SYNCHRONOUS DRAM

MT48LC4M4A1/A2 S - 2 Meg x 4 x 2 banks
MT48LC2M8A1/A2 S - 1 Meg x 8 x 2 banks

FEATURES

- PC100-compliant functionality
- Fully synchronous; all signals registered on positive edge of system clock
- Internal pipelined operation; column address can be changed every clock cycle
- Internal banks for hiding row access / precharge:
  4 Meg x 4 - 2 Meg x 4 x 2 banks architecture with 11 row, 10 column addresses per bank
  2 Meg x 8 - 1 Meg x 8 x 2 banks architecture with 11 row, 9 column addresses per bank
- Programmable burst lengths: 1, 2, 4, 8 or full page
- Auto Precharge and Auto Refresh Modes
- Self Refresh Mode
- 64ms, 4,096-cycle refresh (15.6µs / row)
- LVTTL-compatible inputs and outputs
- Single +3.3V ±0.3V power supply
- One- and two-clock WRITE recovery (^{t}WR) versions

OPTIONS — MARKING

- Architectures
  4 Meg x 4 — 4M4
  2 Meg x 8 — 2M8
- Write Recovery (^{t}WR / ^{t}DPL)
  ^{t}WR = 1 CLK — A1
  ^{t}WR = 2 CLK — A2
- Plastic Package - OCPL
  44-pin TSOP (400 mil) — TG
- Timing (Cycle Time)
  8ns cycle time (≤ 125 MHz clock rate) — -8A
  10ns cycle time (≤ 100 MHz clock rate) — -10
  12ns cycle time (≤ 83 MHz clock rate) — -12
- Part Number Example: MT48LC2M8A1TG-10 S

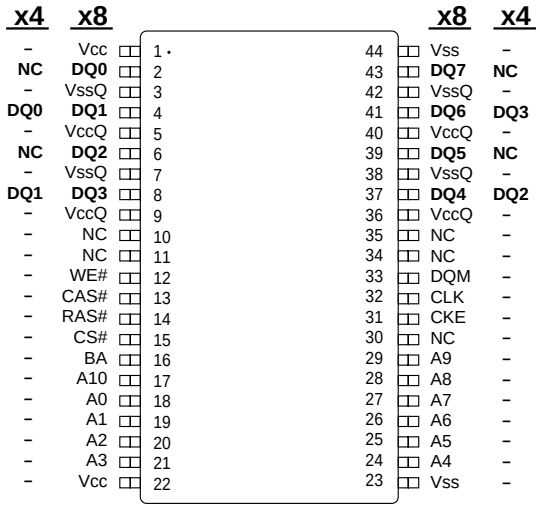
Note: *The 16Mb SDRAM base number differentiates the offerings in two places:* MT48LC2M8A1 S. *The fourth field distinguishes the architecture offering: 4M4 designates 4 Meg x 4, and 2M8 designates 2 Meg x 8. The fifth field distinguishes the WRITE recovery offering: A1 designates one CLK and A2 designates two CLKs.*

KEY TIMING PARAMETERS

SPEED GRADE	CLOCK FREQUENCY	ACCESS TIME *CL = 2	ACCESS TIME *CL = 3	SETUP TIME	HOLD TIME
-8A	125 MHz	9ns	6ns	2ns	1ns
-10	100 MHz	9ns	7.5ns	3ns	1ns
-12	83 MHz	9ns	9ns	3ns	1ns

*CL = CAS (READ) Latency

PIN ASSIGNMENT (Top View)
44-Pin TSOP



Note: The # symbol indicates signal is active LOW. A dash (-) indicates x4 pin function is same as x8 pin function.

	4 MEG x 4	2 MEG x 8
Configuration	2 Meg x 4 x 2 banks	1 Meg x 8 x 2 banks
Refresh Count	4K	4K
Row Addressing	2K (A0-A10)	2K (A0-A10)
Bank Addressing	1 (BA)	1 (BA)
Column Addressing	1K (A0-A9)	512 (A0-A8)

16 MEG (x4/x8) SDRAM PART NUMBERS

PART NUMBER	ARCHITECTURE
MT48LC4M4A1TG S	4 Meg x 4 (^{t}WR = 1 CLK)
MT48LC4M4A2TG S	4 Meg x 4 (^{t}WR = 2 CLK)
MT48LC2M8A1TG S	2 Meg x 8 (^{t}WR = 1 CLK)
MT48LC2M8A2TG S	2 Meg x 8 (^{t}WR = 2 CLK)

GENERAL DESCRIPTION

The Micron 16Mb SDRAM is a high-speed CMOS, dynamic random-access memory containing 16,777,216 bits. It is internally configured as a dual memory array (the 4 Meg x 4 is a dual 2 Meg x 4, and the 2 Meg x 8 is a dual 1 Meg x 8) with a synchronous interface (all signals are

GENERAL DESCRIPTION (continued)

registered on the positive edge of the clock signal, CLK). Each of the two internal banks is organized with 2,048 rows and either 1,024 columns by 4 bits (4 Meg x 4) or 512 columns by 8 bits (2 Meg x 8).

Read and write accesses to the 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 (BA selects the bank, A0-A10 select the row). The address bits registered coincident with the READ or WRITE command are used to select the starting column location for the burst access.

The SDRAM provides for programmable READ or WRITE burst lengths of 1, 2, 4 or 8 locations, or the full page, with a BURST TERMINATE option. An AUTO PRECHARGE function may be enabled to provide a self-timed row precharge that is initiated at the end of the burst sequence.

The Micron 16Mb SDRAM uses an internal pipelined architecture to achieve high-speed operation. This architecture is compatible with the 2*n* rule of prefetch architectures, but it also allows the column address to be changed on every clock cycle to achieve a high-speed, fully random access. Precharging one bank while accessing the alternate bank will hide the PRECHARGE cycles and provide seamless, high-speed, random-access operation.

The Micron 16Mb SDRAM is designed to operate in 3.3V, low-power memory systems. An auto refresh mode is provided, along with a power-saving power-down mode. All inputs and outputs are LVTTL-compatible.

SDRAMs offer substantial advances in DRAM operating performance, including the ability to synchronously burst data at a high data rate with automatic column-address generation, the ability to interleave between internal banks in order to hide precharge time, and the capability to randomly change column addresses on each clock cycle during a burst access.

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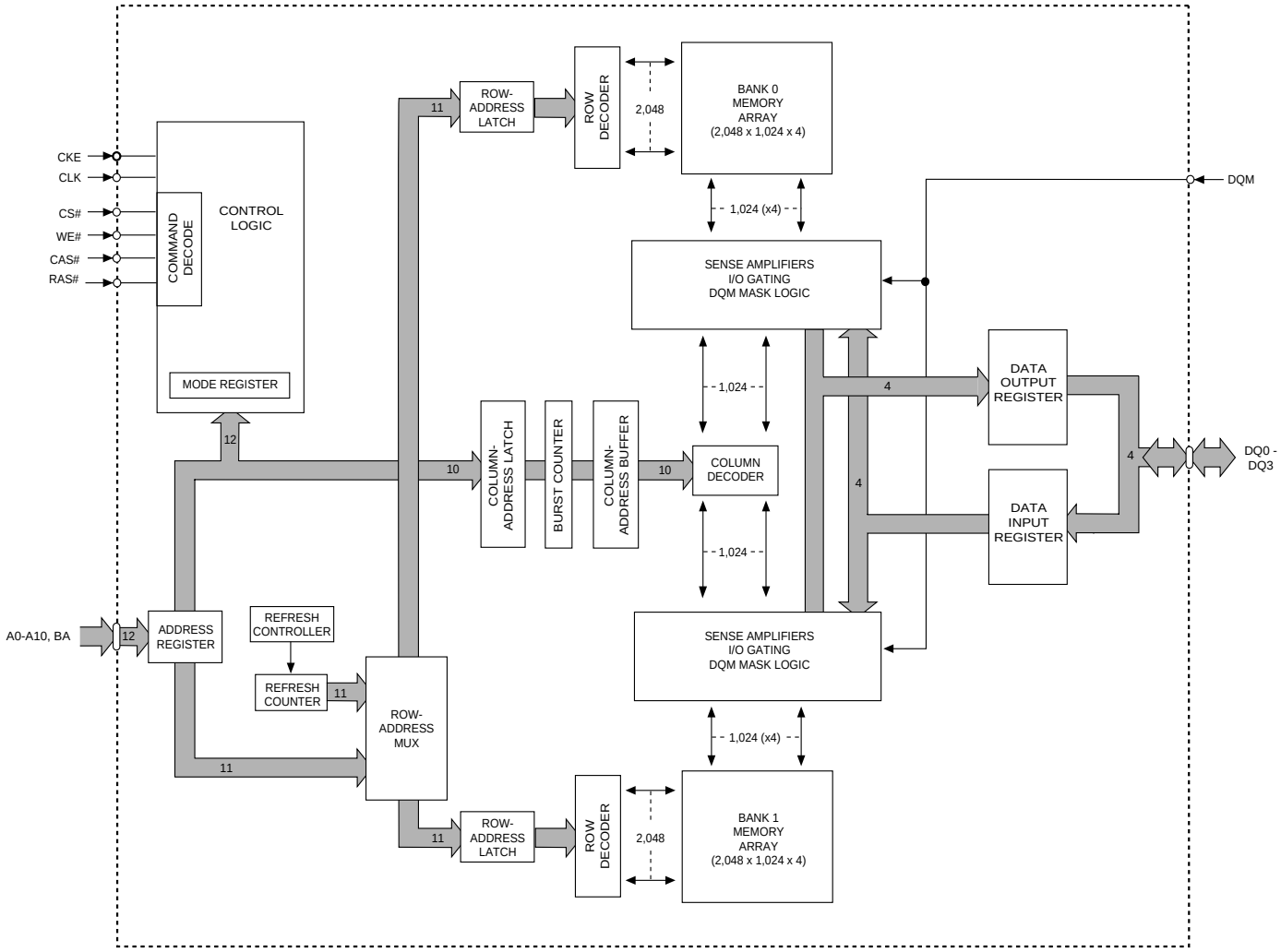
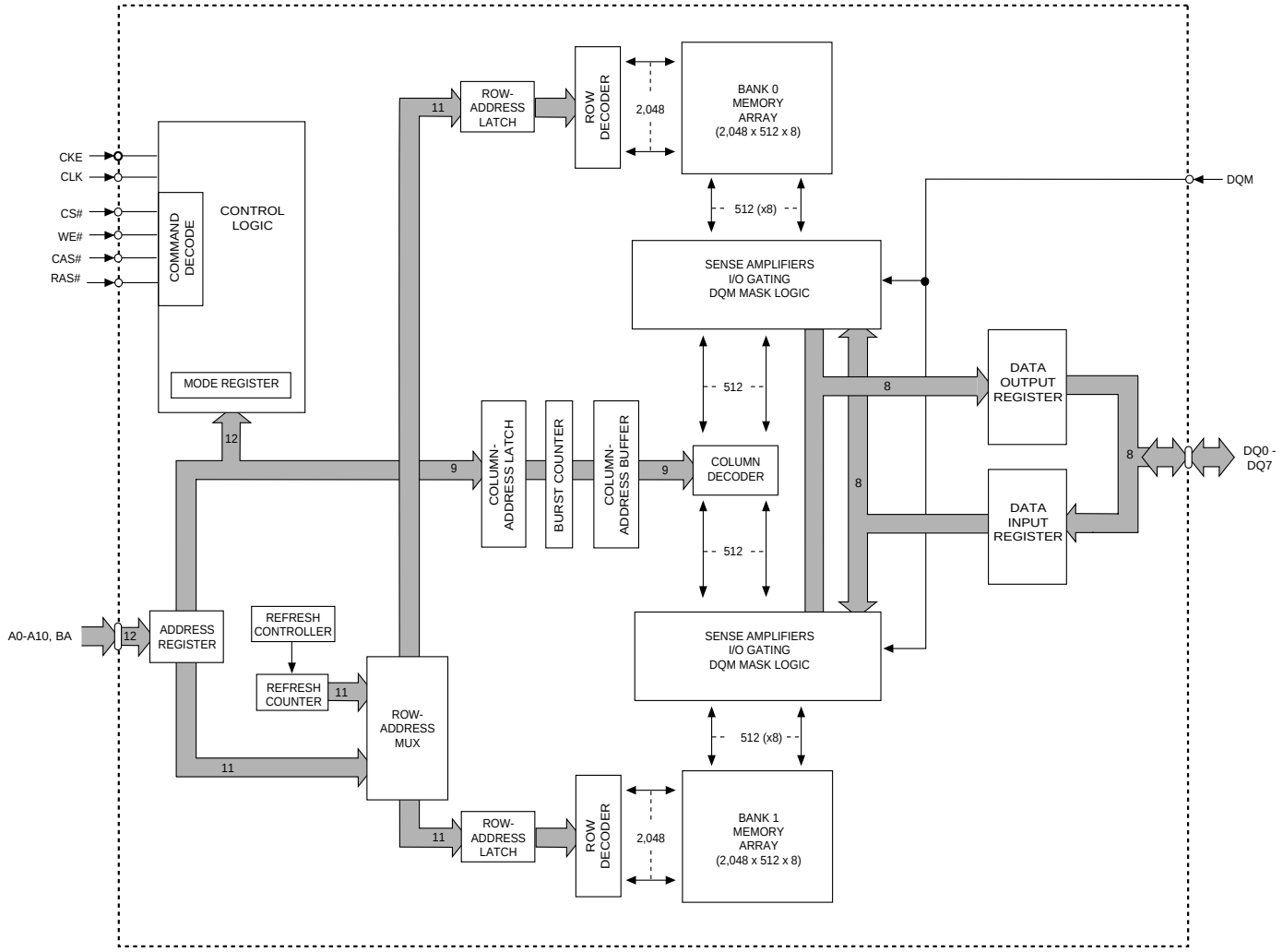
FUNCTIONAL BLOCK DIAGRAM
4 Meg x 4 SDRAM



FUNCTIONAL BLOCK DIAGRAM
2 Meg x 8 SDRAM



PIN DESCRIPTIONS

TSOP PIN NUMBERS	SYMBOL	TYPE	DESCRIPTION
32	CLK	Input	Clock: CLK is driven by the system clock. All SDRAM input signals are sampled on the positive edge of CLK. CLK also increments the internal burst counter and controls the output registers.
31	CKE	Input	Clock Enable: CKE activates (HIGH) and deactivates (LOW) the CLK signal. Deactivating the clock provides PRECHARGE POWER-DOWN and SELF REFRESH operations (all banks idle), ACTIVE POWER-DOWN (row ACTIVE in either bank), or CLOCK SUSPEND operation (burst/access in progress). CKE is synchronous except after the device enters power-down and self refresh modes, where CKE becomes asynchronous until after exiting the same mode. The input buffers, including CLK, are disabled during power-down and self refresh modes, providing low standby power. CKE may be tied HIGH.
15	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.
14, 13, 12	RAS#, CAS#, WE#	Input	Command Inputs: RAS#, CAS# and WE# (along with CS#) define the command being entered.
33	DQM	Input	Input/Output Mask: DQM is an input mask signal for write accesses and an output enable signal for read accesses. Input data is masked when DQM is sampled HIGH during a WRITE cycle. The output buffers are placed in a High-Z state (after a two-clock latency) when DQM is sampled HIGH during a READ cycle.
16	BA	Input	Bank Address: BA defines to which bank the ACTIVE, READ, WRITE or PRECHARGE command is being applied. BA is also used to program the 12th bit of the Mode Register.
18-21, 24-29, 17	A0-A10	Input	Address Inputs: A0-A10 are sampled during the ACTIVE command (row-address A0-A10) and READ/WRITE command (x4: column-address A0-A9; x8: column-address A0-A8, with A9 as a “Don’t Care,” and A10 defining AUTO PRECHARGE) to select one location out of the memory array in the respective bank. A10 is sampled during a PRECHARGE command to determine if both banks are to be precharged (A10 HIGH). The address inputs also provide the op-code during a LOAD MODE REGISTER command.
4, 8, 37, 41	x4: DQ0, 1, 2, 3 x8: DQ1, 3, 4, 6	Input	Data I/O: Data bus.
2, 6, 39, 43	x4: NC	—	No Connect: These pins should be left unconnected.
	x8: DQ0, 2, 5, 7	Input	Data I/O: Data bus.
10, 11, 30, 34, 35	NC	—	No Connect: These pins should be left unconnected.
5, 9, 36, 40	$V_{CC}Q$	Supply	DQ Power.
3, 7, 38, 42	$V_{SS}Q$	Supply	DQ Ground.
1, 22	V_{CC}	Supply	Power Supply: +3.3V ±0.3V.
23, 44	V_{SS}	Supply	Ground.

FUNCTIONAL DESCRIPTION

In general, the SDRAM is a dual memory array (the 4 Meg x 4 is a dual 2 Meg x 4, and the 2 Meg x 8 is a dual 1 Meg x 8) which operates at 3.3V and includes a synchronous interface (all signals are registered on the positive edge of the clock signal, CLK). Each of the two internal banks is organized with 2,048 rows and either 1,024 columns by 4 bits (4 Meg x 4) or 512 columns by 8 bits (2 Meg x 8).

Read and write accesses to the 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 (BA selects the bank, A0-A10 select the row). The address bits (A0-A9; A9 is a "Don't Care" for x8) registered coincident with the READ or WRITE command are used to select the starting column location for the burst access.

Prior to normal operation, the SDRAM must be initialized. The following sections provide detailed information covering device initialization, register definition, command descriptions and device operation.

INITIALIZATION

SDRAMs must be powered up and initialized in a predefined manner. Operational procedures other than those specified may result in undefined operation. Once power is applied to V_{CC} and $V_{CC}Q$ (simultaneously) and the clock is stable, the SDRAM requires a 100µs delay prior to applying an executable command. The RAS#, CAS#, WE# and CS# inputs should be held HIGH during this phase of power-up.

Once the 100µs delay has been satisfied, CKE HIGH and the PRECHARGE command can be applied (set up and held with respect to a positive edge of CLK). Both banks must be precharged, thereby placing the device in the All Banks Idle state.

Once in the Idle state, two AUTO REFRESH cycles must be performed. Once the AUTO REFRESH cycles are complete, the SDRAM is ready for Mode Register programming. Because the Mode Register will power up in an unknown state, it should be loaded prior to applying any operational command.

REGISTER DEFINITION

MODE REGISTER

The Mode Register is used to define the specific mode of operation of the SDRAM. This definition includes the selection of a burst length, a burst type, a CAS latency, an operating mode, and a write burst mode, as shown in Figure 1. The Mode Register is programmed via the LOAD MODE REGISTER command and will retain the stored information until it is programmed again or the device loses power.

Mode Register bits M0-M2 specify the burst length, M3 specifies the type of burst (sequential or interleaved), M4-M6 specify the CAS latency, M7 and M8 specify the operating mode, M9 specifies the write burst mode, and M10 and M11 are reserved for future use.

The Mode Register must be loaded when both banks are idle, and the controller must wait the specified time before initiating the subsequent operation. Violating either of these requirements will result in unspecified operation.

Burst Length

Read and write accesses to the SDRAM are burst oriented, with the burst length being programmable, as shown in Figure 1. The burst length determines the maximum number of column locations that can be accessed for a given READ or WRITE command. Burst lengths of 1, 2, 4 or 8 locations are available for both the sequential and the interleaved burst types, and a full-page burst is available for the sequential type. The full-page burst is used in conjunction with the BURST TERMINATE command to generate arbitrary burst lengths.

Reserved states should not be used, as unknown operation or incompatibility with future versions may result.

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 within the block if a boundary is reached. The block is uniquely selected by A1-A9 (A9 is "Don't Care" for x8) when the burst length is set to two, by A2-A9 (A9 is "Don't Care" for x8) when the burst length is set to four, and by A3-A9 (A9 is "Don't Care" for x8) when the burst length is set to eight. The remaining (least significant) address bit(s) are used to select the starting location within the block. Full-page bursts wrap within the page if the boundary is reached.

Burst Type

Accesses within a given burst may be programmed to be either sequential or interleaved; this is referred to as the burst type and is selected via bit M3.

The ordering of accesses within a burst is determined by the burst length, the burst type and the starting column address, as shown in Table 1.

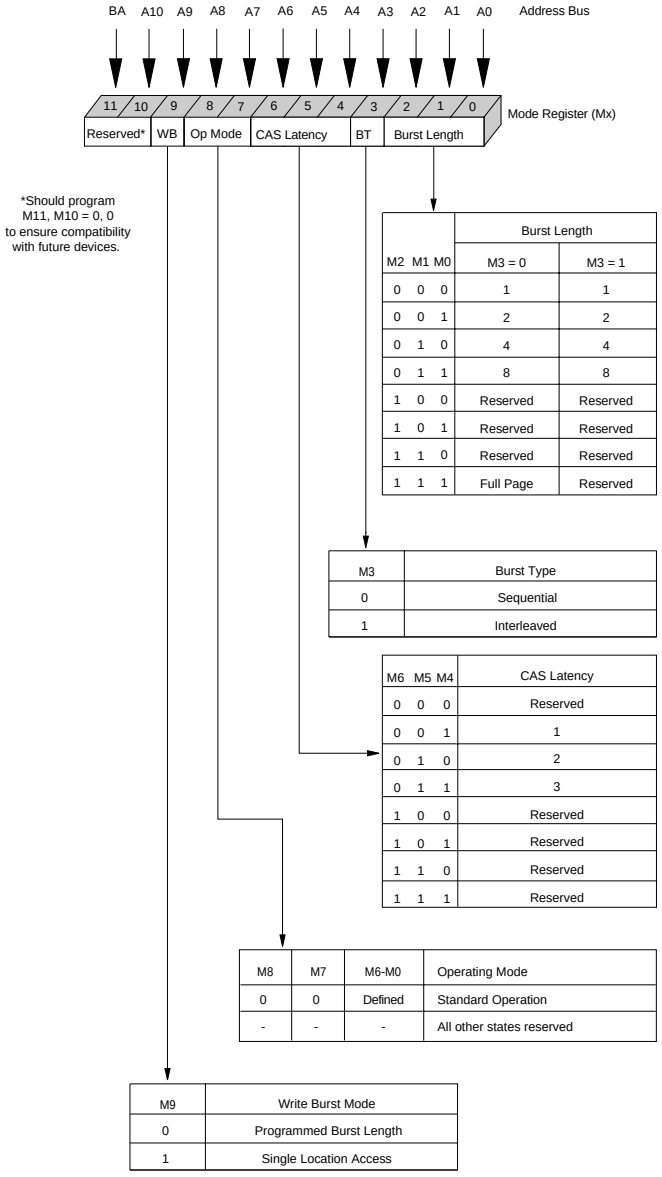


Figure 1
MODE REGISTER DEFINITION

Table 1
BURST DEFINITION

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
Full Page (x4: 1,024) (x8: 512)	x4: n = A0-A9 x8: n = A0-A8 (location 0-1,023) (location 0-511)			Cn, Cn+1, Cn+2 Cn+3, Cn+4... …Cn-1, Cn…	Not supported

NOTE:
1. For a burst length of two, A1-A9 (A9 is a “Don’t Care” for x8) select the block of two burst; A0 selects the starting column within the block.
2. For a burst length of four, A2-A9 (A9 is a “Don’t Care” for x8) select the block of four burst; A0-A1 select the starting column within the block.
3. For a burst length of eight, A3-A9 (A9 is a “Don’t Care” for x8) select the block of eight burst; A0-A2 select the starting column within the block.
4. For a full-page burst, the full row is selected and A0-A9 (A9 is a “Don’t Care” for x8) select the starting column.
5. Whenever a boundary of the block is reached within a given sequence above, the following access wraps within the block.
6. For a burst length of one, A0-A9 (A9 is a “Don’t Care” for x8) select the unique column to be accessed, and Mode Register bit M3 is ignored.

CAS Latency

The CAS latency is the delay, in clock cycles, between the registration of a READ command and the availability of the first piece of output data. The latency can be set to 1, 2 or 3 clocks.

If a READ command is registered at clock edge *n*, and the latency is *m* clocks, the data will be available by clock edge *n* + *m*. The DQs will start driving as a result of the clock edge one cycle earlier (*n* + *m* - 1) and, provided that the relevant access times are met, the data will be valid by clock edge *n* + *m*. For example, assuming that the clock cycle time is such that all relevant access times are met, if a READ command is registered at T0, and the latency is programmed to two clocks, the DQs will start driving after T1 and the data will be valid by T2, as shown in Figure 2. Table 2 below indicates the operating frequencies at which each CAS latency setting can be used.

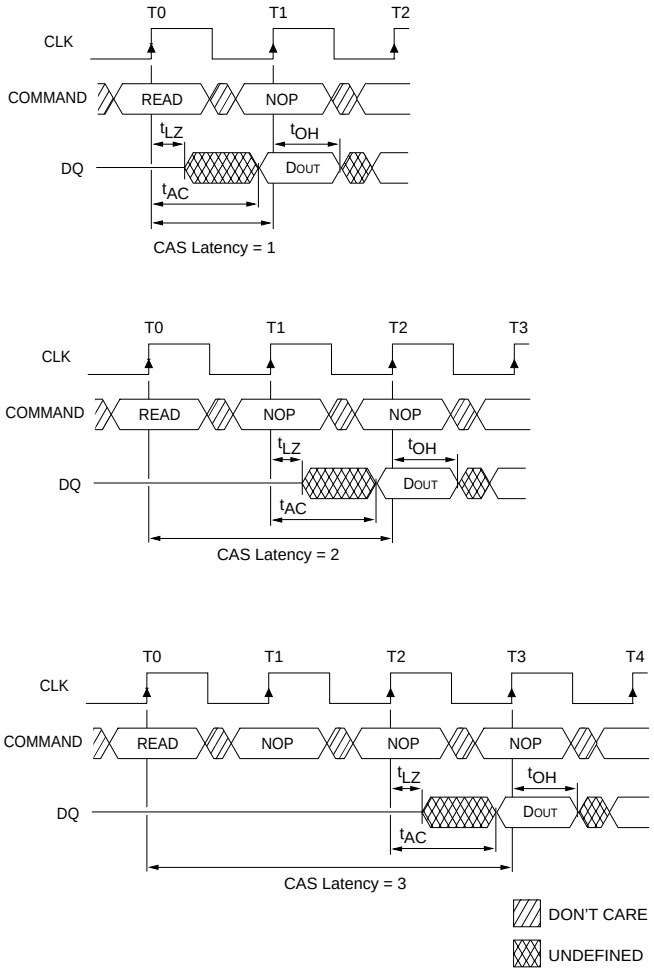


Figure 2
CAS LATENCY

Reserved states should not be used, as unknown operation or incompatibility with future versions may result.

Operating Mode

The normal operating mode is selected by setting M7 and M8 to zero; the other combinations of values for M7 and M8 are reserved for future use and/or test modes. The programmed burst length applies to both READ and WRITE bursts.

Test modes and reserved states should not be used because unknown operation or incompatibility with future versions may result.

Write Burst Mode

When M9 = 0, the burst length programmed via M0-M2 applies to both READ and WRITE bursts; when M9 = 1, the programmed burst length applies to READ bursts, but write accesses are single-location (nonburst) accesses.

Table 2
CAS LATENCY

SPEED	ALLOWABLE OPERATING FREQUENCY (MHz)		
	CAS LATENCY = 1	CAS LATENCY = 2	CAS LATENCY = 3
-8A	≤ 33	≤ 76	≤ 125
-10	≤ 33	≤ 66	≤ 100
-12	≤ 33	≤ 66	≤ 83

COMMANDS

Truth Table 1 provides a quick reference of available commands. This is followed by a verbal description of each command. Two additional Truth Tables appear following the Operation section; these tables provide current state / next state information.

TRUTH TABLE 1 – Commands and DQM Operation

(Notes: 1)

NAME (FUNCTION)	CS#	RAS#	CAS#	WE#	DQM	ADDR	DQs	NOTES
COMMAND INHIBIT (NOP)	H	X	X	X	X	X	X	
NO OPERATION (NOP)	L	H	H	H	X	X	X	
ACTIVE (select bank and activate row)	L	L	H	H	X	Bank/Row	X	3
READ (select bank and column and start READ burst)	L	H	L	H	X	Bank/Col	X	4
WRITE (select bank and column and start WRITE burst)	L	H	L	L	X	Bank/Col	Valid	4
BURST TERMINATE	L	H	H	L	X	X	Active	
PRECHARGE (deactivate row in bank or banks)	L	L	H	L	X	Code	X	5
AUTO REFRESH or SELF REFRESH (enter self refresh mode)	L	L	L	H	X	X	X	6, 7
LOAD MODE REGISTER	L	L	L	L	X	Op-code	X	2
Write Enable/Output Enable	-	-	-	-	L	-	Active	8
Write Inhibit/Output High-Z	-	-	-	-	H	-	High-Z	8

NOTE:
1. CKE is HIGH for all commands shown except SELF REFRESH.
2. A0-A10 and BA define the op-code written to the Mode Register.
3. A0-A10 provide row address, and BA determines which bank is made active (BA LOW = Bank 0 and BA HIGH = Bank 1).
4. A0-A9 (A9 is a “Don’t Care” for x8) provide column address; A10 HIGH enables the AUTO PRECHARGE feature (nonpersistent); while A10 LOW disables the AUTO PRECHARGE feature; BA determines which bank is being read from or written to (BA LOW = Bank 0 and BA HIGH = Bank 1).
5. For A10 LOW, BA determines bank being precharged (BA LOW = Bank 0 and BA HIGH = Bank 1); for A10 HIGH, both banks are precharged and BA is a “Don’t Care.”
6. This command is AUTO REFRESH if CKE is HIGH, SELF REFRESH if CKE is LOW.
7. Internal refresh counter controls row addressing; all inputs and I/Os are “Don’t Care” except for CKE.
8. Activates or deactivates the DQs during WRITEs (zero-clock delay) and READs (two-clock delay).

COMMAND INHIBIT

The COMMAND INHIBIT function prevents new commands from being executed by the SDRAM, regardless of whether the CLK signal is enabled. The SDRAM is effectively deactivated, or deselected.

NO OPERATION (NOP)

The NO OPERATION (NOP) command is used to perform a NOP to an SDRAM which is selected (CS# is LOW). This prevents unwanted commands from being registered during idle or wait states.

LOAD MODE REGISTER

The Mode Register is loaded via inputs A0-A10 and BA. See Mode Register heading in Register Definition section. The LOAD MODE REGISTER command can only be issued when both 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 value on the BA input selects the bank, and the address provided on inputs A0-A10 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.

READ

The READ command is used to initiate a burst read access to an active row. The value on the BA input selects the bank, and the address provided on inputs A0-A9 (A9 is a "Don't Care" on x8) selects the starting column location. The value on input A10 determines whether or not 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. Read data appears on the DQs, subject to the logic level on the DQM input, two clocks earlier. If the DQM signal was registered HIGH, the DQs will be High-Z two clocks later; if the DQM signal was registered LOW, the DQs will provide valid data.

WRITE

The WRITE command is used to initiate a burst write access to an active row. The value on the BA input selects the bank, and the address provided on inputs A0-A9 (A9 is a "Don't Care" on x8) selects the starting column location. The value on input A10 determines whether or not 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 DQM input logic level appearing coincident with the data. If the DQM signal is registered LOW, the corresponding data will be written to memory; if the DQM signal is registered HIGH, the corresponding data inputs will be ignored, and a write will not be executed to that location.

PRECHARGE

The PRECHARGE command is used to deactivate the open row in a particular bank or the open row in both 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 both banks are to be precharged, and in the case where only one bank is to be precharged, input BA selects the bank. Otherwise BA is treated as a "Don't Care." Once 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.

AUTO PRECHARGE

AUTO PRECHARGE is a feature which performs the same individual-bank PRECHARGE function described above, 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, except in the full-page burst mode, where AUTO PRECHARGE does not apply. 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. The user must not issue another command until the precharge time (^{t}RP) is completed. This is determined as if an explicit PRECHARGE command was issued at the earliest possible time, as described for each burst type in the Operation section of this data sheet.

BURST TERMINATE

The BURST TERMINATE command is used to truncate either fixed-length or full-page bursts. The most recently registered READ or WRITE command prior to the BURST TERMINATE command will be truncated, as shown in the Operation section of this data sheet.

AUTO REFRESH

AUTO REFRESH is used during normal operation of the SDRAM and is analagous to CAS#-BEFORE-RAS# (CBR) REFRESH in conventional DRAMs. This command is non-persistent, so it 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. The Micron 16Mb SDRAM requires all of its 4,096 rows to be refreshed every 64ms (^{t}REF). Providing a distributed AUTO REFRESH command every 15.6µs will meet the refresh requirement and ensure that each row is refreshed. Alternatively, all 4,096 AUTO REFRESH commands can be issued in a burst at the minimum cycle rate (^{t}RC) once every 64ms.

SELF REFRESH

The SELF REFRESH command can be used to retain data in the SDRAM, even if the rest of the system is powered down. When in the self refresh mode, the SDRAM retains data without external clocking. The SELF REFRESH command is initiated like an AUTO REFRESH command except CKE is disabled (LOW). Once the SELF REFRESH command is registered, all the inputs to the SDRAM become "Don't Cares," with the exception of CKE, which must remain LOW.

Once self refresh mode is engaged, the SDRAM provides its own internal clocking, causing it to perform its own auto refresh cycles. The SDRAM must remain in self refresh mode for a minimum period equal to ^{t}RAS and may remain in self refresh mode for an indefinite period beyond that.

The procedure for exiting self refresh requires a sequence of commands. First, CLK must be stable prior to CKE going back HIGH. Once CKE is HIGH, the SDRAM must have NOP commands issued (a minimum of two clocks) for ^{t}XSR because time is required for the completion of any internal refresh in progress.

A burst of 4,096 auto refresh cycles should be completed just prior to entering and just after exiting the self refresh mode.

OPERATION

BANK/ROW ACTIVATION

Before any READ or WRITE commands can be issued to a bank within the 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.

After opening a row (issuing an ACTIVE command), a READ or WRITE command may be issued to that row, subject to the ^{t}RCD specification. ^{t}RCD (MIN) should be divided by the clock period and rounded up to the next whole number to determine the earliest clock edge after the ACTIVE command on which a READ or WRITE command can be entered. For example, a ^{t}RCD specification of 30ns with a 90 MHz clock (11.11ns period) results in 2.7 clocks, rounded to 3. This is reflected in Figure 4, which covers any case where 2 < ^{t}RCD (MIN) / ^{t}CK < 3. (The same procedure is used to convert other specification limits from time units to clock cycles.)

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

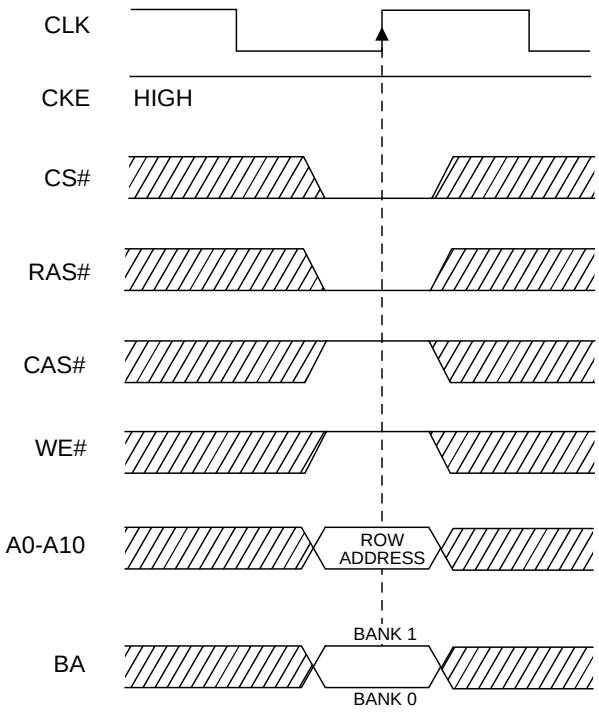


Figure 3
ACTIVATING A SPECIFIC ROW IN A SPECIFIC BANK

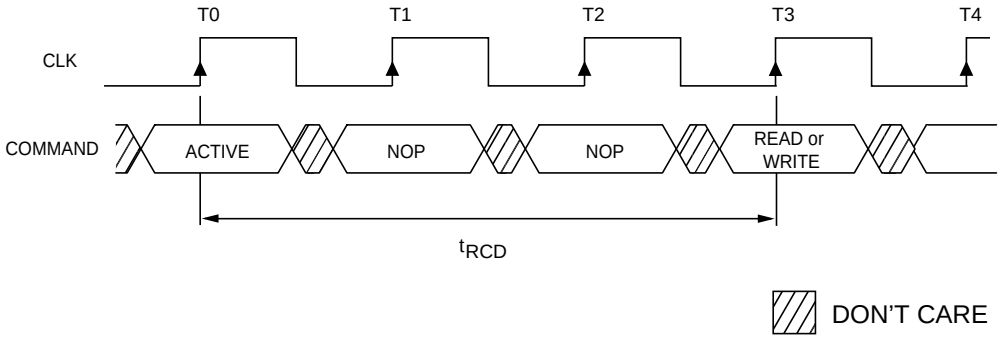


Figure 4
EXAMPLE: MEETING ^{t}RCD (MIN) WHEN 2 < ^{t}RCD (MIN)/^{t}CK < 3

READs

READ bursts are initiated with a READ command, as shown in Figure 5 (A9 is a "Don't Care"on x8).

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 generic 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 by the next positive clock edge. Figure 6 shows general timing for each possible CAS latency setting.

Upon completion of a burst, assuming no other commands have been initiated, the DQs will go High-Z. A full-page burst will continue until terminated. (At the end of the page it will wrap to column 0 and continue.)

A fixed-length READ burst may be followed by, or truncated with, a subsequent READ burst (provided that AUTO PRECHARGE is not activated), and a full-page READ burst can be truncated with a subsequent READ burst. In either case, a continuous flow of data can be maintained. The first data element from the new burst follows either 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 before the clock edge at which the last desired data element is valid, where

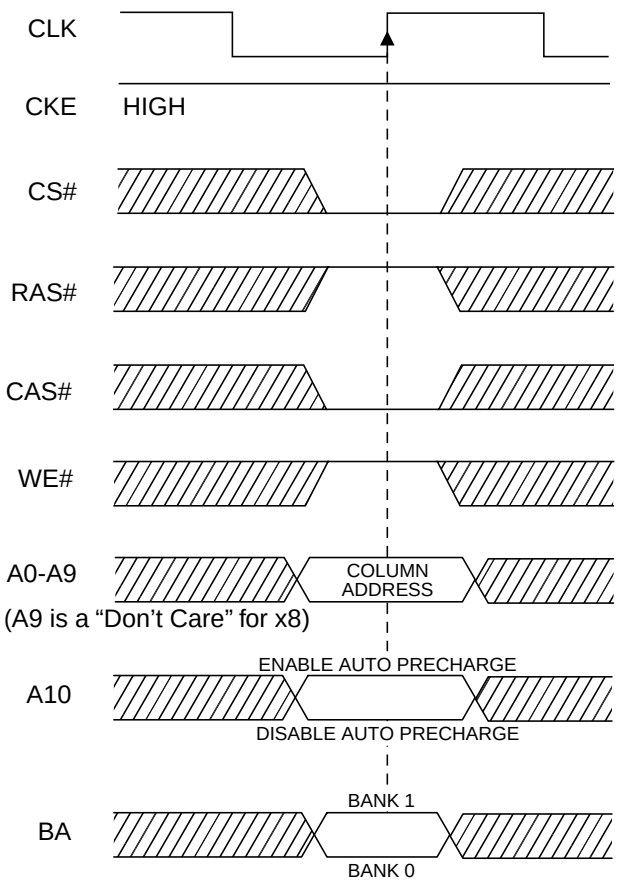


Figure 5
READ COMMAND

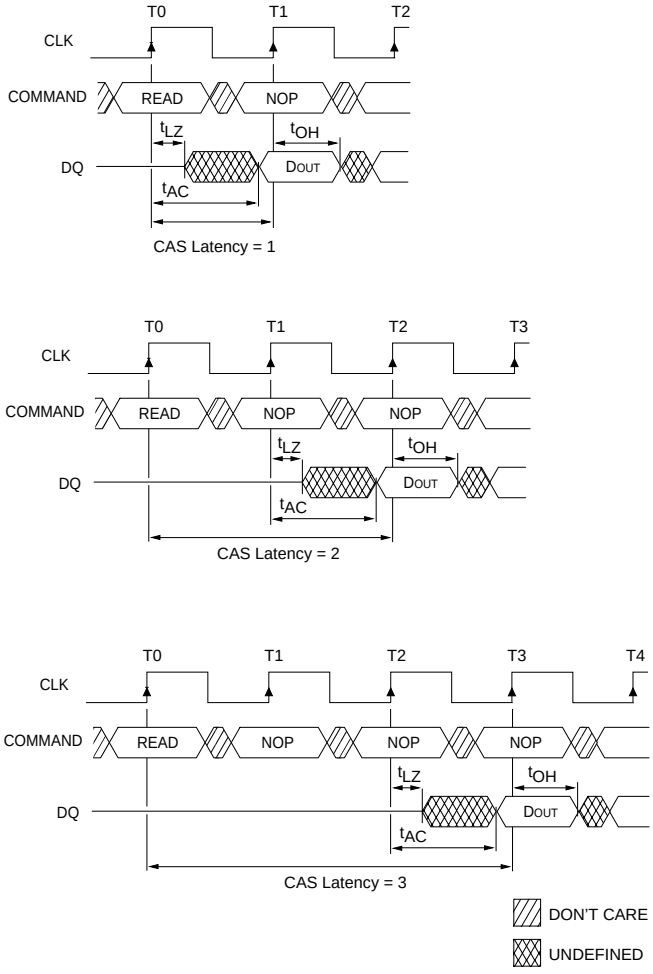
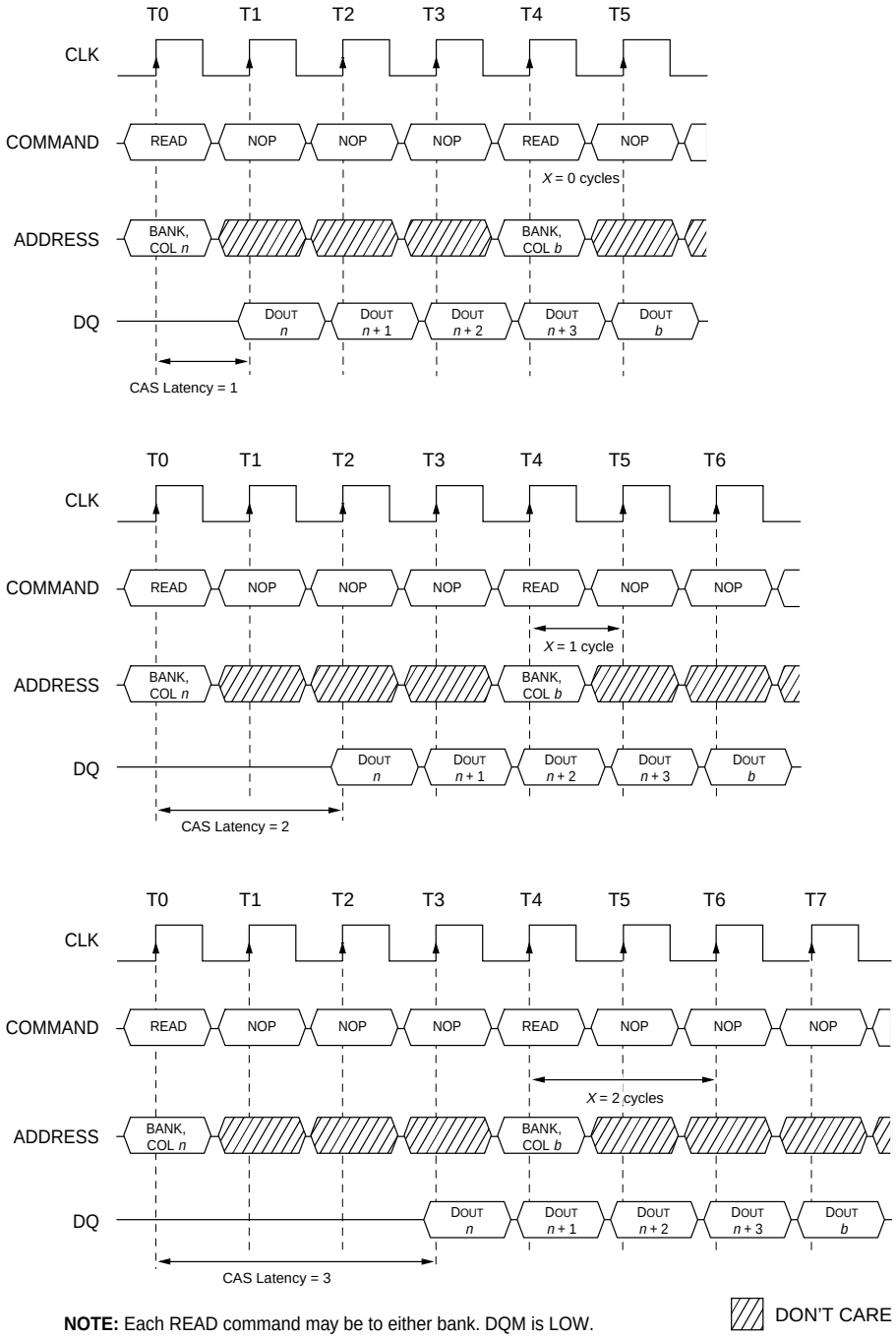


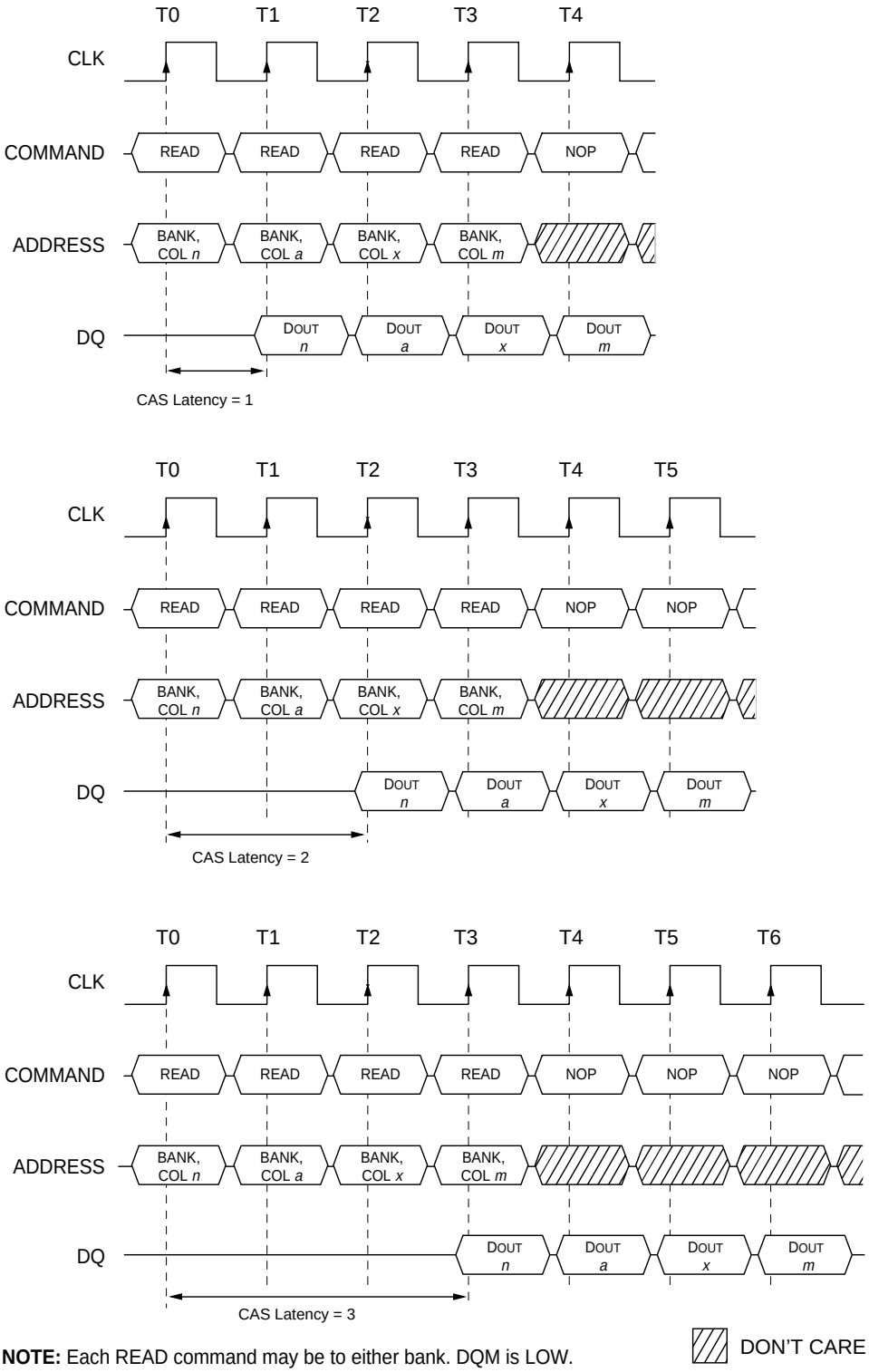
Figure 6
CAS LATENCY

x equals the CAS latency minus one. This is shown in Figure 7 for CAS latencies of one, two and three; data element *n* + 3 is either the last of a burst of four or the last desired of a longer burst. The Micron 16Mb SDRAM uses a pipelined architecture and therefore does not require the 2*n* rule associated with a prefetch architecture. A READ command can be initiated on any clock cycle following a previous READ command. Full-speed random read accesses within a page can be performed as shown in Figure 8.



NOTE: Each READ command may be to either bank. DQM is LOW.

Figure 7
CONSECUTIVE READ BURSTS

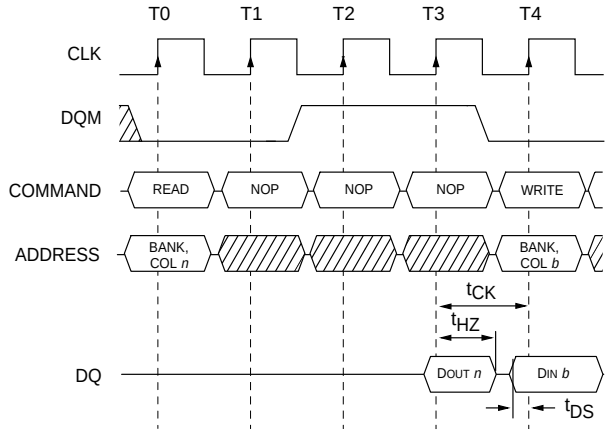


NOTE: Each READ command may be to either bank. DQM is LOW.

Figure 8
RANDOM READ ACCESSES WITHIN A PAGE

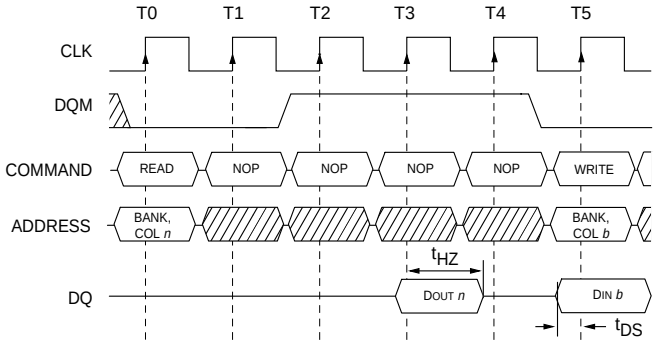
A fixed-length READ burst may be followed by, or truncated with, a WRITE burst (provided that AUTO PRECHARGE was not activated), and a full-page READ burst may be truncated by a WRITE burst. The WRITE burst may be initiated on the clock edge immediately following the last (or last desired) data element from the READ burst, provided that I/O contention can be avoided. In a given system design, there may be the possibility that the device driving the input data would go Low-Z before the SDRAM DQs go High-Z. In this case, a single-cycle delay should occur between the last read data and the WRITE command.

The DQM input is used to avoid I/O contention, as shown in Figures 9 and 10. The DQM signal must be asserted (HIGH) at least two clocks (DQM latency is two clocks for output buffers) prior to the WRITE command to suppress data-out from the READ. Once the WRITE command is registered, the DQs will go High-Z (or remain High-Z) regardless of the state of the DQM signal. The DQM signal must be de-asserted (DQM latency is zero clocks for input buffers) prior to the WRITE command to ensure that the written data is not masked. Figure 9 shows the case where the clock frequency allows for bus contention to be avoided without adding a NOP cycle, and Figure 10 shows the case where the additional NOP is needed.



NOTE: A CAS latency of three is used for illustration. The READ command may be to either bank, and the WRITE command may be to either bank. If a CAS latency of one is used, then DQM is not required.

Figure 9
READ TO WRITE



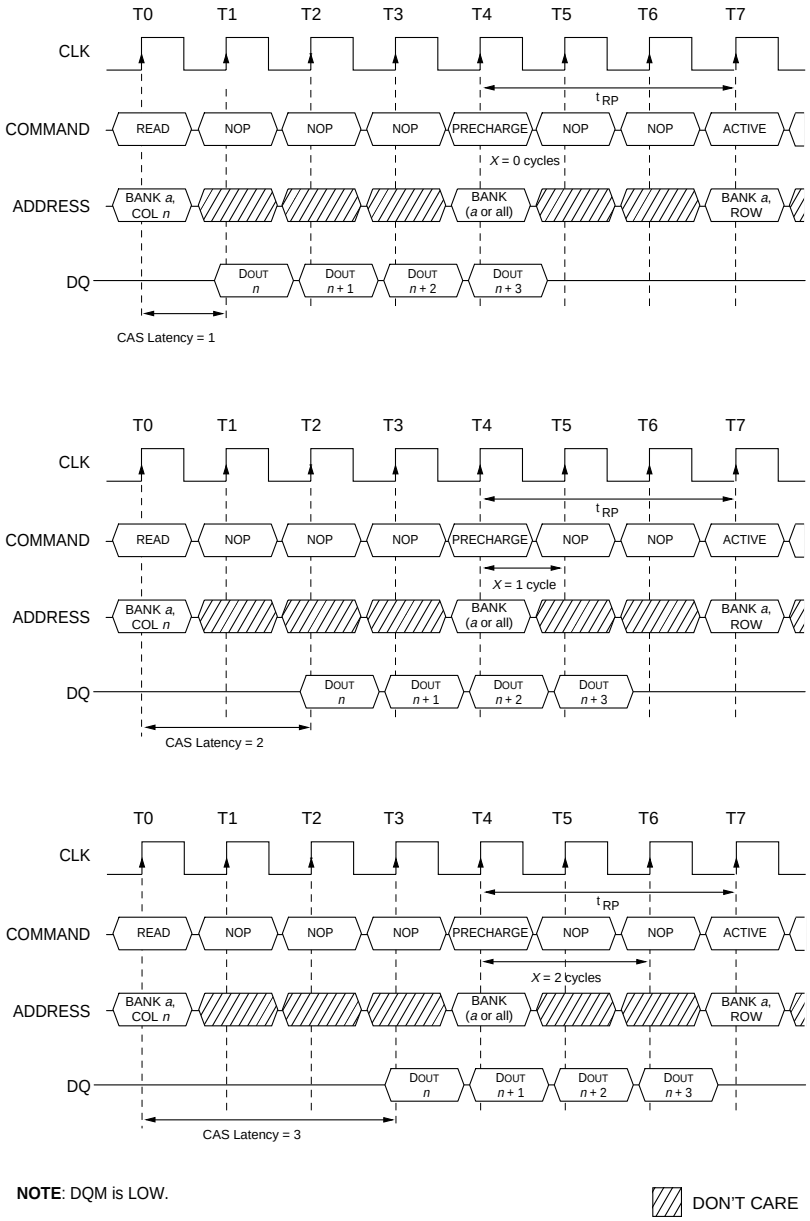
NOTE: A CAS latency of three is used for illustration. The READ command may be to either bank, and the WRITE command may be to either bank.

DON'T CARE

Figure 10
READ TO WRITE WITH EXTRA CLOCK CYCLE

A fixed-length READ burst may be followed by, or truncated with, a PRECHARGE command to the same bank (provided that AUTO PRECHARGE was not activated), and a full-page burst may be truncated with a PRECHARGE command to the same bank. The PRECHARGE command should be issued *x* cycles before the clock edge at which the last desired data element is valid, where *x* equals the CAS latency minus one. This is shown in Figure 11 for each possible CAS latency; data element *n* + 3 is either the last of a burst of four or the last desired of a longer burst. Following the PRECHARGE command, a subsequent command to the same bank cannot be issued until ^{t}RP is met. Note that part of the row precharge time is hidden during the access of the last data element(s).

In the case of a fixed-length burst being executed to completion, a PRECHARGE command issued at the optimum time (as described above) provides the same operation that would result from the same fixed-length burst



NOTE: DQM is LOW.

DON'T CARE

Figure 11
READ TO PRECHARGE

with AUTO PRECHARGE. The disadvantage of the PRECHARGE command is that it requires that the command and address buses be available at the appropriate time to issue the command, but the advantage of the PRECHARGE command is that it can be used to truncate fixed-length or full-page bursts. The AUTO PRECHARGE command does not truncate fixed-length bursts and does not apply to full-page bursts.

Full-page READ bursts can be truncated with the BURST TERMINATE command, and fixed-length READ bursts may be truncated with a BURST TERMINATE command, provided that AUTO PRECHARGE was not activated. The BURST TERMINATE command should be issued *x* cycles before the clock edge at which the last desired data element is valid, where *x* equals the CAS latency minus one. This is shown in Figure 12 for each possible CAS latency; data element *n* + 3 is the last desired data element of a longer burst.

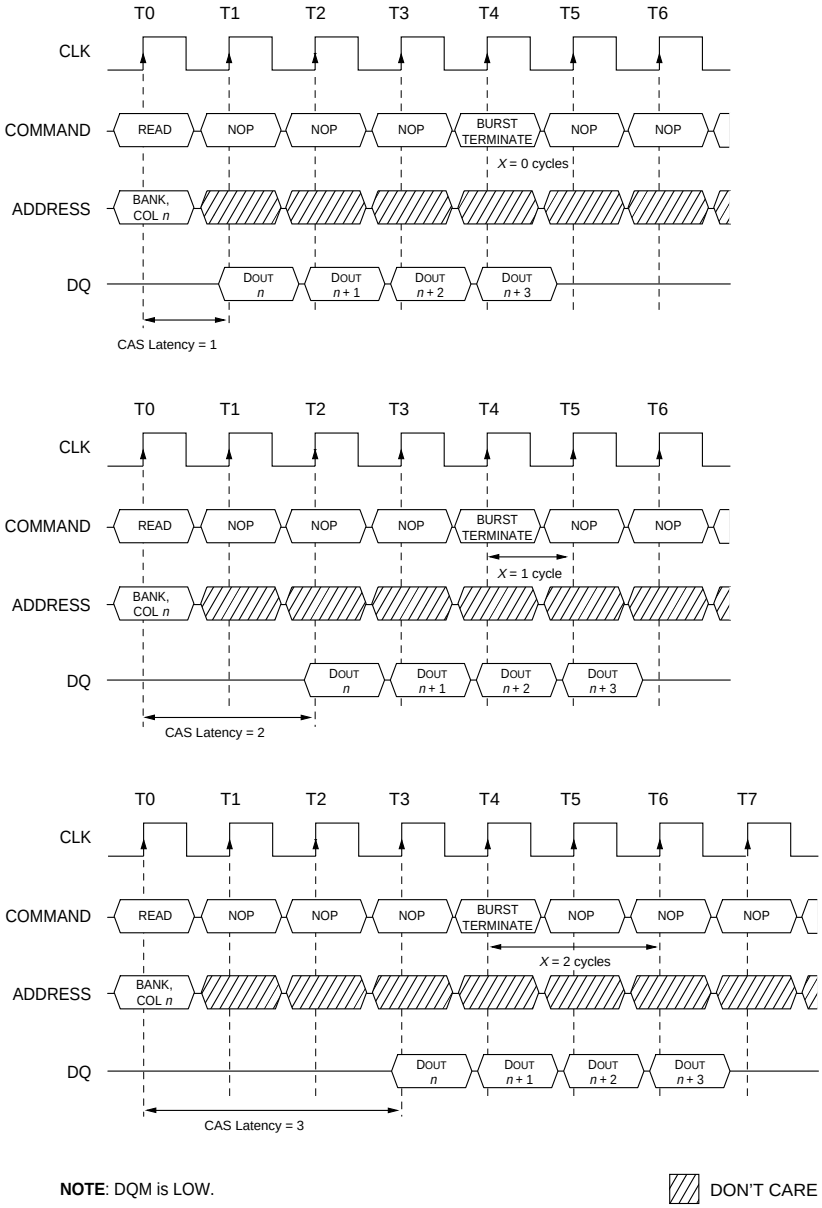


Figure 12
TERMINATING A READ BURST

WRITEs

WRITE bursts are initiated with a WRITE command, as shown in Figure 13 (A9 is a "Don't Care" on x8).

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 generic WRITE commands used in the following illustrations, AUTO PRECHARGE is disabled.

During WRITE bursts, the first valid data-in element will be registered coincident with the WRITE command. Subsequent data elements will be registered on each successive positive clock edge. Upon completion of a fixed-length burst, assuming no other commands have been initiated, the DQs will remain High-Z, and any additional input data will be ignored (see Figure 14). A full-page burst will continue until terminated (at the end of the page it will wrap to column 0 and continue).

A fixed-length WRITE burst may be followed by, or truncated with, a subsequent WRITE burst (provided that AUTO PRECHARGE was not activated) and a full-page WRITE burst can be truncated with a subsequent WRITE burst. The new WRITE command can be issued on any clock following the previous WRITE command, and the data provided coincident with the new command applies to the new command. An example is shown in Figure 15. Data $n + 1$ is either the last of a burst of two or the last desired of a longer burst. The Micron 16Mb SDRAM uses a pipelined architecture and therefore does not require the 2n rule associated with a prefetch architecture. A WRITE command can be initiated on any clock cycle following a previ-

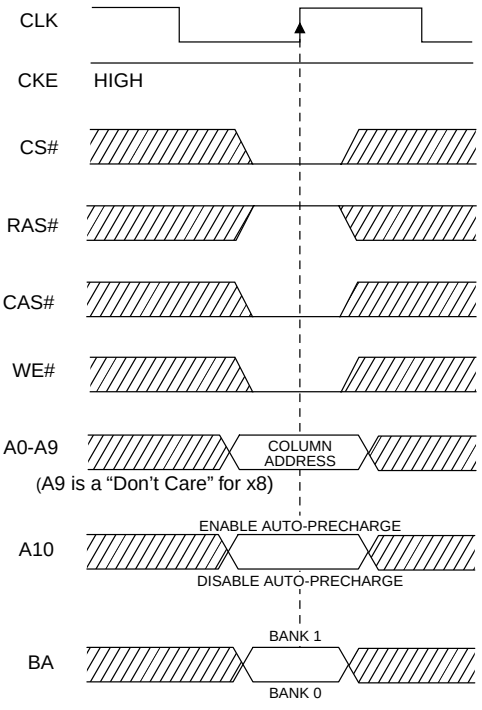
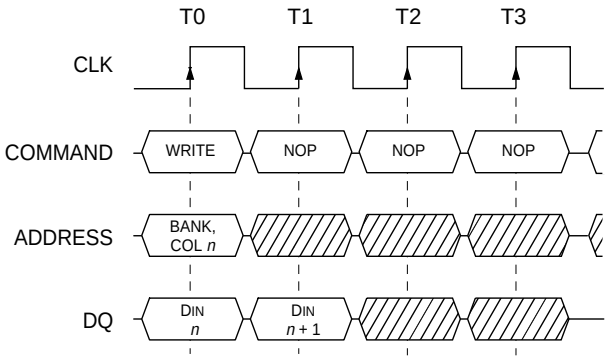
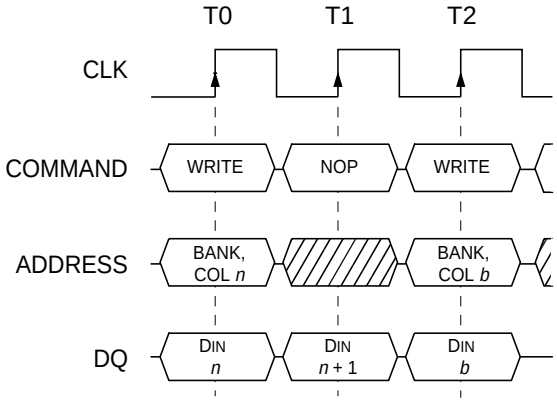


Figure 13
WRITE COMMAND



NOTE: Burst length = 2. DQM is LOW.

Figure 14
WRITE BURST



NOTE: DQM is LOW. Each WRITE command may be to either bank.

DON'T CARE

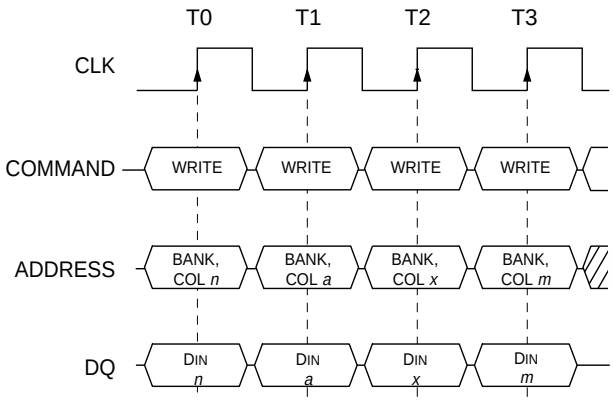
Figure 15
WRITE TO WRITE

ous WRITE command. Full-speed random write accesses within a page can be performed as shown in Figure 16.

A fixed-length WRITE burst may be followed by, or truncated with, a subsequent READ burst (provided that AUTO PRECHARGE was not activated), and a full-page WRITE burst can be truncated with a subsequent READ burst. Once the READ command is registered, the data inputs will be ignored, and WRITEs will not be executed. An example is shown in Figure 17. Data *n* + 1 is either the last of a burst of two or the last desired of a longer burst.

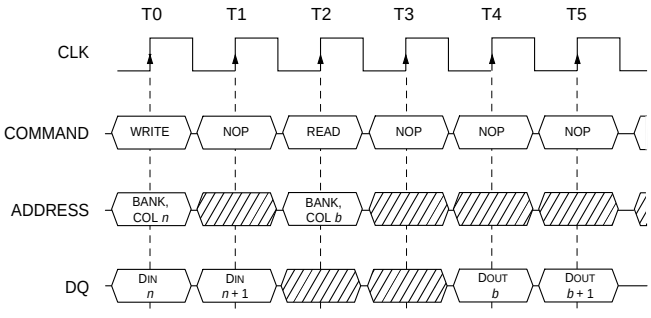
A fixed-length WRITE burst may be followed by, or truncated with, a PRECHARGE command to the same bank (provided that AUTO PRECHARGE was not activated), and a full-page WRITE burst may be truncated with a PRECHARGE command to the same bank. The PRECHARGE command should be issued ^{t}WR after the clock edge at which the last desired input data element is registered. The two-clock WRITE recovery version (A2) requires at least two clocks, regardless of frequency, as well as ^{t}WR being met. In addition, when truncating a WRITE burst, the DQM signal must be used to mask input data for the clock edge on which the PRECHARGE command is entered. An example is shown in Figure 18. Data *n* + 1 is either the last of a burst of two or the last desired of a longer burst. Following the PRECHARGE command, a subsequent command to the same bank cannot be issued until ^{t}RP is met.

In the case of a fixed-length burst being executed to completion, a PRECHARGE command issued at the optimum time (as described above) provides the same operation that would result from the same fixed-length burst with AUTO PRECHARGE. The disadvantage of the PRECHARGE command is that it requires that the command and address buses be available at the appropriate time to issue the command, but the advantage of the PRECHARGE command is that it can be used to truncate



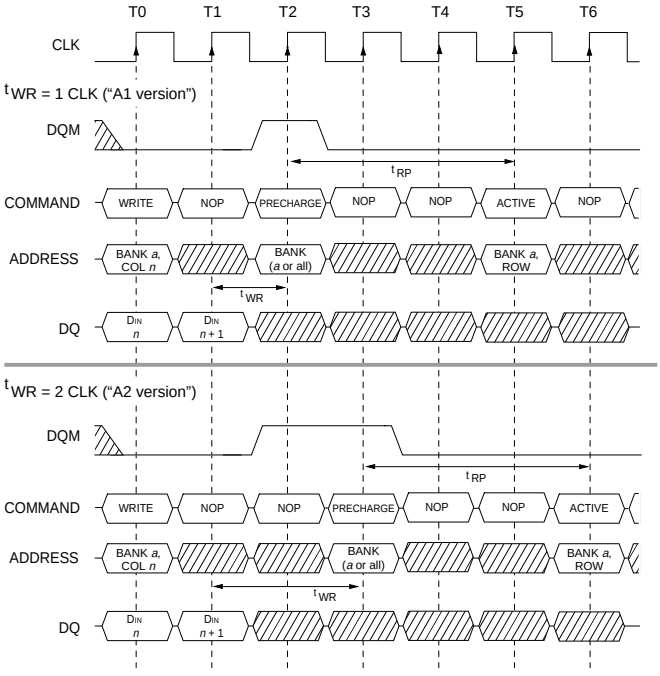
NOTE: Each WRITE command may be to either bank. DQM is LOW.

Figure 16
RANDOM WRITE CYCLES WITHIN A PAGE



NOTE: The WRITE command may be to either bank, and the READ command may be to either bank. DQM is LOW. CAS latency = 2 for illustration.

Figure 17
WRITE TO READ



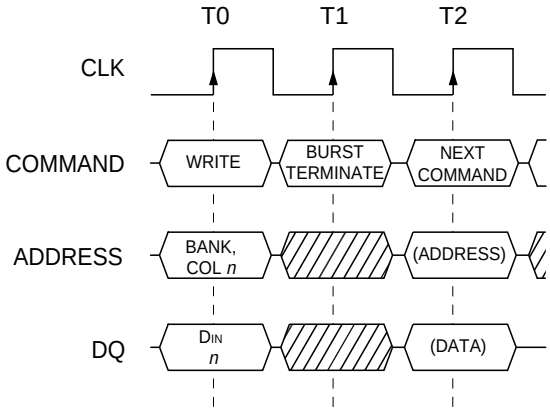
NOTE: DQM could remain LOW in this example if the WRITE burst is a fixed length of two.

DON'T CARE

Figure 18
WRITE TO PRECHARGE

fixed-length or full-page bursts. The AUTO PRECHARGE command does not truncate fixed-length bursts and does not apply to full page bursts.

Fixed-length or full-page WRITE bursts can be truncated with the BURST TERMINATE command. When truncating a WRITE burst, the input data applied coincident with the BURST TERMINATE command will be ignored. The last data written (provided that DQM is LOW at that time) will be the input data applied one clock previous to the BURST TERMINATE command. This is shown in Figure 19, where data *n* is the last desired data element of a longer burst.



NOTE: DQMs are LOW.

Figure 19
TERMINATING A WRITE BURST

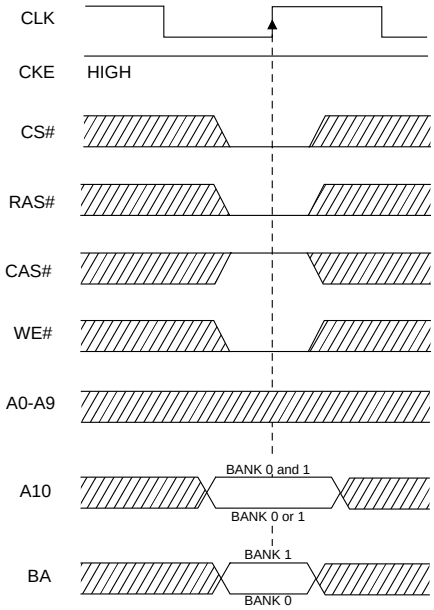


Figure 20
PRECHARGE COMMAND

PRECHARGE

The PRECHARGE command is used to deactivate the open row in a particular bank or the open row in both 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 both banks are to be precharged, and in the case where only one bank is to be precharged, input BA selects the bank. When both banks are to be precharged, input BA is treated as a "Don't Care." Once 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.

POWER-DOWN

POWER-DOWN occurs if CKE is registered LOW coincident with a NOP or COMMAND INHIBIT, when no accesses are in progress. If POWER-DOWN occurs when both banks are idle, this mode is referred to as precharge power-down; if POWER-DOWN occurs when there is a row active in either bank, this mode is referred to as active power-down. Entering power-down deactivates the input and output buffers, excluding CKE, for maximum power savings while in standby. The device may not remain in the power-down state longer than the refresh period (64ms) since no refresh operations are performed in this mode.

The power-down state is exited by registering a NOP or COMMAND INHIBIT and CKE HIGH at the desired clock edge (meeting ^{t}CKS).

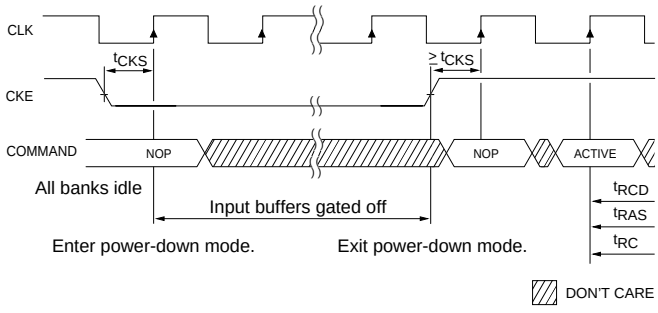


Figure 21
POWER-DOWN

CLOCK SUSPEND

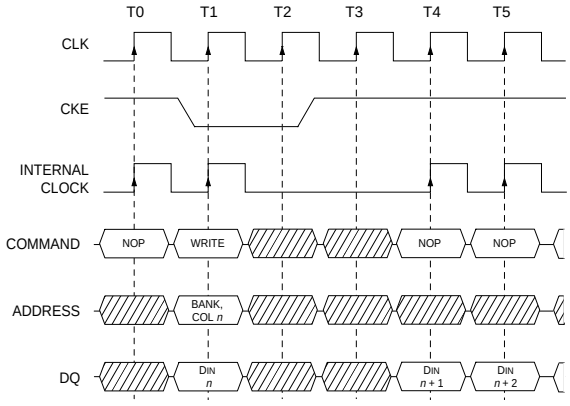
The clock suspend mode occurs when a column access / burst is in progress and CKE is registered LOW. In the clock suspend mode, the internal clock is deactivated, "freezing" the synchronous logic.

For each positive clock edge on which CKE is sampled LOW, the next internal positive clock edge is suspended. Any command or data present on the input pins at the time of a suspended internal clock edge are ignored, any data present on the DQ pins will remain driven, and burst counters are not incremented, as long as the clock is suspended (see examples in Figures 22 and 23).

Clock suspend mode is exited by registering CKE HIGH; the internal clock and related operation will resume on the subsequent positive clock edge.

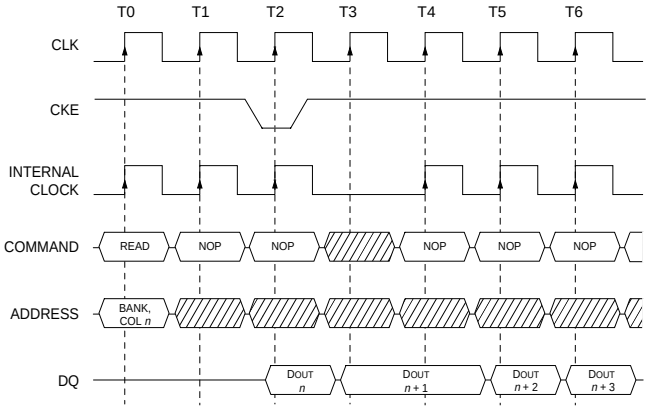
BURST READ/SINGLE WRITE

The burst read / single write mode is entered by programming the write burst mode bit (M9) in the Mode Register to a logic 1. In this mode, all WRITE commands result in the access of a single column location (burst of 1) regardless of the programmed burst length. READ commands access columns according to the programmed burst length and sequence, just as in the normal mode of operation (M9 = 0).



NOTE: For this example, burst length = 4 or greater, and DQM is LOW.

Figure 22
CLOCK SUSPEND DURING WRITE BURST



NOTE: For this example, CAS latency = 2, burst length = 4 or greater, and DQM is LOW.

DON'T CARE

Figure 23
CLOCK SUSPEND DURING READ BURST

TRUTH TABLE 2 – CKE

(Notes 1-4)

CKE_{n-1}	CKE_n	CURRENT STATE	$COMMAND_n$	$ACTION_n$	NOTES
L	L	Power-Down	X	Maintain Power-Down	
		Self Refresh	X	Maintain Self Refresh	
		Clock Suspend	X	Maintain Clock Suspend	
L	H	Power-Down	COMMAND INHIBIT or NOP	Exit Power-Down	5
		Self Refresh	COMMAND INHIBIT or NOP	Exit Self Refresh	6
		Clock Suspend	X	Exit Clock Suspend	7
H	L	Both Banks Idle	COMMAND INHIBIT or NOP	Power-Down Entry	
		Both Banks Idle	AUTO REFRESH	Self Refresh Entry	
		Reading or Writing	VALID	Clock Suspend Entry	
H	H		See Truth Table 3		

NOTE:
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 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. Exiting POWER-DOWN at clock edge *n* will put the device in the All Banks Idle state in time for clock edge *n + 1* (provided that ^tCKS is met).
6. Exiting SELF REFRESH at clock edge *n* will put the device in the All Banks Idle state once ^tXSR is met. COMMAND INHIBIT or NOP commands should be issued on any clock edges occurring during the ^tXSR period. A minimum of two NOP commands must be provided during the ^tXSR period.
7. After exiting CLOCK SUSPEND at clock edge *n*, the device will resume operation and recognize the next command at clock edge *n + 1*.

TRUTH TABLE 3 – Current State

(Notes 1-7)

CURRENT STATE	CS#	RAS#	CAS#	WE#	COMMAND/ACTION	NOTES
Any	H	X	X	X	COMMAND INHIBIT (NOP/continue previous operation)	
	L	H	H	H	NO OPERATION (NOP/continue previous operation)	
Idle	L	L	H	H	ACTIVE (select bank and activate row)	
	L	L	L	H	AUTO REFRESH	8
	L	L	L	L	LOAD MODE REGISTER	8
Row Active	L	H	L	H	READ (select bank and column and start READ burst)	
	L	H	L	L	WRITE (select bank and column and start WRITE burst)	
	L	L	H	L	PRECHARGE (deactivate row in bank or banks)	10
Read (Auto-Precharge Disabled)	L	H	L	H	READ (select bank and column and start new READ burst)	9
	L	H	L	L	WRITE (select bank and column and start WRITE burst)	9
	L	L	H	L	PRECHARGE (truncate READ burst, start precharge)	10
	L	H	H	L	BURST TERMINATE	11
Write (Auto-Precharge Disabled)	L	H	L	H	READ (select bank and column and start READ burst)	9
	L	H	L	L	WRITE (select bank and column and start new WRITE burst)	9
	L	L	H	L	PRECHARGE (truncate WRITE burst, start precharge)	10
	L	H	H	L	BURST TERMINATE	11

NOTES:

1. This table applies when CKE_{n-1} was HIGH and CKE_n is HIGH (see Truth Table 2) and after ^tXSR has been met (if the previous state was self refresh).
2. This table is bank-specific, except where noted; i.e., the current state is for a specific bank, and the commands shown are those allowed to be issued to that bank when it is 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 the other bank are determined by its current state and Truth Table 3, with exceptions as listed in Note 5.
   - Precharging: Starts with registration of a PRECHARGE command and ends when ^tRP is met. Once ^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. Once ^tRCD is met, the bank will be in the Row Active state.

NOTES (continued):

Read w/Auto-Precharge Enabled: Starts with registration of a READ command with AUTO PRECHARGE enabled, and ends when ^{t}RP has been met. Once ^{t}RP 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 ^{t}RP has been met. Once ^{t}RP is met, the bank will be in the Idle state.

5. When issuing commands to a given bank (referred to as the second bank, for discussion) the state of the other (first) bank must be considered as well. Below is a list of additional restrictions on allowable commands to the second bank, based on the state of the first bank.

State of First Bank	Additional Restrictions on Command to Second Bank
Idle	None
Row Activating	ACTIVE command not allowed (^{t}RRD specification)
Row Active	None
Read	None
Write	None
Precharging	None
Read w/Auto-Precharge Enabled	See following text
Write w/Auto-Precharge Enabled	See following text

The Read w/Auto Precharge Enabled or Write w/Auto Precharge Enabled states can each be broken into two parts, the access period and the precharge period. 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. The access period starts with registration of the command and ends where the precharge period (or ^{t}RP) begins.

During the precharge period of the Read w/Auto Precharge Enabled or Write w/Auto Precharge Enabled states, ACTIVE, PRECHARGE, READ and WRITE commands to the other bank may be applied; during the access period, only ACTIVE and PRECHARGE commands to the other bank may be applied. *Future SDRAM designs will not have this restriction during the access period.*

6. The following states must not be interrupted by any executable command; COMMAND INHIBIT 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}RC is met. Once ^{t}RC is met, the 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}MTC has been met. Once ^{t}MTC is met, the SDRAM will be in the All Banks Idle state.

7. All states and sequences not shown are illegal or reserved.
8. Not bank-specific; requires that both banks are idle.
9. READ and WRITE accesses will interact between banks as they do within a bank.
10. May or may not be bank specific; if both banks are to be precharged, both must be in a valid state for precharging.
11. Not bank specific; BURST TERMINATE affects the most recent READ or WRITE burst, regardless of bank.

ABSOLUTE MAXIMUM RATINGS*

Voltage on V_{CC} / $V_{CC}Q$ Supply
Relative to V_{SS} ..... -1V to +4.6V
Voltage on Inputs, NC or I/O Pins
Relative to V_{SS} ..... -1V to +4.6V
Operating Temperature, T_A (ambient) ..... 0°C to +70°C
Storage Temperature (plastic)..... -55°C to +150°C
Power Dissipation 1W
Short Circuit Output Current 50mA

*Stresses greater than those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

DC ELECTRICAL CHARACTERISTICS AND OPERATING CONDITIONS

(Notes: 1, 6) (0°C ≤ T_A ≤ 70°C; V_{CC}/$V_{CC}Q$ = +3.3V ±0.3V)

PARAMETER/CONDITION	SYMBOL	MIN	MAX	UNITS	NOTES
Supply Voltage	V_{CC}/$V_{CC}Q$	3.0	3.6	V	
Input High (Logic 1) Voltage, all inputs	V_{IH}	2.0	V_{CC} +0.3	V	
Input Low (Logic 0) Voltage, all inputs	V_{IL}	-0.3	0.8	V	
INPUT LEAKAGE CURRENT Any input 0V ≤ V_{IN} ≤ V_{CC} (All other pins not under test = 0V)	I_I	-5	5	µA	
OUTPUT LEAKAGE CURRENT (DQs are disabled; 0V ≤ V_{OUT} ≤ $V_{CC}Q$)	I_{OZ}	-5	5	µA	
OUTPUT LEVELS Output High Voltage (I_{OUT} = -2mA)	V_{OH}	2.4		V	
Output Low Voltage (I_{OUT} = 2mA)	V_{OL}		0.4	V	

Icc SPECIFICATIONS AND CONDITIONS

(Notes: 1, 6, 13) (0°C ≤ T_A ≤ 70°C; V_{CC}/$V_{CC}Q$ = +3.3V ±0.3V)

		MAX				
PARAMETER/CONDITION	SYMBOL	-8A	-10	-12	UNITS	NOTES
OPERATING CURRENT: Active Mode, Burst = 2, READ or WRITE, ^tRC ≥ ^tRC (MIN), CAS latency = 3	I_{CC1}	105	90	85	mA	3, 18, 19
STANDBY CURRENT: Power-Down Mode, ^tCK = 15ns (10ns for -8), CKE ≤ V_{IL} (MAX), All banks idle	I_{CC2}	3	2	3	mA	
STANDBY CURRENT: CS# ≥ V_{IH} (MIN), CKE ≥ V_{IH} (MIN), ^tCK = 15ns (10ns for -8), All banks idle	I_{CC3}	40	30	30	mA	12, 19
STANDBY CURRENT: CS# ≥ V_{IH} (MIN), CKE ≥ V_{IH} (MIN), ^tCK = 15ns (10ns for -8), All banks active after ^tRCD met, No accesses in progress	I_{CC4}	45	40	40	mA	12, 19
OPERATING CURRENT: Burst Mode, Continuous burst, READ or WRITE, ^tCK = 15ns (10ns for -8), All banks active, Addresses transition once per clock cycle, CAS latency = 3	I_{CC5}	125	85	80	mA	3, 18, 19
AUTO REFRESH CURRENT: ^tRC ≥ ^tRC (MIN), CAS latency = 3	I_{CC6}	95	85	80	mA	3, 18, 19
SELF REFRESH CURRENT: CKE ≤ 0.2V	I_{CC7}	2	2	2	mA	4

CAPACITANCE

PARAMETER	SYMBOL	MAX	UNITS	NOTES
Input Capacitance: A0-A10, BA	C_{I1}	5	pF	2
Input Capacitance: RAS#, CAS#, WE#, DQM, CLK, CKE, CS#	C_{I2}	5	pF	2
Input/Output Capacitance: DQs	C_{IO}	6	pF	2

ELECTRICAL CHARACTERISTICS AND RECOMMENDED AC OPERATING CONDITIONS

(Notes: 5, 6, 8, 9, 11) ($0°C \le T_A \le +70°C$)

AC CHARACTERISTICS			-8A		-10		-12			
PARAMETER		SYM	MIN	MAX	MIN	MAX	MIN	MAX	UNITS	NOTES
Access time from CLK (pos. edge)	CL = 3	^tAC		6		7.5		9	ns	
	CL = 2	^tAC		9		9		9	ns	
	CL = 1	^tAC		27		27		27	ns	
Address hold time		^tAH	1		1		1		ns	
Address setup time		^tAS	2		3		3		ns	
CLK high-level width		^tCH	3		3.5		3.5		ns	
CLK low-level width		^tCL	3		3.5		3.5		ns	
Clock cycle time	CL = 3	^tCK	8		10		12		ns	
	CL = 2	^tCK	13		15		15		ns	
	CL = 1	^tCK	30		30		30		ns	
CKE hold time		^tCKH	1		1		1		ns	
CKE setup time		^tCKS	2		3		3		ns	
CS#, RAS#, CAS#, WE#, DQM hold time		^tCMH	1		1		1		ns	
CS#, RAS#, CAS#, WE#, DQM setup time		^tCMS	2		3		3		ns	
Data-in hold time		^tDH	1		1		1		ns	
Data-in setup time		^tDS	2		3		3		ns	
Data-out high-impedance time	CL = 3	^tHZ		6		8		9	ns	10
	CL = 2	^tHZ		7		10		10	ns	10
	CL = 1	^tHZ		15		15		15	ns	10
Data-out low-impedance time		^tLZ	1		2		2		ns	
Data-out hold time		^tOH	3		3		3		ns	
ACTIVE to PRECHARGE command		^tRAS	50	120K	60	120K	72	120K	ns	
AUTO REFRESH, ACTIVE command period		^tRC	80		90		105		ns	
ACTIVE to READ or WRITE delay		^tRCD	30		30		30		ns	
Refresh period - 2,048 or 4,096 rows		^tREF		64		64		64	ms	
PRECHARGE command period		^tRP	30		30		36		ns	21
ACTIVE bank A to ACTIVE bank B command		^tRRD	20		20		20		ns	
Transition time		^tT	0.3	1.2	0.3	10	1	20	ns	7
WRITE recovery time	A1	^tWR	1		1		1		^tCK	21
	A2	^tWR	2		2		2		^tCK	22
Exit SELF REFRESH to ACTIVE command		^tXSR	80		96		105		ns	20

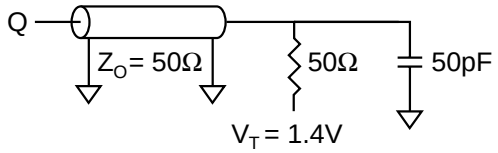
AC FUNCTIONAL CHARACTERISTICS

(Notes: 5, 6, 7, 8, 9, 11) (0°C ≤ T_A ≤ +70°C)

PARAMETER		SYM	-8A	-10	-12	UNITS	NOTES
READ/WRITE command to READ/WRITE command		tCCD	1	1	1	tCK	17
CKE to clock disable or power-down entry mode		tCKED	1	1	1	tCK	14
CKE to clock enable or power-down exit setup mode		tPED	1	1	1	tCK	14
DQM to input data delay		tDQD	0	0	0	tCK	17
DQM to data mask during WRITEs		tDQM	0	0	0	tCK	17
DQM to data high-impedance during READs		tDQZ	2	2	2	tCK	17
WRITE command to input data delay		tDWD	0	0	0	tCK	17
Data-in to ACTIVE command	A1	tDAL	4	3	4	tCK	15
	A2	tDAL	5	4	5	tCK	15
Data-in to PRECHARGE	A1	tDPL	1	1	1	tCK	16
	A2	tDPL	2	2	2	tCK	16
Last data-in to PRECHARGE command	A1	tRDL	1	1	1	tCK	16
	A2	tRDL	2	2	2	tCK	16
Last data-in to burst STOP command		tBDL	0	0	0	tCK	17
Last data-in to new READ/WRITE command		tCDL	1	1	1	tCK	17
LOAD MODE REGISTER command to command		tMRD	2	2	2	tCK	17
Data-out to high-impedance from PRECHARGE command	CL = 3	tROH	3	3	3	tCK	17
	CL = 2	tROH	2	2	2	tCK	17
	CL = 1	tROH	1	1	1	tCK	17

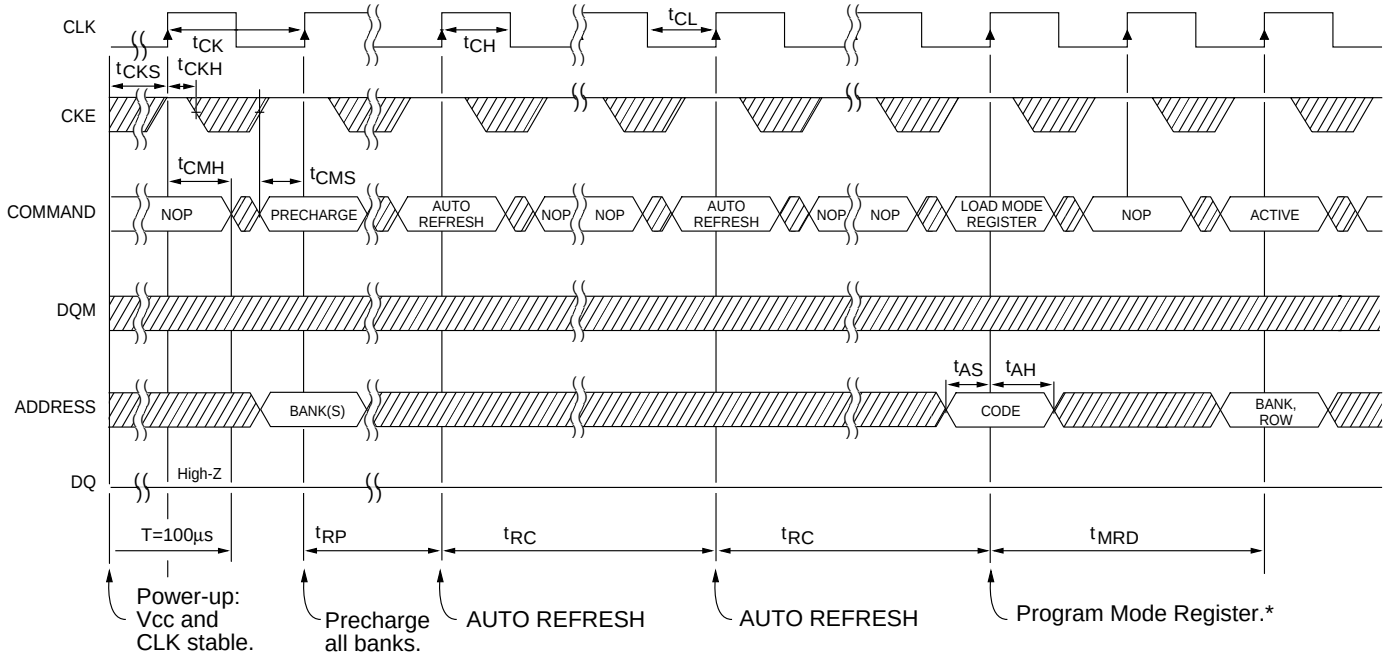
NOTES

1. All voltages referenced to V_{SS}.
2. This parameter is sampled. V_{CC}, $V_{CC}Q$ = +3.3V ±0.3V; f = 1 MHz, ^{t}A = 25°C.
3. I_{CC} is dependent on output loading and cycle rates. Specified values are obtained with minimum cycle time and the outputs open.
4. Enables on-chip refresh and address counters.
5. The minimum specifications are used only to indicate cycle time at which proper operation over the full temperature range (0°C ≤ T_A ≤ 70°C) is ensured.
6. An initial pause of 100µs is required after power-up, followed by two AUTO REFRESH commands, before proper device operation is ensured. (V_{CC} and $V_{CC}Q$ must be powered up simultaneously. V_{SS} and $V_{SS}Q$ must be at same potential.) The two AUTO REFRESH command wake-ups should be repeated any time the ^{t}REF refresh requirement is exceeded.
7. AC characteristics assume ^{t}T = 1ns.
8. In addition to meeting the transition rate specification, the clock and CKE must transit between V_{IH} and V_{IL} (or between V_{IL} and V_{IH}) in a monotonic manner.
9. Outputs measured at 1.4V with equivalent load:



10. ^{t}HZ defines the time at which the output achieves the open circuit condition; it is not a reference to V_{OH} or V_{OL}. The last valid data element will meet ^{t}OH before going High-Z.
11. AC timing and I_{CC} tests have V_{IL} = 0V and V_{IH} = 3V with timing referenced to 1.4V crossover point.
12. Other input signals are allowed to transition no more than once in any 30ns period (20ns on -8)and are otherwise at valid V_{IH} or V_{IL} levels.
13. I_{CC} specifications are tested after the device is properly initialized.
14. Timing actually specified by ^{t}CKS; clock(s) specified as a reference only at minimum cycle rate.
15. Timing actually specified by ^{t}WR plus ^{t}RP; clock(s) specified as a reference only at minimum cycle rate.
16. Timing actually specified by ^{t}WR.
17. Clocks required are specified by JEDEC functionality and are not dependent on any timing parameter.
18. The I_{CC} current will decrease as the CAS latency is reduced. This is due to the fact that the maximum cycle rate is slower as the CAS latency is reduced.
19. Address transitions average one transition every 30ns (20ns on -8).
20. CLK must be toggled a minimum of two times during this period.
21. The device is designed to trade off ^{t}RP for faster ^{t}WR, i.e., 30ns and one clock, respectively.
22. The device is designed to trade off ^{t}WR for faster ^{t}RP, i.e., 20ns and two clocks, respectively.
23. Based on ^{t}CK = 100 MHz for -8 and 66 MHz for -10.

INITIALIZE AND LOAD MODE REGISTER



*The Mode Register may be loaded prior to the AUTO REFRESH cycles if desired.

DON'T CARE

UNDEFINED

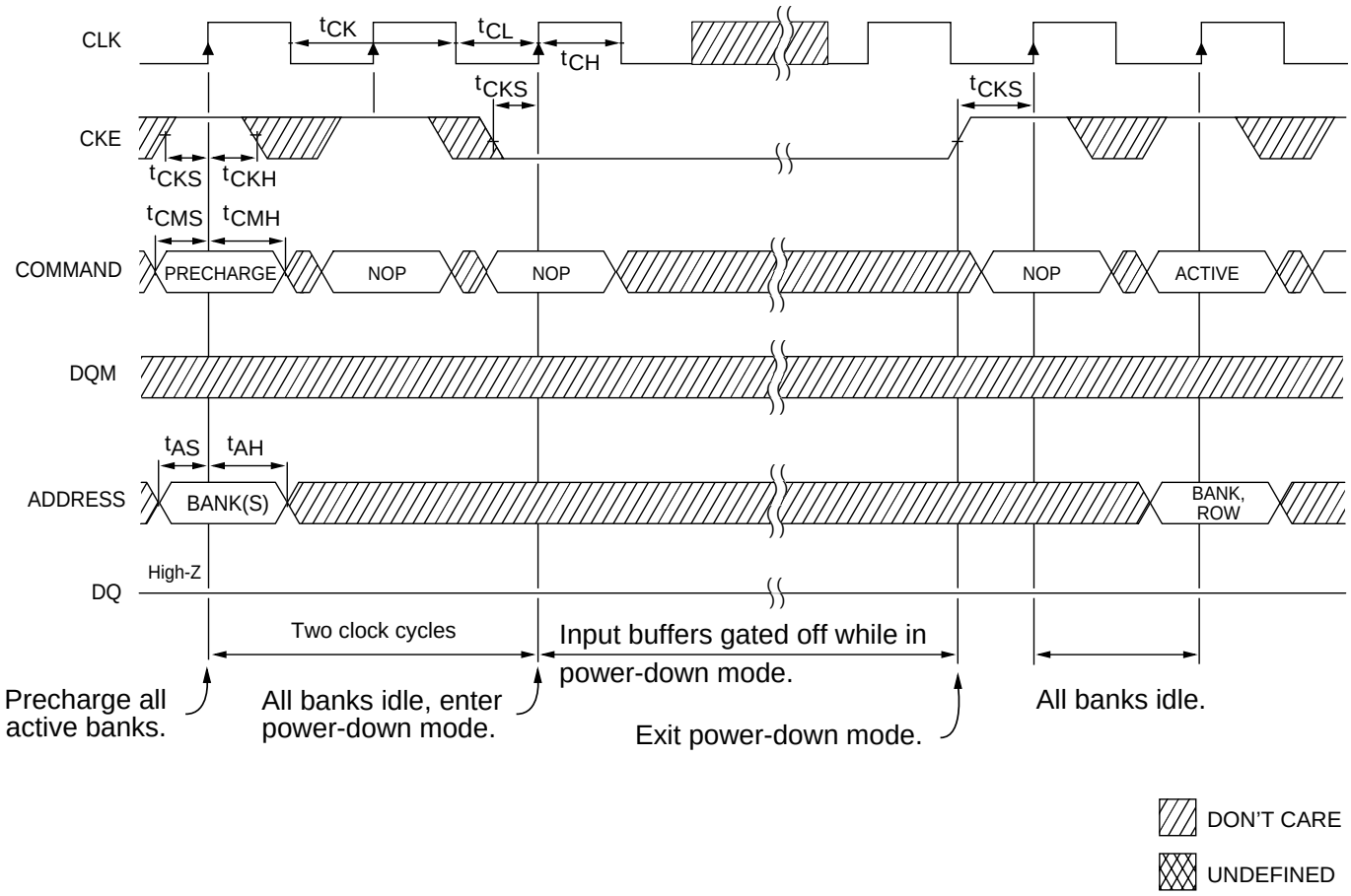
TIMING PARAMETERS

	-8A		-10		-12		
SYMBOL**	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tAH	1		1		1		ns
tAS	2		3		3		ns
tCH	3		3.5		3.5		ns
tCL	3		3.5		3.5		ns
tCK (3)	8		10		12		ns
tCK (2)	13		15		15		ns
tCK (1)	30		30		30		ns

	-8A		-10		-12		
SYMBOL**	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tCKH	1		1		1		ns
tCKS	2		3		3		ns
tCMH	1		1		1		ns
tCMS	2		3		3		ns
tMRD	2		2		2		tCK
tRC	80		90		105		ns
tRP	30		30		36		ns

**CAS latency indicated in parentheses.

POWER-DOWN MODE [1]



TIMING PARAMETERS

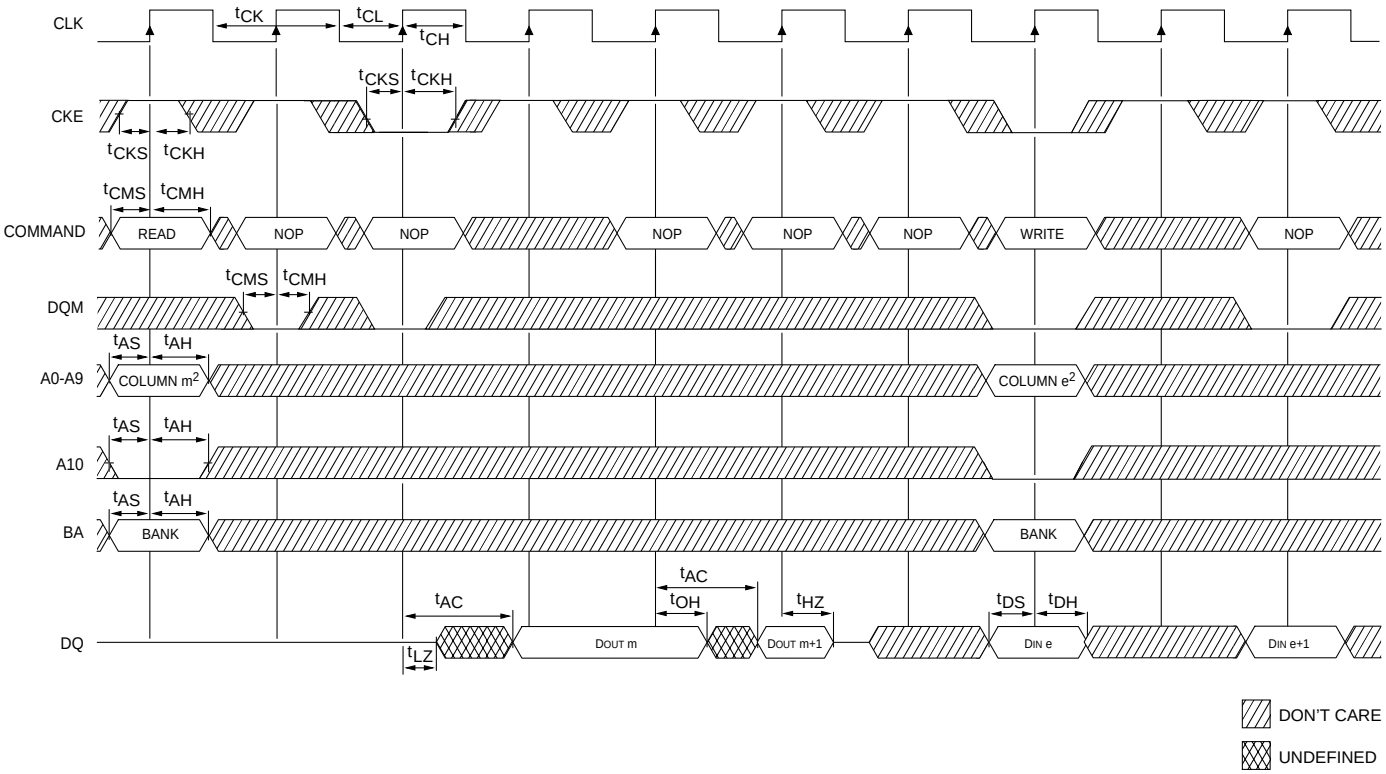
	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tAH	1		1		1		ns
tAS	2		3		3		ns
tCH	3		3.5		3.5		ns
tCL	3		3.5		3.5		ns
tCK (3)	8		10		12		ns
tCK (2)	13		15		15		ns

	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tCK (1)	30		30		30		ns
tCKH	1		1		1		ns
tCKS	2		3		3		ns
tCMH	1		1		1		ns
tCMS	2		3		3		ns

*CAS latency indicated in parentheses.

NOTE: 1. Violating refresh requirements during power-down may result in loss of data.

CLOCK SUSPEND MODE [1]



TIMING PARAMETERS

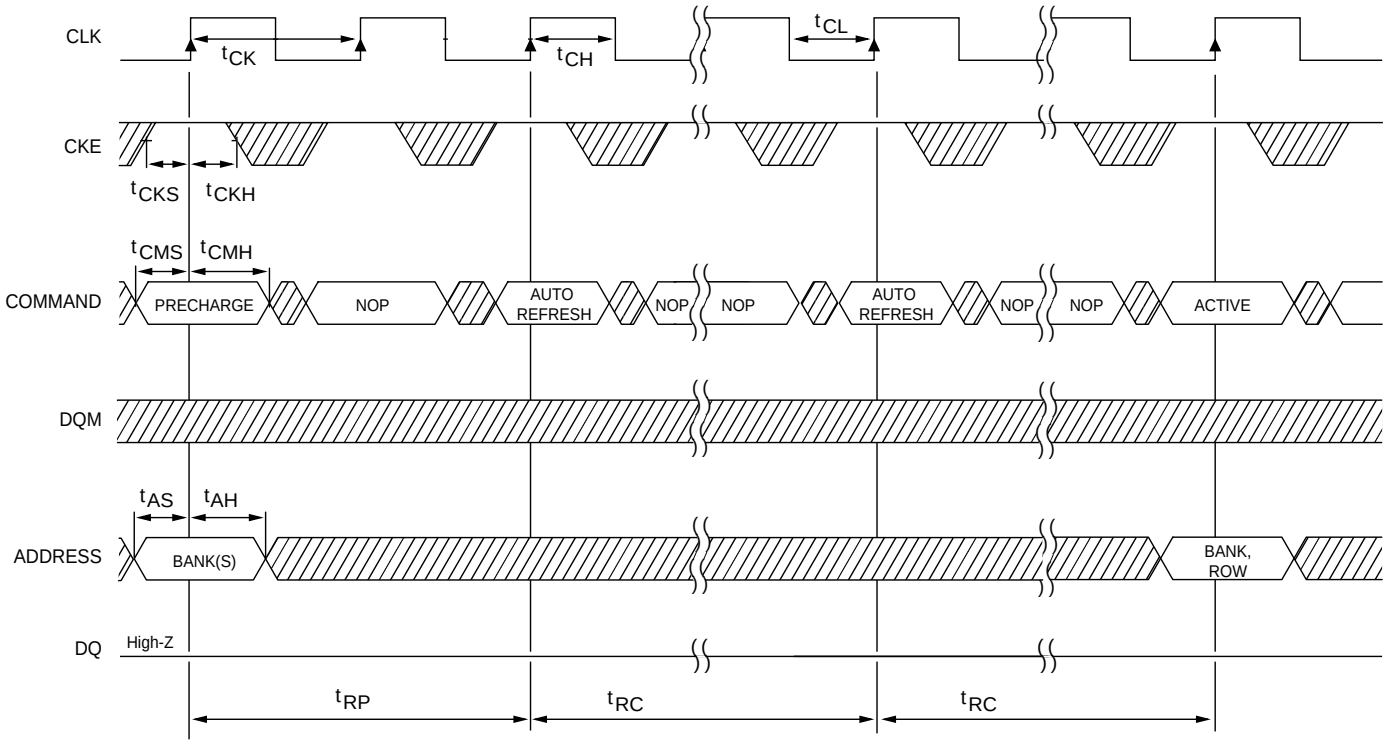
	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tAC(3)		6		7.5		9	ns
tAC(2)		9		9		9	ns
tAC(1)		27		27		27	ns
tAH	1		1		1		ns
tAS	2		3		3		ns
tCH	3		3.5		3.5		ns
tCL	3		3.5		3.5		ns
tCK (3)	8		10		12		ns
tCK (2)	13		15		15		ns
tCK (1)	30		30		30		ns
tCKH	1		1		1		ns

	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tCKS	2		3		3		ns
tCMH	1		1		1		ns
tCMS	2		3		3		ns
tDH	1		1		1		ns
tDS	2		3		3		ns
tHZ (3)		6		8		9	ns
tHZ (2)		7		10		10	ns
tHZ (1)		15		15		15	ns
tLZ	1		2		2		ns
tOH	3		3		3		ns

*CAS latency indicated in parentheses.

NOTE: 1. For this example, the burst length = 2, the CAS latency = 3 and AUTO PRECHARGE is disabled.
2. COLUMN = A9 is a "Don't Care" for x8.

AUTO REFRESH MODE



Precharge all active banks.

DON'T CARE

UNDEFINED

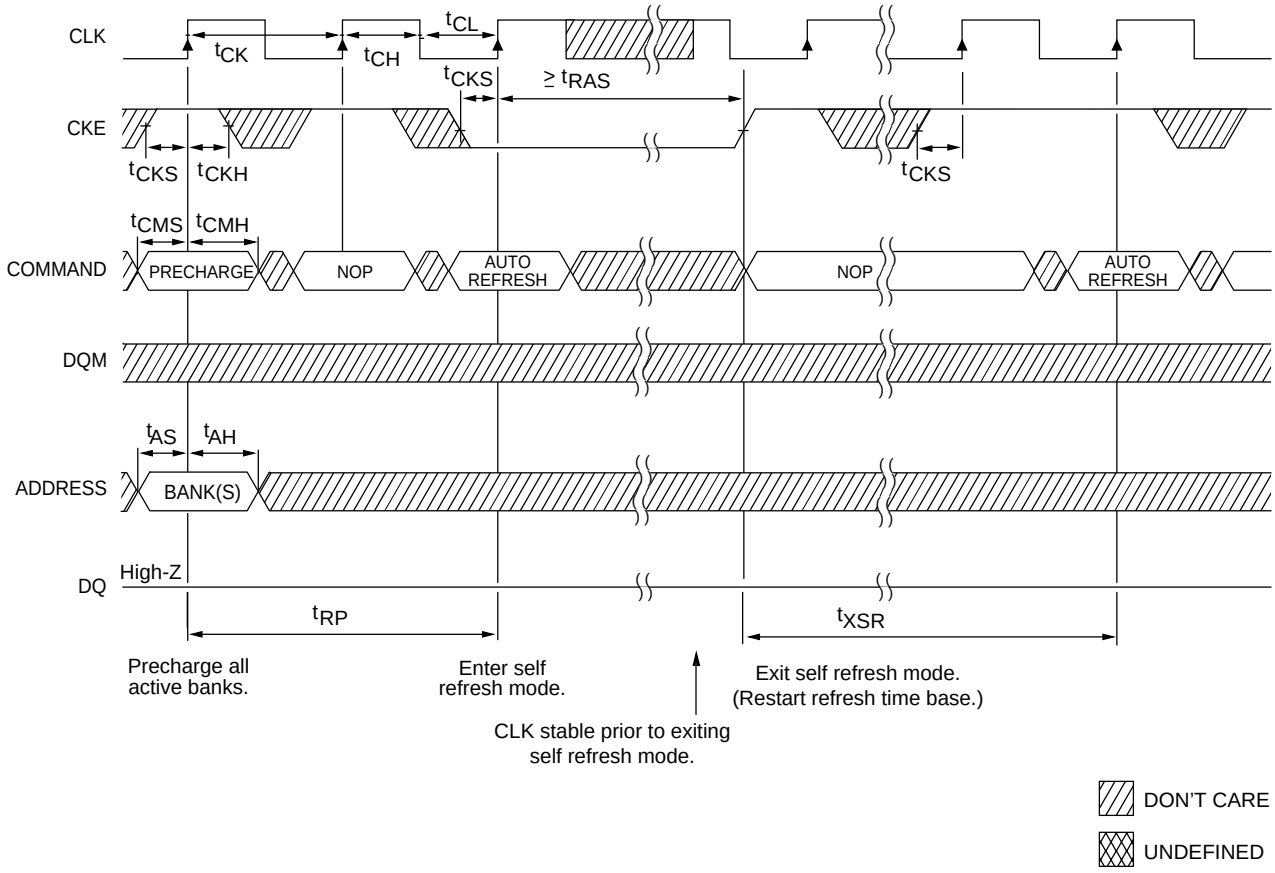
TIMING PARAMETERS

SYMBOL*	-8A MIN	-8A MAX	-10 MIN	-10 MAX	-12 MIN	-12 MAX	UNITS
tAH	1		1		1		ns
tAS	2		3		3		ns
tCH	3		3.5		3.5		ns
tCL	3		3.5		3.5		ns
tCK (3)	8		10		12		ns
tCK (2)	13		15		15		ns
tCK (1)	30		30		30		ns

SYMBOL*	-8A MIN	-8A MAX	-10 MIN	-10 MAX	-12 MIN	-12 MAX	UNITS
tCKH	1		1		1		ns
tCKS	2		3		3		ns
tCMH	1		1		1		ns
tCMS	2		3		3		ns
tRC	80		90		105		ns
tRP	30		30		36		ns

*CAS latency indicated in parentheses.

SELF REFRESH MODE



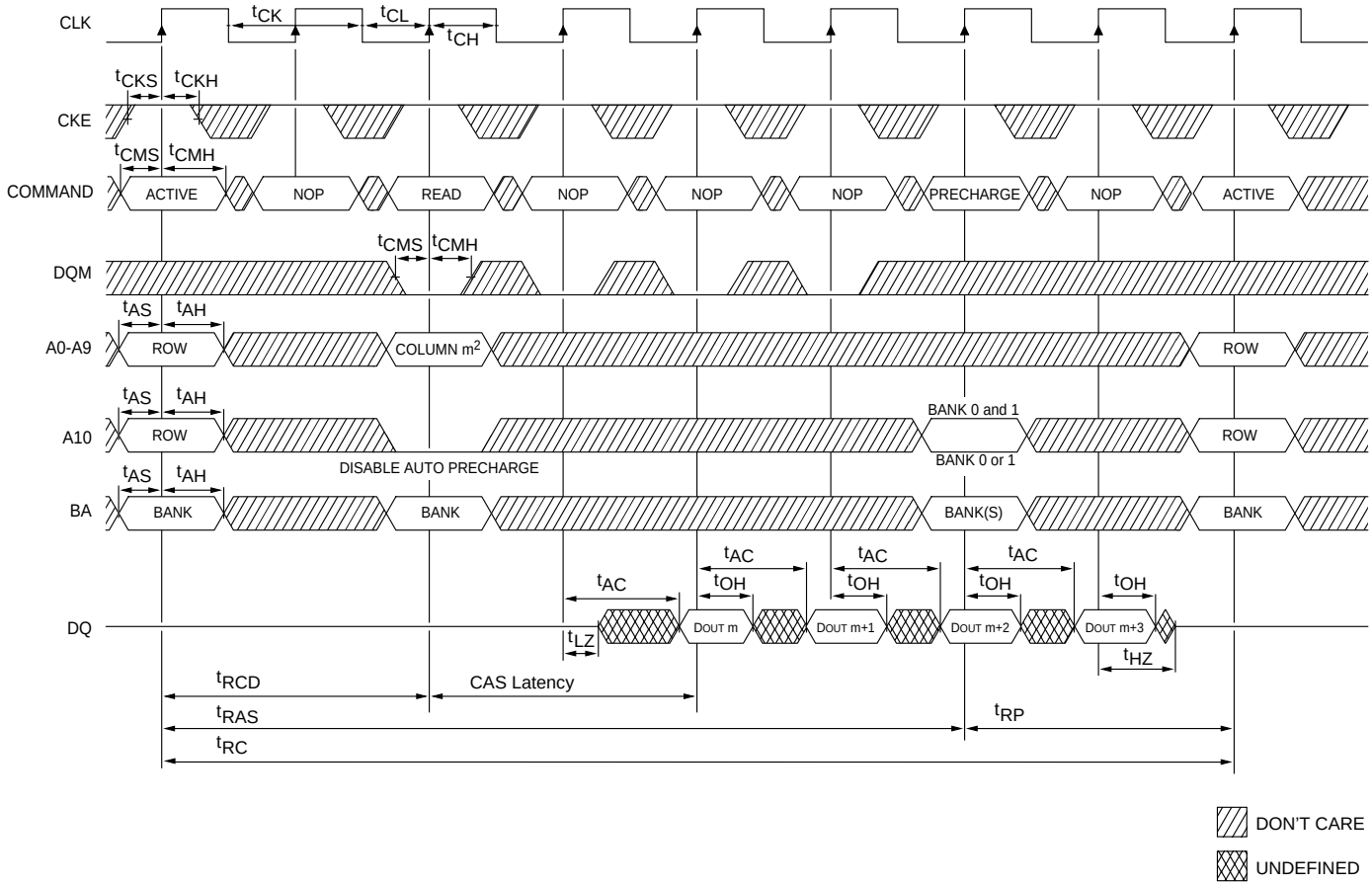
TIMING PARAMETERS

	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tAH	1		1		1		ns
tAS	2		3		3		ns
tCH	3		3.5		3.5		ns
tCL	3		3.5		3.5		ns
tCK (3)	8		10		12		ns
tCK (2)	13		15		15		ns
tCK (1)	30		30		30		ns

	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tCKH	1		1		1		ns
tCKS	2		3		3		ns
tCMH	1		1		1		ns
tCMS	2		3		3		ns
tRAS	50	120K	60	120K	72	120K	ns
tRP	30		30		36		ns
tXSR	80		96		105		ns

*CAS latency indicated in parentheses.

READ – WITHOUT AUTO PRECHARGE [1]



TIMING PARAMETERS

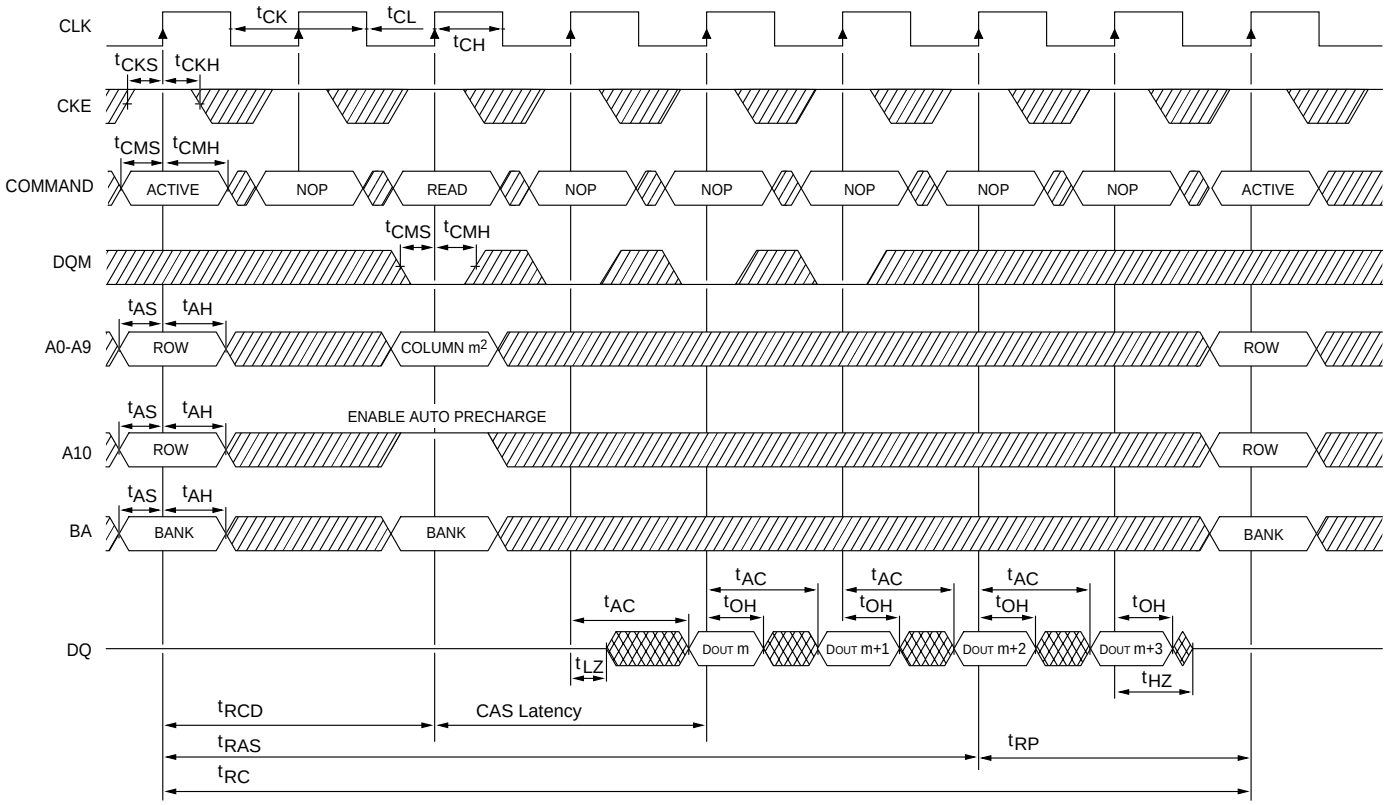
	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tAC(3)		6		7.5		9	ns
tAC(2)		9		9		9	ns
tAC(1)		27		27		27	ns
tAH	1		1		1		ns
tAS	2		3		3		ns
tCH	3		3.5		3.5		ns
tCL	3		3.5		3.5		ns
tCK (3)	8		10		12		ns
tCK (2)	13		15		15		ns
tCK (1)	30		30		30		ns
tCKH	1		1		1		ns
tCKS	2		3		3		ns

	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tCMH	1		1		1		ns
tCMS	2		3		3		ns
tHZ (3)		6		8		9	ns
tHZ (2)		7		10		10	ns
tHZ (1)		15		15		15	ns
tLZ	1		2		2		ns
tOH	3		3		3		ns
tRAS	50	120K	60	120K	72	120K	ns
tRC	80		90		105		ns
tRCD	30		30		30		ns
tRP	30		30		36		ns

*CAS latency indicated in parentheses.

NOTE: 1. For this example, the burst length = 4, the CAS latency = 2 and the READ burst is followed by a "manual" PRECHARGE.
2. COLUMN = A9 is a "Don't Care" for x8.

READ – WITH AUTO PRECHARGE [1]



TIMING PARAMETERS

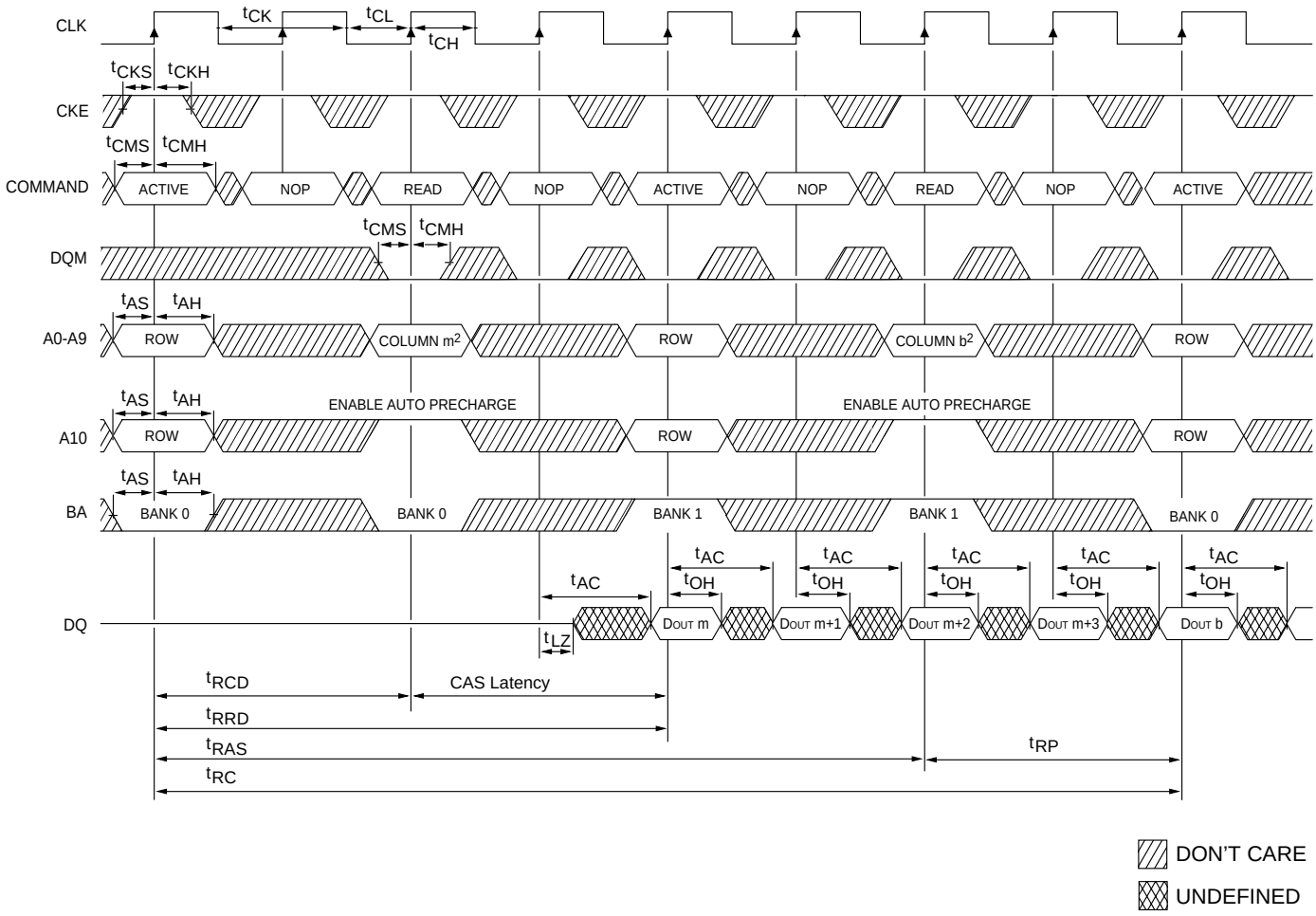
SYMBOL*	-8A MIN	-8A MAX	-10 MIN	-10 MAX	-12 MIN	-12 MAX	UNITS
tAC(3)		6		7.5		9	ns
tAC(2)		9		9		9	ns
tAC(1)		27		27		27	ns
tAH	1		1		1		ns
tAS	2		3		3		ns
tCH	3		3.5		3.5		ns
tCL	3		3.5		3.5		ns
tCK (3)	8		10		12		ns
tCK (2)	13		15		15		ns
tCK (1)	30		30		30		ns
tCKH	1		1		1		ns
tCKS	2		3		3		ns

SYMBOL*	-8A MIN	-8A MAX	-10 MIN	-10 MAX	-12 MIN	-12 MAX	UNITS
tCMH	1		1		1		ns
tCMS	2		3		3		ns
tHZ (3)		6		8		9	ns
tHZ (2)		7		10		10	ns
tHZ (1)		15		15		15	ns
tLZ	1		2		2		ns
tOH	3		3		3		ns
tRAS	50	120K	60	120K	72	120K	ns
tRC	80		90		105		ns
tRCD	30		30		30		ns
tRP	30		30		36		ns

*CAS latency indicated in parentheses.

NOTE: 1. For this example, the burst length = 4, and the CAS latency = 2.
2. COLUMN = A9 is a "Don't Care" for x8.

ALTERNATING BANK READ ACCESSES [1]



TIMING PARAMETERS

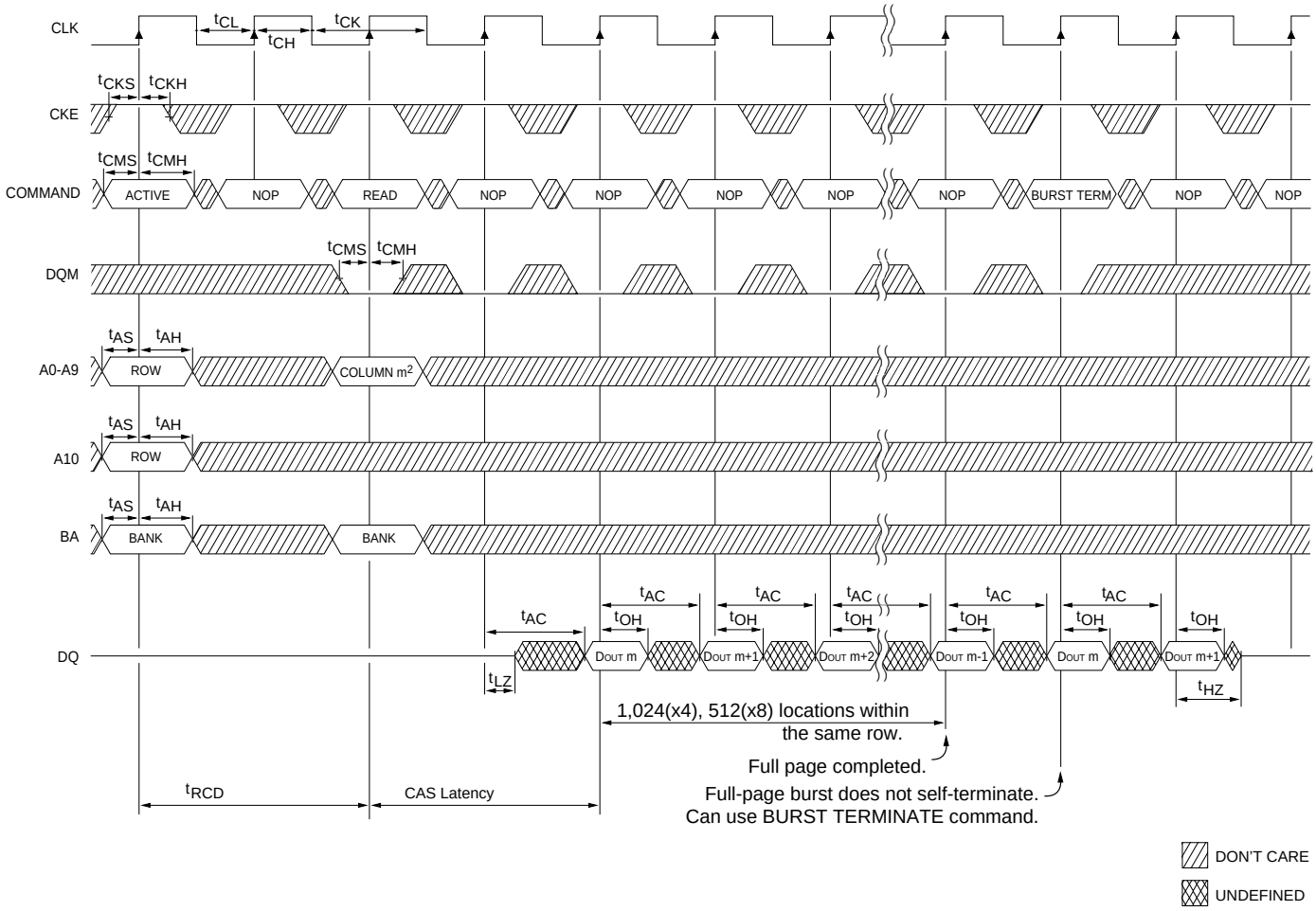
SYMBOL*	-8A MIN	-8A MAX	-10 MIN	-10 MAX	-12 MIN	-12 MAX	UNITS
tAC(3)		6		7.5		9	ns
tAC(2)		9		9		9	ns
tAC(1)		27		27		27	ns
tAH	1		1		1		ns
tAS	2		3		3		ns
tCH	3		3.5		3.5		ns
tCL	3		3.5		3.5		ns
tCK (3)	8		10		12		ns
tCK (2)	13		15		15		ns
tCK (1)	30		30		30		ns
tCKH	1		1		1		ns

SYMBOL*	-8A MIN	-8A MAX	-10 MIN	-10 MAX	-12 MIN	-12 MAX	UNITS
tCKS	2		3		3		ns
tCMH	1		1		1		ns
tCMS	2		3		3		ns
tLZ	1		2		2		ns
tOH	3		3		3		ns
tRAS	50	120K	60	120K	72	120K	ns
tRC	80		90		105		ns
tRCD	30		30		30		ns
tRP	30		30		36		ns
tRRD	20		20		20		ns

*CAS latency indicated in parentheses.

NOTE: 1. For this example, the burst length = 4, and the CAS latency = 2.
2. COLUMN = A9 is a "Don't Care" for x8.

READ – FULL-PAGE BURST [1]



TIMING PARAMETERS

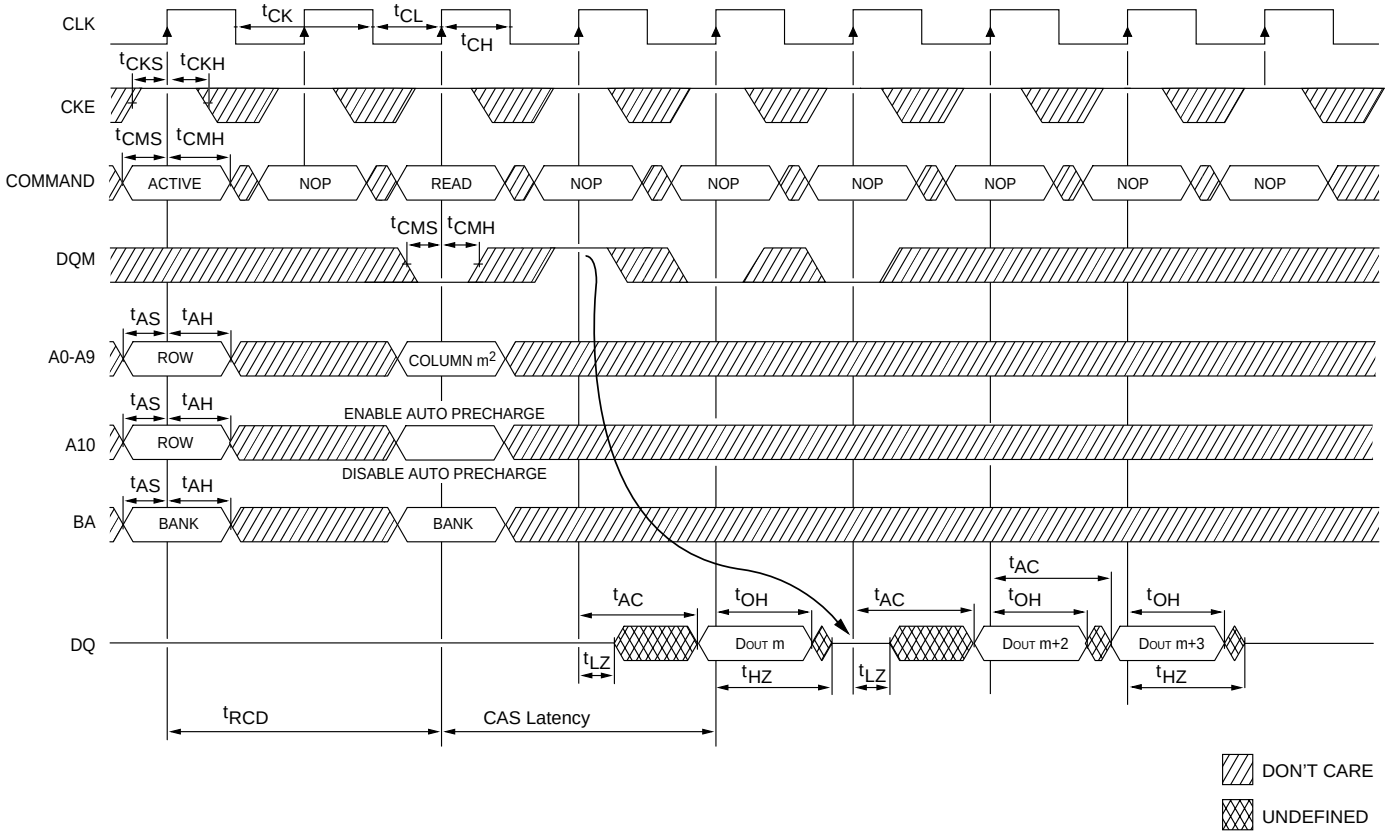
	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tAC(3)		6		7.5		9	ns
tAC(2)		9		9		9	ns
tAC(1)		27		27		27	ns
tAH	1		1		1		ns
tAS	2		3		3		ns
tCH	3		3.5		3.5		ns
tCL	3		3.5		3.5		ns
tCK (3)	8		10		12		ns
tCK (2)	13		15		15		ns
tCK (1)	30		30		30		ns

	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tCKH	1		1		1		ns
tCKS	2		3		3		ns
tCMH	1		1		1		ns
tCMS	2		3		3		ns
tHZ (3)		6		8		9	ns
tHZ (2)		7		10		10	ns
tHZ (1)		15		15		15	ns
tLZ	1		2		2		ns
tOH	3		3		3		ns
tRCD	30		30		30		ns

*CAS latency indicated in parentheses.

NOTE: 1. For this example, the CAS latency = 2.
2. COLUMN = A9 is a "Don't Care" for x8.

READ – DQM OPERATION [1]



TIMING PARAMETERS

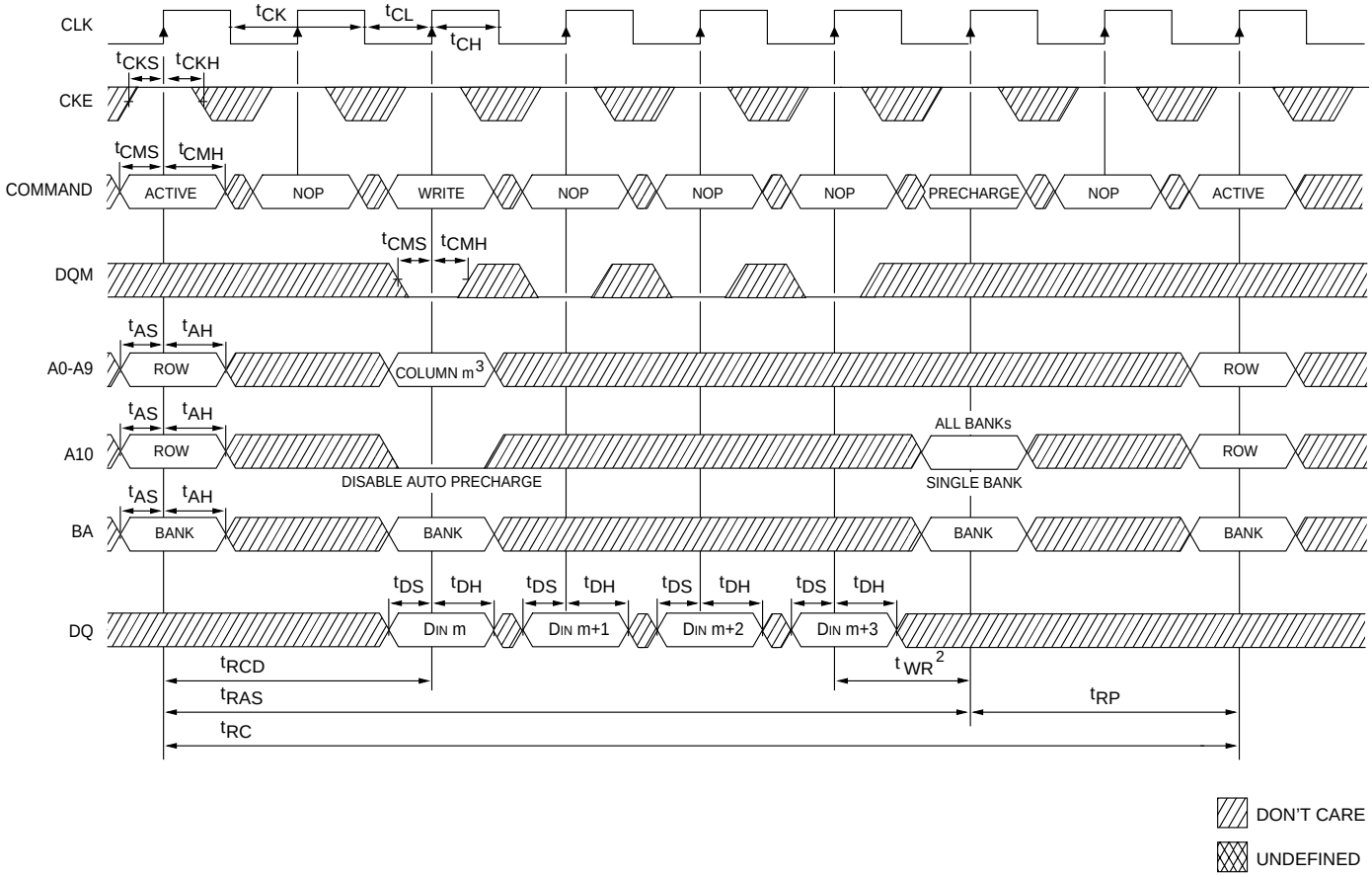
SYMBOL*	-8A MIN	-8A MAX	-10 MIN	-10 MAX	-12 MIN	-12 MAX	UNITS
tAC(3)		6		7.5		9	ns
tAC(2)		9		9		9	ns
tAC(1)		27		27		27	ns
tAH	1		1		1		ns
tAS	2		3		3		ns
tCH	3		3.5		3.5		ns
tCL	3		3.5		3.5		ns
tCK (3)	8		10		12		ns
tCK (2)	13		15		15		ns
tCK (1)	30		30		30		ns

SYMBOL*	-8A MIN	-8A MAX	-10 MIN	-10 MAX	-12 MIN	-12 MAX	UNITS
tCKH	1		1		1		ns
tCKS	2		3		3		ns
tCMH	1		1		1		ns
tCMS	2		3		3		ns
tHZ (3)		6		8		9	ns
tHZ (2)		7		10		10	ns
tHZ (1)		15		15		15	ns
tLZ	1		2		2		ns
tOH	3		3		3		ns
tRCD	30		30		30		ns

*CAS latency indicated in parentheses.

NOTE: 1. For this example, the burst length = 4, and the CAS latency = 2.
2. COLUMN = A9 is a “Don’t Care” for x8.

WRITE – WITHOUT AUTO PRECHARGE [1]



TIMING PARAMETERS

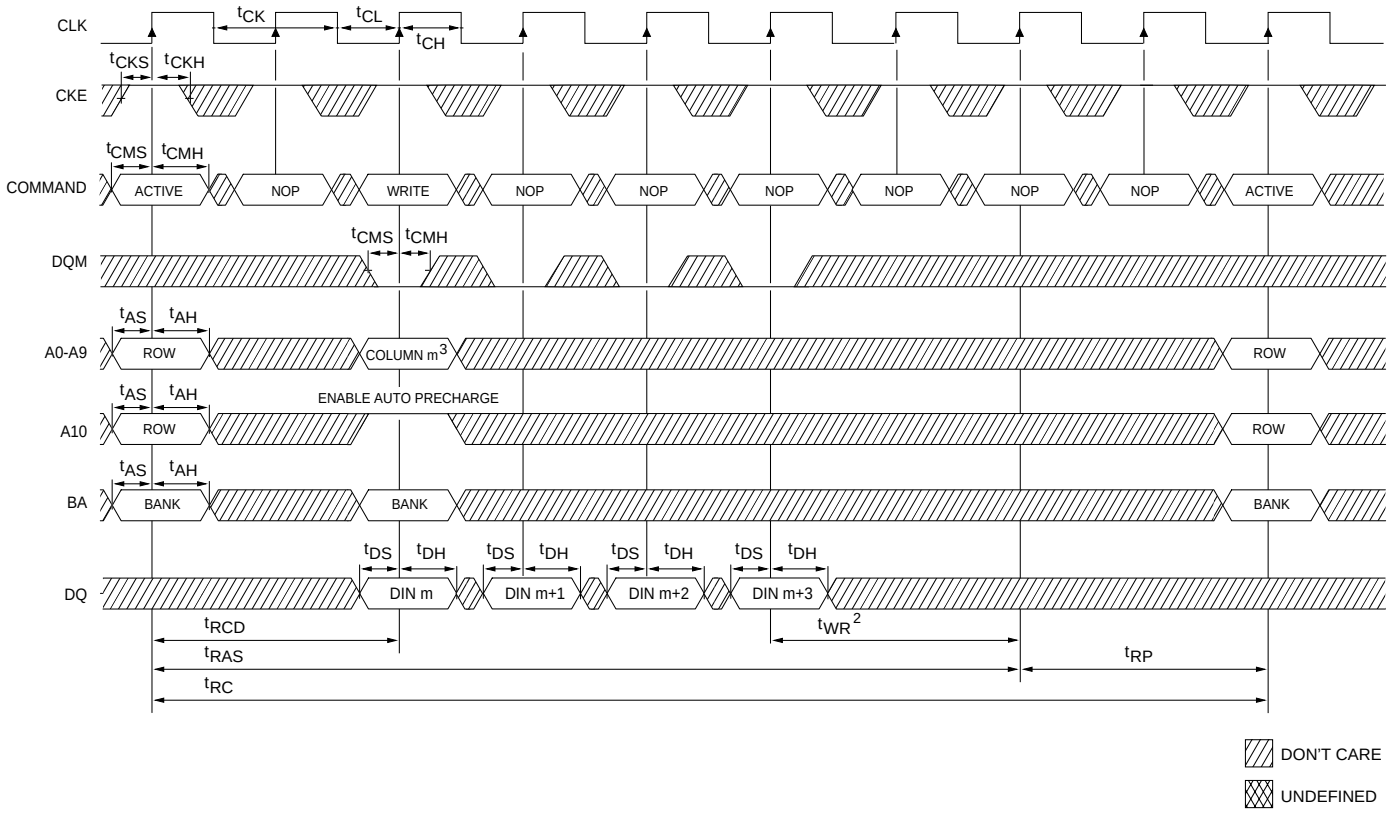
SYMBOL*	-8A MIN	-8A MAX	-10 MIN	-10 MAX	-12 MIN	-12 MAX	UNITS
tAH	1		1		1		ns
tAS	2		3		3		ns
tCH	3		3.5		3.5		ns
tCL	3		3.5		3.5		ns
tCK (3)	8		10		12		ns
tCK (2)	13		15		15		ns
tCK (1)	30		30		30		ns
tCKH	1		1		1		ns
tCKS	2		3		3		ns
tCMH	1		1		1		ns

SYMBOL*	-8A MIN	-8A MAX	-10 MIN	-10 MAX	-12 MIN	-12 MAX	UNITS
tCMS	2		3		3		ns
tDH	1		1		1		ns
tDS	2		3		3		ns
tRAS	50	120K	60	120K	72	120K	ns
tRC	80		90		105		ns
tRCD	30		30		30		ns
tRP	30		30		36		ns
tWR- A1	1		1		1		tCK
tWR- A2	2		2		2		tCK

*CAS latency indicated in parentheses.

NOTE: 1. For this example, the burst length = 4, and the WRITE burst is followed by a "manual" PRECHARGE with the A1 version.
2. A2 version requires two clocks between <DIN m+3> and the PRECHARGE command.
3. x8: A9 = "Don't Care."

WRITE – WITH AUTO PRECHARGE [1]



TIMING PARAMETERS

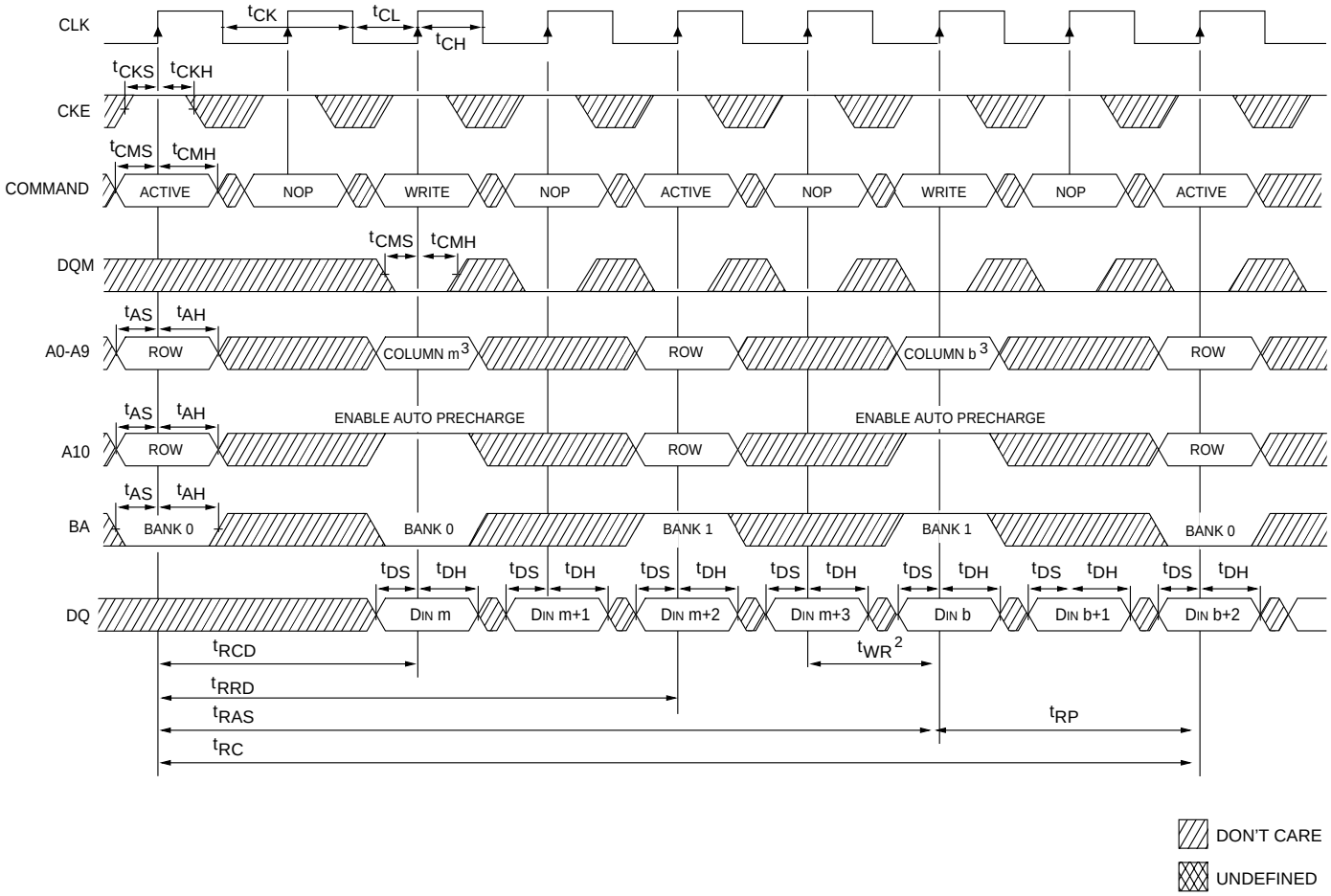
SYMBOL*	-8A MIN	-8A MAX	-10 MIN	-10 MAX	-12 MIN	-12 MAX	UNITS
tAH	1		1		1		ns
tAS	2		3		3		ns
tCH	3		3.5		3.5		ns
tCL	3		3.5		3.5		ns
tCK (3)	8		10		12		ns
tCK (2)	13		15		15		ns
tCK (1)	30		30		30		ns
tCKH	1		1		1		ns
tCKS	2		3		3		ns
tCMH	1		1		1		ns

SYMBOL*	-8A MIN	-8A MAX	-10 MIN	-10 MAX	-12 MIN	-12 MAX	UNITS
tCMS	2		3		3		ns
tDH	1		1		1		ns
tDS	2		3		3		ns
tRAS	50	120K	60	120K	72	120K	ns
tRC	80		90		105		ns
tRCD	30		30		30		ns
tRP	30		30		36		ns
tWR- A1	1		1		1		tCK
tWR- A2	2		2		2		tCK

*CAS latency indicated in parentheses.

NOTE: 1. For this example, the burst length = 4 with the A2 version, i.e., two clock minimum for tWR.
2. The A1 version requires only one clock between <DIN m+3> and the PRECHARGE command.
3. x8: A9 = "Don't Care."

ALTERNATING BANK WRITE ACCESSES [1]



TIMING PARAMETERS

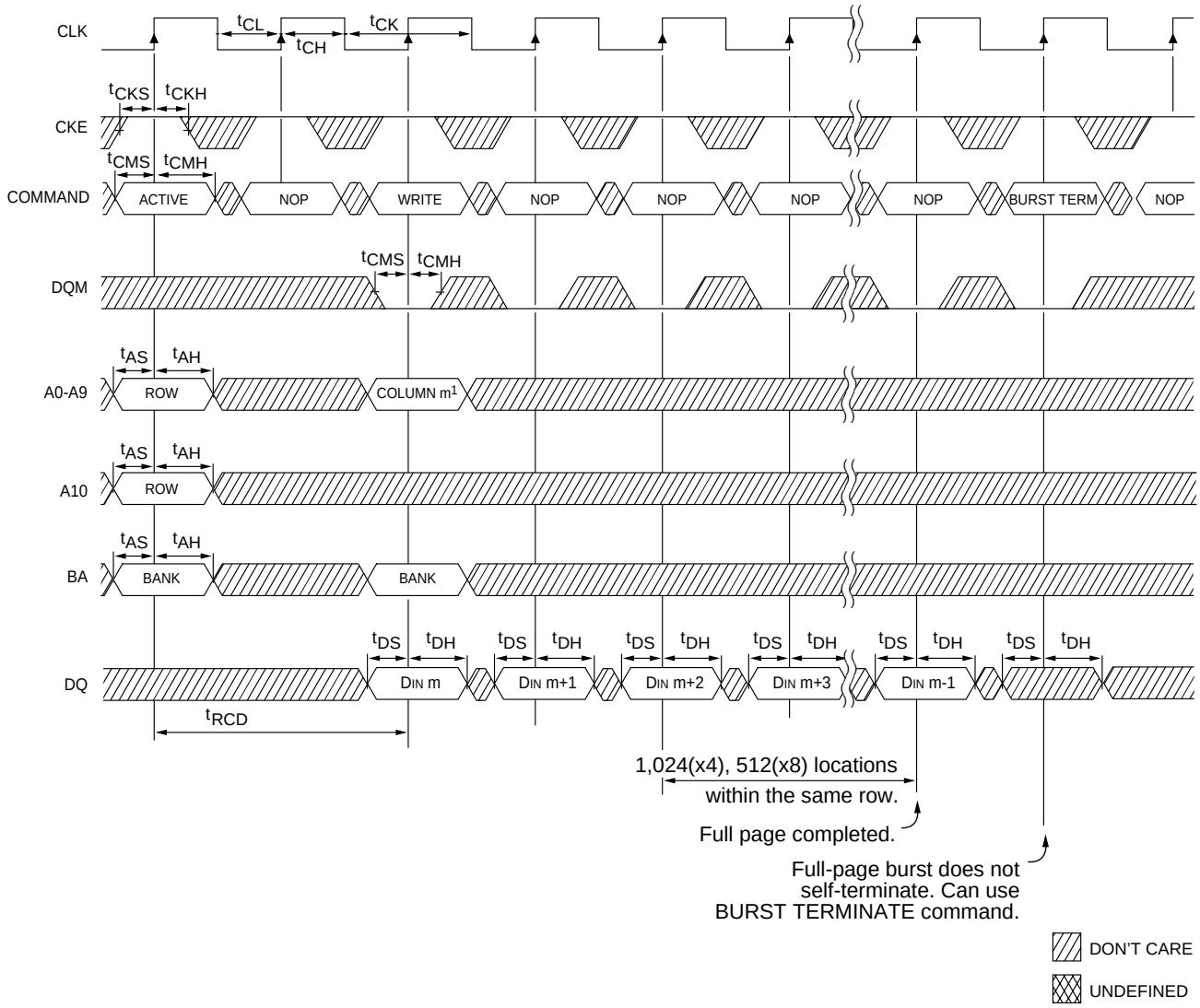
	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tAH	1		1		1		ns
tAS	2		3		3		ns
tCH	3		3.5		3.5		ns
tCL	3		3.5		3.5		ns
tCK (3)	8		10		12		ns
tCK (2)	13		15		15		ns
tCK (1)	30		30		30		ns
tCKH	1		1		1		ns
tCKS	2		3		3		ns
tCMH	1		1		1		ns

	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tCMS	2		3		3		ns
tDH	1		1		1		ns
tDS	2		3		3		ns
tRAS	50	120K	60	120K	72	120K	ns
tRC	80		90		105		ns
tRCD	30		30		30		ns
tRP	30		30		36		ns
tRRD	20		20		20		ns
tWR- A1	1		1		1		tCK
tWR- A2	2		2		2		tCK

*CAS latency indicated in parentheses.

NOTE: 1. For this example, the burst length = 4 with the A1 version, i.e., one clock minimum for tWR.
2. The A2 version inserts two clocks between <DIN m+3> and the PRECHARGE command.
3. x8: A9 = "Don't Care."

WRITE – FULL-PAGE BURST



TIMING PARAMETERS

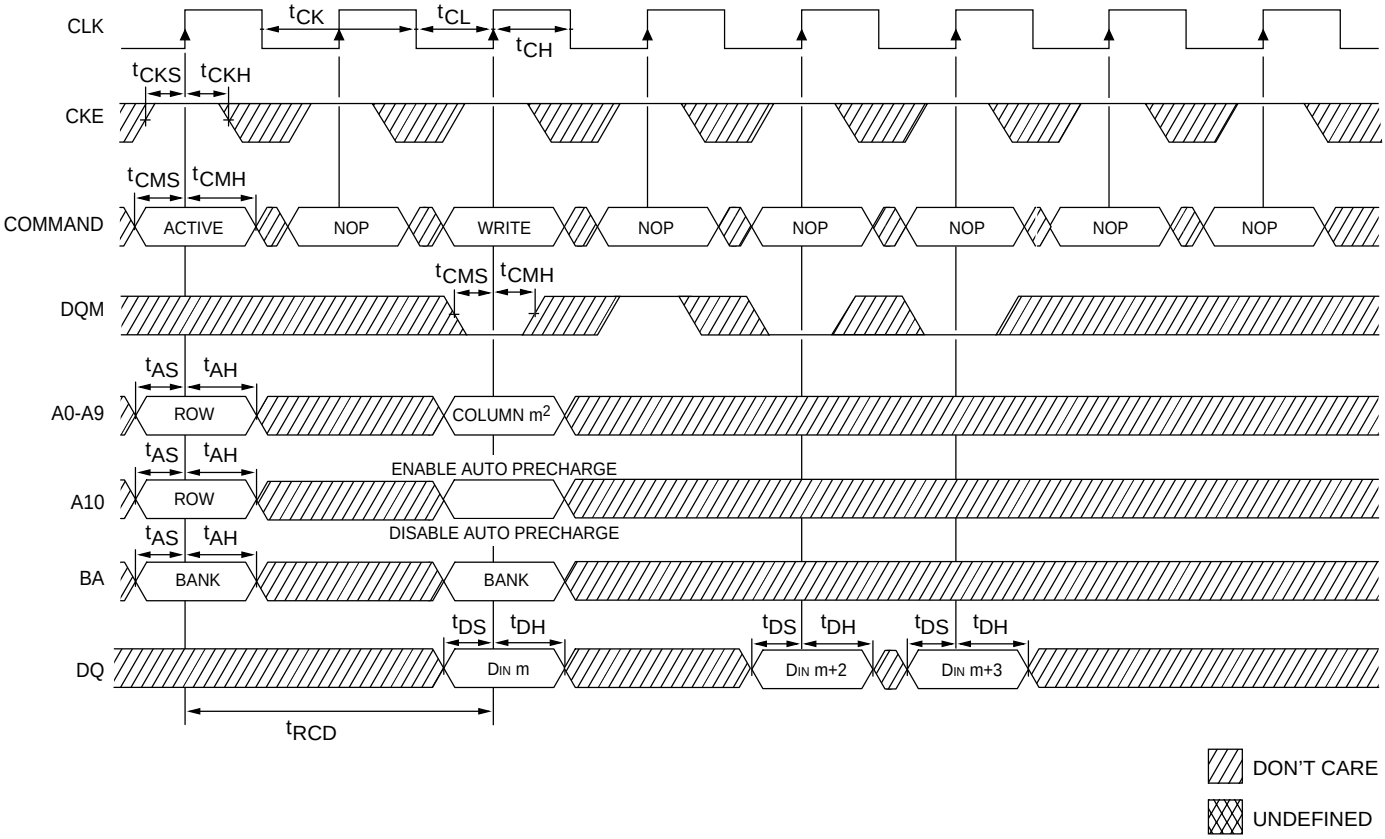
	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tAH	1		1		1		ns
tAS	2		3		3		ns
tCH	3		3.5		3.5		ns
tCL	3		3.5		3.5		ns
tCK (3)	8		10		12		ns
tCK (2)	13		15		15		ns
tCK (1)	30		30		30		ns

	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tCKH	1		1		1		ns
tCKS	2		3		3		ns
tCMH	1		1		1		ns
tCMS	2		3		3		ns
tDH	1		1		1		ns
tDS	2		3		3		ns
tRCD	30		30		30		ns

*CAS latency indicated in parentheses.

NOTE: 1. COLUMN = A9 is a "Don't Care" for x8.

WRITE – DQM OPERATION [1]



TIMING PARAMETERS

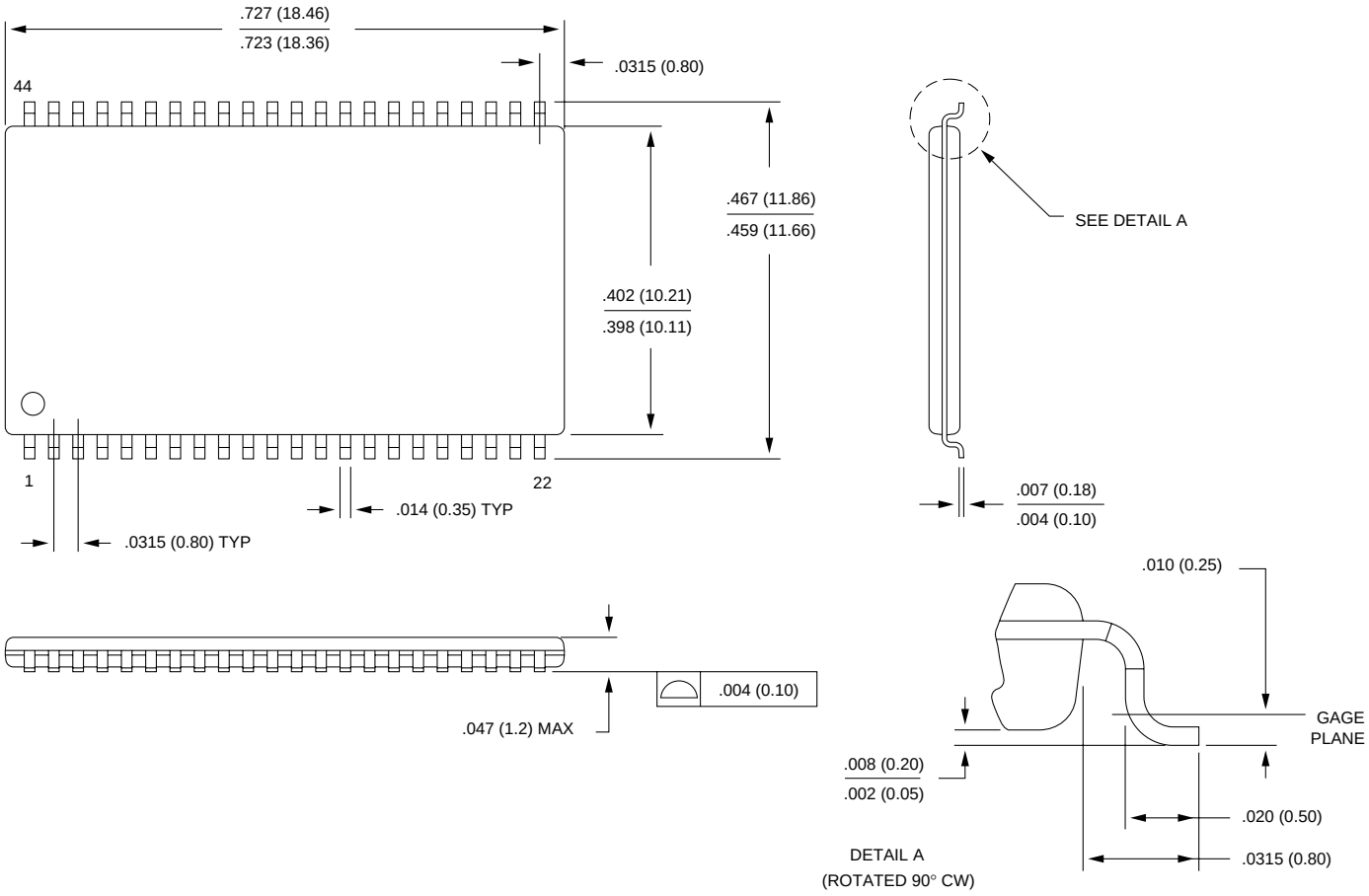
	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tAH	1		1		1		ns
tAS	2		3		3		ns
tCH	3		3.5		3.5		ns
tCL	3		3.5		3.5		ns
tCK (3)	8		10		12		ns
tCK (2)	13		15		15		ns
tCK (1)	30		30		30		ns

	-8A		-10		-12		
SYMBOL*	MIN	MAX	MIN	MAX	MIN	MAX	UNITS
tCKH	1		1		1		ns
tCKS	2		3		3		ns
tCMH	1		1		1		ns
tCMS	2		3		3		ns
tDH	1		1		1		ns
tDS	2		3		3		ns
tRCD	30		30		30		ns

*CAS latency indicated in parentheses.

NOTE: 1. For this example, the burst length = 4.
2. COLUMN = A9 is a "Don't Care" for x8.

44-PIN PLASTIC TSOP (400 mil)



NOTE: 1. All dimensions in inches (millimeters) $\frac{\text{MAX}}{\text{MIN}}$ or typical where noted.

2. Package width and length do not include mold protrusion; allowable mold protrusion is .01" per side.

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