



16M × 4 BANKS × 4 BIT DDR SDRAM

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1. GENERAL DESCRIPTION

W942504CH is a CMOS Double Data Rate synchronous dynamic random access memory (DDR SDRAM), organized as 16,777,216 words \times 4 banks \times 4 bits. Using pipelined architecture and 0.13 μ m process technology, W942504CH delivers a data bandwidth of up to 286M words per second (-7). To fully comply with the personal computer industrial standard, W942504CH is sorted into three speed grades: -7, -75 and The -7 is compliant to the 143 MHz/CL2.5 or DDR266/CL2 specification, the -75 is compliant to the DDR266/CL2.5 specification.

All Inputs reference to the positive edge of CLK (except for DQ, DM, and CKE). The timing reference point for the differential clock is when the CLK and $\overline{\text{CLK}}$ signals cross during a transition. And Write and Read data are synchronized with the both edges of DQS (Data Strobe).

By having a programmable Mode Register, the system can change burst length, latency cycle, interleave or sequential burst to maximize its performance. W942504CH is ideal for main memory in high performance applications.

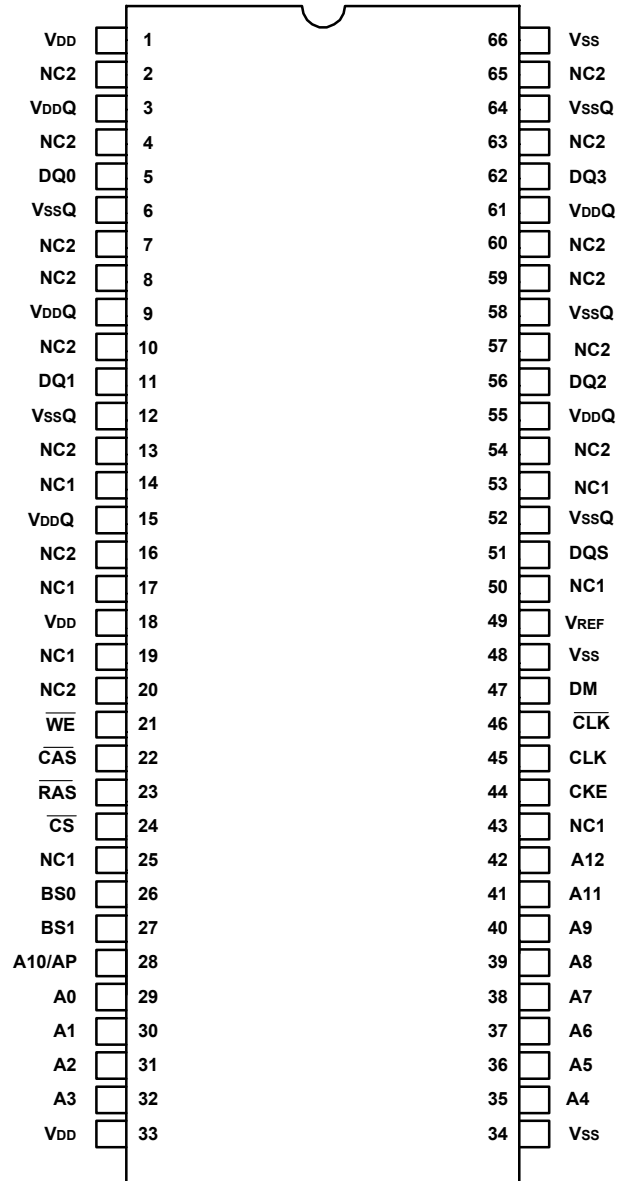
2. FEATURES

- 2.5V \pm 0.2V Power Supply
- Up to 143 MHz Clock Frequency
- Double Data Rate architecture; two data transfers per clock cycle
- Differential Clock Inputs (CLK and $\overline{\text{CLK}}$)
- DQS is edge-aligned with data for Read; center-aligned with data for Write
- CAS Latency: 2 and 2.5
- Burst Length: 2, 4 and 8
- Auto Refresh and Self Refresh
- Precharged Power Down and Active Power Down
- Write Data Mask
- Write Latency = 1
- 8K Refresh Cycles /64 mS
- Interface: SSTL-2
- Packaged in TSOP II 66-pin, 400 x 875 mil, 0.65 mm pin pitch

3. KEY PARAMETERS

| SYMBOL | DESCRIPTION | | MIN./MAX. | -7 | -75 |
|------------------|-------------------------------------|----------|-----------|--------|--------|
| t _{CK} | Clock Cycle Time | CL = 2 | Min. | 7.5 nS | 8 nS |
| | | CL = 2.5 | Min. | 7 nS | 7.5 nS |
| t _{RAS} | Active to Precharge Command Period | | Min. | 45 nS | 45 nS |
| t _{RC} | Active to Ref/Active Command Period | | Min. | 65 nS | 65 nS |
| I _{DD1} | Operation Current (Single bank) | | Max. | 120 mA | 120 mA |
| I _{DD4} | BURST OPERATION CURRENT | | Max. | 165 mA | 155 mA |
| I _{DD6} | Self-Refresh Current | | Max. | 3 mA | 3 mA |

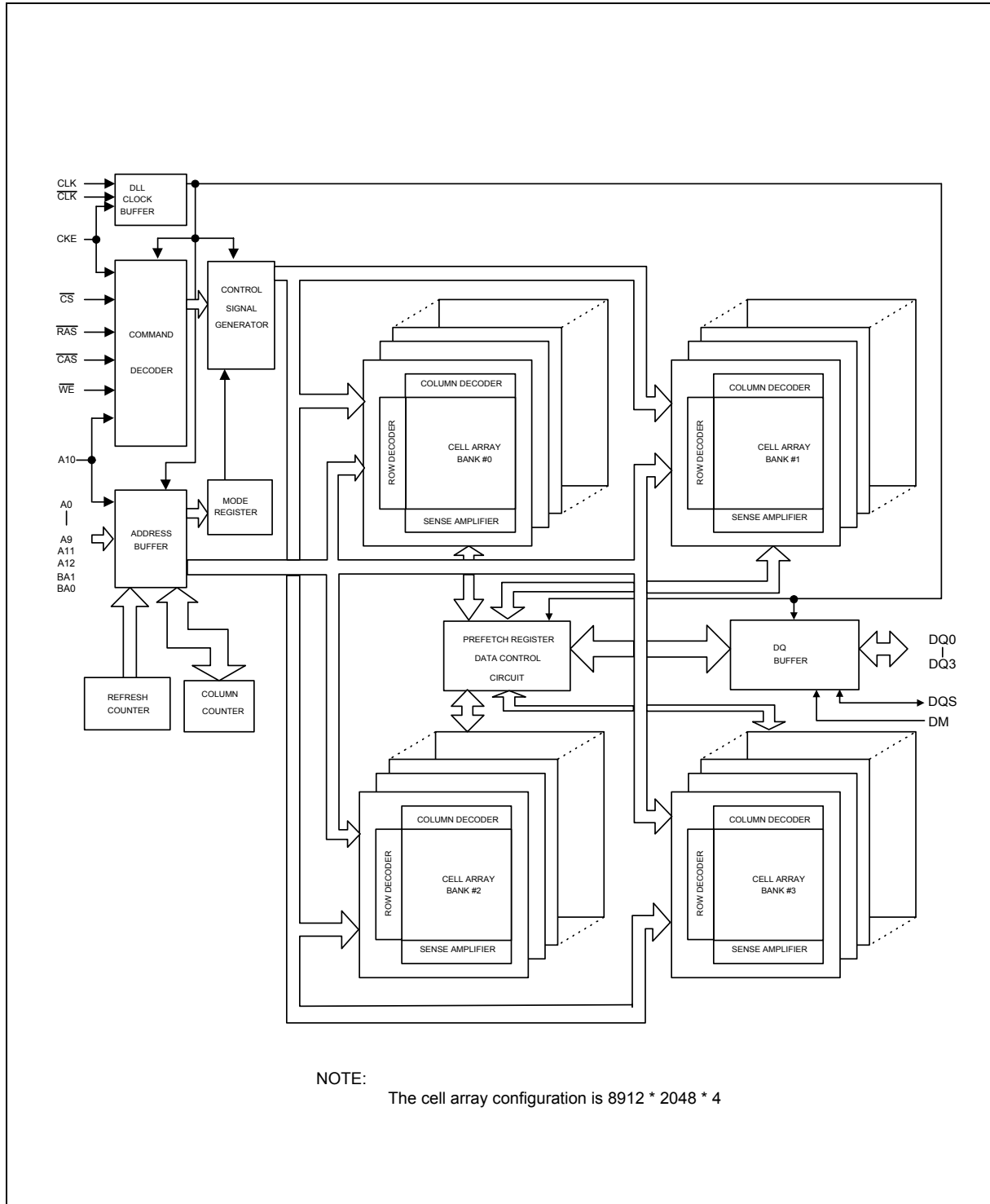
4. PIN CONFIGURATION



5. PIN DESCRIPTION

| PIN NUMBER | PIN NAME | FUNCTION | DESCRIPTION |
|--|--|------------------------------------|--|
| 28 – 32, 35 – 42 | A0 – A12 | Address | Multiplexed pins for row and column address. Row address: A0 – A12. Column address: A0 – A9, A11. (A10 is used for Auto Precharge) |
| 26,27 | BS0, BS1 | Bank Select | Select bank to activate during row address latch time, or bank to read/write during column address latch time. |
| 5, 11, 56, 62 | DQ0 – DQ3 | Data Input/ Output | The DQ0 – DQ7 input and output data are synchronized with both edges of DQS. |
| 51 | DQS | Data Strobe | DQS is Bi-directional signal. DQS is input signal during write operation and output signal during read operation. It is Edge-aligned with read data, Center-aligned with write data. |
| 24 | \overline{CS} | Chip Select | Disable or enable the command decoder. When command decoder is disabled, new command is ignored and previous operation continues. |
| 23, 22, 21 | \overline{RAS} , \overline{CAS} , \overline{WE} | Command Inputs | Command inputs (along with \overline{CS}) define the command being entered. |
| 47 | DM | Write mask | When DM is asserted "high" in burst write, the input data is masked. DM is synchronized with both edges of DQS. |
| 45, 46 | CLK, \overline{CLK} | Differential clock inputs | All address and control input signals are sampled on the crossing of the positive edge of CLK and negative edge of \overline{CLK} . |
| 44 | CKE | Clock Enable | CKE controls the clock activation and deactivation. When CKE is low, Power Down mode, Suspend mode, or Self Refresh mode is entered. |
| 49 | VREF | Reference Voltage | VREF is reference voltage for inputs. |
| 1, 18, 33 | VDD | Power (+2.5V) | Power for logic circuit inside DDR SDRAM. |
| 34, 48, 66 | VSS | Ground | Ground for logic circuit inside DDR SDRAM. |
| 3, 9, 15, 55, 61 | VDDQ | Power (+2.5V) for I/O buffer | Separated power from VDD, used for output buffer, to improve noise. |
| 6, 12, 52, 58, 64 | VSSQ | Ground for I/O buffer | Separated ground from VSS, used for output buffer, to improve noise. |
| 2, 4, 7, 8, 10, 13, 14, 16, 17, 19, 20, 25, 43, 50, 53, 54, 57, 59, 60, 63, 65 | NC1, NC2 | No Connection | No connection |

6. BLOCK DAIAGRAM



7. ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings

| PARAMETER | SYMBOL | RATING | UNIT |
|------------------------------|------------------------------------|------------------------------|------|
| Input, Output Voltage | V _{IN} , V _{OUT} | -0.3 – V _{DDQ} +0.3 | V |
| Power Supply Voltage | V _{DD} , V _{DDQ} | -0.3 – 3.6 | V |
| Operating Temperature | T _{OPR} | 0 – 70 | °C |
| Storage Temperature | T _{STG} | -55 – 150 | °C |
| Soldering Temperature (10s) | T _{SOLDER} | 260 | °C |
| Power Dissipation | P _D | 1 | W |
| Short Circuit Output Current | I _{OUT} | 50 | mA |

Note: Exposure to conditions beyond those listed under Absolute Maximum Ratings may adversely affect the life and reliability of the device.

Recommended DC Operating Conditions

(T_A = 0 to 70°C)

| SYMBOL | PARAMETER | MIN. | TYP. | MAX. | UNIT | NOTES |
|-----------------------|---|--------------------------|-------------------------|--------------------------|------|--------|
| V _{DD} | Power Supply Voltage | 2.3 | 2.5 | 2.7 | V | 2 |
| V _{DDQ} | Power Supply Voltage (for I/O Buffer) | 2.3 | 2.5 | V _{DD} | V | 2 |
| V _{REF} | Input reference Voltage | 0.49 x V _{DDQ} | 0.50 x V _{DDQ} | 0.51 x V _{DDQ} | V | 2, 3 |
| V _{TT} | Termination Voltage (System) | V _{REF} -0.04 | V _{REF} | V _{REF} +0.04 | V | 2, 8 |
| V _{IH} (DC) | Input High Voltage (DC) | V _{REF} +0.15 | - | V _{DDQ} +0.3 | V | 2 |
| V _{IL} (DC) | Input Low Voltage (DC) | -0.3 | - | V _{REF} -0.15 | V | 2 |
| V _{ICK} (DC) | Differential Clock DC Input Voltage | -0.3 | - | V _{DDQ} +0.3 | V | 15 |
| V _{ID} (DC) | Input Differential Voltage. CLK and $\overline{\text{CLK}}$ inputs (DC) | 0.36 | - | V _{DDQ} +0.6 | V | 13, 15 |
| V _{IH} (AC) | Input High Voltage (AC) | V _{REF} +0.31 | - | - | V | 2 |
| V _{IL} (AC) | Input Low Voltage (AC) | - | - | V _{REF} -0.31 | V | 2 |
| V _{ID} (AC) | Input Differential Voltage. CLK and $\overline{\text{CLK}}$ inputs (AC) | 0.7 | - | V _{DDQ} +0.6 | V | 13, 15 |
| V _X (AC) | Differential AC input Cross Point Voltage | V _{DDQ} /2 -0.2 | - | V _{DDQ} /2 +0.2 | V | 12, 15 |
| V _{ISO} (AC) | Differential Clock AC Middle Point | V _{DDQ} /2 -0.2 | - | V _{DDQ} /2 +0.2 | V | 14, 15 |

Note: Undershoot Limit : V_{IL} (min.) = -0.9V with a pulse width ≤ 5 nS
Overshoot Limit : V_{IH} (max.) = V_{DDQ} +0.9V with a pulse width ≤ 5 nS
V_{IH} (DC) and V_{IL} (DC) are levels to maintain the current logic state.
V_{IH} (AC) and V_{IL} (AC) are levels to change to the new logic state.

Capacitance

($V_{DD} = V_{DDQ} = 2.5V \pm 0.2V$, $f = 1\text{ MHz}$, $T_A = 25^\circ\text{C}$, $V_{OUT(DC)} = V_{DDQ}/2$, $V_{OUT}(\text{Peak to Peak}) = 0.2V$)

| SYM. | PARAMETER | MIN. | MAX. | DELTA (MAX.) | UNIT |
|------|---|------|------|--------------|------|
| CIN | Input Capacitance (except for CLK pins) | 2.0 | 3.0 | 0.5 | pF |
| CCLK | Input Capacitance (CLK pins) | 2.0 | 3.0 | 0.25 | pF |
| CI/O | DQ, DQS, DM Capacitance | 4.0 | 5.0 | 0.5 | pF |
| CNC1 | NC1 pin Capacitance | - | 1.5 | - | pF |
| CNC2 | NC2 Pin Capacitance | 4.0 | 5.0 | - | pF |

Note: These parameters are periodically sampled and not 100% tested.

The NC2 pins have additional capacitance for adjustment of the adjacent pin capacitance.

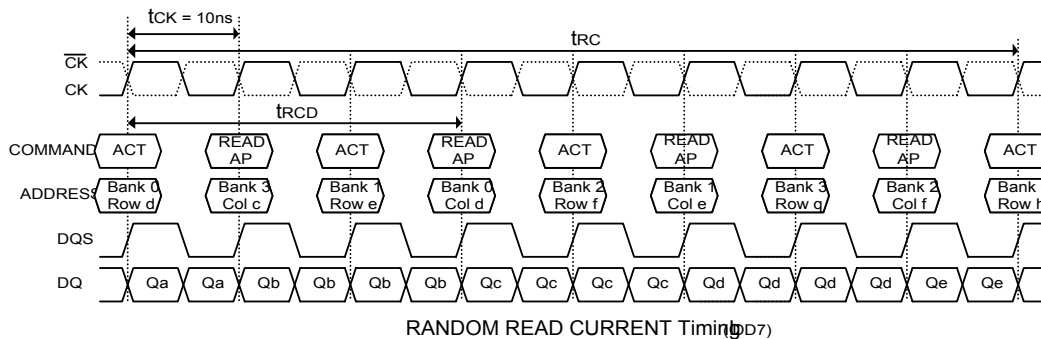
The NC2 pins have Power and Ground clamp.

Leakage and Output Buffer Characteristics

| SYM. | PARAMETER | MIN. | MAX. | UNITS | NOTES |
|----------|---|------------------|-----------------|---------------|-------|
| II(L) | Input Leakage Current ($0V \leq V_{IN} \leq V_{DDQ}$, All other pins not under test = $0V$) | -2 | 2 | μA | |
| IO(L) | Output Leakage Current (Output disabled, $0V \leq V_{OUT} \leq V_{DDQ}$) | -5 | 5 | μA | |
| VOH | Output High Voltage (Under AC test load condition) | Full Strength | $V_{TT} + 0.76$ | V | |
| VOL | Output Low Voltage (Under AC test load condition) | | $V_{TT} - 0.76$ | V | |
| IOH (DC) | Output Minimum Source DC Current | | -15.2 | mA | 4, 6 |
| IOL (DC) | Output Minimum Sink DC Current | | 15.2 | mA | 4, 6 |
| IOH (DC) | Output Minimum Source DC Current | Half Strength | -10.4 | mA | 5 |
| IOL (DC) | Output Minimum Sink DC Current | | 10.4 | mA | 5 |

DC Characteristics

| SYM. | PARAMETER | -7 | -75 | UNIT | NOTES |
|-------|--|-----|-----|------|-------|
| IDD0 | OPERATING CURRENT: One Bank Active-Precharge; $t_{RC} = t_{RC} \text{ min}$; $t_{CK} = t_{CK} \text{ min}$; DQ, DM and DQS inputs changing twice per clock cycle; Address and control inputs changing once per clock cycle | 110 | 110 | mA | 7 |
| IDD1 | OPERATING CURRENT: One Bank Active-Read-Precharge; Burst = 2; $t_{RC} = t_{RC} \text{ min}$; $CL=2.5$; $t_{CK} = t_{CK} \text{ min}$; $I_{OUT} = 0 \text{ mA}$; Address and control inputs changing once per clock cycle. | 120 | 120 | | 7, 9 |
| IDD2P | PRECHARGE-POWER-DOWN STANDBY CURRENT: All Banks Idle; Power down mode; $CKE \leq V_{IL} \text{ max}$; $t_{CK} = t_{CK} \text{ min}$; $V_{in} = V_{REF}$ for DQ, DQS and DM | 2 | 2 | | |
| IDD2F | IDLE FLOATING STANDBY CURRENT: $\overline{CS} \geq V_{IH} \text{ min}$; All Banks Idle; $CKE \geq V_{IH} \text{ min}$; Address and other control inputs changing once per clock cycle; $V_{in} = V_{ref}$ for DQ, DQS and DM | 45 | 40 | | 7 |
| IDD2N | IDLE STANDBY CURRENT: $\overline{CS} \geq V_{IH} \text{ min}$; All Banks Idle; $CKE \geq V_{IH} \text{ min}$; $t_{CK} = t_{CK} \text{ min}$; Address and other control inputs changing once per clock cycle; $V_{in} \geq V_{IH} \text{ min}$ or $V_{in} \leq V_{IL} \text{ max}$ for DQ, DQS and DM | 45 | 40 | | 7 |
| IDD2Q | IDLE QUIET STANDBY CURRENT: $\overline{CS} \geq V_{IH} \text{ min}$; All Banks Idle; $CKE \geq V_{IH} \text{ min}$; $t_{CK} = t_{CK} \text{ min}$; Address and other control inputs stable; $V_{in} \geq V_{REF}$ for DQ, DQS and DM | 40 | 35 | | 7 |
| IDD3P | ACTIVE POWER-DOWN STANDBY CURRENT: One Bank Active; Power down mode; $CKE \leq V_{IL} \text{ max}$; $t_{CK} = t_{CK} \text{ min}$ | 20 | 20 | | |
| IDD3N | ACTIVE STANDBY CURRENT: $\overline{CS} \geq V_{IH} \text{ min}$; $CKE \geq V_{IH} \text{ min}$; One Bank Active-Precharge; $t_{RC} = t_{RAS} \text{ max}$; $t_{CK} = t_{CK} \text{ min}$; DQ, DM and DQS inputs changing twice per clock cycle; Address and other control inputs changing once per clock cycle | 70 | 65 | | 7 |
| IDD4R | OPERATING CURRENT: Burst=2; Reads; Continuous burst; One Bank Active; Address and control inputs changing once per clock cycle; $CL=2.5$; $t_{CK} = t_{CK} \text{ min}$; $I_{OUT}=0\text{mA}$ | 165 | 155 | | 7, 9 |
| IDD4W | OPERATING CURRENT: Burst=2; Write; Continuous burst; One Bank Active; Address and control inputs changing once per clock cycle; $CL=2.5$; $t_{CK} = t_{CK} \text{ min}$; DQ, DM and DQS inputs changing twice per clock cycle | 165 | 155 | | 7 |
| IDD5 | AUTO REFRESH CURRENT: $t_{RC} = t_{RFC} \text{ min}$ | 190 | 190 | | 7 |
| IDD6 | SELF REFRESH CURRENT: $CKE \leq 0.2V$ | 3 | 3 | | |
| IDD7 | RANDOM READ CURRENT: 4 Banks Active Read with activate every 20ns, Auto-Precharge Read every 20ns; Burst=4; $t_{RCD} = 3$; $I_{OUT} = 0 \text{ mA}$; DQ, DM and DQS inputs changing twice per clock cycle; Address changing once per clock cycle | 270 | 270 | | |



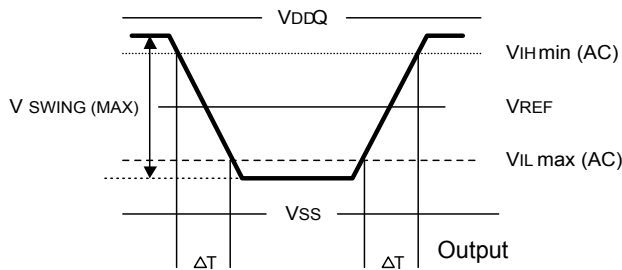
AC Characteristics and Operating Condition

(Notes: 10, 12)

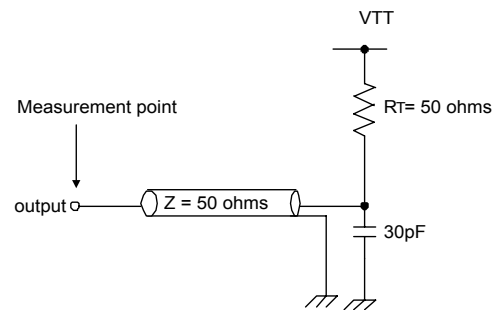
| SYM. | PARAMETER | -70 | | -75 | | UNITS | NOTES |
|--------|--|-------------------|--------|-------------------|--------|-------|-------|
| | | MIN. | MAX. | MIN. | MAX. | | |
| trc | Active to Ref/Active Command Period | 65 | | 65 | | nS | |
| trfc | Ref to Ref/Active Command Period | 75 | | 75 | | | |
| trac | Active to Precharge Command Period | 45 | 100000 | 45 | 100000 | | |
| trcd | Active to Read/Write Command Delay Time | 20 | | 20 | | | |
| trap | Active to Read with Auto Precharge Enable | 15 | | 15 | | | |
| tccd | Read/Write(a) to Read/Write(b) Command Period | 1 | | 1 | | tck | |
| trp | Precharge to Active Command Period | 20 | | 20 | | nS | |
| trrd | Active(a) to Active(b) Command Period | 15 | | 15 | | | |
| twr | Write Recovery Time | 15 | | 15 | | | |
| tdal | Auto Precharge Write Recovery + Precharge Time | 30 | | 30 | | | |
| tck | CLK Cycle Time | CL = 2 | 7.5 | 15 | 8 | | |
| | | CL = 2.5 | 7 | 15 | 7.5 | | |
| tac | Data Access Time from CLK, $\overline{\text{CLK}}$ | -0.75 | 0.75 | -0.75 | 0.75 | | 16 |
| tdqack | DQS Output Access Time from CLK, $\overline{\text{CLK}}$ | -0.75 | 0.75 | -0.75 | 0.75 | | |
| tdqsq | Data Strobe Edge to Output Data Edge Skew | | 0.5 | | 0.5 | | |
| tch | CLK High Level Width | 0.45 | 0.55 | 0.45 | 0.55 | tck | 11 |
| tcl | CLK Low Level Width | 0.45 | 0.55 | 0.45 | 0.55 | | |
| thp | CLK Half Period (minimum of actual tch, tcl) | Min. (tcl,tch) | | Min. (tcl,tch) | | nS | |
| tqh | DQ Output Data Hold Time from DQS | THP -0.75 | | THP -0.75 | | | |
| trpre | DQS Read Preamble Time | 0.9 | 1.1 | 0.9 | 1.1 | tck | 11 |
| trpst | DQS Read Postamble Time | 0.4 | 0.6 | 0.4 | 0.6 | | |
| tds | DQ and DM Setup Time | 0.5 | | 0.5 | | nS | |
| tdh | DQ and DM Hold Time | 0.5 | | 0.5 | | | |
| tdipw | DQ and DM Input Pulse Width (for each input) | 1.75 | | 1.75 | | | |
| tdqsh | DQS Input High Pulse Width | 0.35 | | 0.35 | | tck | 11 |
| tdqsl | DQS Input Low Pulse Width | 0.35 | | 0.35 | | | |
| tdss | DQS Falling Edge to CLK Setup Time | 0.2 | | 0.2 | | | |
| tdsh | DQS Falling Edge Hold Time from CLK | 0.2 | | 0.2 | | | |
| twpres | Clock to DQS Write Preamble Set-up Time | 0 | | 0 | | nS | |
| twpre | DQS Write Preamble Time | 0.25 | | 0.25 | | tck | 11 |
| twpst | DQS Write Postamble Time | 0.4 | | 0.4 | | | |
| tdqss | Write Command to First DQS Latching Transition | 0.75 | 1.25 | 0.75 | 1.25 | | |
| tdssk | UDQS – LDQS Skew (x 16) | -0.25 | 0.25 | -0.25 | 0.25 | | |
| tis | Input Setup Time | 0.9 | | 0.9 | | nS | |
| tih | Input Hold Time | 0.9 | | 0.9 | | | |
| tipw | Control & Address Input Pulse Width (for each input) | 2.2 | | 2.2 | | | |
| thz | Data-out High-impedance Time from CLK, $\overline{\text{CLK}}$ | -0.75 | 0.75 | -0.75 | 0.75 | | |
| tlz | Data-out Low-impedance Time from CLK, $\overline{\text{CLK}}$ | -0.75 | 0.75 | -0.75 | 0.75 | | |
| tt(ss) | SSTL Input Transition | 0.5 | 1.5 | 0.5 | 1.5 | | |
| twtr | Internal Write to Read Command Delay | 1 | | 1 | | tck | |
| txsnr | Exit Self Refresh to non-Read Command | 75 | | 75 | | nS | |
| txsrd | Exit Self Refresh to Read Command | 10 | | 10 | | tck | |
| tref | Refresh Time (8k) | | 64 | | 64 | mS | |
| tmrdr | Mode Register Set Cycle Time | 15 | | 15 | | nS | |

AC Test Conditions

| PARAMETER | SYMBOL | VALUE | UNIT |
|--|--------------|----------------------|------|
| Input High Voltage (AC) | V_{IH} | $V_{REF} + 0.31$ | V |
| Input Low Voltage (AC) | V_{IL} | $V_{REF} - 0.31$ | V |
| Input Reference Voltage | V_{REF} | $0.5 \times V_{DDQ}$ | V |
| Termination Voltage | V_{TT} | $0.5 \times V_{DDQ}$ | V |
| Input Signal Peak to Peak Swing | V_{SWING} | 1.0 | V |
| Differential Clock Input Reference Voltage | V_R | V_x (AC) | V |
| Input Difference Voltage. CLK and \overline{CLK} inputs (AC) | $V_{ID(AC)}$ | 1.5 | V |
| Input Signal Minimum Slew Rate | SLEW | 1.0 | V/nS |
| Output timing Measurement Reference Voltage | V_{OTR} | $0.5 \times V_{DDQ}$ | V |



$$SLEW = (V_{IHmin}(AC) - V_{ILmax}(AC)) / \Delta T$$

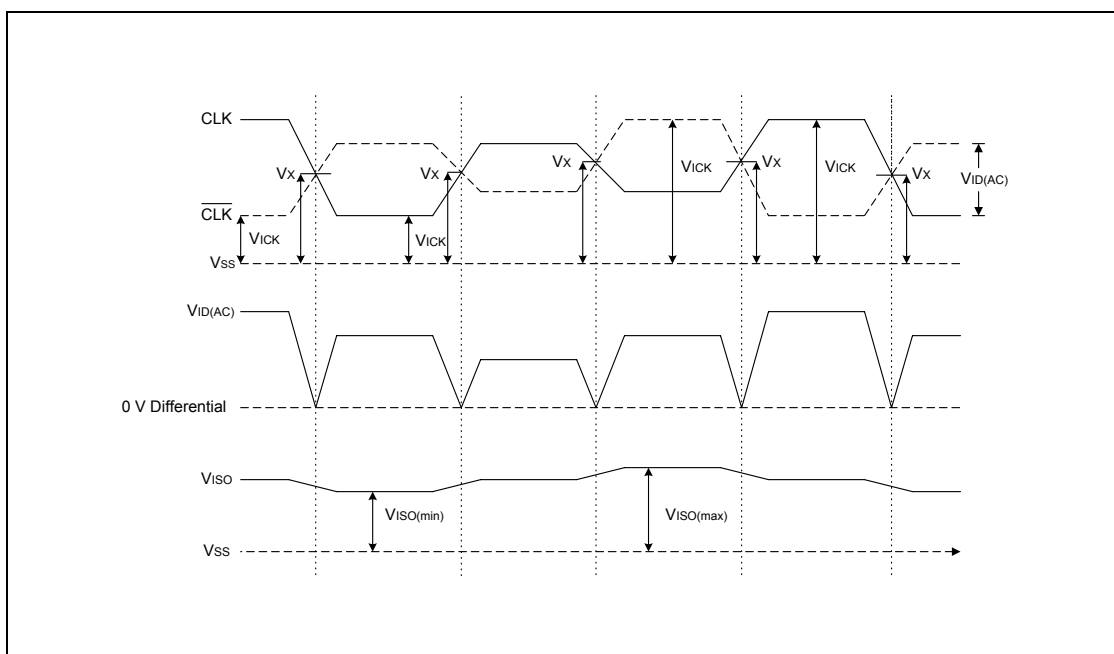


A.C. TEST LOAD (A)

Notes:

- (1) Conditions outside the limits listed under "ABSOLUTE MAXIMUM RATINGS" may cause permanent damage to the device.
- (2) All voltages are referenced to V_{SS} , V_{SSQ} .
- (3) Peak to peak AC noise on V_{REF} may not exceed $\pm 2\% V_{REF(DC)}$.
- (4) $V_{OH} = 1.95V$, $V_{OL} = 0.35V$
- (5) $V_{OH} = 1.9V$, $V_{OL} = 0.4V$
- (6) The values of $I_{OH(DC)}$ is based on $V_{DDQ}=2.3V$ and $V_{TT} = 1.19V$.
The values of $I_{OL(DC)}$ is based on $V_{DDQ}=2.3V$ and $V_{TT} = 1.11V$.
- (7) These parameters depend on the cycle rate and these values are measured at a cycle rate with the minimum values of t_{CK} and t_{rc} .

- (8) V_{TT} is not applied directly to the device. V_{TT} is a system supply for signal termination resistors, is expected to be set equal to V_{REF} and must track variations in the DC level of V_{REF} .
- (9) These parameters depend on the output loading. Specified values are obtained with the output open.
- (10) Transition times are measured between $V_{IH \min(AC)}$ and $V_{IL \max(AC)}$. Transition (rise and fall) of input signals have a fixed slope.
- (11) IF the result of nominal calculation with regard to t_{CK} contains more than one decimal place, the result is rounded up to the nearest decimal place.
(i.e., $t_{DQSS} = 0.75 \times t_{CK}$, $t_{CK} = 7.5 \text{ nS}$, $0.75 \times 7.5 \text{ ns} = 5.625 \text{ ns}$ is rounded up to 5.6 nS.)
- (12) V_x is the differential clock cross point voltage where input timing measurement is referenced.
- (13) V_{ID} is magnitude of the difference between CLK input level and $\overline{\text{CLK}}$ input level.
- (14) V_{ISO} means $\{V_{ICK}(\text{CLK}) + V_{ICK}(\overline{\text{CLK}})\}/2$.
- (15) Refer to the figure below.



- (16) t_{AC} and t_{DQCK} depend on the clock jitter. These timing are measured at stable clock.



8. OPERATION MODE

The following table shows the operation commands.

Simplified Truth Table

| SYM. | COMMAND | DEVICE STATE | CKE _{N-1} | CKE _N | DM ⁽⁴⁾ | BS0, BS1 | A10 | A12, A11, A9-A0 | $\overline{\text{CS}}$ | $\overline{\text{RAS}}$ | $\overline{\text{CAS}}$ | $\overline{\text{WE}}$ |
|-------|----------------------------|----------------------------|--------------------|------------------|-------------------|----------|-----|-----------------|------------------------|-------------------------|-------------------------|------------------------|
| ACT | Bank Active | Idle ⁽³⁾ | H | X | X | V | V | V | L | L | H | H |
| PRE | Bank Precharge | Any ⁽³⁾ | H | X | X | V | L | X | L | L | H | L |
| PREA | Precharge All | Any | H | X | X | X | H | X | L | L | H | L |
| WRIT | Write | Active ⁽³⁾ | H | X | X | V | L | V | L | H | L | L |
| WRITA | Write with Auto Precharge | Active ⁽³⁾ | H | X | X | V | H | V | L | H | L | L |
| READ | Read | Active ⁽³⁾ | H | X | X | V | L | V | L | H | L | H |
| READA | Read with Auto Precharge | Active ⁽³⁾ | H | X | X | V | H | V | L | H | L | H |
| MRS | Mode Register Set | Idle | H | X | X | L, L | C | C | L | L | L | L |
| EMRS | Extended Mode Register Set | Idle | H | X | X | H, L | V | V | L | L | L | L |
| NOP | No Operation | Any | H | X | X | X | X | X | L | H | H | H |
| BST | Burst Read Stop | Active | H | X | X | X | X | X | L | H | H | L |
| DSL | Device Deselect | Any | H | X | X | X | X | X | H | X | X | X |
| AREF | Auto Refresh | Idle | H | H | X | X | X | X | L | L | L | H |
| SELF | Self Refresh Entry | Idle | H | L | X | X | X | X | L | L | L | H |
| SELEX | Self Refresh Exit | Idle (Self Refresh) | L | H | X | X | X | X | H | X | X | X |
| | | | | | | | | | L | H | H | X |
| PD | Power Down Mode Entry | Idle/Active ⁽⁵⁾ | H | L | X | X | X | X | H | X | X | X |
| | | | | | | | | | L | H | H | X |
| PDEX | Power Down Mode Exit | Any (Power Down) | L | H | X | X | X | X | H | X | X | X |
| | | | | | | | | | L | H | H | X |
| WDE | Data Write Enable | Active | H | X | L | X | X | X | X | X | X | X |
| WDD | Data Write Disable | Active | H | X | H | X | X | X | X | X | X | X |

Notes:

1. V = Valid X = Don't Care L = Low level H = High level
2. CKE_N signal is input level when commands are issued.
CKE_{N-1} signal is input level one clock cycle before the commands are issued.
3. These are state designated by the BS0, BS1 signals.
4. LDM, UDM (W942516CH)
5. Power Down Mode can not entry in the burst cycle.

Function Truth Table

(Note 1)

| CURRENT STATE | \overline{CS} | \overline{RAS} | \overline{CAS} | \overline{WE} | ADDRESS | COMMAND | ACTION | NOTES |
|---------------|-----------------|------------------|------------------|-----------------|-------------|-------------|--------------------------------------|-------|
| Idle | H | X | X | X | X | DSL | Nop | |
| | L | H | H | X | X | NOP/BST | Nop | |
| | L | H | L | H | BS, CA, A10 | READ/READA | ILLEGAL | 3 |
| | L | H | L | L | BS, CA, A10 | WRIT/WRITA | ILLEGAL | 3 |
| | L | L | H | H | BS, RA | ACT | Row activating | |
| | L | L | H | L | BS, A10 | PRE/PREA | Nop | |
| | L | L | L | H | X | AREF/SELF | Refresh or Self refresh | 2 |
| | L | L | L | L | Op-Code | MRS/EMRS | Mode register accessing | 2 |
| Row Active | H | X | X | X | X | DSL | Nop | |
| | L | H | H | X | X | NOP/BST | Nop | |
| | L | H | L | H | BS, CA, A10 | READ/READAA | Begin read: Determine AP | 4 |
| | L | H | L | L | BS, CA, A10 | WRIT/WRITA | Begin write: Determine AP | 4 |
| | L | L | H | H | BS, RA | ACT | ILLEGAL | 3 |
| | L | L | H | L | BS, A10 | PRE/PREA | Precharge | 5 |
| | L | L | L | H | X | AREF/SELF | ILLEGAL | |
| | L | L | L | L | Op-Code | MRS/EMRS | ILLEGAL | |
| Read | H | X | X | X | X | DSL | Continue burst to end | |
| | L | H | H | H | X | NOP | Continue burst to end | |
| | L | H | H | L | X | BST | Burst stop | |
| | L | H | L | H | BS, CA, A10 | READ/READA | Term burst, new read: Determine AP | 6 |
| | L | H | L | L | BS, CA, A10 | WRIT/WRITA | ILLEGAL | |
| | L | L | H | H | BS, RA | ACT | ILLEGAL | 3 |
| | L | L | H | L | BS, A10 | PRE/PREA | Term burst, precharging | |
| | L | L | L | H | X | AREF/SELF | ILLEGAL | |
| | L | L | L | L | Op-Code | MRS/EMRS | ILLEGAL | |
| Write | H | X | X | X | X | DSL | Continue burst to end | |
| | L | H | H | H | X | NOP | Continue burst to end | |
| | L | H | H | L | X | BST | ILLEGAL | |
| | L | H | L | H | BS, CA, A10 | READ/READA | Term burst, start read: Determine AP | 6, 7 |
| | L | H | L | L | BS, CA, A10 | WRIT/WRITA | Term burst, start read: Determine AP | 6 |
| | L | L | H | H | BS, RA | ACT | ILLEGAL | 3 |
| | L | L | H | L | BS, A10 | PRE/PREA | Term burst. precharging | 8 |
| | L | L | L | H | X | AREF/SELF | ILLEGAL | |
| | L | L | L | L | Op-Code | MRS/EMRS | ILLEGAL | |

Function Truth Table, continued

| CURRENT STATE | CS | RAS | CAS | WE | ADDRESS | COMMAND | ACTION | NOTES |
|---------------------------|----|-----|-----|----|-------------|------------|-----------------------------|-------|
| Read with Auto Precharge | H | X | X | X | X | DSL | Continue burst to end | |
| | L | H | H | H | X | NOP | Continue burst to end | |
| | L | H | H | L | X | BST | ILLEGAL | |
| | L | H | L | H | BS, CA, A10 | READ/READA | ILLEGAL | |
| | L | H | L | L | BS, CA, A10 | WRIT/WRITA | ILLEGAL | 3 |
| | L | L | H | H | BS, RA | ACT | ILLEGAL | 3 |
| | L | L | H | L | BS, A10 | PRE/PREA | ILLEGAL | |
| | L | L | L | H | X | AREF/SELF | ILLEGAL | |
| | L | L | L | L | Op-Code | MRS/EMRS | ILLEGAL | |
| Write with Auto Precharge | H | X | X | X | X | DSL | Continue burst to end | |
| | L | H | H | H | X | NOP | Continue burst to end | |
| | L | H | H | L | X | BST | ILLEGAL | |
| | L | H | L | H | BS, CA, A10 | READ/READA | ILLEGAL | |
| | L | H | L | L | BS, CA, A10 | WRIT/WRITA | ILLEGAL | |
| | L | L | H | H | BS, RA | ACT | ILLEGAL | 3 |
| | L | L | H | L | BS, A10 | PRE/PREA | ILLEGAL | 3 |
| | L | L | L | H | X | AREF/SELF | ILLEGAL | |
| | L | L | L | L | Op-Code | MRS/EMRS | ILLEGAL | |
| Precharging | H | X | X | X | X | DSL | Nop-> Idle after trP | |
| | L | H | H | H | X | NOP | Nop-> Idle after trP | |
| | L | H | H | L | X | BST | ILLEGAL | |
| | L | H | L | H | BS, CA, A10 | READ/READA | ILLEGAL | 3 |
| | L | H | L | L | BS, CA, A10 | WRIT/WRITA | ILLEGAL | 3 |
| | L | L | H | H | BS, RA | ACT | ILLEGAL | 3 |
| | L | L | H | L | BS, A10 | PRE/PREA | Nop-> Idle after trP | |
| | L | L | L | H | X | AREF/SELF | ILLEGAL | |
| | L | L | L | L | Op-Code | MRS/EMRS | ILLEGAL | |
| Row Activating | H | X | X | X | X | DSL | Nop-> Row active after trCD | |
| | L | H | H | H | X | NOP | Nop-> Row active after trCD | |
| | L | H | H | L | X | BST | ILLEGAL | |
| | L | H | L | H | BS, CA, A10 | READ/READA | ILLEGAL | 3 |
| | L | H | L | L | BS, CA, A10 | WRIT/WRITA | ILLEGAL | 3 |
| | L | L | H | H | BS, RA | ACT | ILLEGAL | 3 |
| | L | L | H | L | BS, A10 | PRE/PREA | ILLEGAL | 3 |
| | L | L | L | H | X | AREF/SELF | ILLEGAL | |
| | L | L | L | L | Op-Code | MRS/EMRS | ILLEGAL | |



Function Truth Table, continued

| CURRENT STATE | CS | RAS | CAS | WE | ADDRESS | COMMAND | ACTION | NOTES |
|--------------------------------------|----|-----|-----|----|-------------|---------------------------------|--------------------------------|-------|
| Write Recovering | H | X | X | X | X | DSL | Nop->Row active after twr | |
| | L | H | H | H | X | NOP | Nop->Row active after twr | |
| | L | H | H | L | X | BST | ILLEGAL | |
| | L | H | L | H | BS, CA, A10 | READ/READA | ILLEGAL | 3 |
| | L | H | L | L | BS, CA, A10 | WRIT/WRITA | ILLEGAL | 3 |
| | L | L | H | H | BS, RA | ACT | ILLEGAL | 3 |
| | L | L | H | L | BS,A10 | PRE/PREA | ILLEGAL | 3 |
| | L | L | L | H | X | AREF/SELF | ILLEGAL | |
| | L | L | L | L | Op-Code | MRS/EMRS | ILLEGAL | |
| Write Recovering with Auto Precharge | H | X | X | X | X | DSL | Nop->Enter precharge after twr | |
| | L | H | H | H | X | NOP | Nop->Enter precharge after twr | |
| | L | H | H | L | X | BST | ILLEGAL | |
| | L | H | L | H | BS, CA, A10 | READ/READA | ILLEGAL | 3 |
| | L | H | L | L | BS, CA, A10 | WRIT/WRITA | ILLEGAL | 3 |
| | L | L | H | H | BS, RA | ACT | ILLEGAL | 3 |
| | L | L | H | L | BS, A10 | PRE/PREA | ILLEGAL | 3 |
| | L | L | L | H | X | AREF/SELF | ILLEGAL | |
| | L | L | L | L | Op-Code | MRS/EMRS | ILLEGAL | |
| Refreshing | H | X | X | X | X | DSL | Nop->Idle after trc | |
| | L | H | H | H | X | NOP | Nop->Idle after trc | |
| | L | H | H | L | X | BST | ILLEGAL | |
| | L | H | L | H | X | READ/WRIT | ILLEGAL | |
| | L | L | H | X | X | ACT/PRE/PREA | ILLEGAL | |
| | L | L | L | X | X | AREF/SELF/MRS/EMRS | ILLEGAL | |
| Mode Register Accessing | H | X | X | X | X | DSL | Nop->Row after tMRD | |
| | L | H | H | H | X | NOP | Nop->Row after tMRD | |
| | L | H | H | L | X | BST | ILLEGAL | |
| | L | H | L | X | X | READ/WRIT | ILLEGAL | |
| | L | L | X | X | X | ACT/PRE/PREA/AREF/SELF/MRS/EMRS | ILLEGAL | |

Notes:

1. All entries assume that CKE was active (High level) during the preceding clock cycle and the current clock cycle.
2. Illegal if any bank is not idle.
3. Illegal to bank in specified states; Function may be legal in the bank indicated by Bank Address (BS), depending on the state of that bank.
4. Illegal if trCD is not satisfied.
5. Illegal if trAS is not satisfied.
6. Must satisfy burst interrupt condition.
7. Must avoid bus contention, bus turn around, and/or satisfy write recovery requirements.
8. Must mask preceding data which don't satisfy twr

Remark: H = High level, L = Low level, X = High or Low level (Don't care), V = Valid data

Function Truth Table for CKE

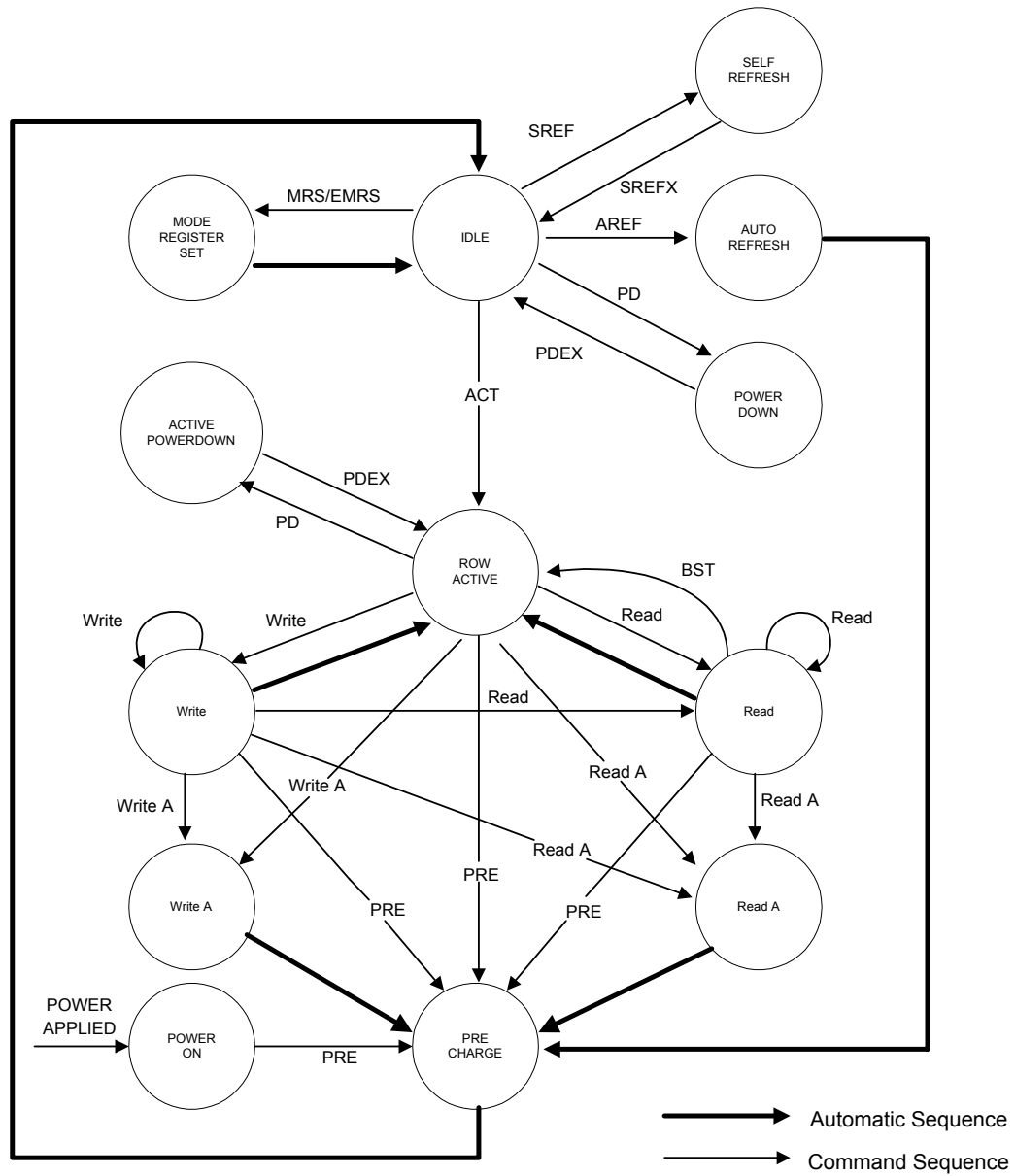
| CURRENT STATE | CKE | | $\overline{\text{CS}}$ | $\overline{\text{RAS}}$ | $\overline{\text{CAS}}$ | $\overline{\text{WE}}$ | ADDRESS | ACTION | NOTES |
|-----------------------------------|-----|---|------------------------|-------------------------|-------------------------|------------------------|---------|--|-------|
| | n-1 | n | | | | | | | |
| Self Refresh | H | X | X | X | X | X | X | INVALID | |
| | L | H | H | X | X | X | X | Exit Self Refresh→Idle after t _{XSNR} | |
| | L | H | L | H | H | X | X | Exit Self Refresh→Idle after t _{XSNR} | |
| | L | H | L | H | L | X | X | ILLEGAL | |
| | L | H | L | L | X | X | X | ILLEGAL | |
| | L | L | X | X | X | X | X | Maintain Self Refresh | |
| Power Down | H | X | X | X | X | X | X | INVALID | |
| | L | H | X | X | X | X | X | Exit Power down→Idle after t _{is} | |
| | L | L | X | X | X | X | X | Maintain power down mode | |
| All Banks Idle | H | H | X | X | X | X | X | Refer to Function Truth Table | |
| | H | L | H | X | X | X | X | Enter Power down | 2 |
| | H | L | L | H | H | X | X | Enter Power down | 2 |
| | H | L | L | L | L | H | X | Self Refresh | 1 |
| | H | L | L | H | L | X | X | ILLEGAL | |
| | H | L | L | L | X | X | X | ILLEGAL | |
| | L | X | X | X | X | X | X | Power down | 2 |
| Row Active | H | H | X | X | X | X | X | Refer to Function Truth Table | |
| | H | L | H | X | X | X | X | Enter Power down | 2 |
| | H | L | L | H | H | X | X | Enter Power down | 2 |
| | H | L | L | L | L | H | X | ILLEGAL | |
| | H | L | L | H | L | X | X | ILLEGAL | |
| | H | L | L | L | X | X | X | ILLEGAL | |
| | L | X | X | X | X | X | X | Power down | |
| Any State Other Than Listed Above | H | H | X | X | X | X | X | Refer to Function Truth Table | |

Notes:

1. Self refresh can enter only from the all banks idle state.
2. Power down can enter only from bank idle or row active state.

Remark: H = High level, L = Low level, X = High or Low level (Don't care), V = Valid data

Simplified State Diagram



9. FUNCTIONAL DESCRIPTION

Power Up Sequence

1. Apply power and attempt to CKE at a low state ($\leq 0.2V$), all other inputs may be undefined
 - 1) Apply VDD before or at the same time as VDDQ.
 - 2) Apply VDDQ before or at the same time as VTT and VREF.
2. Start Clock and maintain stable condition for 200 μ S(min).
3. After stable power and clock, apply NOP and take CKE high.
4. Issue EMRS (Extended Mode Register Set) to enable DLL and establish Output Driver Type.
5. Issue MRS (Mode Register Set) to reset DLL and set device to idle with bit A8.
(an additional 200 cycles(min) of clock are required for DLL Lock)
6. Issue precharge command for all banks of the device.
7. Issue two or more Auto Refresh commands.
8. Issue MRS-Initialize device operation.
(If device operation mode is set at sequence 5, sequence 8 can be skipped.)

Command Function

1. Bank Activate Command

(\overline{RAS} = "L", \overline{CAS} = "H", \overline{WE} = "H", BS0, BS1 = Bank, A0 to A12 = Row Address)

The Bank Activate command activates the bank designated by the BS (Bank address) signal. Row addresses are latched on A0 to A12 when this command is issued and the cell data is read out of the sense amplifiers. The maximum time that each bank can be held in the active state is specified as tRAS (max). After this command is issued, Read or Write operation can be executed.

2. Bank Precharge Command

(\overline{RAS} = "L", \overline{CAS} = "H", \overline{WE} = "L", BS0, BS1 = Bank, A10 = "L", A0 to A9, A11, A12 = Don't care)

The Bank Precharge command precharges the bank designated by BS. The precharged bank is switched from the active state to the idle state.

3. Precharge All Command

(\overline{RAS} = "L", \overline{CAS} = "H", \overline{WE} = "L", BS0, BS1 = Don't care, A10 = "H", A0 to A9, A11, A12 = Don't care)

The Precharge All command precharges all banks simultaneously. Then all banks are switched to the idle state.

4. Write Command

(\overline{RAS} = "H", \overline{CAS} = "L", \overline{WE} = "L", BS0, BS1 = Bank, A10 = "L", A0 to A9, A11 = Column Address)

The write command performs a Write operation to the bank designated by BS. The write data are latched at both edges of DQS. The length of the write data (Burst Length) and column access sequence (Addressing Mode) must be in the Mode Register at power-up prior to the Write operation.



5. Write with Auto Precharge Command

(\overline{RAS} = "H", \overline{CAS} = "L", \overline{WE} = "L", BS0, BS1 = Bank, A10 = "H", A0 to A9, A11 = Column Address)

The Write with Auto Precharge command performs the Precharge operation automatically after the Write operation. This command must not be interrupted by any other commands.

6. Read Command

(\overline{RAS} = "H", \overline{CAS} = "L", \overline{WE} = "H", BS0, BS1 = Bank, A10 = "L", A0 to A9, A11 = Column Address)

The Read command performs a Read operation to the bank designated by BS. The read data are synchronized with both edges of DQS. The length of read data (Burst Length), Addressing Mode and \overline{CAS} Latency (access time from \overline{CAS} command in a clock cycle) must be programmed in the Mode Register at power-up prior to the Read operation.

7. Read with Auto Precharge Command

(\overline{RAS} = "H", \overline{CAS} = "L", \overline{WE} = "H", BS0, BS1 = Bank, A10 = "H", A0 to A9, A11 = Column Address)

The Read with Auto precharge command automatically performs the Precharge operation after the Read operation.

$$1) \text{READA} \geq t_{RAS}(\text{min}) - (\text{BL}/2) \times t_{CK}$$

Internal precharge operation begins after BL/2 cycle from Read with Auto Precharge command.

$$2) t_{RCD}(\text{min}) \leq \text{READA} < t_{RAS}(\text{min}) - (\text{BL}/2) \times t_{CK}$$

Data can be read with shortest latency, but the internal Precharge operation does not begin until after $t_{RAS}(\text{min})$ has completed.

This command must not be interrupted by any other command.

8. Mode Register Set Command

(\overline{RAS} = "L", \overline{CAS} = "L", \overline{WE} = "L", BS0 = "L", BS1 = "L", A0 to A12 = Register Data)

The Mode Register Set command programs the values of \overline{CAS} latency, Addressing Mode, Burst Length and DLL reset in the Mode Register. The default values in the Mode Register after power-up are undefined, therefore this command must be issued during the power-up sequence. Also, this command can be issued while all banks are in the idle state. Refer to the table for specific codes.

9. Extended Mode Register Set Command

(\overline{RAS} = "L", \overline{CAS} = "L", \overline{WE} = "L", BS0 = "H", BS1 = "L", A0 to A12 = Register data)

The Extended Mode Register Set command can be implemented as needed for function extensions to the standard (SDR-SDRAM). Currently the only available mode in EMRS is DLL enable/disable, decoded by A0. The default value of the extended mode register is not defined; therefore this command must be issued during the power-up sequence for enabling DLL. Refer to the table for specific codes.



10. No-Operation Command

($\overline{\text{RAS}}$ = "H", $\overline{\text{CAS}}$ = "H", $\overline{\text{WE}}$ = "H")

The No-Operation command simply performs no operation (same command as Device Deselect).

11. Burst Read Stop Command

($\overline{\text{RAS}}$ = "H", $\overline{\text{CAS}}$ = "H", $\overline{\text{WE}}$ = "L")

The Burst stop command is used to stop the burst operation. This command is only valid during a Burst Read operation.

12. Device Deselect Command

($\overline{\text{CS}}$ = "H")

The Device Deselect command disables the command decoder so that the $\overline{\text{RAS}}$, $\overline{\text{CAS}}$, $\overline{\text{WE}}$ and Address inputs are ignored. This command is similar to the No-Operation command.

13. Auto Refresh Command

($\overline{\text{RAS}}$ = "L", $\overline{\text{CAS}}$ = "L", $\overline{\text{WE}}$ = "H", CKE = "L", BS0, BS1, A0 to A12 = Don't care)

The Auto Refresh command is used to refresh the row address provided by the internal refresh counter. The Refresh operation must be performed 8192 times within 64 mS. The next command can be issued after tREF from the end of the Auto Refresh command. When the Auto Refresh command is used, all banks must be in the idle state.

14. Self Refresh Entry Command

($\overline{\text{RAS}}$ = "L", $\overline{\text{CAS}}$ = "L", $\overline{\text{WE}}$ = "H", CKE = "L", BS0, BS1, A0 to A12 = Don't care)

The Self Refresh Entry command is used to enter Self Refresh mode. While the device is in Self Refresh mode, all input and output buffer (except the CKE buffer) are disabled and the Refresh operation is automatically performed. Self Refresh mode is exited by taking CKE "high" (the Self Refresh Exit command). During self refresh, DLLI is disable.

15. Self Refresh Exit Command

(CKE = "H", $\overline{\text{CS}}$ = "H" or CKE = "H", $\overline{\text{RAS}}$ = "H", $\overline{\text{CAS}}$ = "H")

This command is used to exit from Self Refresh mode. Any subsequent commands can be issued after tXSNR (tXSRD for Read Command) from the end of this command.

16. Data Write Enable /Disable Command

(DM = "L/H" or LDM, UDM = "L/H")

During a Write cycle, the DM or LDM, UDM signal functions as Data Mask and can control every word of the input data. The LDM signal controls DQ0 to DQ7 and UDM signal controls DQ8 to DQ15.



Read Operation

Issuing the Bank Activate command to the idle bank puts it into the active state. When the Read command is issued after t_{RCD} from the Bank Activate command, the data is read out sequentially, synchronized with both edges of DQS (Burst Read operation). The initial read data becomes available after \overline{CAS} latency from the issuing of the Read command. The \overline{CAS} latency must be set in the Mode Register at power-up.

When the Precharge Operation is performed on a bank during a Burst Read and operation, the Burst operation is terminated.

When the Read with Auto Precharge command is issued, the Precharge operation is performed automatically after the Read cycle, then the bank is switched to the idle state. This command cannot be interrupted by any other commands. Refer to the diagrams for Read operation.

Write Operation

Issuing the Write command after t_{RCD} from the bank activate command. The input data is latched sequentially, synchronizing with both edges(rising & falling) of DQS after the Write command (Burst write operation). The burst length of the Write data (Burst Length) and Addressing Mode must be set in the Mode Register at power-up.

When the Precharge operation is performed in a bank during a Burst Write operation, the Burst operation is terminated.

When the Write with Auto Precharge command is issued, the Precharge operation is performed automatically after the Write cycle, then the bank is switched to the idle state, The Write with Auto Precharge command cannot be interrupted by any other command for the entire burst data duration.

Refer to the diagrams for Write operation.

Precharge

There are two Commands, which perform the precharge operation (Bank Precharge and Precharge All). When the Bank Precharge command is issued to the active bank, the bank is precharged and then switched to the idle state. The Bank Precharge command can precharge one bank independently of the other bank and hold the unprecharged bank in the active state. The maximum time each bank can be held in the active state is specified as $t_{RAS(max)}$. Therefore, each bank must be precharged within $t_{RAS(max)}$ from the bank activate command.

The Precharge All command can be used to precharge all banks simultaneously. Even if banks are not in the active state, the Precharge All command can still be issued. In this case, the Precharge operation is performed only for the active bank and the precharge bank is then switched to the idle state.

Burst Termination

When the Precharge command is used for a bank in a Burst cycle, the Burst operation is terminated. When Burst Read cycle is interrupted by the Precharge command, read operation is disabled after clock cycle of (\overline{CAS} latency) from the Precharge command. When the Burst Write cycle is interrupted by the Precharge command, the input circuit is reset at the same clock cycle at which the precharge command is issued. In this case, the DM signal must be asserted "high": during t_{WR} to prevent writing the invalidated data to the cell array.



When the Burst Read Stop command is issued for the bank in a Burst Read cycle, the Burst Read operation is terminated. The Burst read Stop command is not supported during a write burst operation. Refer to the diagrams for Burst termination.

Refresh Operation

Two types of Refresh operation can be performed on the device: Auto Refresh and Self Refresh. By repeating the Auto Refresh cycle, each bank in turn refreshed automatically. The Refresh operation must be performed 8192 times (rows) within 64 mS. The period between the Auto Refresh command and the next command is specified by t_{RFC} .

Self Refresh mode enter issuing the Self Refresh command (CKE asserted "low"). while all banks are in the idle state. The device is in Self Refresh mode for as long as cke held "low". In the case of 8192 burst Auto Refresh commands, 8192 burst Auto Refresh commands must be performed within 7.8us before entering and after exiting the Self Refresh mode. In the case of distributed Auto Refresh commands, distributed auto refresh commands must be issued every 7.8 μ S and the last distributed Auto Refresh commands must be performed within 7.8us before entering the self refresh mode. After exiting from the Self Refresh mode, the refresh operation must be performed within 7.8 μ S. In Self Refresh mode, all input/output buffers are disable, resulting in lower power dissipation (except CKE buffer). Refer to the diagrams for Refresh operation.

Power Down Mode

Two types of Power Down Mode can be performed on the device: Active Standby Power Down Mode and Precharge Standby Power Down Mode.

When the device enters the Power Down Mode, all input/output buffers and DLL are disabled resulting in low power dissipation (except CKE buffer).

Power Down Mode enter asserting CKE "low" while the device is not running a burst cycle. Taking CKE: "high" can exit this mode. When CKE goes high, a No operation command must be input at next CLK rising edge. Refer to the diagrams for Power Down Mode.

Mode Register Operation

The mode register is programmed by the Mode Register Set command (MRS/EMRS) when all banks are in the idle state. The data to be set in the Mode Register is transferred using the A0 to A12 and BS0, BS1 address inputs.

The Mode Register designates the operation mode for the read or write cycle. The register is divided into five filed: (1) Burst Length field to set the length of burst data (2) Addressing Mode selected bit to designate the column access sequence in a Burst cycle (3) \overline{CAS} Latency field to set the assess time in clock cycle (4) DLL reset field to reset the dll (5) Regular/Extended Mode Register filed to select a type of MRS (Regular/Extended MRS). EMRS cycle can be implemented the extended function (DLL enable/Disable mode)

The initial value of the Mode Register (including EMRS) after power up is undefined; therefore the Mode Register Set command must be issued before power operation.

1. Burst Length field (A2 to A0)

This field specifies the data length for column access using the A2 to A0 pins and sets the Burst Length to be 2, 4, and 8 words.

| A2 | A1 | A0 | Burst Length |
|----|----|----|--------------|
| 0 | 0 | 0 | Reserved |
| 0 | 0 | 1 | 2 words |
| 0 | 1 | 0 | 4 words |
| 0 | 1 | 1 | 8 words |
| 1 | x | x | Reserved |

2. Addressing Mode Select (A3)


The Addressing Mode can be one of two modes; Interleave mode or Sequential Mode, When the A3 bit is "0", Sequential mode is selected. When the A3 bit is "1", Interleave mode is selected. Both addressing Mode support burst length 2, 4, and 8 words.

| A3 | Addressing mode |
|----|-----------------|
| 0 | Sequential |
| 1 | Interleave |

- Address sequence of Sequential mode

A column access is performed by incrementing the column address input to the device. The address is varied by the Burst Length as the following.

Addressing Sequence of Sequential Mode

| DATA | ACCESS ADDRESS | BURST LENGTH |
|--------|----------------|---|
| Data 0 | n |  2 words (address bits is A0) not carried from A0 to A1 4 words (address bit A0, A1) not carried from A1 to A2 8 words(address bits A2, A1 and A0) not carried from A2 to A3 |
| Data 1 | n + 1 | |
| Data 2 | n + 2 | |
| Data 3 | n + 3 | |
| Data 4 | n + 4 | 8 words(address bits A2, A1 and A0) not carried from A2 to A3 |
| Data 5 | n + 5 | |
| Data 6 | n + 6 | |
| Data 7 | n + 7 | |

- Addressing sequence of Interleave mode

A Column access is started from the inputted column address and is performed by interleaving the address bits in the sequence shown as the following.

Address Sequence for Interleave Mode

| DATA | ACCESS ADDRESS | BURST LENGTH |
|--------|---|--------------|
| Data 0 | A8 A7 A6 A5 A4 A3 A2 A1 A0 | 2 words |
| Data 1 | A8 A7 A6 A5 A4 A3 A2 A1 $\overline{A0}$ | |
| Data 2 | A8 A7 A6 A5 A4 A3 A2 $\overline{A1}$ A0 | 4 words |
| Data 3 | A8 A7 A6 A5 A4 A3 A2 $\overline{A1}$ $\overline{A0}$ | |
| Data 4 | A8 A7 A6 A5 A4 A3 $\overline{A2}$ A1 A0 | 8 words |
| Data 5 | A8 A7 A6 A5 A4 A3 $\overline{A2}$ A1 $\overline{A0}$ | |
| Data 6 | A8 A7 A6 A5 A4 A3 $\overline{A2}$ $\overline{A1}$ A0 | |
| Data 7 | A8 A7 A6 A5 A4 A3 $\overline{A2}$ $\overline{A1}$ $\overline{A0}$ | |

3. $\overline{\text{CAS}}$ Latency field (A6 to A4)

This field specifies the number of clock cycles from the assertion of the Read command to the first data read. The minimum values of $\overline{\text{CAS}}$ Latency depends on the frequency of CLK.

| A6 | A5 | A4 | $\overline{\text{CAS}}$ Latency |
|----|----|----|---------------------------------|
| 0 | 0 | 0 | Reserved |
| 0 | 0 | 1 | Reserved |
| 0 | 1 | 0 | 2 |
| 0 | 1 | 1 | Reserved |
| 1 | 0 | 0 | Reserved |
| 1 | 0 | 1 | Reserved |
| 1 | 1 | 0 | 2.5 |
| 1 | 1 | 1 | Reserved |

4. DLL Reset bit (A8)

This bit is used to reset DLL. When the A8 bit is "1", DLL is reset.

5. Mode Register /Extended Mode register change bits (BS0, BS1)

These bits are used to select MRS/EMRS.

| BS1 | BS0 | A12-A0 |
|-----|-----|--------------------|
| 0 | 0 | Regular MRS cycle |
| 0 | 1 | Extended MRS cycle |
| 1 | x | Reserved |

6. Extended Mode Register field

1) DLL Switch field (A0)

This bit is used to select DLL enable or disable

| A0 | DLL |
|----|---------|
| 0 | Enable |
| 1 | Disable |

2) Output Driver Size Control field (A1)

This bit is used to select Output Driver Size, both Full strength and Half strength are based on JEDEC standard.

| A1 | Output Driver |
|----|---------------|
| 0 | Full strength |
| 1 | Half strength |

7. Reserved field

- Test mode entry bit (A7)

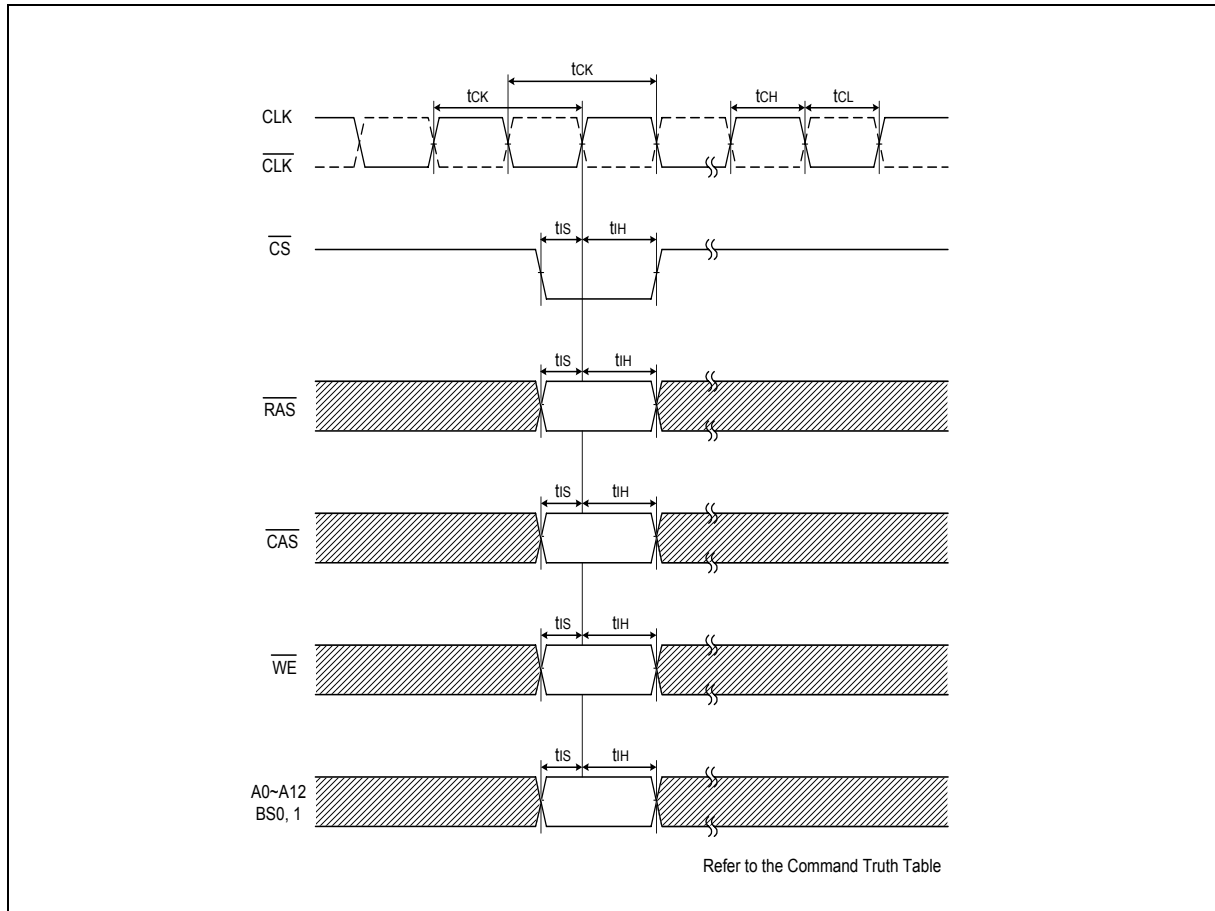
This bit is used to enter Test mode and must be set to "0" for normal operation.

- Reserved bits (A9, A10, A11, A12)

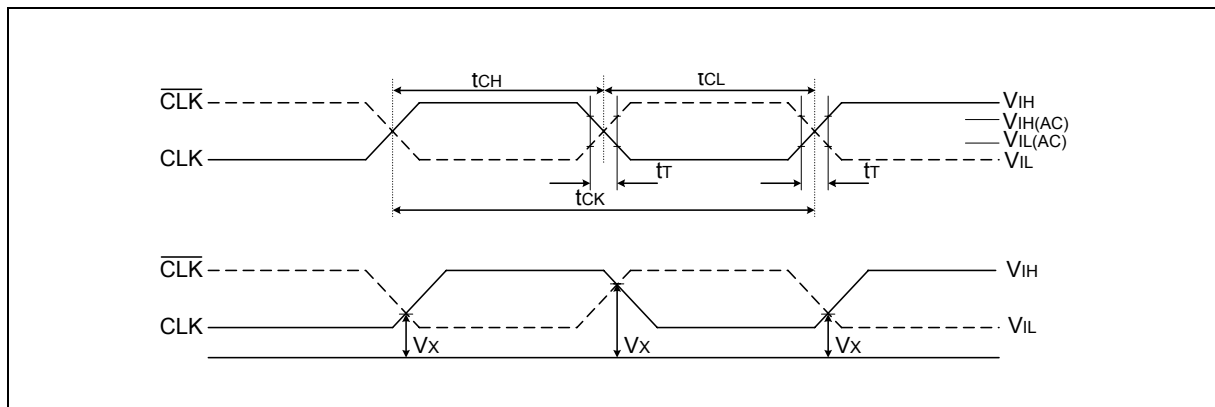
These bits are reserved for future operations. They must be set to "0" for normal operation.

10. TIMING WAVEFORMS

Command Input Timing

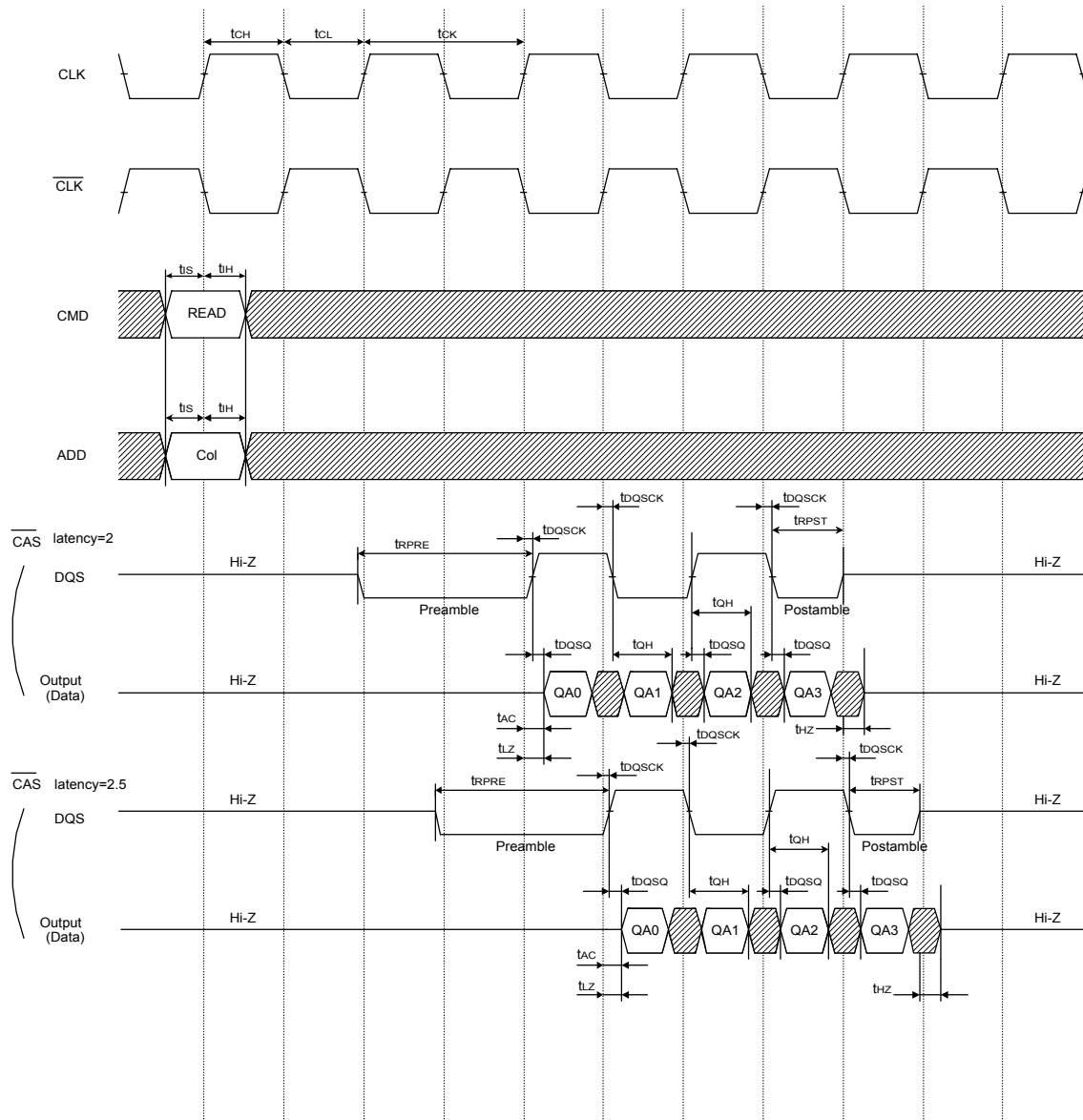


Timing of the CLK Signals



Timing Waveforms, continued

Read Timing (Burst Length = 4)

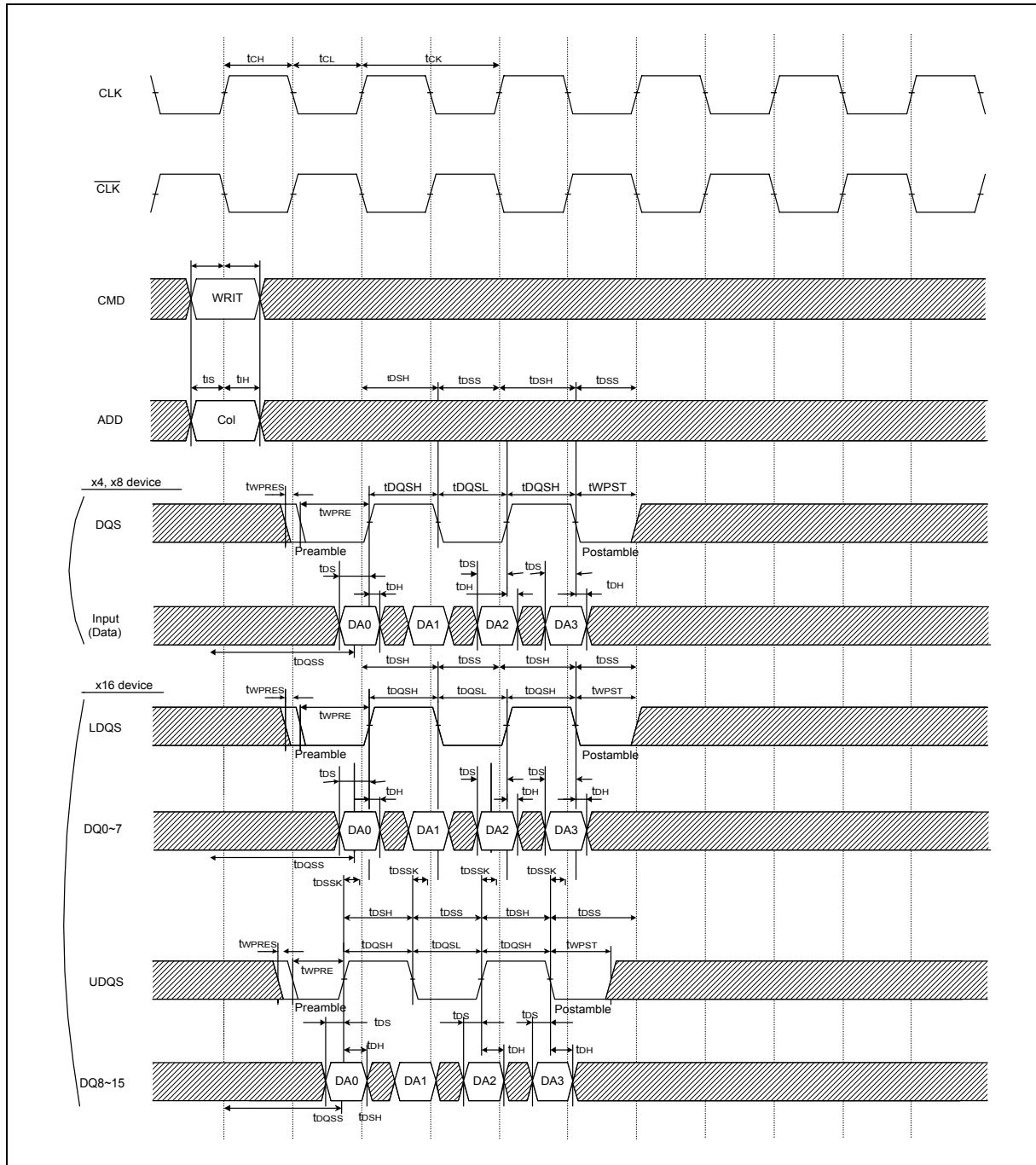


Note: The correspondence of LDQS, UDQS to DQ. (W942516AH)

| | |
|------|--------|
| LDQS | DQ0~7 |
| UDQS | DQ8~15 |

Timing Waveforms, continued

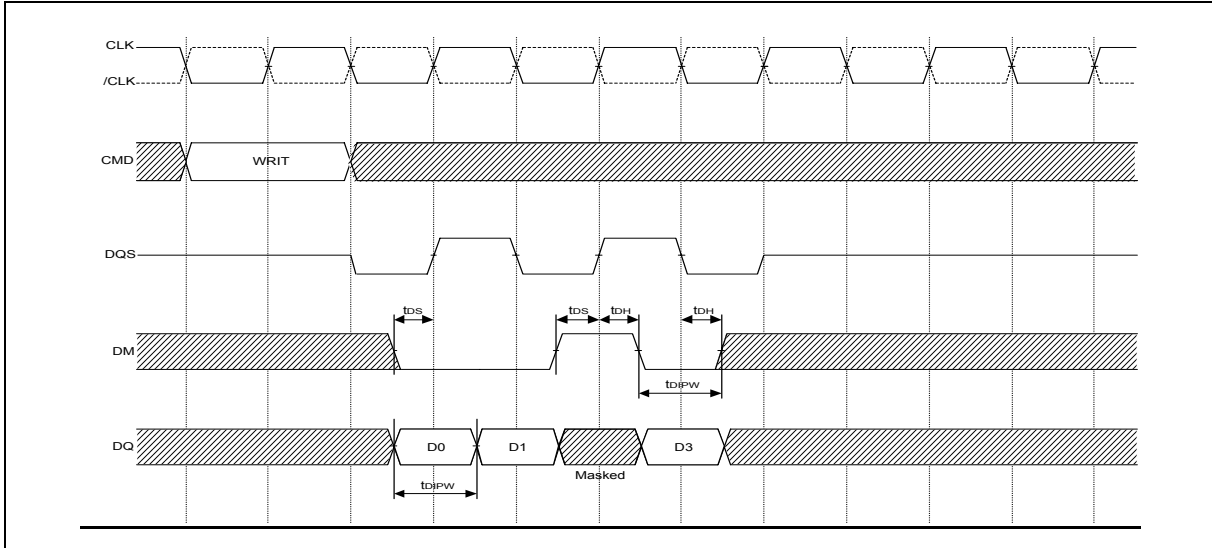
Write Timing (Burst Length = 4)



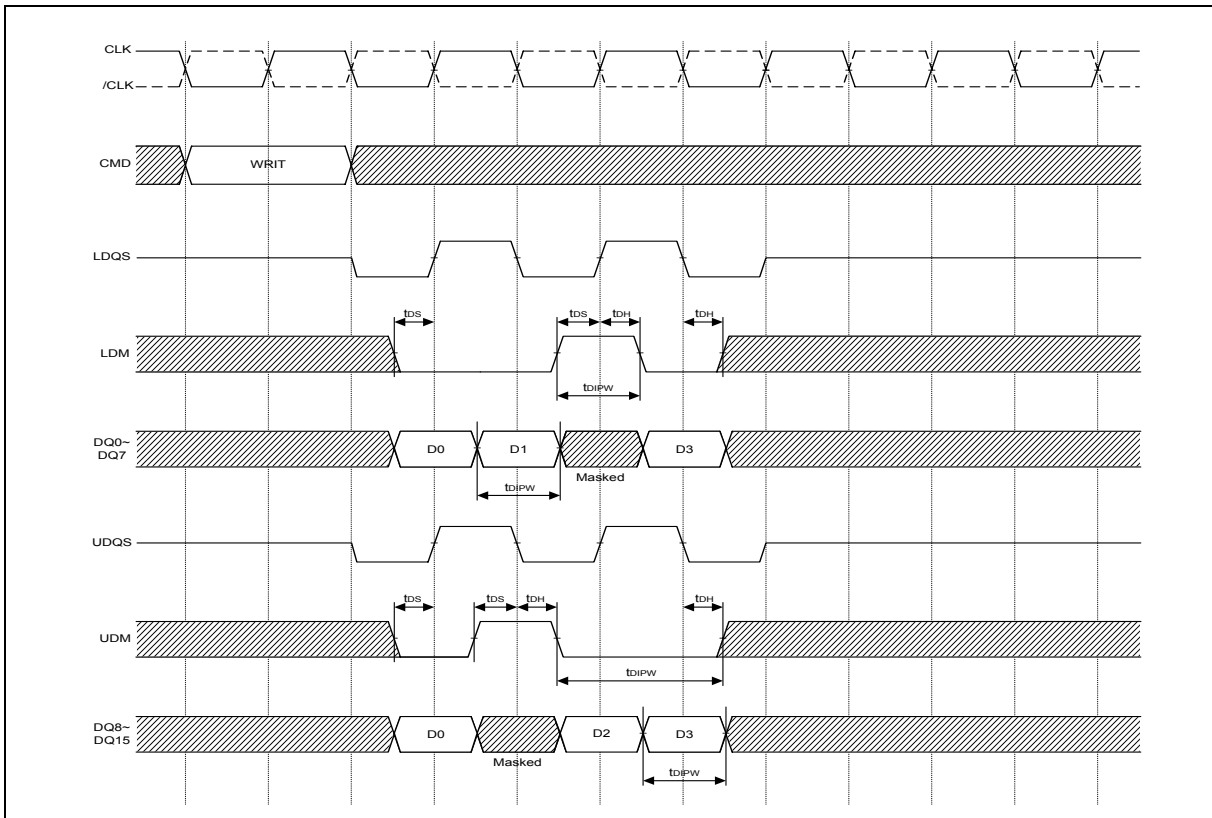
Note: x16 has 2DQS's (UDQS for uper byte and LDQS for lower byte).Even if one of the 2 bytes is not used, both UDQS and LDQS must be toggled.

Timing Waveforms, continued

DM, DATA MASK (W942508CH /W942504CH)

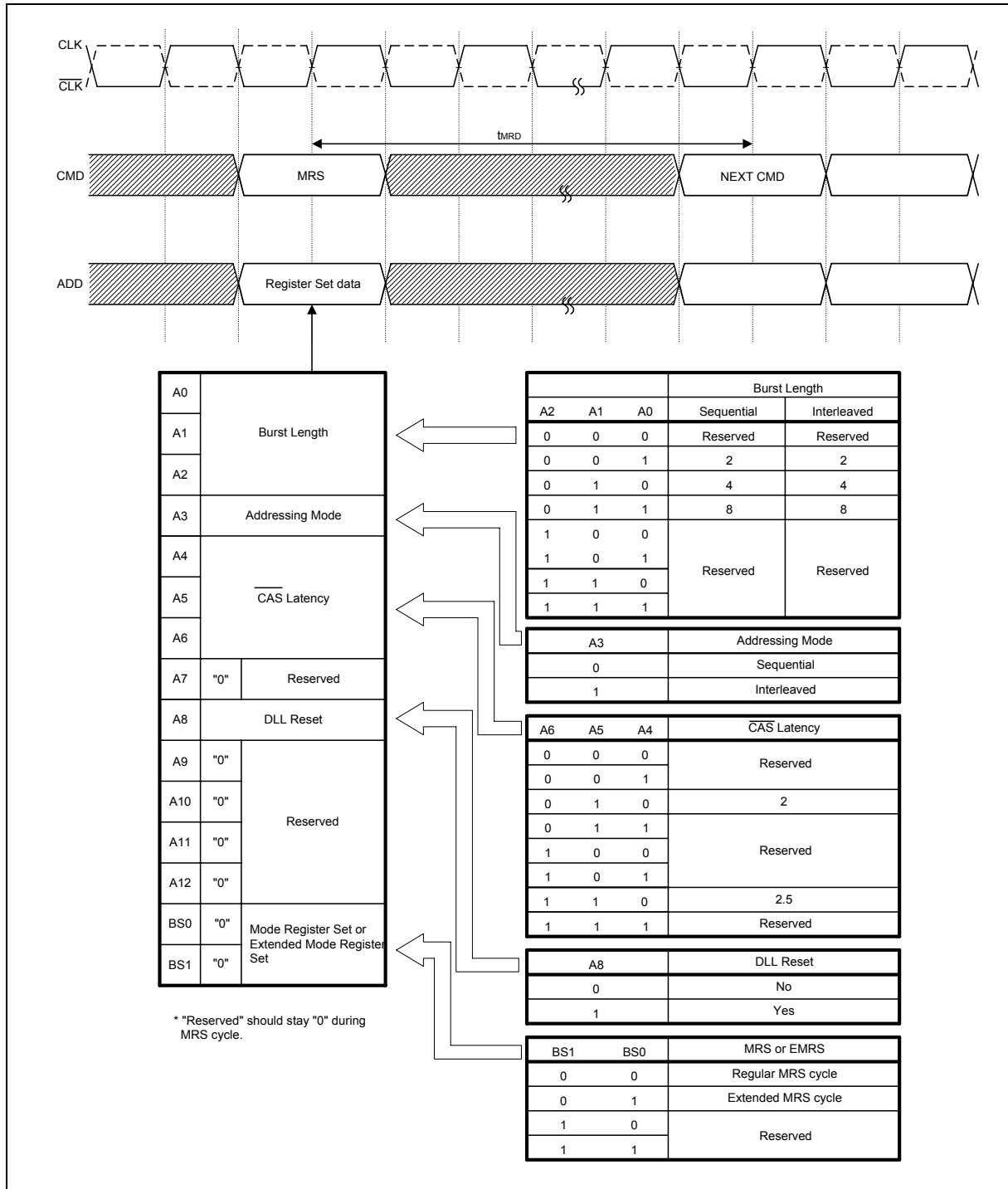


DM, DATA MASK (W942516CH)

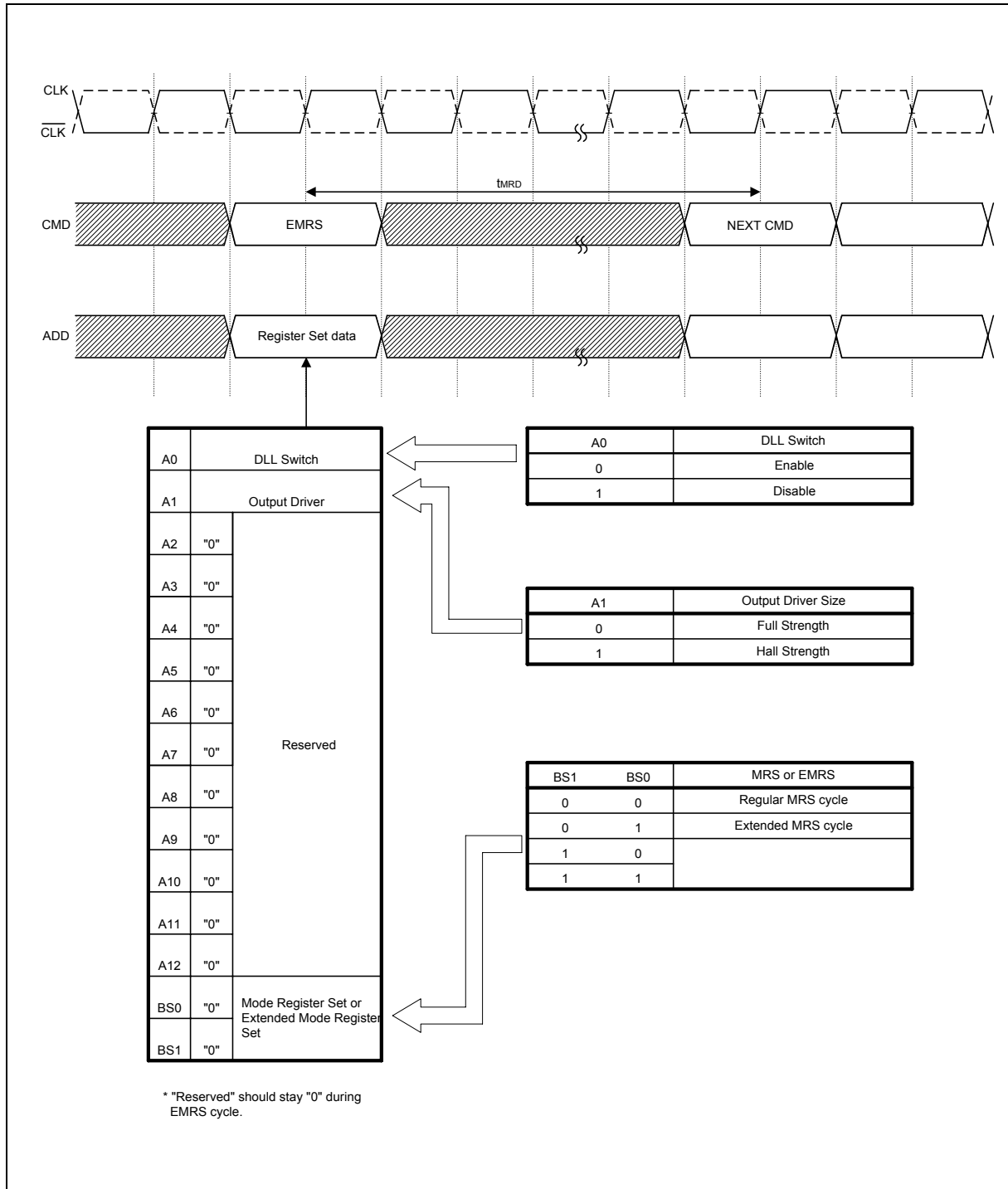


Timing Waveforms, continued

Mode Register Set (MRS) Timing



Timing Waveforms, continued

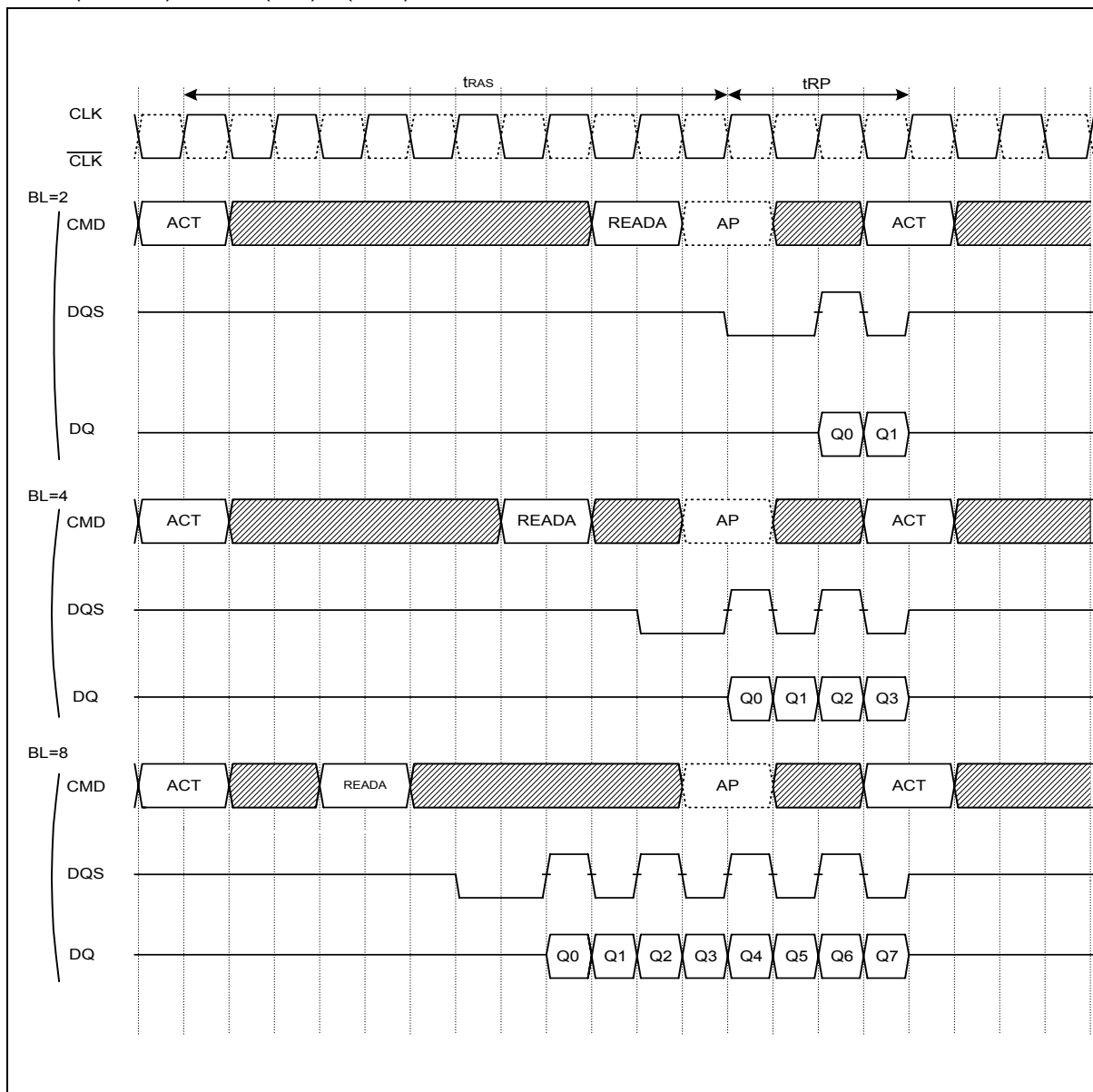
Extend Mode Register Set (EMRS) Timing



Timing Waveforms, continued

Auto Precharge Timing (Read Cycle, CL = 2)

$$t_{RCD}(\text{READA}) \geq t_{RAS}(\text{min}) - (\text{BL}/2) \times t_{CK}$$



Notes: CL2 shown; same command operation timing with CL = 2.5

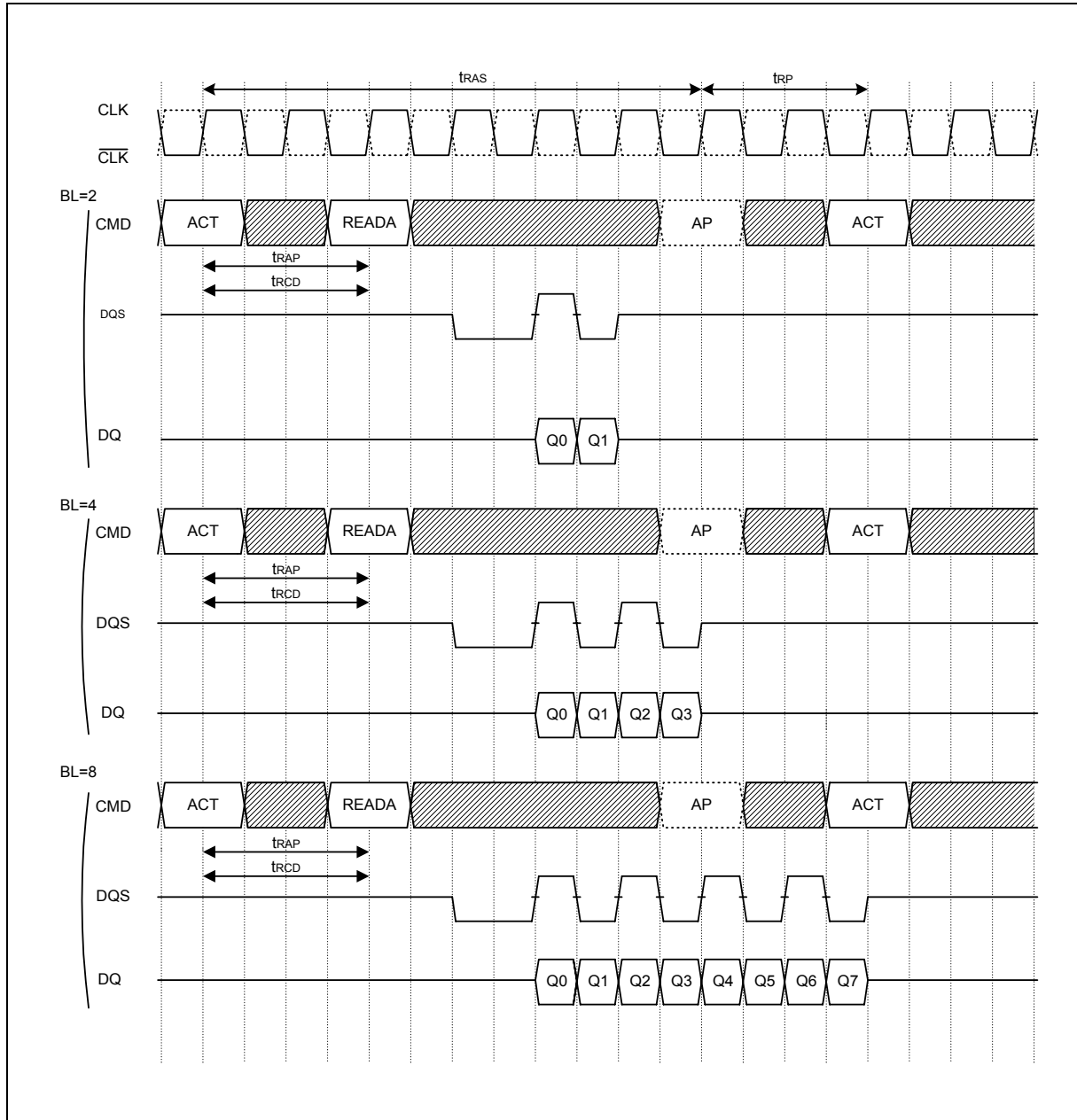
In this case, the internal precharge operation begins after BL/2 cycle from READA command.

AP represents the start of internal precharging.

The Read with Auto precharge command cannot be interrupted by any other command.

Auto Precharge Timing (Read Cycle, CL = 2), continued

$$t_{RCD}/t_{AP}(\min) \leq t_{RCD}(\text{READA}) < t_{RAS}(\min) - (BL/2) \times t_{CK}$$



Notes: CL2 shown; same command operation timing with CL = 2.5

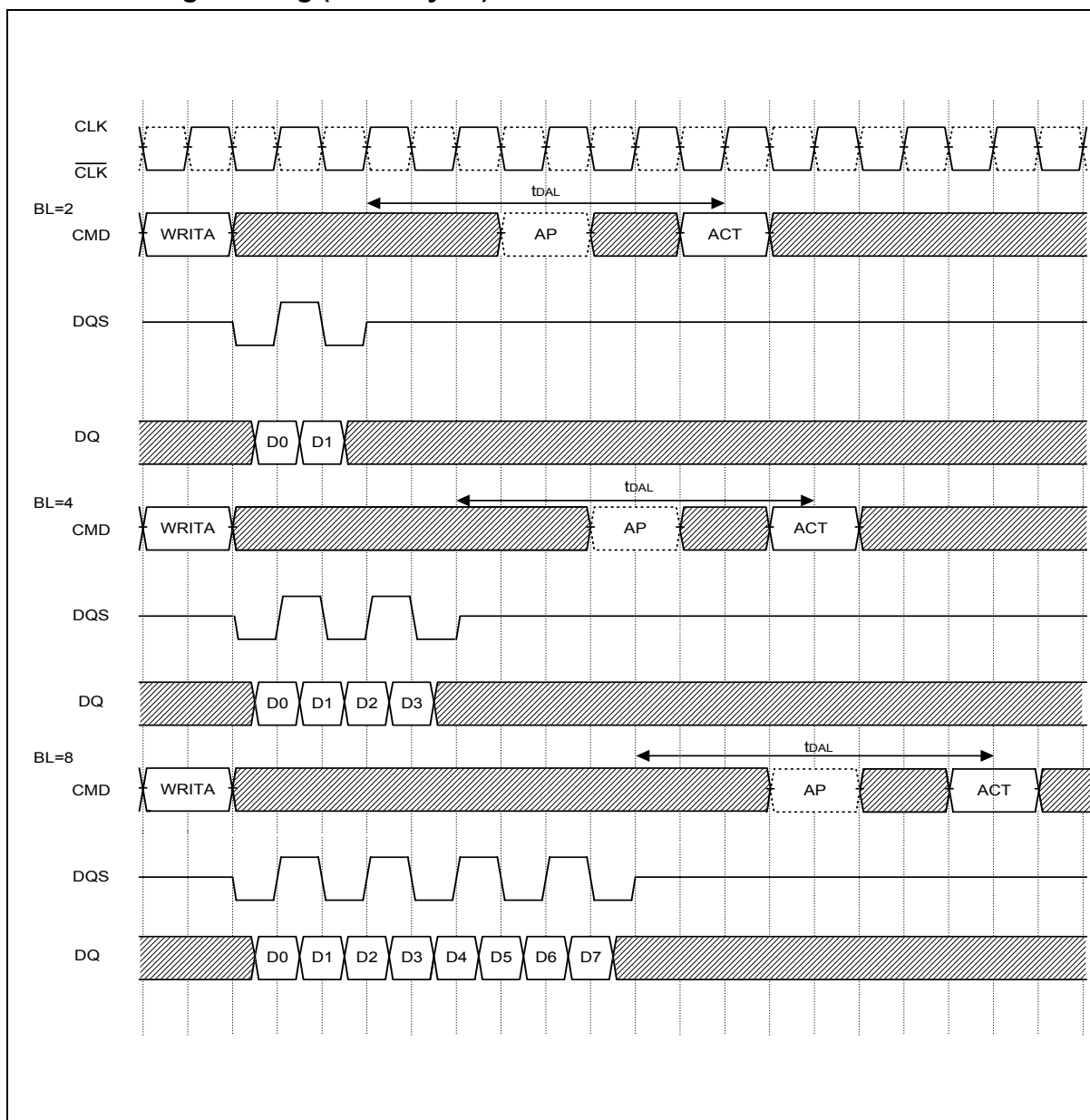
In this case, the internal precharge operation does not begin until after $t_{RAS}(\min)$ has command.

AP represents the start of internal precharging.

The Read with Auto Precharge command cannot be interrupted by any other command.



Timing Waveforms, continued

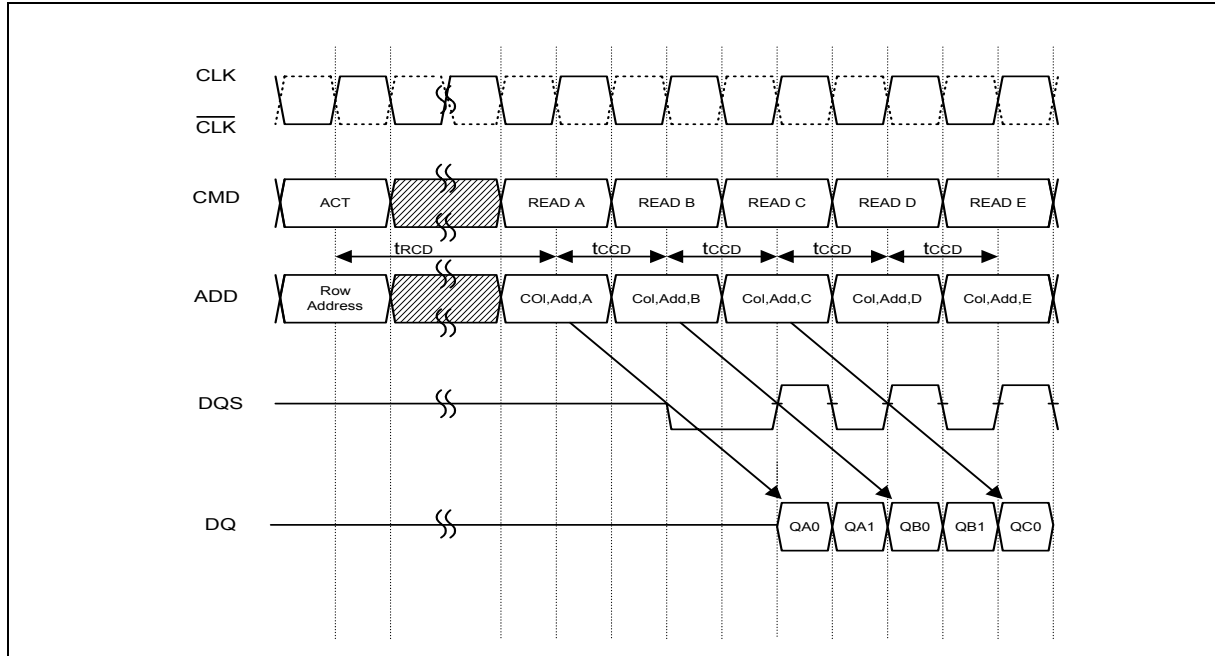
Auto Precharge Timing (Write Cycle)

The Write with Auto Precharge command cannot be interrupted by any other command.

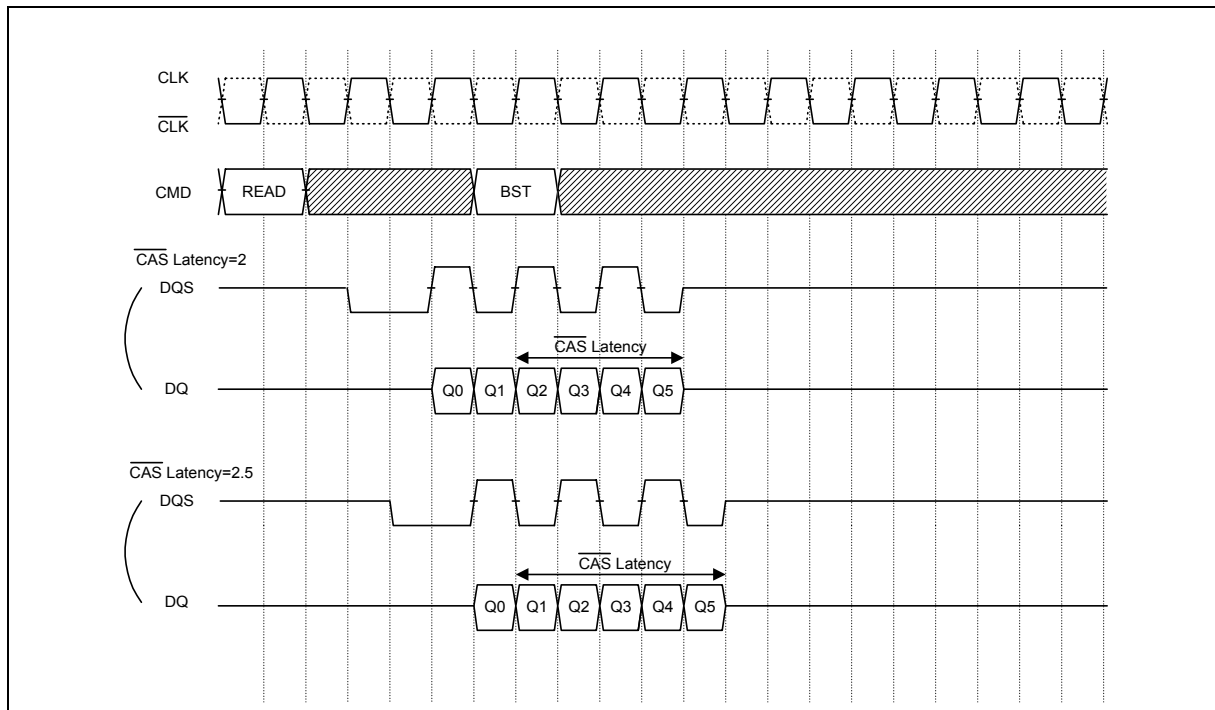
AP represents the start of internal precharging .

Timing Waveforms, continued

Read interrupted by Read (CL = 2, BL = 2, 4, 8)

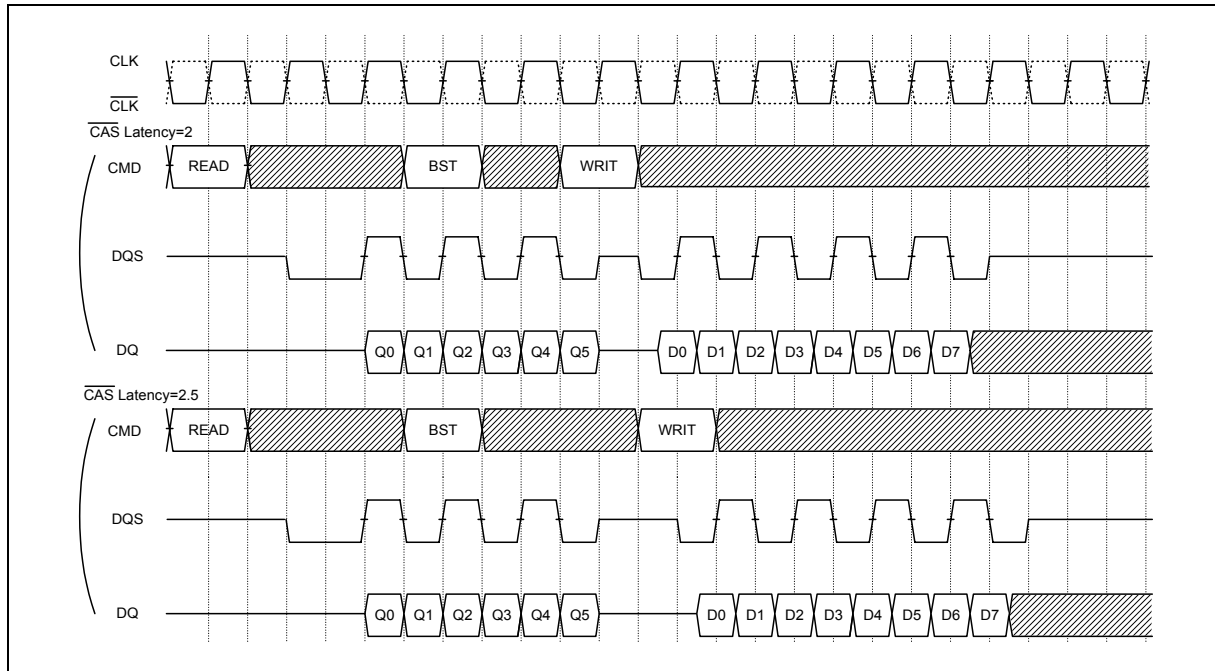


Burst Read Stop (BL = 8)



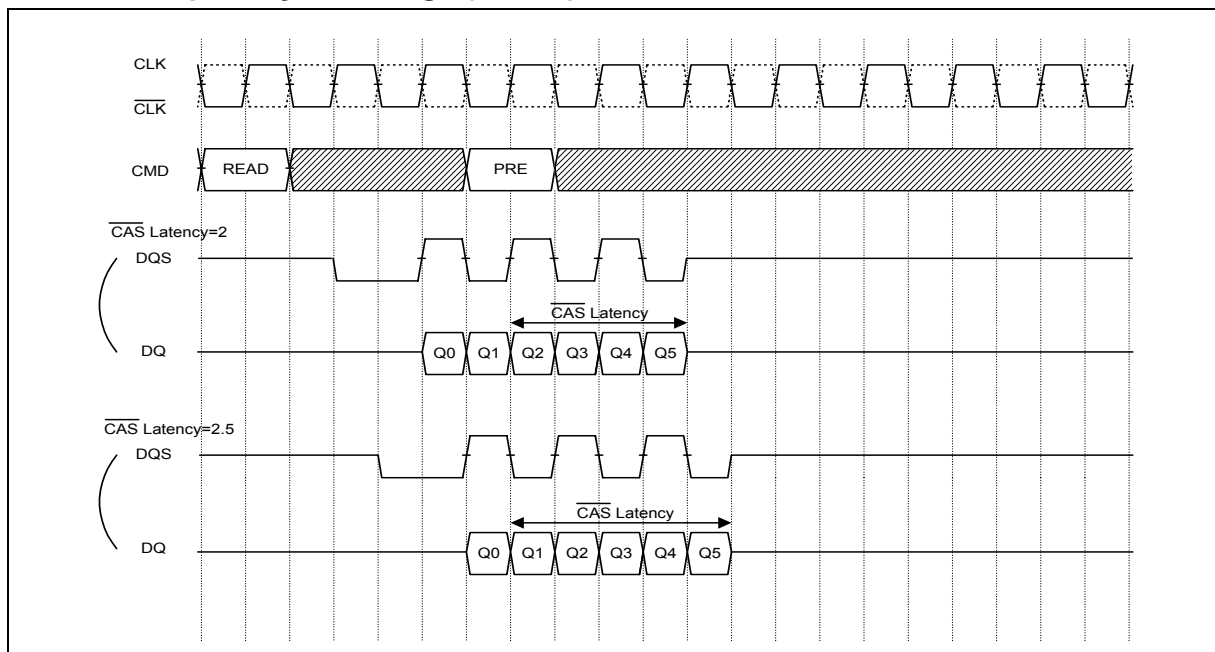
Timing Waveforms, continued

Read Interrupted by Write & BST (BL = 8)



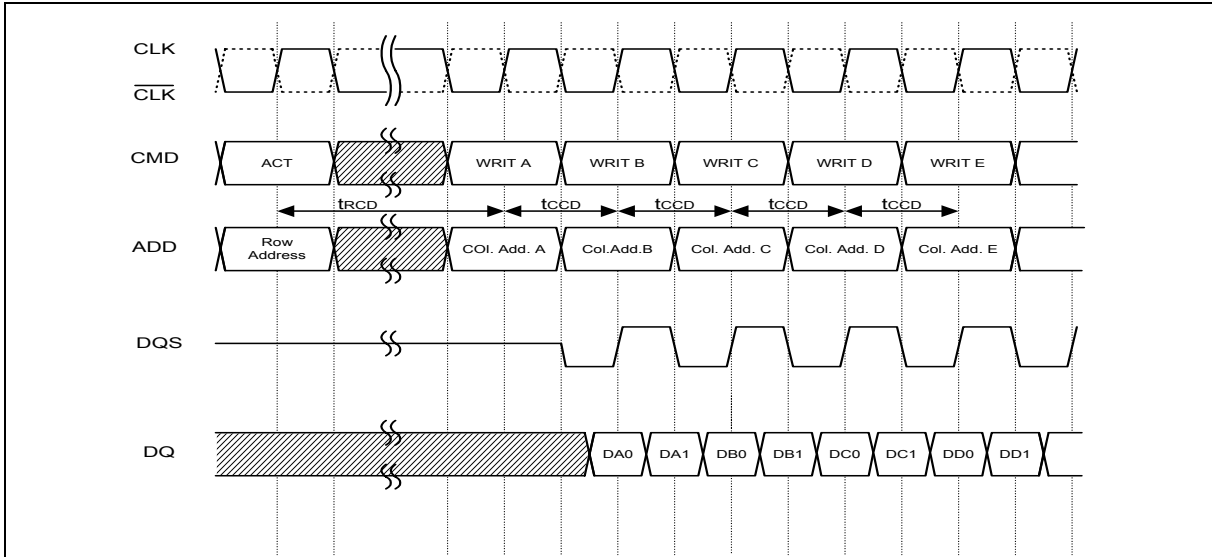
Burst Read cycle must be terminated by BST Command to avoid I/O conflict.

Read Interrupted by Precharge (BL = 8)

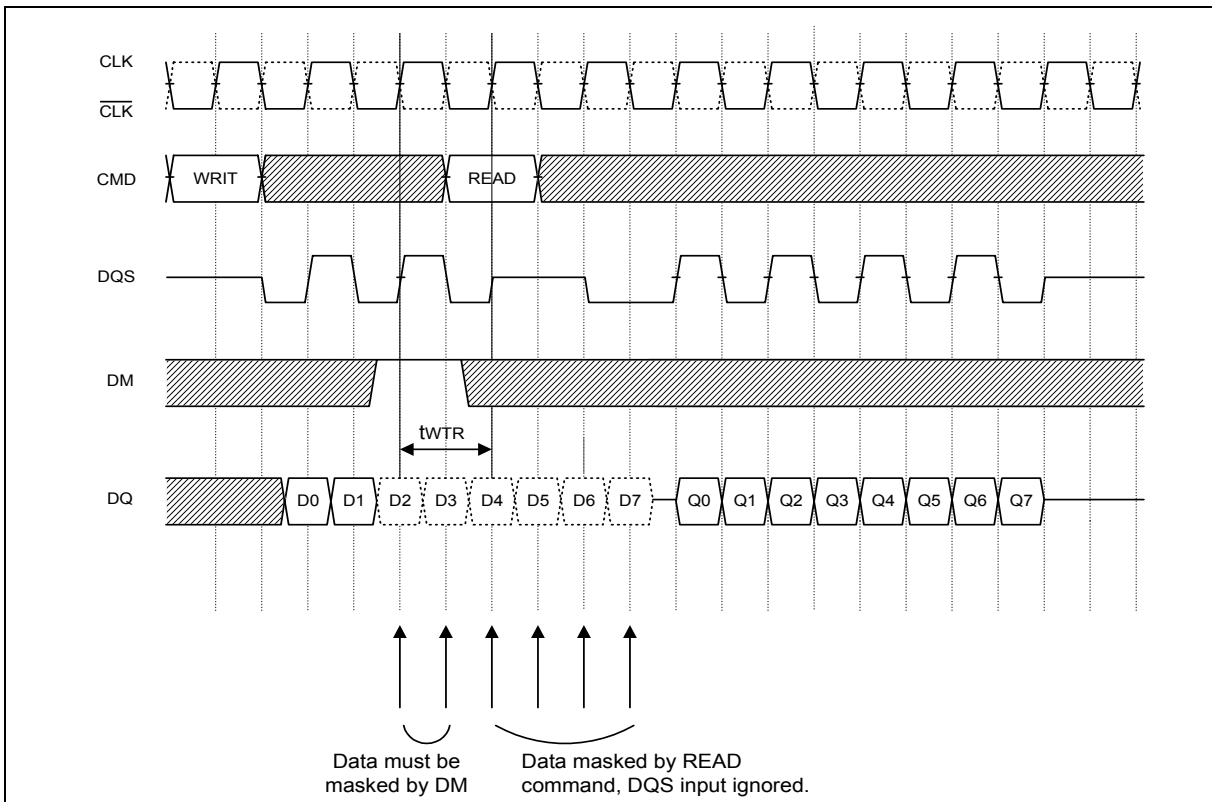


Timing Waveforms, continued

Write Interrupted by Write (BL = 2, 4, 8)

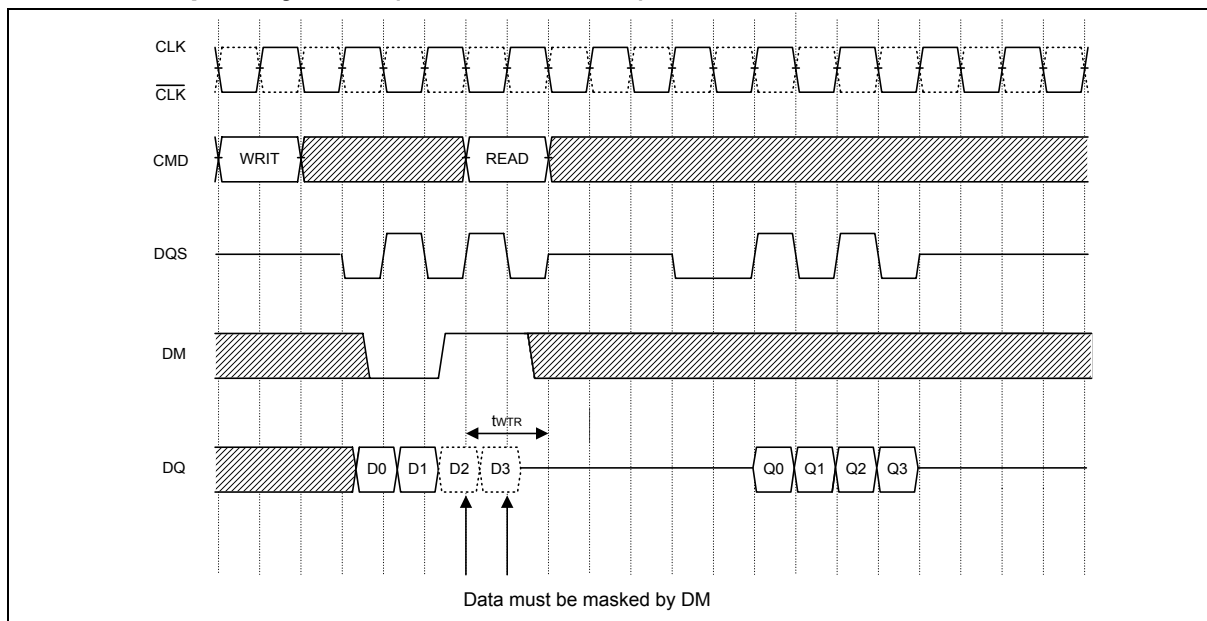
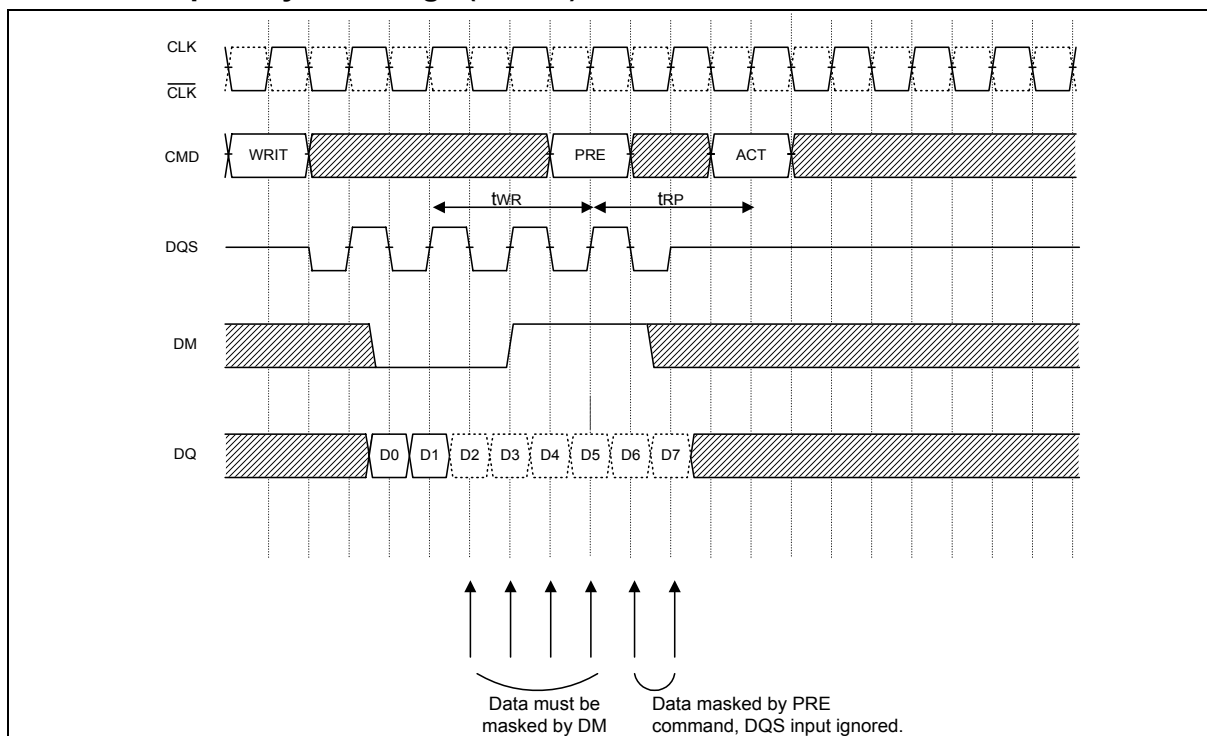


Write Interrupted by Read (CL = 2, BL = 8)



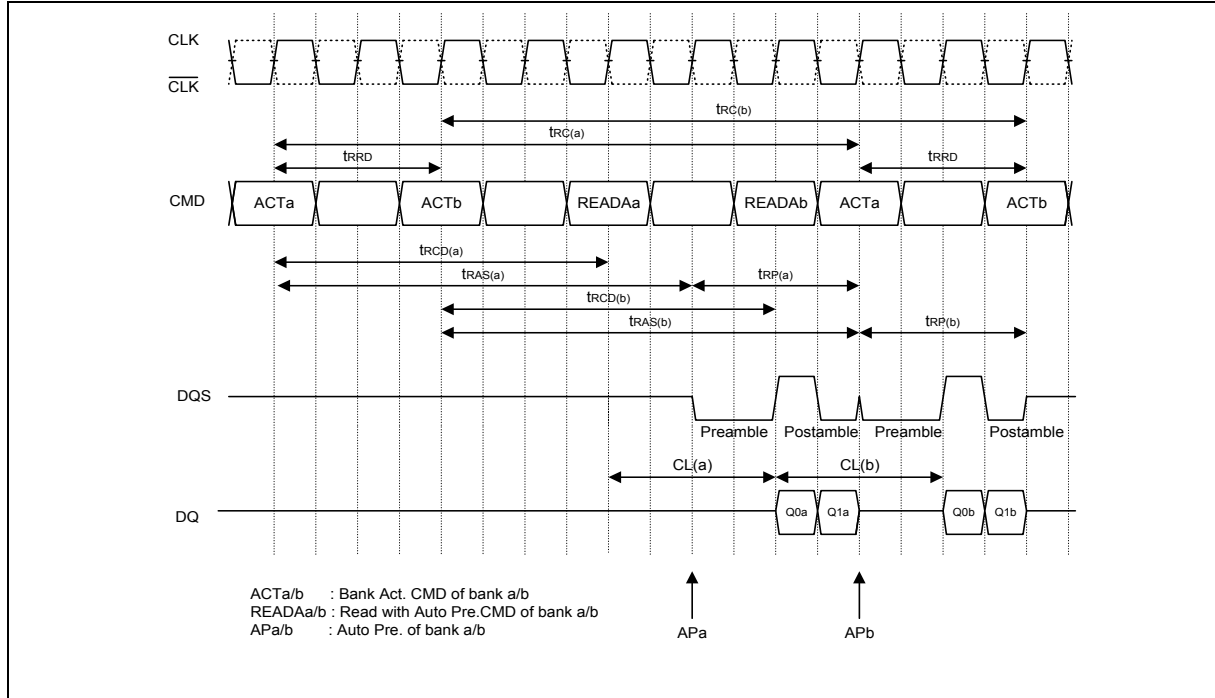


Timing Waveforms, continued

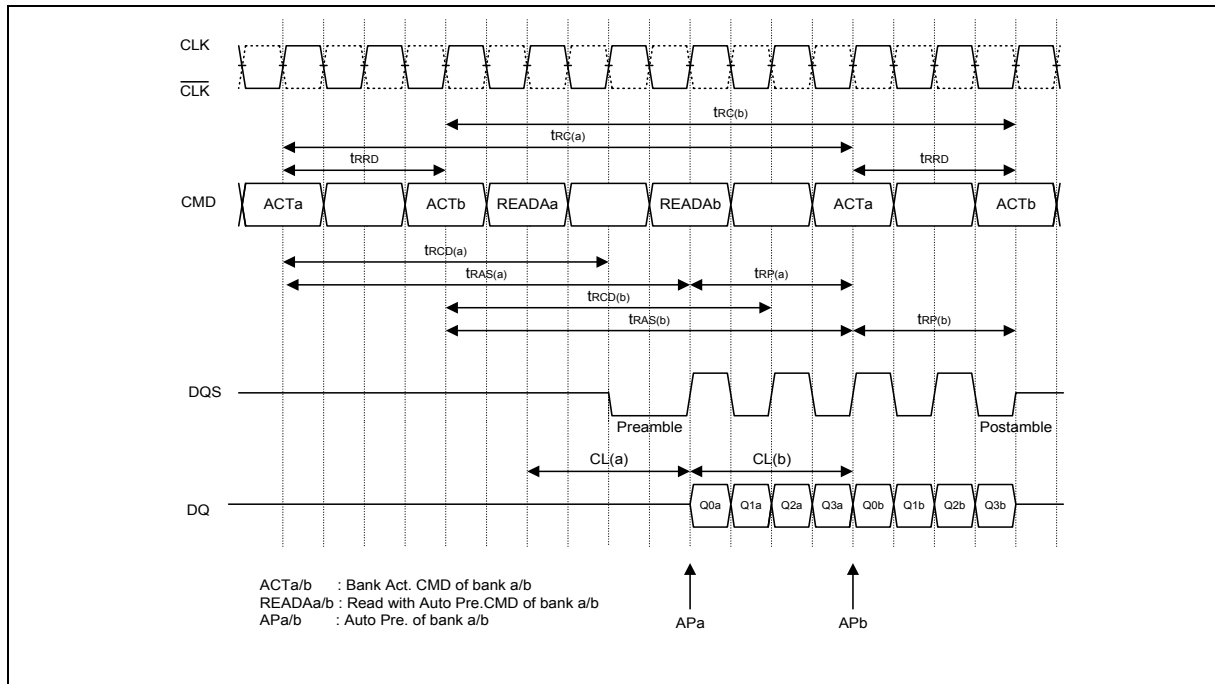
Write Interrupted by Read (CL = 2.5, BL = 4)**Write Interrupted by Precharge (BL = 8)**

Timing Waveforms, continued

2 Bank Interleave Read Operation (CL = 2, BL = 2) *tCK = 100 MHz

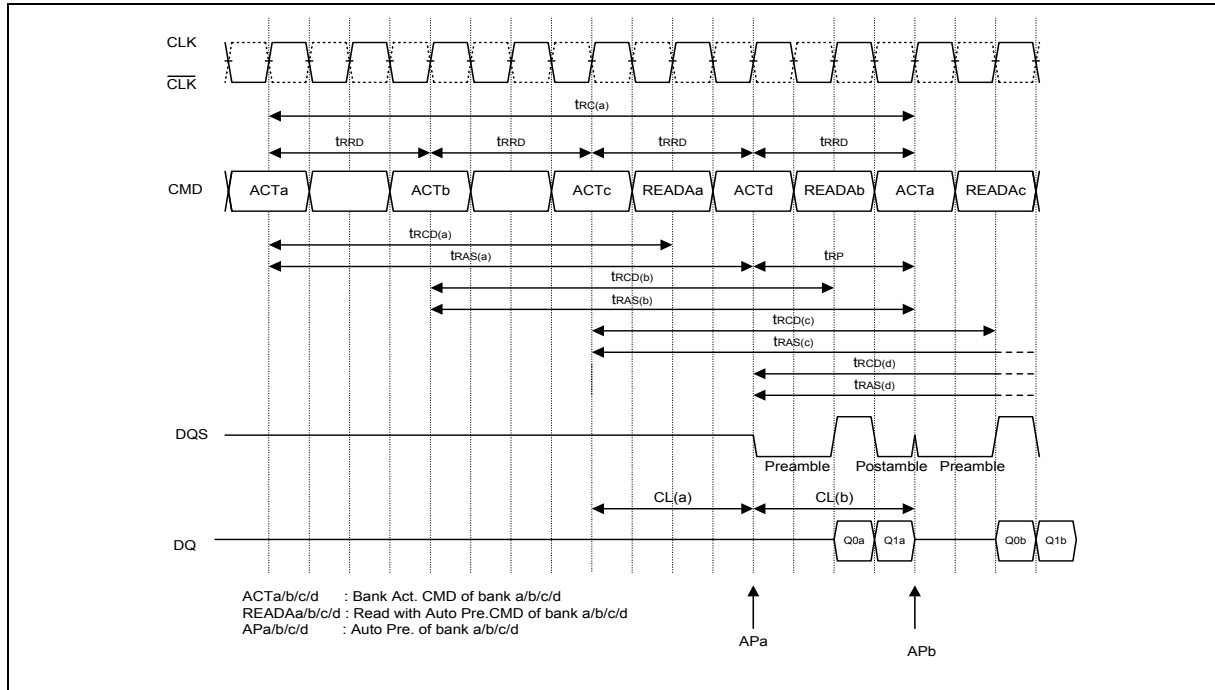


2 Bank Interleave Read Operation (CL = 2, BL = 4)

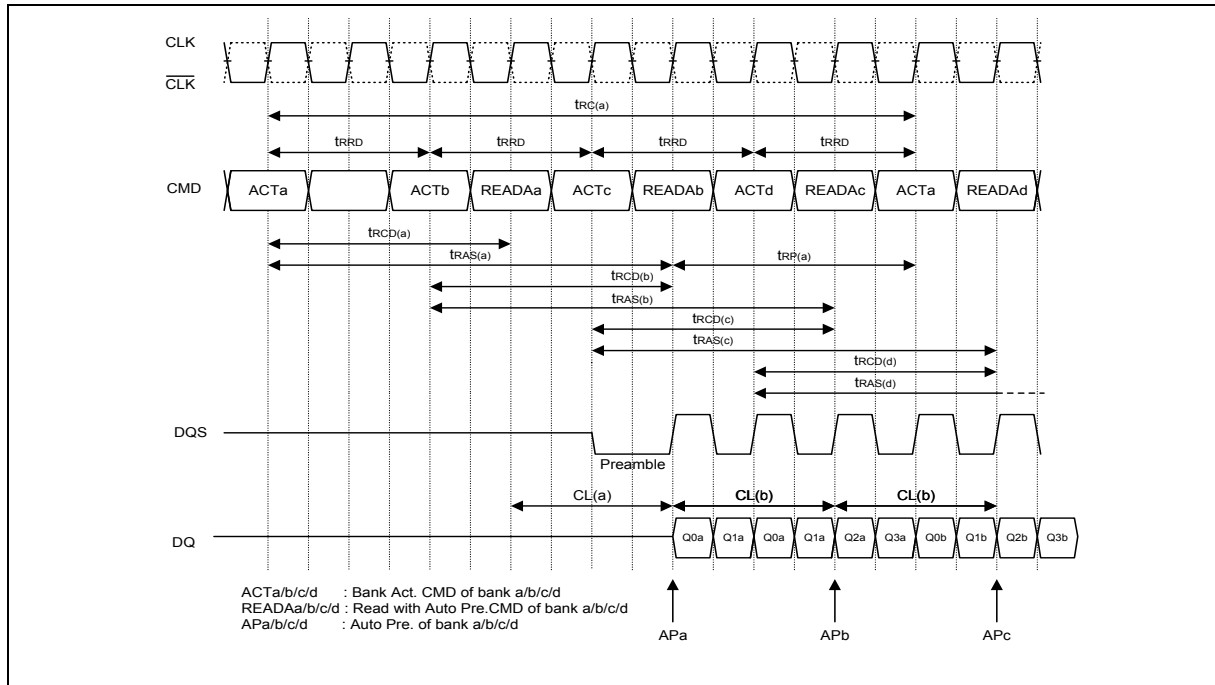


Timing Waveforms, continued

4 Bank Interleave Read Operation (CL = 2, BL = 2)

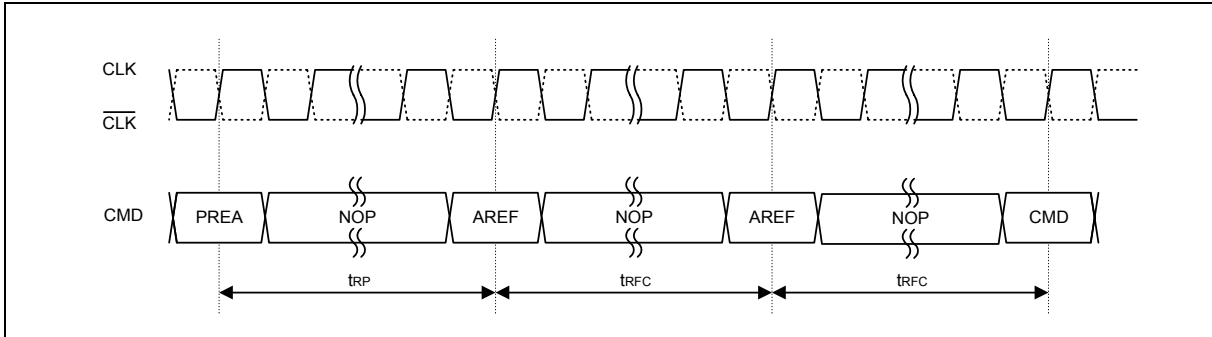


4 Bank Interleave Read Operation (CL = 2, BL = 4)



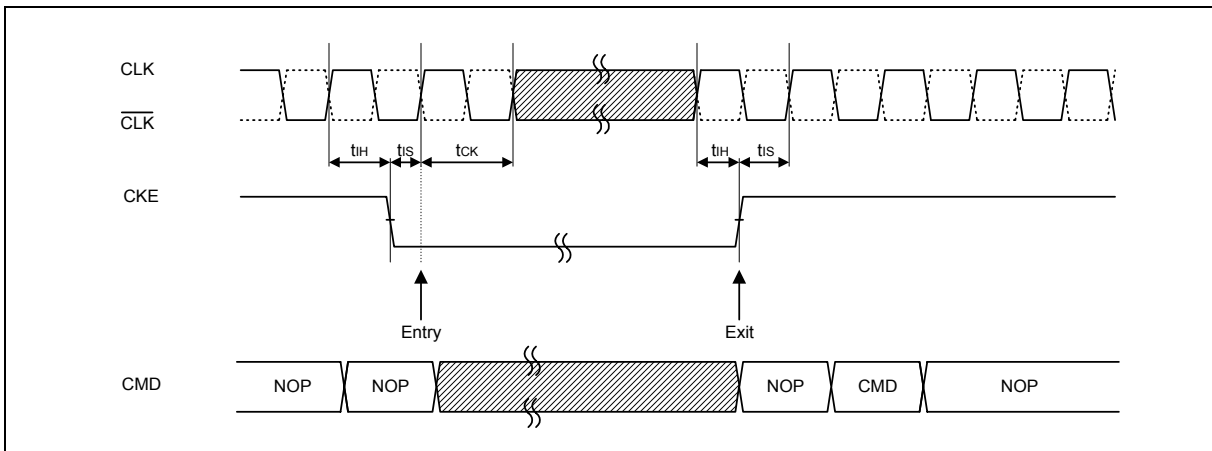
Timing Waveforms, continued

Auto Refresh Cycle

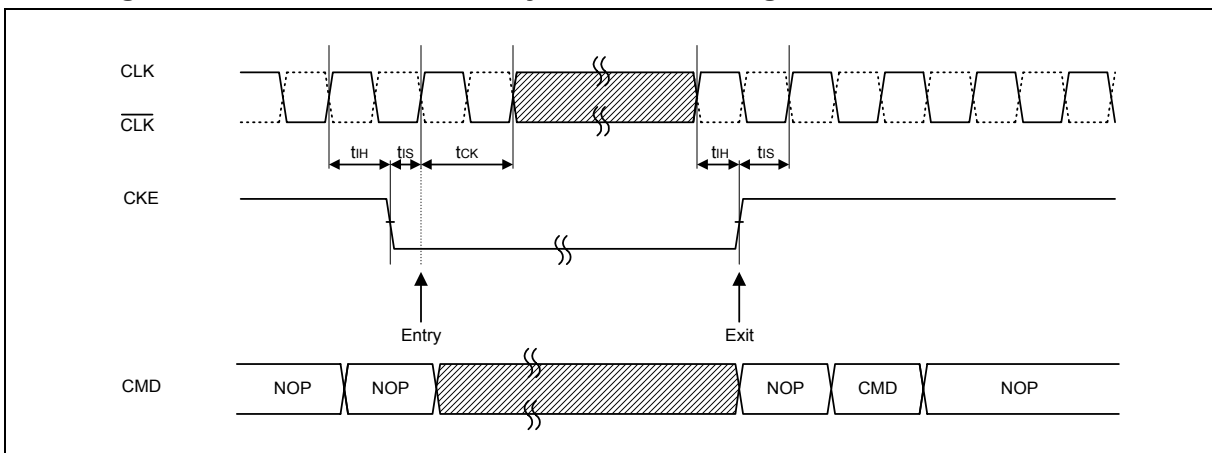


CKE has to be kept "High" level for Auto-Refresh cycle.

Active Power Down Mode Entry and Exit Timing

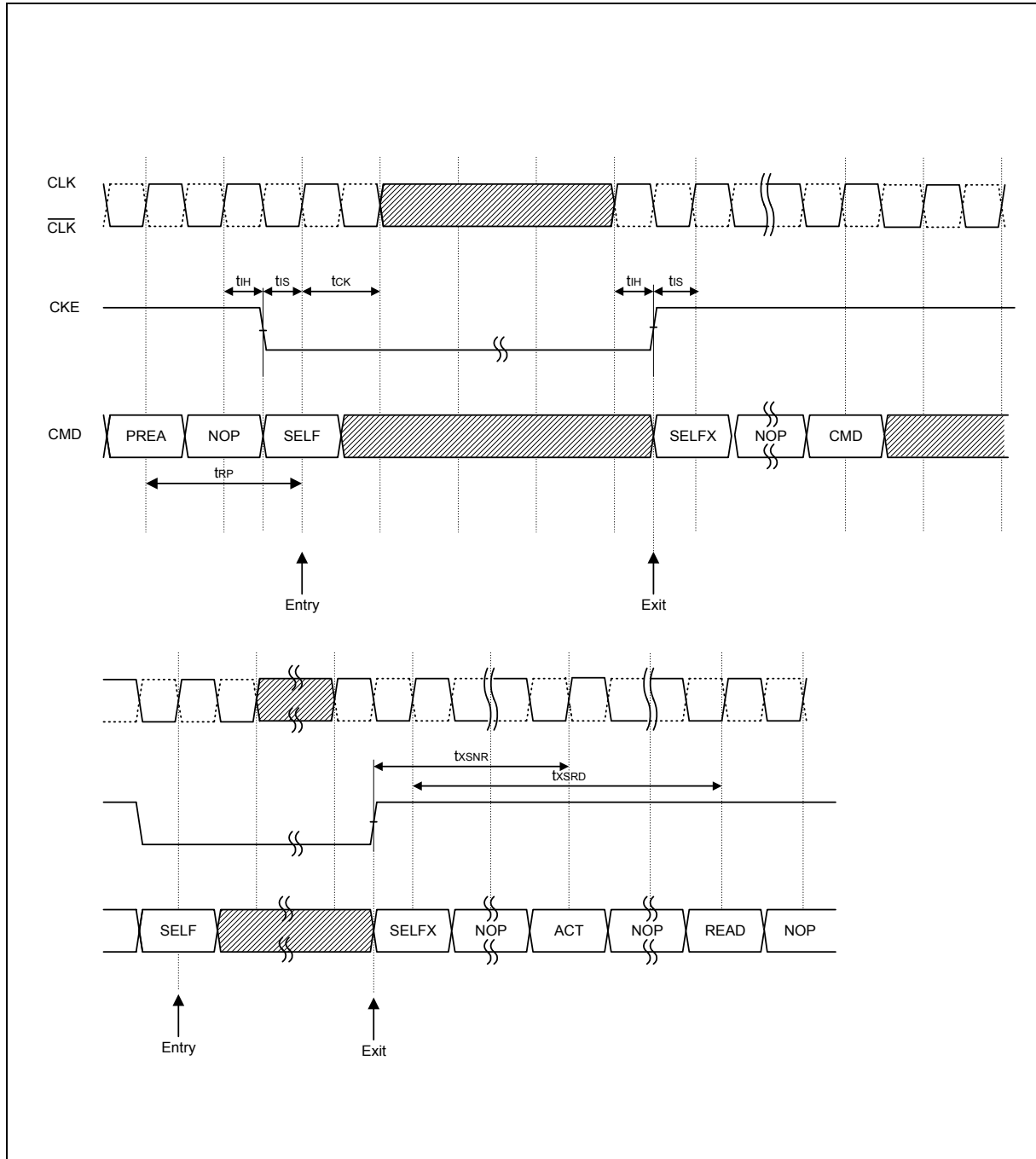


Precharged Power Down Mode Entry and Exit Timing



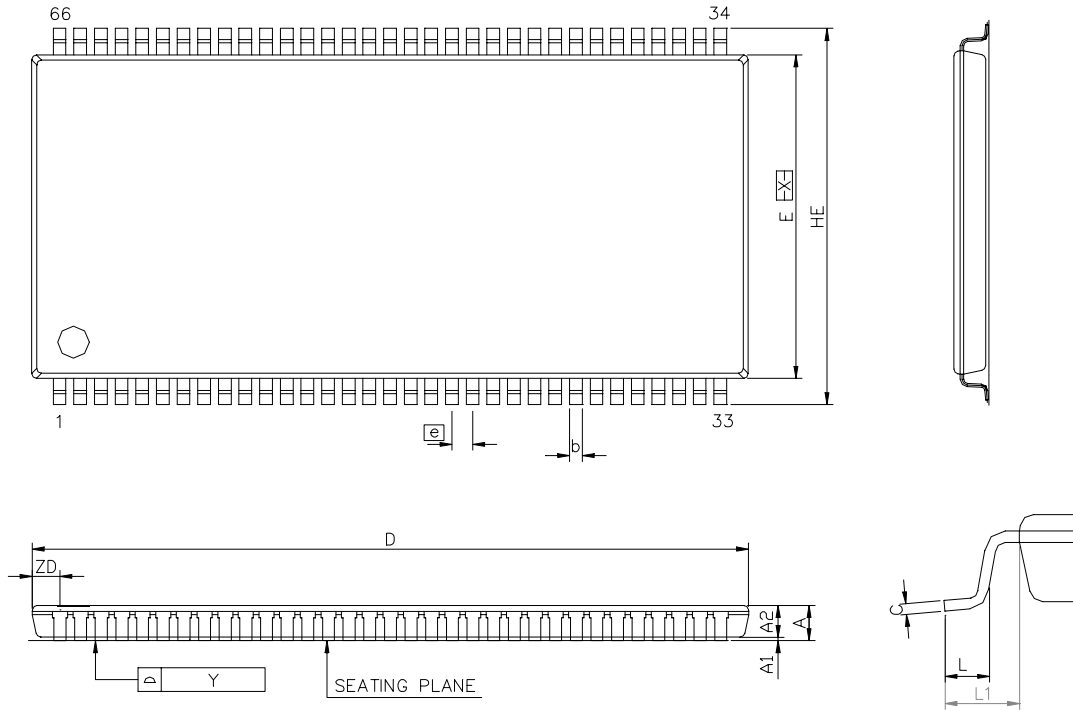
Timing Waveforms, continued

Self Refresh Entry and Exit Timing



11. PACKAGE DIMENSION

TSOP 66I - 400 mil



| SYMBOL | DIMENSION (MM) | | | DIMENSION (INCH) | | |
|--------|----------------|-------|-------|------------------|-------|--------|
| | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. |
| A | - | - | 1.20 | - | - | 0.047 |
| A1 | 0.05 | - | 0.15 | 0.002 | - | 0.006 |
| A2 | 0.95 | 1.00 | 1.05 | 0.037 | 0.039 | 0.042 |
| b | 0.17 | 0.24 | 0.32 | 0.007 | 0.009 | 0.013 |
| c | 0.09 | 0.145 | 0.2 | 0.004 | 0.006 | 0.008 |
| D | - | - | 22.62 | - | - | 0.891 |
| HE | 11.74 | 11.76 | 11.78 | 0.462 | 0.463 | 0.464 |
| E | 10.15 | 10.16 | 10.17 | 0.3996 | 0.400 | 0.4004 |
| L | 0.40 | 0.50 | 0.60 | 0.016 | 0.020 | 0.024 |
| L1 | 0.6 | 0.8 | 0.10 | 0.024 | 0.031 | 0.0039 |
| e | 0.65 BASIC | | | 0.026 BASIC | | |
| Y | 0.1 BASIC | | | 0.004 BASIC | | |
| ZD | 0.71 REF | | | 0.028 REF | | |



12. VERSION HISTORY

| VERSION | DATE | PAGE | DESCRIPTION |
|---------|---------------|------|-----------------------|
| A1 | Feb. 14, 2003 | - | Preliminary datasheet |



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