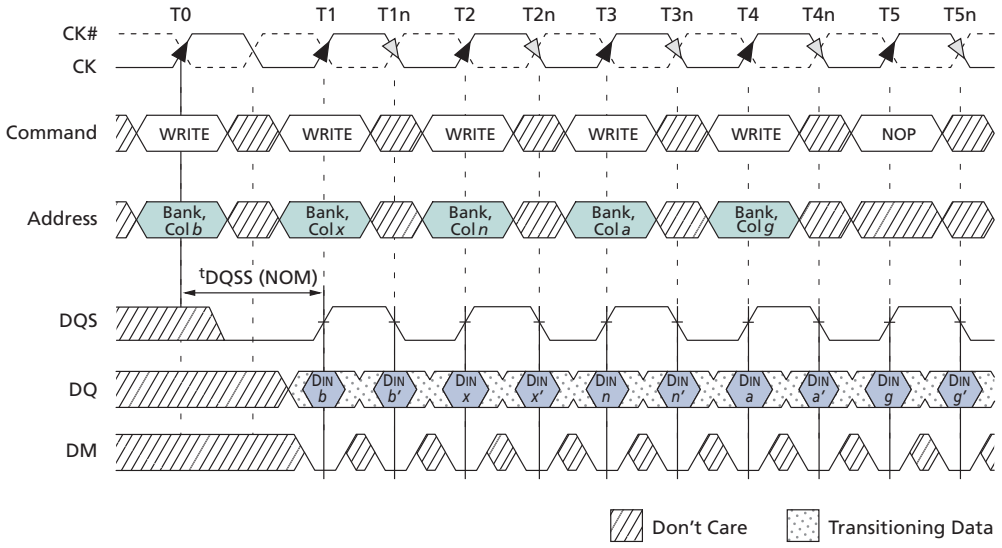
Notes:
1. DIN *b* (*n*) = data-in for column *b* (*n*).
2. An uninterrupted burst of 4 is shown.
3. Each WRITE command may be to any bank.

Figure 36: Nonconsecutive WRITE-to-WRITE



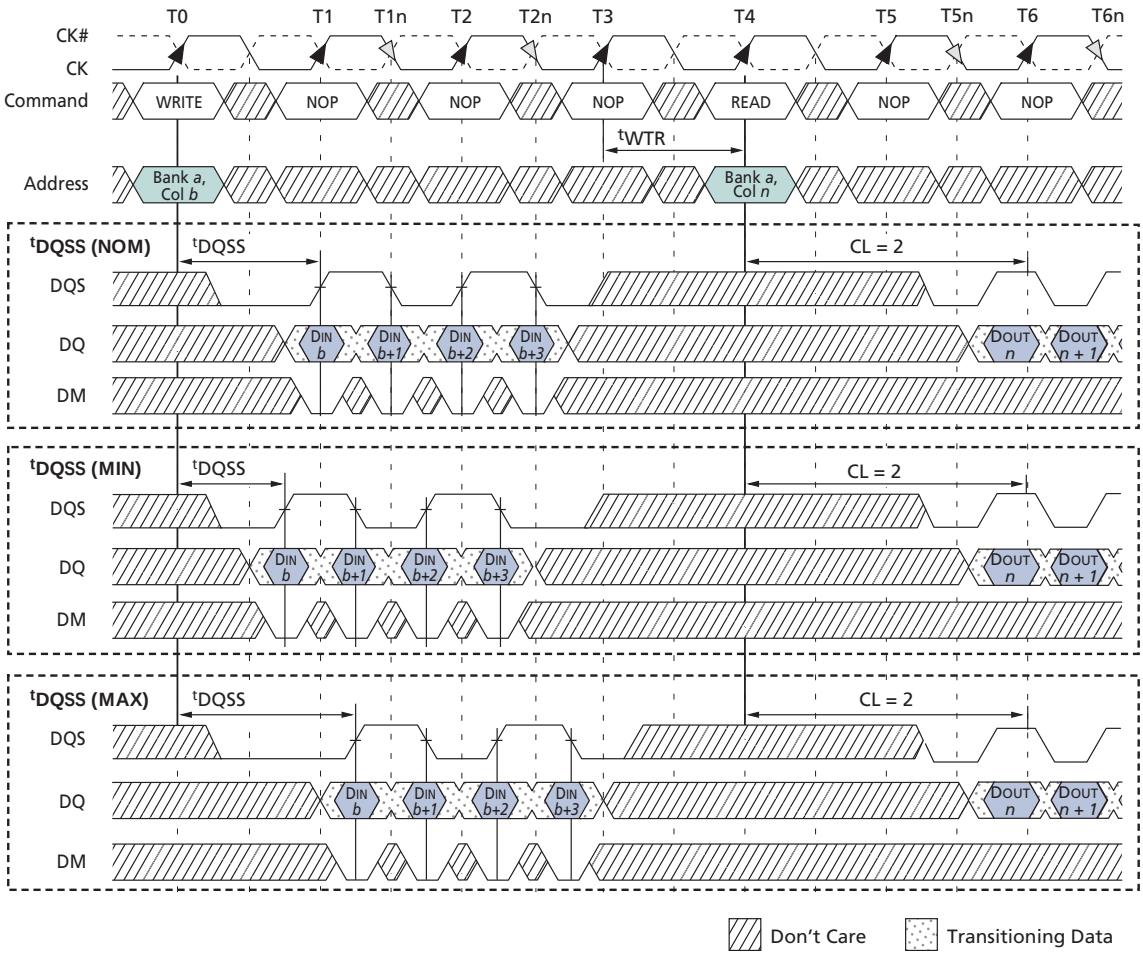
Notes:
1. DIN *b* (*n*) = data-in for column *b* (*n*).
2. An uninterrupted burst of 4 is shown.
3. Each WRITE command may be to any bank.

Figure 37: Random WRITE Cycles



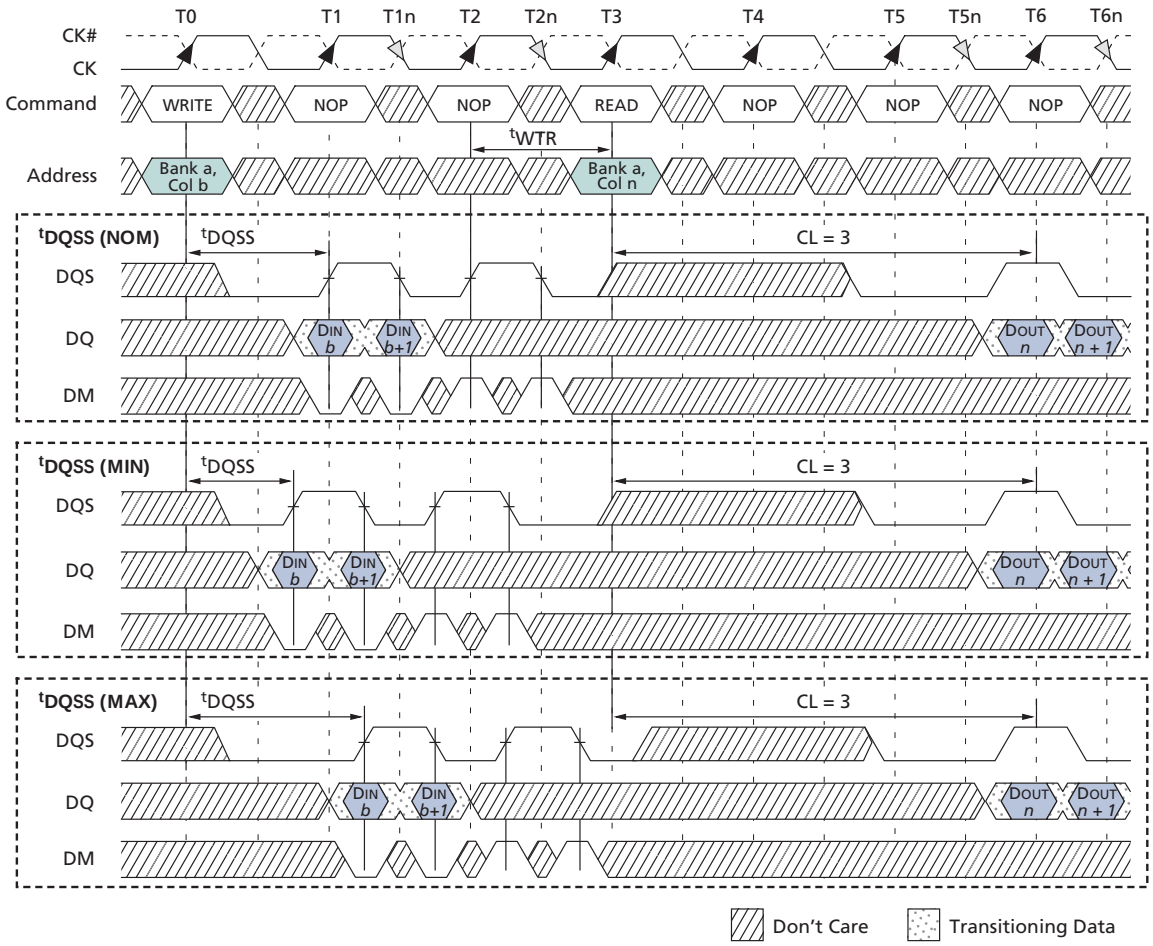
Notes:
1. DIN *b* (*or x*, *n*, *a*, *g*) = data-in for column *b* (or *x, n, q, g*).
2. b' (or *x, n, a, g*) = the next data-in following DIN *b* (*x, n, a, g*) according to the programmed burst order.
3. Programmed BL = 2, 4, 8, or 16 in cases shown.
4. Each WRITE command may be to any bank.

Figure 38: WRITE-to-READ – Uninterrupting



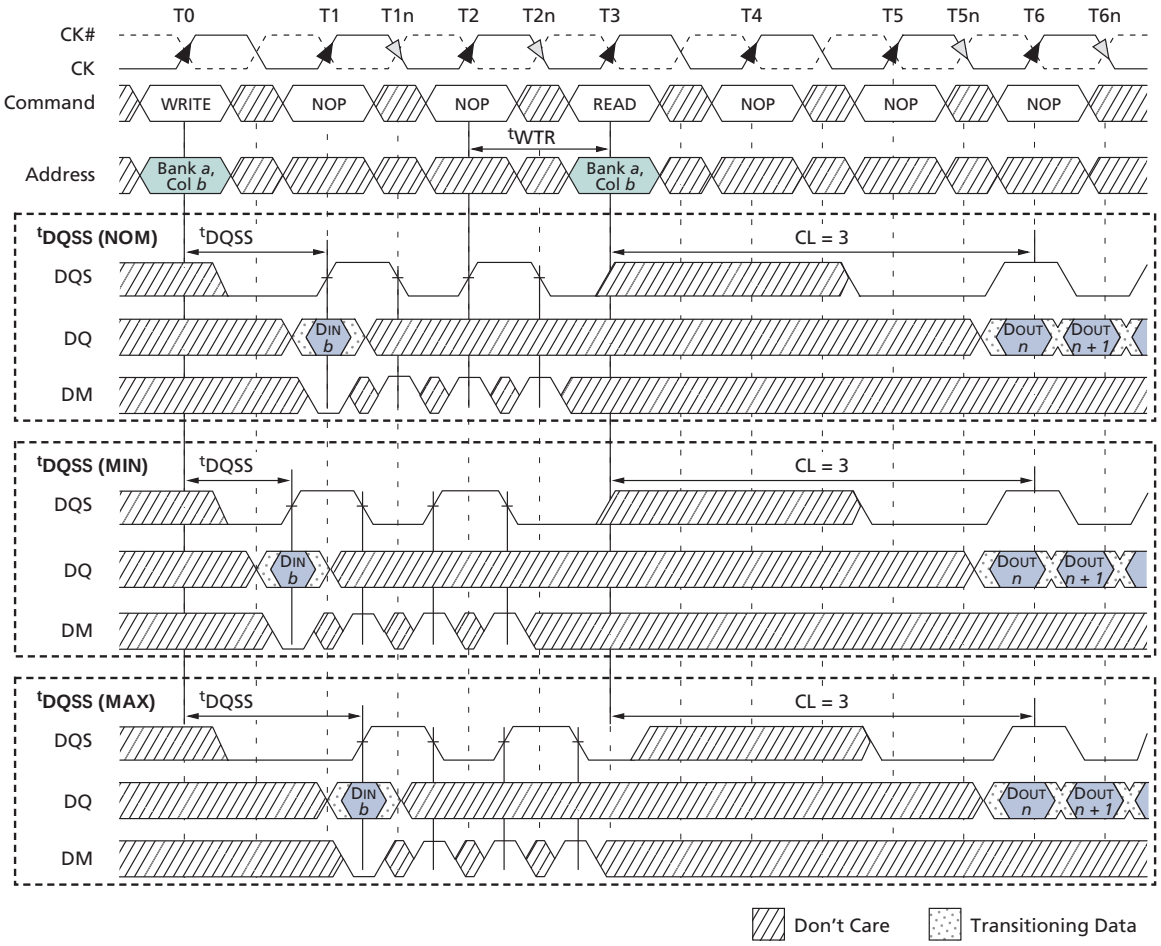
Notes:
1. DIN *b* = data-in for column *b*; DOUT *n* = data-out for column *n*.
2. An uninterrupted burst of 4 is shown.
3. tWTR is referenced from the first positive CK edge after the last data-in pair.
4. The READ and WRITE commands are to the same device. However, the READ and WRITE commands may be to different devices, in which case tWTR is not required and the READ command could be applied earlier.
5. A10 is LOW with the WRITE command (auto precharge is disabled).

Figure 39: WRITE-to-READ – Interrupting



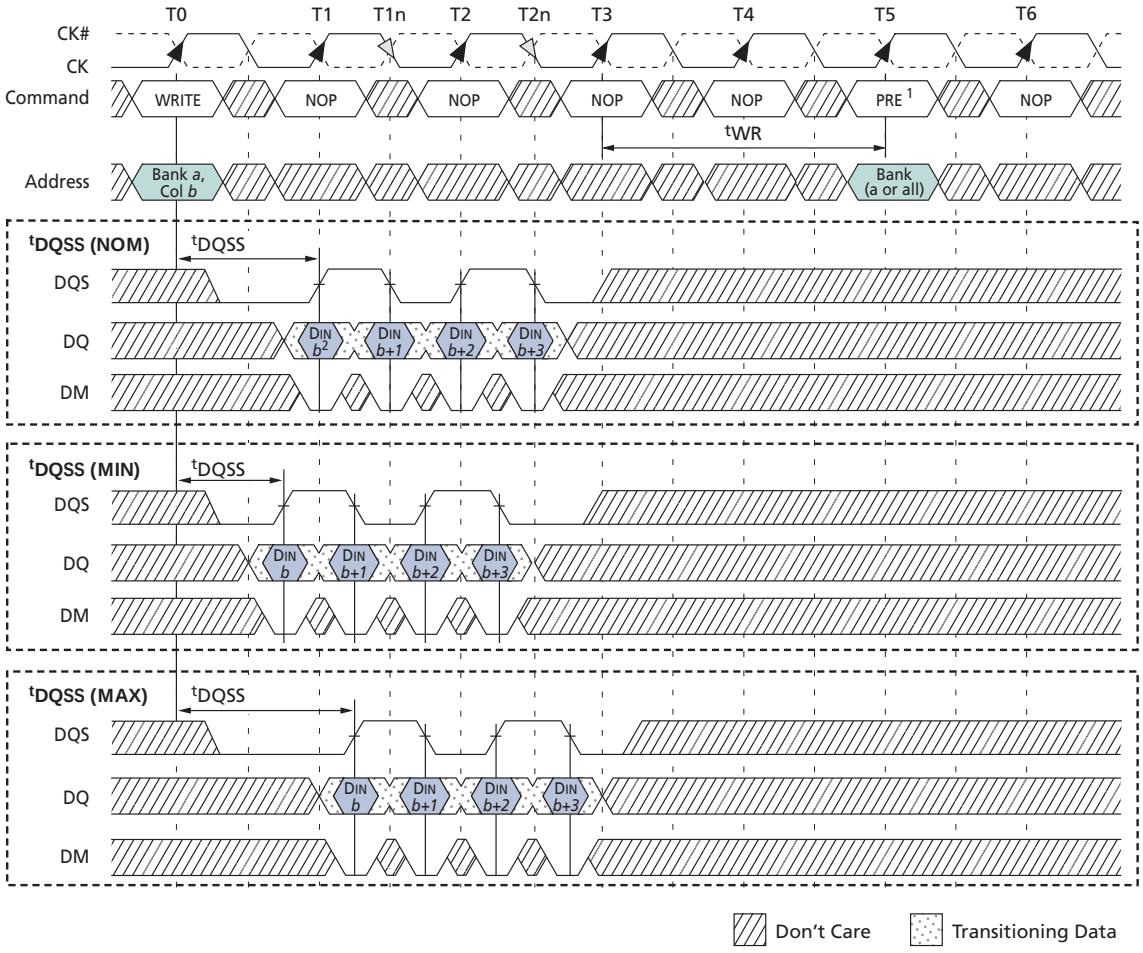
Notes:
1. DIN *b* = data-in for column *b*; DOUT *n* = data-out for column *n*.
2. An interrupted burst of 4 is shown; two data elements are written.
3. tWTR is referenced from the first positive CK edge after the last data-in pair.
4. A10 is LOW with the WRITE command (auto precharge is disabled).
5. DQS is required at T2 and T2n (nominal case) to register DM.

Figure 40: WRITE-to-READ – Odd Number of Data, Interrupting



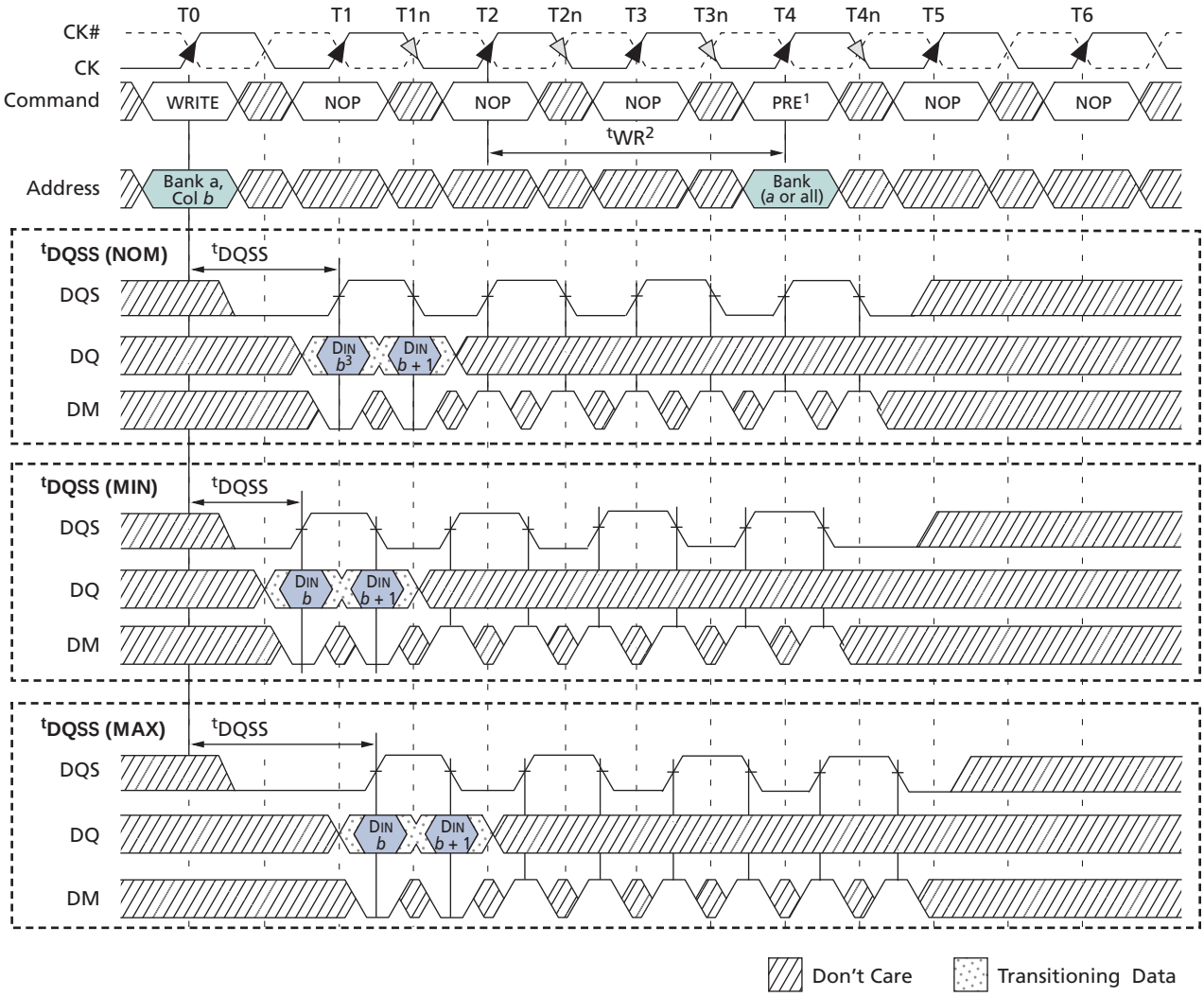
Notes:
1. DIN *b* = data-in for column *b*; DOUT *n* = data-out for column *n*.
2. An interrupted burst of 4 is shown; one data element is written, three are masked.
3. tWTR is referenced from the first positive CK edge after the last data-in pair.
4. A10 is LOW with the WRITE command (auto precharge is disabled).
5. DQS is required at T2 and T2n (nominal case) to register DM.

Figure 41: WRITE-to-PRECHARGE – Uninterrupting



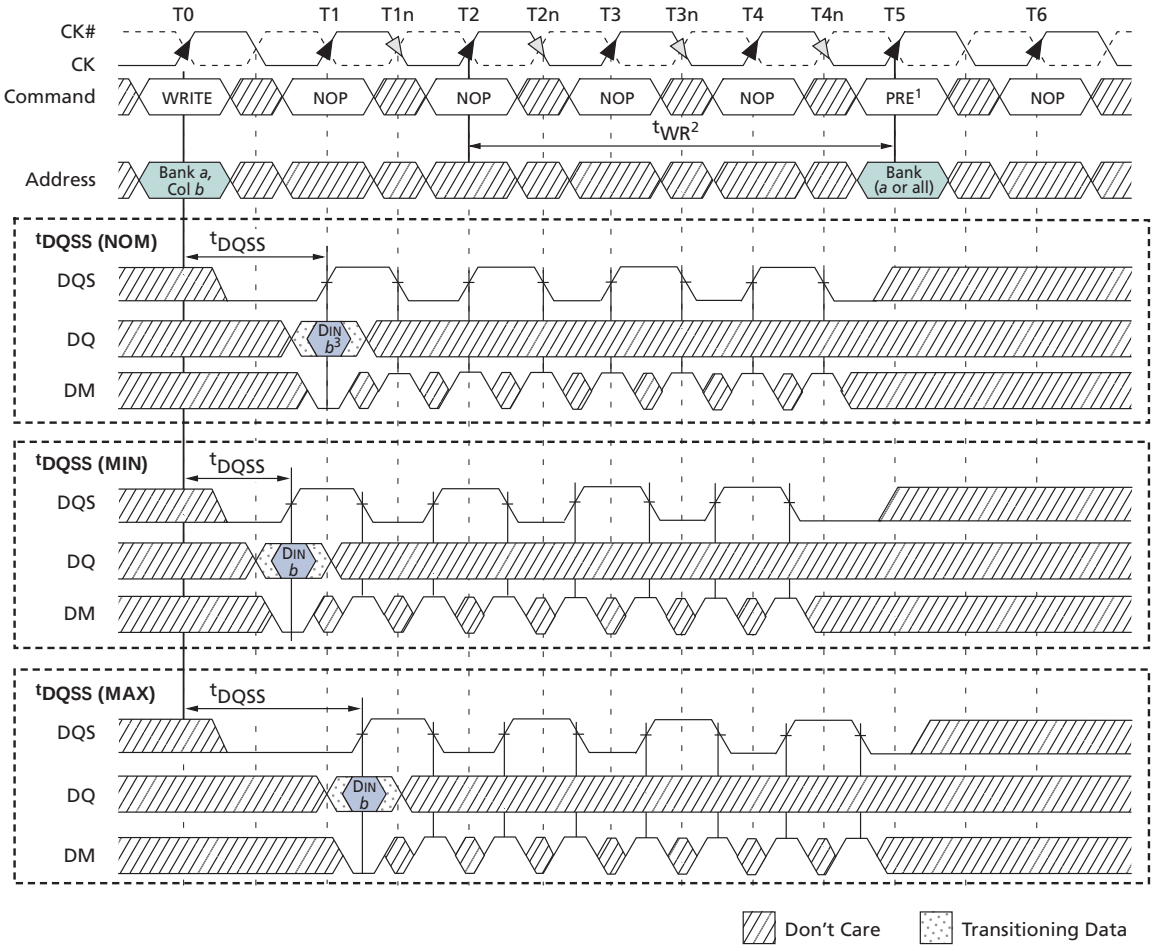
Notes:
1. PRE = PRECHARGE.
2. DIN *b* = data-in for column *b*.
3. An unterrupted burst 4 of is shown.
4. A10 is LOW with the WRITE command (auto precharge is disabled).
5. tWR is referenced from the first positive CK edge after the last data-in pair.
6. The PRECHARGE and WRITE commands are to the same device. However, the PRECHARGE and WRITE commands may be to different devices; in this case, tWR is not required and the PRECHARGE command could be applied earlier.

Figure 42: WRITE-to-PRECHARGE – Interrupting



Notes:
1. PRE = PRECHARGE.
2. ^{t}WR is referenced from the first positive CK edge after the last data-in pair.
3. DIN *b* = data-in for column *b*.
4. An interrupted burst of 8 is shown; two data elements are written.
5. A10 is LOW with the WRITE command (auto precharge is disabled).
6. DQS is required at T4 and T4n to register DM.

Figure 43: WRITE-to-PRECHARGE – Odd Number of Data, Interrupting



Notes:
1. PRE = PRECHARGE.
2. ^{t}WR is referenced from the first positive CK edge after the last data-in pair.
3. DIN *b* = data-in for column *b*.
4. An interrupted burst of 8 is shown; one data element is written.
5. DQS is required at T4 and T4n to register DM.
6. If the burst of 4 is used, DQS and DM are not required at T3, T3n, T4, and T4n.
7. A10 is LOW with the WRITE command (auto precharge is disabled).

PRECHARGE

The PRECHARGE command is used to deactivate the open row in a particular bank or the open row in all banks. The bank(s) will be available for a subsequent row access some specified time (^{t}RP) after the PRECHARGE command is issued. Input A10 determines whether one or all banks are to be precharged, and in the case where only one bank is to be precharged (A10 = LOW), inputs BA0 and BA1 select the bank. When all banks are to be precharged (A10 = HIGH), inputs BA0 and BA1 are treated as a "Don't Care." After a bank has been precharged, it is in the idle state and must be activated prior to any READ or WRITE commands being issued to that bank. A PRECHARGE command will be treated as a NOP if there is no open row in that bank (idle state), or if the previously open row is already in the process of precharging.

Auto Precharge

Auto precharge is a feature that performs the same individual-bank precharge function described previously, but without requiring an explicit command. This is accomplished by using A10 to enable auto precharge in conjunction with a specific READ or WRITE command. A precharge of the bank/row that is addressed with the READ or WRITE command is automatically performed upon completion of the READ or WRITE burst. Auto precharge is nonpersistent in that it is either enabled or disabled for each individual READ or WRITE command.

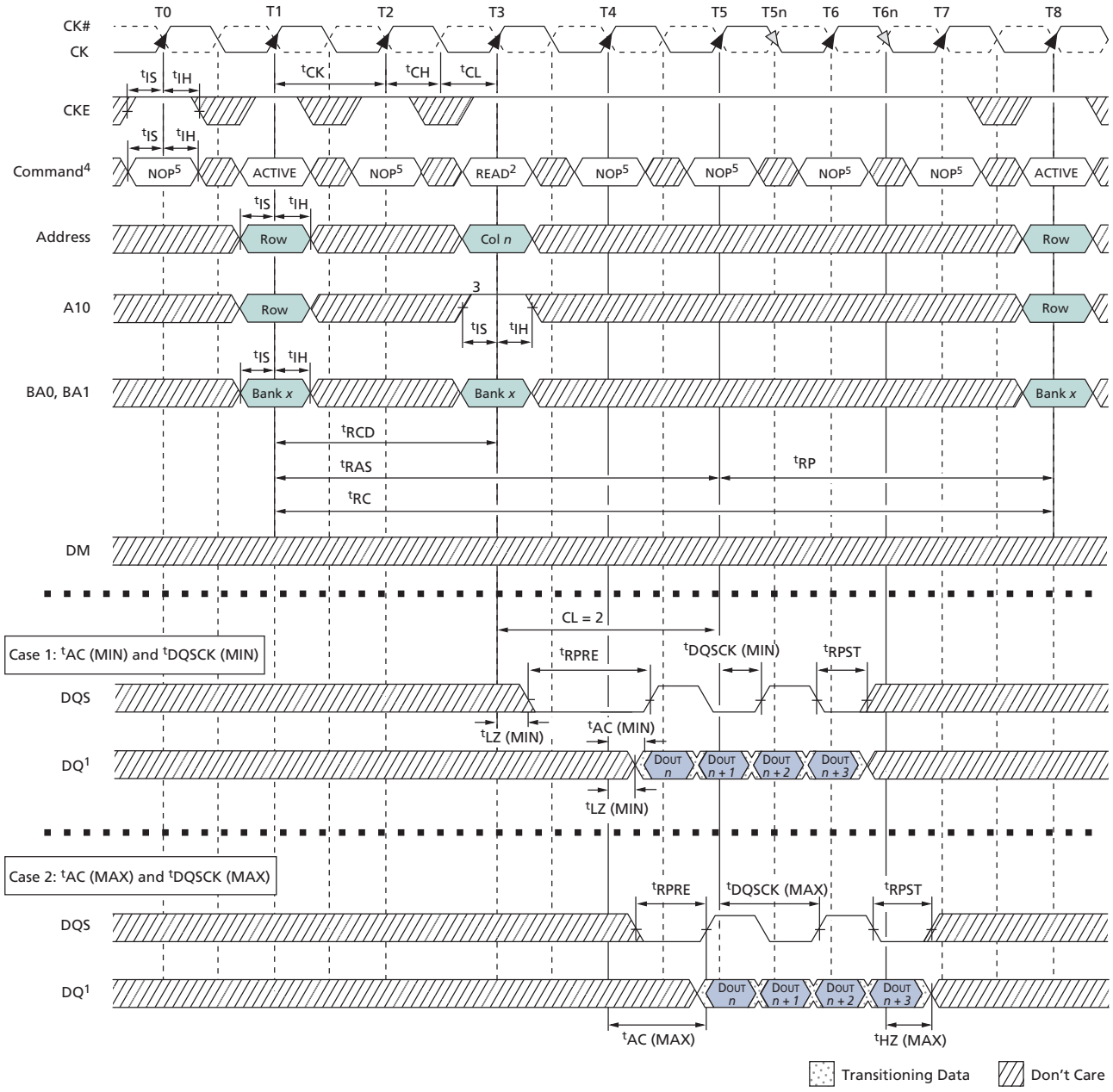
Auto precharge ensures that the precharge is initiated at the earliest valid stage within a burst. This "earliest valid stage" is determined as if an explicit PRECHARGE command was issued at the earliest possible time, without violating ^{t}RAS (MIN), as described for each burst type in "Operations" on page 37. The READ with auto precharge enabled or WRITE with auto precharge enabled states can each be broken into two parts: the access period and the precharge period. The access period starts with registration of the command and ends where the precharge period (or ^{t}RP) begins. For READ with auto precharge, the precharge period is defined as if the same burst was executed with auto precharge disabled and then followed with the earliest possible PRECHARGE command that still accesses all the data in the burst. For WRITE with auto precharge, the precharge period begins when ^{t}WR ends, with ^{t}WR measured as if auto precharge was disabled. In addition, during a WRITE with auto precharge, at least one clock is required during ^{t}WR time. During the precharge period, the user must not issue another command to the same bank until ^{t}RP is satisfied.

Bank READ operations with and without auto precharge are shown in Figure 44 on page 75 and Figure 45 on page 76. Bank WRITE operations with and without auto precharge are shown in Figure 46 on page 77 and Figure 47 on page 78.

Concurrent Auto Precharge

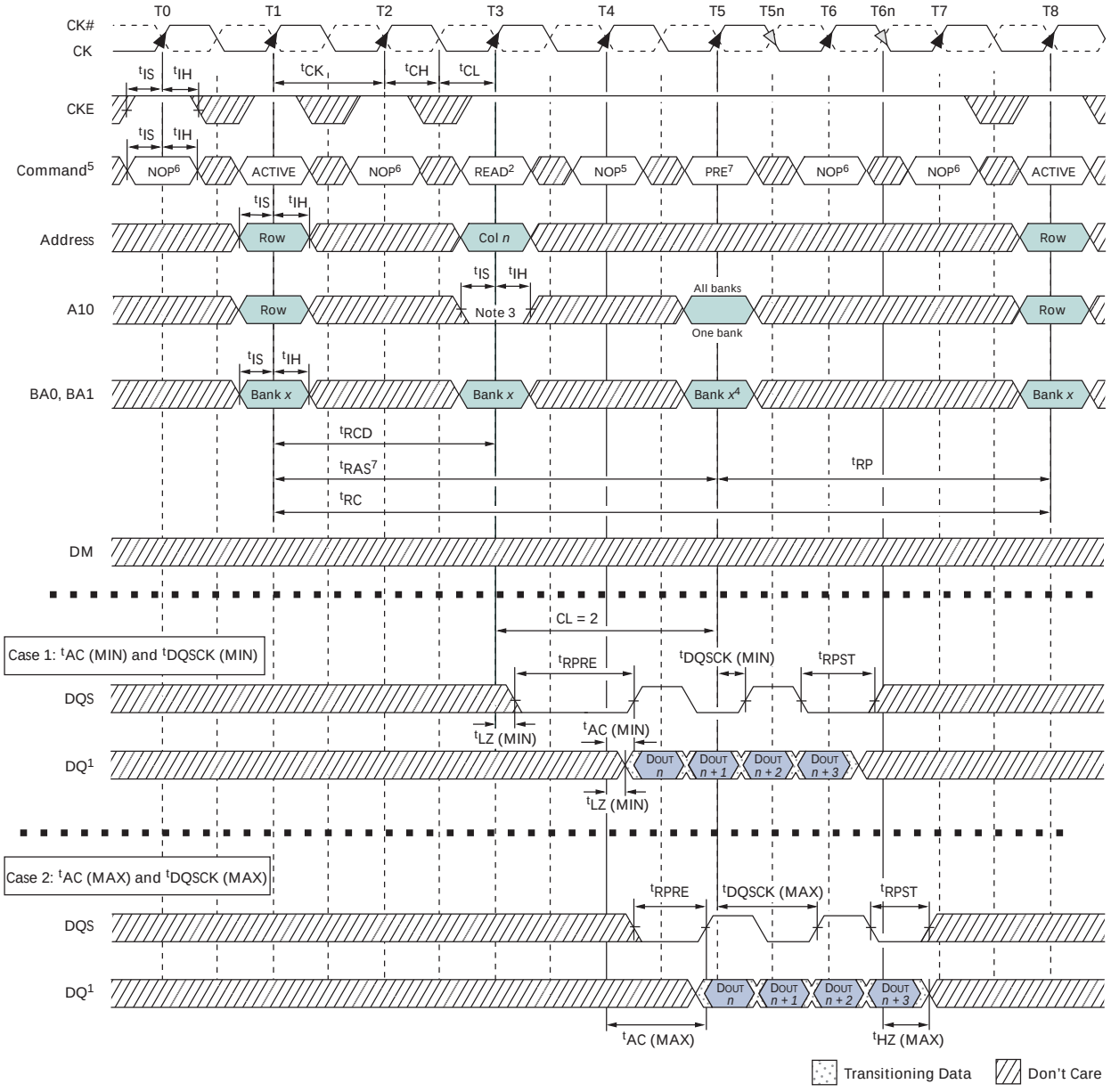
This device supports concurrent auto precharge such that when a READ with auto precharge enabled or a WRITE with auto precharge is enabled any command to another bank is allowed, as long as that command does not interrupt the read or write data transfer already in process. This feature allows the precharge to complete in the bank in which the READ or WRITE with auto precharge was executed, without an explicit PRECHARGE command being required, thus freeing the command bus for operations in other banks. During the access period of a READ or WRITE with auto precharge, only ACTIVE and PRECHARGE commands may be applied to other banks. During the precharge period, ACTIVE, PRECHARGE, READ, and WRITE commands may be applied to other banks. In either situation, all other related limitations apply (for example, contention between READ data and WRITE data must be avoided).

Figure 44: Bank Read – with Auto Precharge



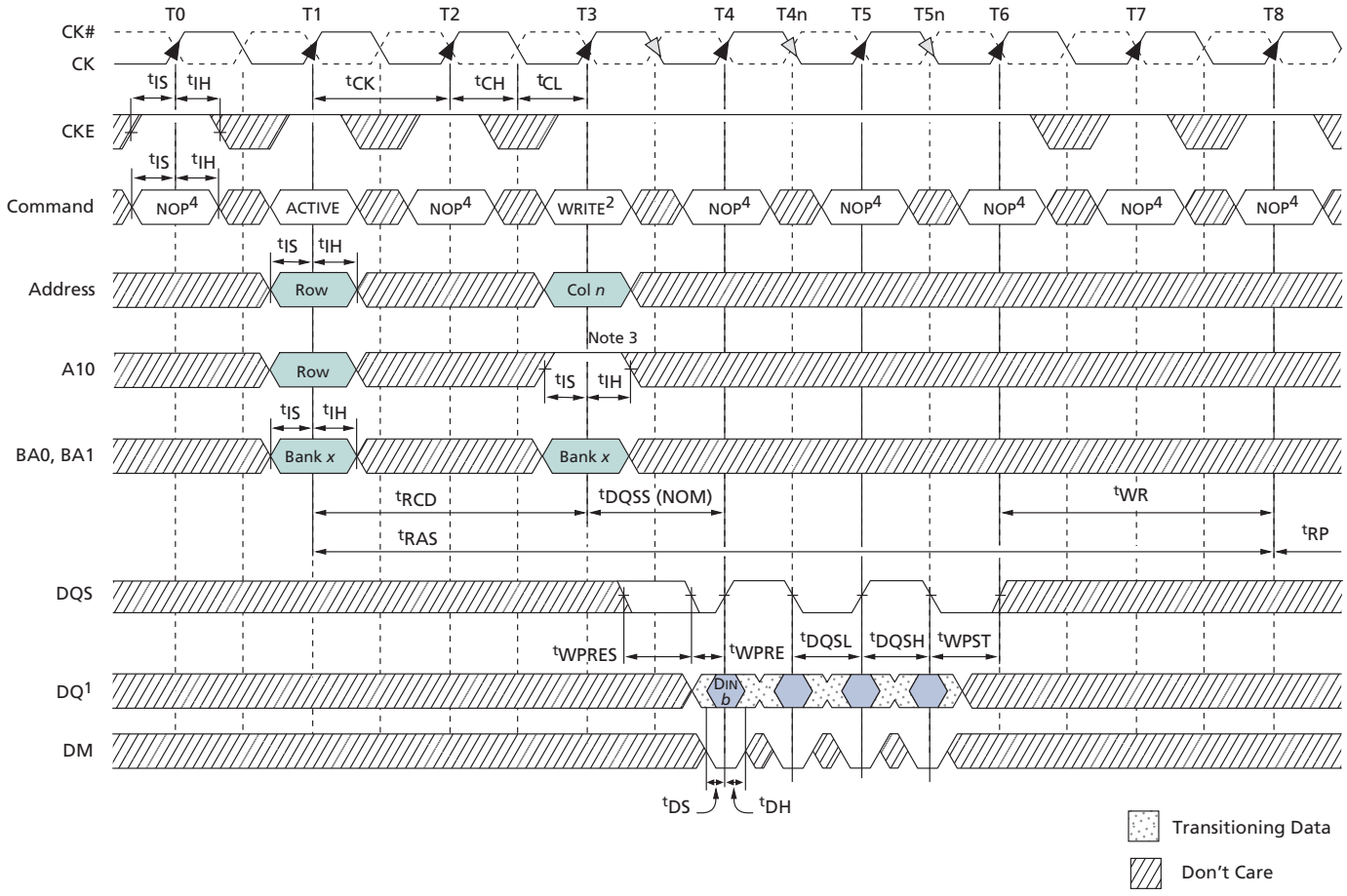
Notes:
1. DOUT *n* = data-out from column *n*.
2. BL = 4 in the case shown.
3. Enable auto precharge.
4. NOP commands are shown for ease of illustration; other commands may be valid at these times.
5. Refer to Figure 29 on page 60 and Figure 30 on page 61 for detailed DQS and DQ timing.

Figure 45: Bank Read – Without Auto Precharge



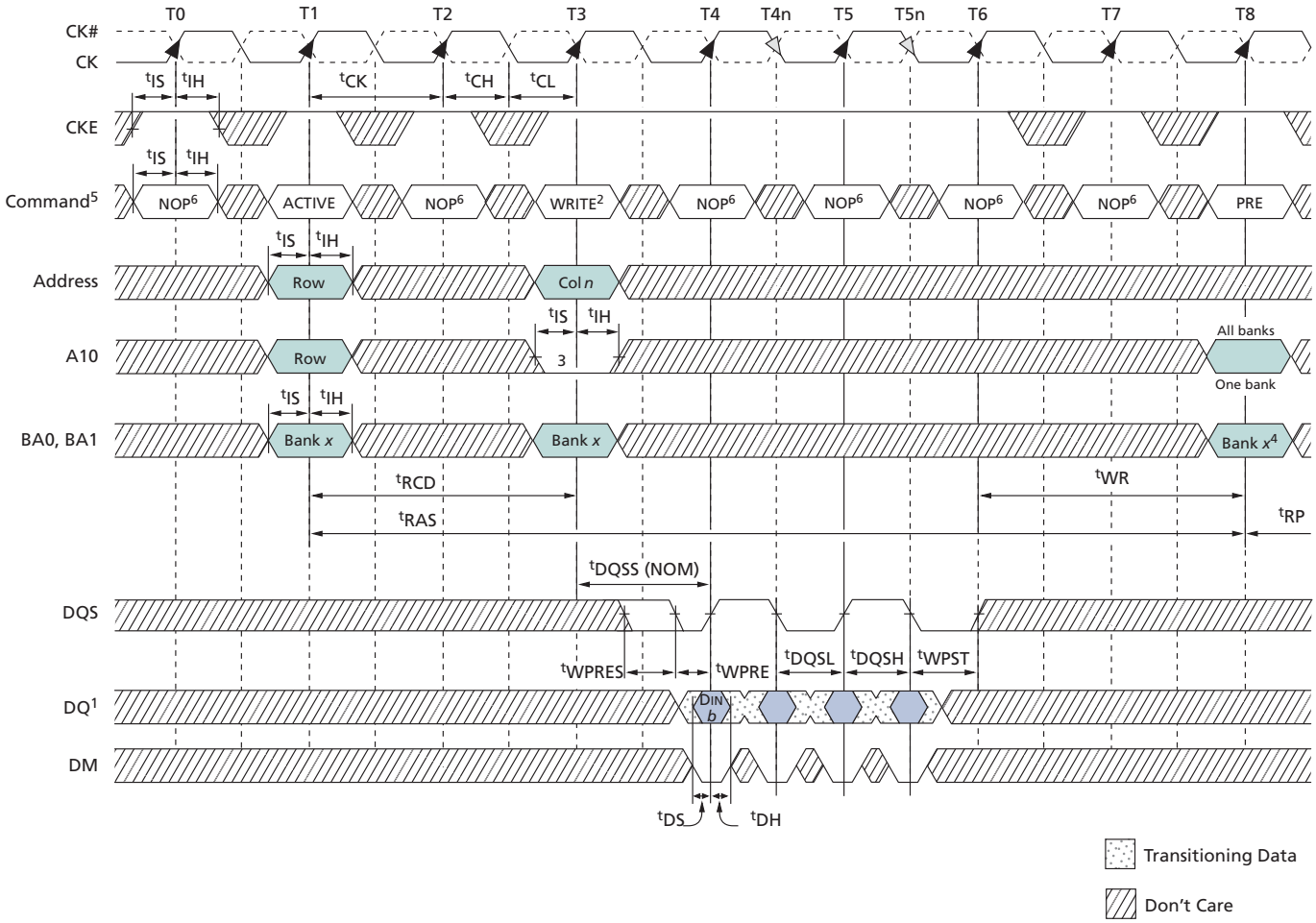
Notes:
1. DOUT *n* = data out from column *n.*
2. BL = 4 in the case shown.
3. Disable auto precharge.
4. "Don't Care" if A10 is HIGH at T5.
5. PRE = PRECHARGE.
6. NOP commands are shown for ease of illustration; other commands may be valid at these times.
7. The PRECHARGE command can only be applied at T5 if tRAS (MIN) is met.
8. Refer to Figure 29 on page 60 and Figure 30 on page 61 for DQS and DQ timing details.

Figure 46: Bank Write – with Auto Precharge



Notes:
1. DIN *n* = data-out from column *n*.
2. BL = 4 in the case shown.
3. Enable auto precharge.
4. NOP commands are shown for ease of illustration; other commands may be valid at these times.

Figure 47: Bank Write – Without Auto Precharge



Notes:
1. DOUT *n* = data-out from column *n*.
2. BL = 4 in the case shown.
3. Disable auto precharge.
4. "Don't Care" if A10 is HIGH at T5.
5. PRE = PRECHARGE.
6. NOP commands are shown for ease of illustration; other commands may be valid at these times.

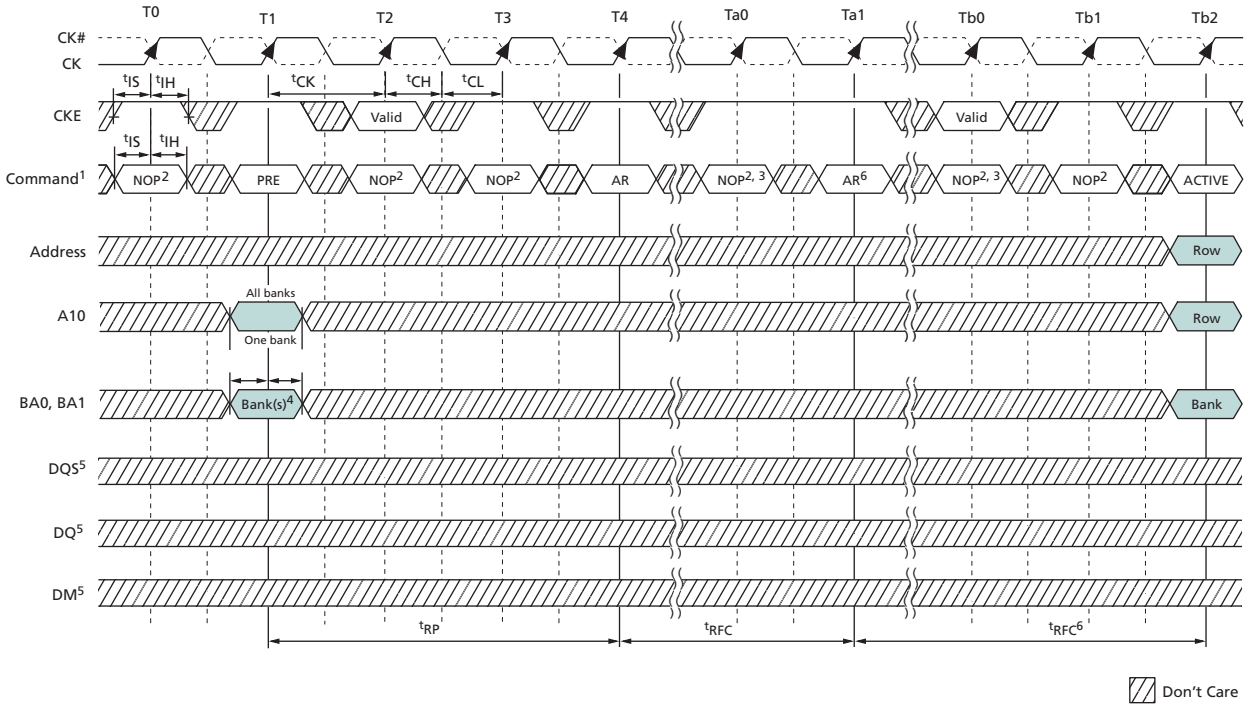
Auto Refresh

Auto refresh mode is used during normal operation of the Mobile DDR SDRAM and is analogous to CAS#-BEFORE-RAS# (CBR) REFRESH in FPM/EDO DRAMs. The AUTO REFRESH command is nonpersistent and must be issued each time a refresh is required.

The addressing is generated by the internal refresh controller. This makes the address bits a "Don't Care" during an AUTO REFRESH command.

To allow for improved efficiency in scheduling and switching between tasks, some flexibility in the absolute refresh interval is provided. The auto refresh period begins when the AUTO REFRESH command is registered and ends ^{t}RFC later.

Figure 48: Auto Refresh Mode



Notes:
1. PRE = PRECHARGE; AR = AUTO REFRESH.
2. NOP commands are shown for ease of illustration; other valid commands may be possible at these times. CKE must be active during clock positive transitions.
3. NOP or COMMAND INHIBIT are the only commands allowed until after ^{t}RFC time; CKE must be active during clock positive transitions.
4. "Don't Care" if A10 is HIGH at this point; A10 must be HIGH if more than one bank is active (for example, must precharge all active banks).
5. DM, DQ, and DQS signals are all "Don't Care"/High-Z for operations shown.
6. The second AUTO REFRESH is not required and is only shown as an example of two back-to-back AUTO REFRESH commands.

Although it is not a JEDEC requirement, CKE must be active (HIGH) during the auto refresh period to allow for future functional features. The auto refresh period begins when the AUTO REFRESH command is registered and ends ^{t}RFC later.

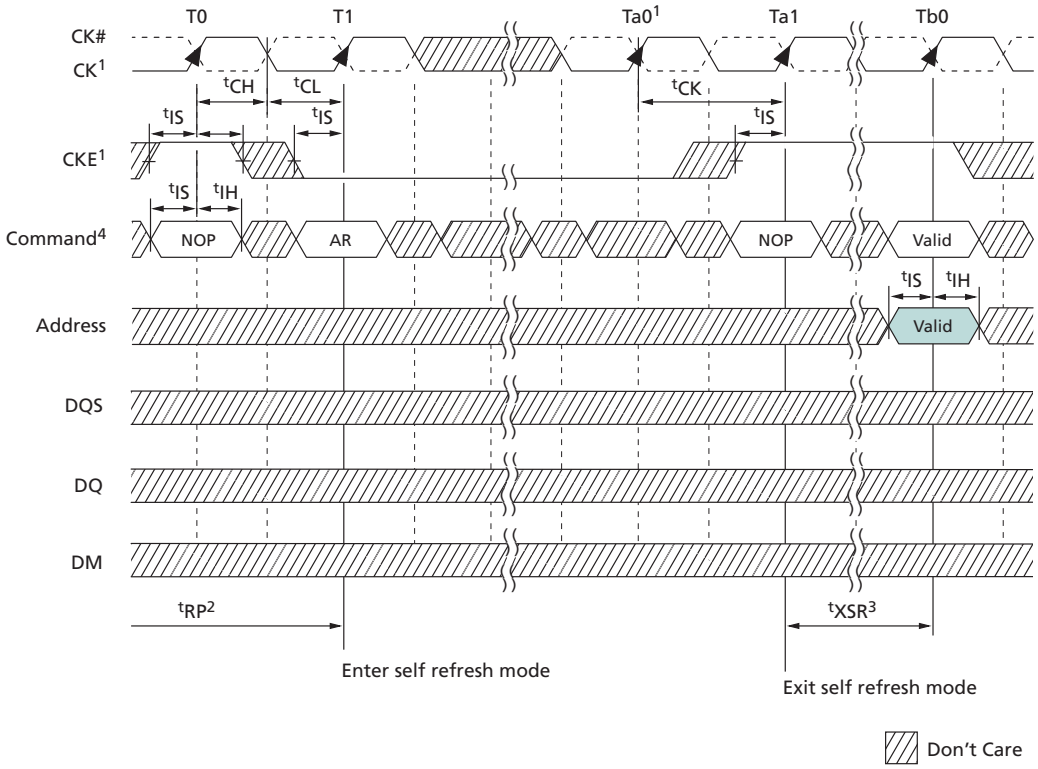
Self Refresh

The self refresh mode can be used to retain data in the Mobile DDR SDRAM even if the rest of the system is powered down. When in the self refresh mode, the Mobile DDR SDRAM retains data without external clocking. The SELF REFRESH command is initiated like an AUTO REFRESH command, except that CKE is disabled (LOW). All command and address input signals except CKE are "Don't Care" during SELF REFRESH. See Figure 49 on page 80 for details on entering and exiting self refresh mode. During SELF REFRESH, the device is refreshed as identified in the extended mode register (see PASR section on page 48).

The procedure for exiting SELF REFRESH requires a sequence of commands. First, CK must be stable prior to CKE going back HIGH. When CKE is HIGH, the Mobile DDR SDRAM must have NOP commands issued for ^{t}XSR to complete any internal refresh already in progress.

During SELF REFRESH operation, refresh intervals are scheduled internally and may vary. These intervals may be different than the specified ^{t}REFI time. For this reason, the SELF REFRESH command must not be used as a substitute for the AUTO REFRESH command.

Figure 49: Self Refresh Mode



Notes:
1. Clock must be stable, cycling within specifications by Ta0, before exiting self refresh mode.
2. Device must be in the all banks idle state prior to entering self refresh mode.
3. NOPs or DESELECTs is required for ^{t}XSR time with at least two clock pulses.
4. AR = AUTO REFRESH.
5. CKE must remain LOW to remain in self refresh.

Power-Down

Power-down (Figure 50 on page 81) is entered when CKE is registered LOW. If power-down occurs when all banks are idle, this mode is referred to as precharge power-down; if power-down occurs when there is a row active in any bank, this mode is referred to as active power-down. Entering power-down deactivates all input and output buffers, including CK and CK# and excluding CKE. Exiting power-down requires the device to be at the same voltage as when it entered power-down and received a stable clock.

Note: The power-down duration is limited by the refresh requirements of the device.

While in power-down, CKE LOW must be maintained at the inputs of the Mobile DDR SDRAM, while all other input signals are "Don't Care." The power-down state is synchronously exited when CKE is registered HIGH (in conjunction with a NOP or DESELECT command). NOP or DESELECT commands must be maintained on the command bus until ^{t}XP is satisfied. See Figure 51 on page 82 for a detailed illustration of the power-down command.

Figure 50: Power-Down Command (in Active or Precharge Modes)

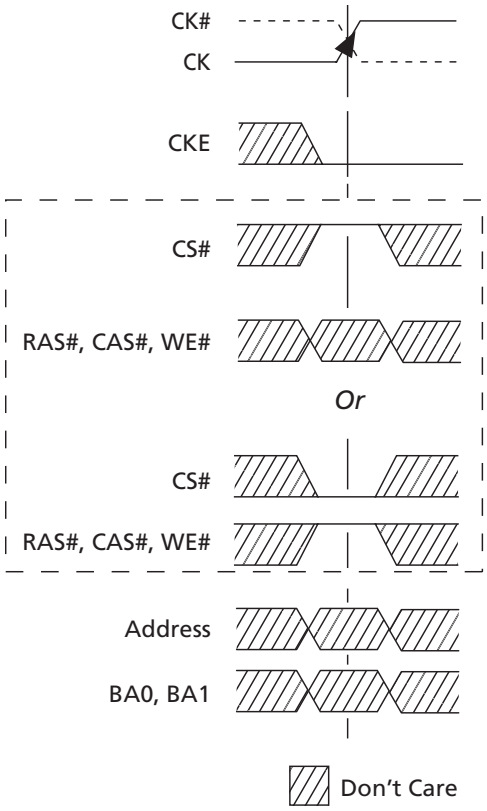
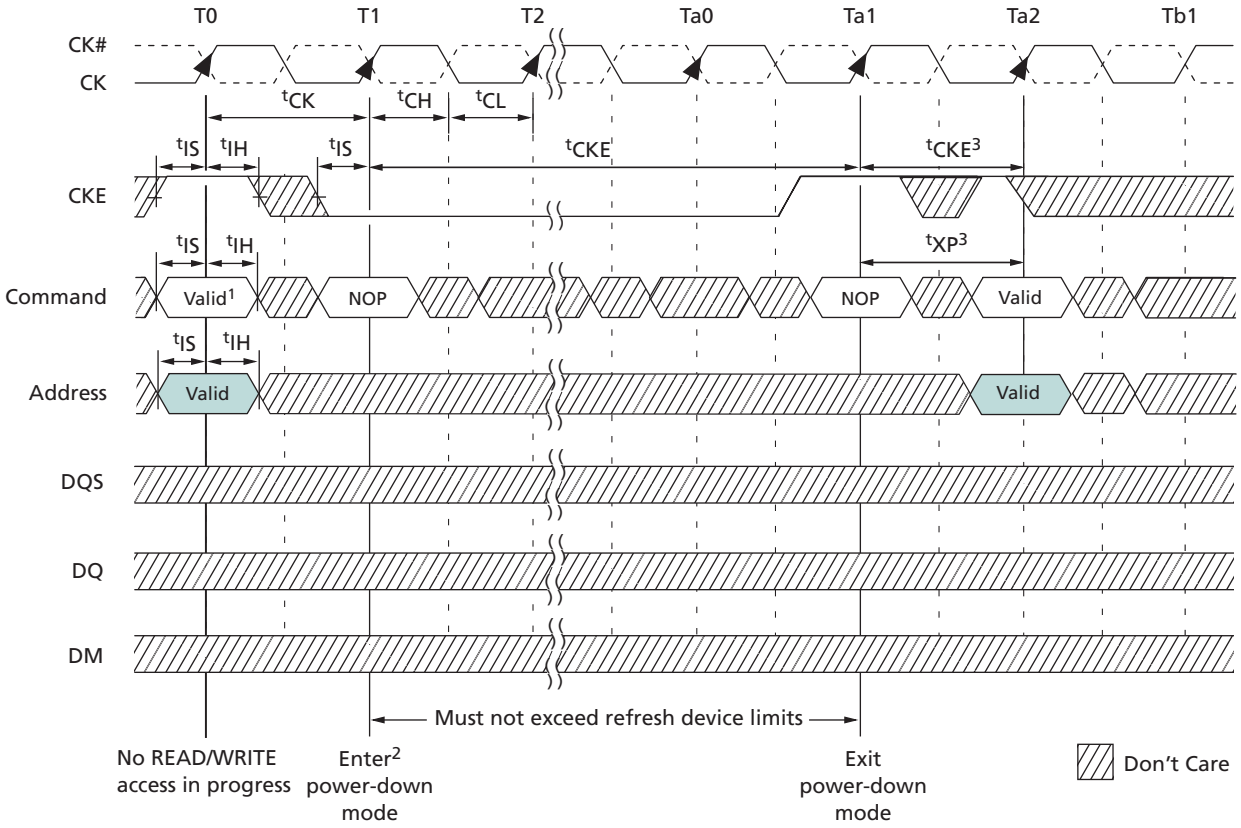


Figure 51: Power-Down Mode (Active or Precharge)



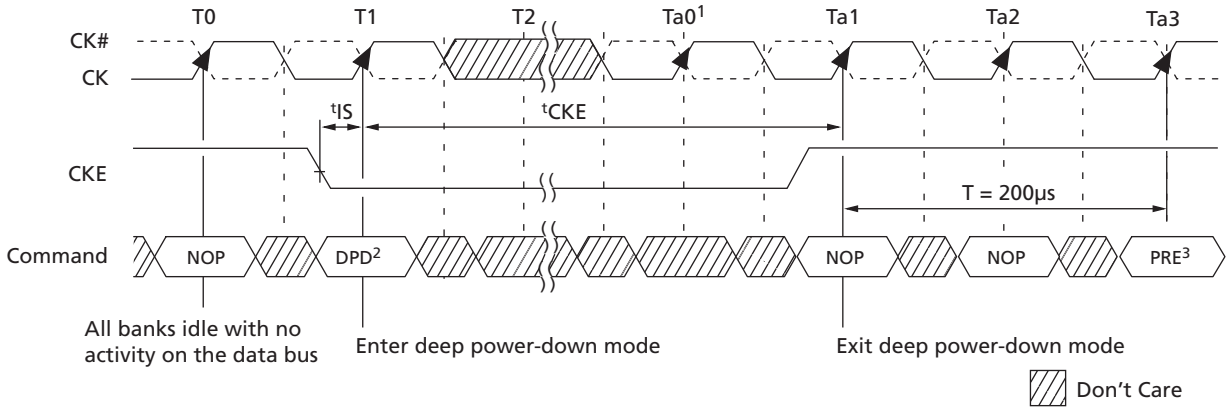
Notes:
1. If this command is a PRECHARGE (or if the device is already in the idle state), then the power-down mode shown is precharge power-down. If this command is an ACTIVE (or if at least one row is already active), then the power-down mode shown is active power-down.
2. No column accesses are allowed to be in progress at the time power-down is entered.
3. ^{t}CKE applies if CKE goes LOW at Ta2 (entering power-down); ^{t}XP applies if CKE remains HIGH at Ta2 (exit power-down).

Deep Power-Down (DPD)

Deep power-down is an operating mode used to achieve maximum power reduction by eliminating the power of the memory array. Data will not be retained after the device enters DPD mode.

Before entering DPD mode the DRAM must be in all banks idle state with no activity on the data bus (^{t}RP time must be met). This mode is entered by holding CS# and WE# LOW with RAS# and CAS# HIGH at the rising edge of the clock while CKE is LOW. CKE must be held LOW to maintain DPD mode. The clock must be stable prior to exiting DPD mode. This mode is exited by asserting CKE HIGH with either a NOP or DESELECT command present on the command bus. Upon exiting DPD mode, a full DRAM initialization sequence is required.

Figure 52: Deep Power-Down



Notes:
1. Clock must be stable prior to CKE going HIGH.
2. DPD = deep power-down.
3. Upon exit of deep power-down mode, a full DRAM initialization sequence is required.

Stopping the External Clock

One method of controlling the power efficiency in applications is to throttle the clock that controls the DDR SDRAM. The clock may be controlled in two ways:

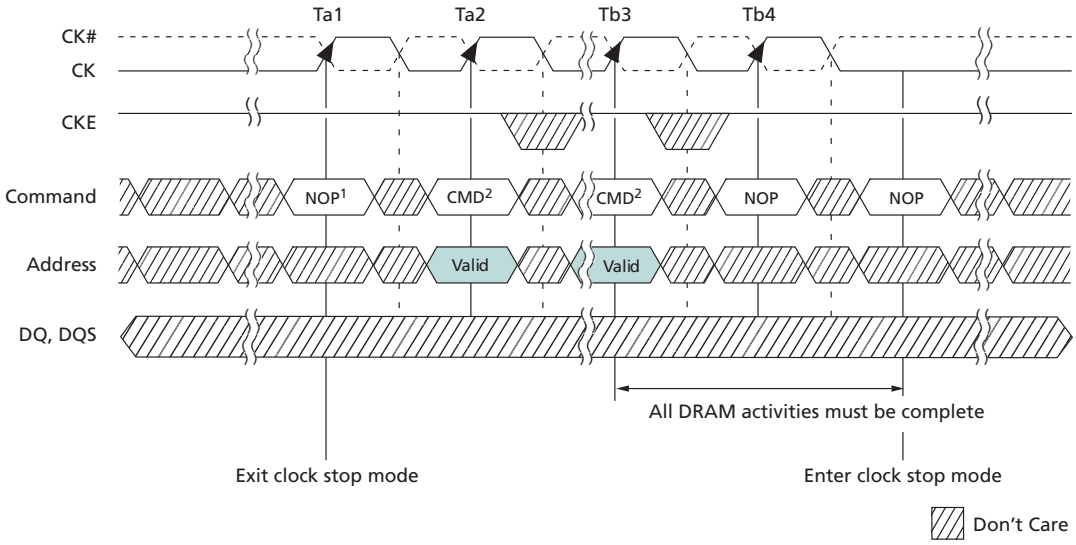
- Change the clock frequency
- Stop the clock.

The Mobile DDR SDRAM allows the clock to change frequency during operation only if all the timing parameters are met and all refresh requirements are satisfied.

The clock can be stopped altogether if there are no DRAM operations in progress that would be affected by this change. Any DRAM operation already in process must be completed before entering clock stop mode; this includes the following timings: ^{t}RCD, ^{t}RP, ^{t}RFC, ^{t}MRD, ^{t}WR, and ^{t}RPST. In addition, any READ or WRITE burst in progress must be complete as defined in the "READs" section on page 52 and the "WRITEs" section on page 63.

CKE must be held HIGH with CK = LOW and CK# = HIGH for the full duration of the clock stop mode. One clock cycle and at least one NOP or DESELECT is required after the clock is restarted before a valid command can be issued. Figure 53 on page 84 illustrates the clock stop mode.

Figure 53: Clock Stop Mode



Notes:
1. Prior to Ta1, the device is in clock stop mode. To exit, at least one NOP is required before any valid command.
2. Any valid command is allowed; device is not in clock suspend mode.

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Revision History

512Mb: x16, x32 Mobile DDR SDRAM

Rev. F, Production 11/08

- Added 1.2V I/O Option
  - "Features," on page 1
  - "Options" on page 1
  - Figure 1: "512Mb Mobile DDR Part Numbering," on page 5
  - Table 6, "1.2V I/O AC/DC Electrical Characteristics and Operating Conditions," on page 16
  - Table 15, "1.2V I/O Target Output Drive Characteristics (Three-Quarter Strength)," on page 29
  - Figure 19: "Extended Mode Register," on page 49

Rev. E, Production 8/08

- Added 9mm x 13mm 90-ball package
  - "Options" on page 1
  - Figure 1: "512Mb Mobile DDR Part Numbering," on page 5
  - Figure 8: "90-Ball VFBGA Package (9mm x 13mm)," on page 14

Rev. D, Production 5/08

- Updated IDD Values
  - Table 8: "IDD Specifications and Conditions (x16)," on page 19
  - Table 9: "IDD Specifications and Conditions (x32)," on page 20
- Added "L" low-power option
  - Figure 1: "512Mb Mobile DDR Part Numbering," on page 5
  - Table 10: "IDD6 Specifications and Conditions," on page 21
- Table 10: "IDD6 Specifications and Conditions," on page 21: Removed 70°C and 15°C values as they are redundant and are shown in Figure 9: "Typical Idd6 Curves," on page 22
- Table 11: "Electrical Characteristics and Recommended AC Operating Conditions," on page 22:
  - Changed the following specification: ^{t}RC -75 to 67.5ns.
  - Removed note 21

Rev. C, Production 3/08

- "Features" on page 1: Added programmable burst length of 16.
- Figure 1: "512Mb Mobile DDR Part Numbering," on page 5: Updated example cycle time to -6.
- Table 9, "IDD Specifications and Conditions (x32)," on page 20: Corrected IDD0 unit value to mA.
- Table 10, "IDD6 Specifications and Conditions," on page 21: Added MAX values.
- Figure 9: "Typical Idd6 Curves," on page 22: Added figure.
- Table 11, "Electrical Characteristics and Recommended AC Operating Conditions," on page 22: Updated ^{t}DIPW (MIN) to 1.4ns, and ^{t}RC -54 (MIN) to 59.4.
- Table 12, "Target Output Drive Characteristics (Full Strength)," on page 26: Updated note 1 and notes references.
- Table 13, "Target Output Drive Characteristics (Three-Quarter Strength)," on page 27, and : Updated note 1 and table title.

- Table 14, “Target Output Drive Characteristics (One-Half Strength),” on page 28: Updated note 1 and deleted former note 4.
- Updated document status to Production.

Rev. B, Preliminary 12/07

- Updated to include -54 speed grade, including:
  - “Options” on page 1
  - Table 1, “Key Timing Parameters (CL = 3),” on page 1
  - Figure 1: “512Mb Mobile DDR Part Numbering,” on page 5
  - Table 8, “IDD Specifications and Conditions (x16),” on page 19
  - Table 9, “IDD Specifications and Conditions (x32),” on page 20
  - Table 11, “Electrical Characteristics and Recommended AC Operating Conditions,” on page 22: Added table.
- Updated all “TBDs” in the -5 columns of Table 8 on page 19 and Table 9 on page 20.
- Changed IDD6A Max to 700µA and changed IDD6c to “TBD” in Table 10 on page 21.
- Change revision back to Rev. B.

Rev. A, Advance 07/07

Initial release (released as “Rev. M” in error).