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### Revision History

#### Revision 0.6(May, 2006) Preliminary Spec

- Delete confidential wording.

#### Revision 0.5(May, 2003) Preliminary Spec

- Revised the AC Timing of tCLK at CL=4 for pure VDD/VDDQ=2.8V spec.

#### Revision 0.4(May, 2003) Preliminary Spec

- Revised the AC Timing of tCLK at CL=4 for pure VDD/VDDQ=2.5V spec.

#### Revision 0.3(March, 2003) Preliminary Spec

- Separated pure VDD/VDDQ=2.8V spec for graphics application.

#### Revision 0.2(March, 2003) Preliminary Spec

- Separated pure VDD/VDDQ=2.5V spec for mobile PC graphics application.
- Initially defined VDD=VDDQ=2.5V 275MHz(-3.6ns) preliminary specification.
- Combined VDD=VDDQ=2.5V 200MHz(-5ns) and 250MHz(-4ns) specification from rev. 0.1 for both 2.8V and 2.5V.

#### Revision 0.1(February, 2003) Preliminary Spec

- Defined EM6AA320BI-3.6(275MHz).
- Added special code "M" in EM6AA320BI-4M for indicating 2.5V power supply.
- Added special code "M" in EM6AA320BI-5M for indicating 2.5V power supply.
- Removed EM6AA320BI-3.5(285MHz).
- Revised the DC current of IDD2P, IDD2N, IDD3P, IDD3N, IDD4R and IDD4W for all speed grade.

#### Revision 0.0(July, 2002) Preliminary Spec

- Initially defined target specification.

## Features

- Fast clock rate: 300/275/250/200 MHz
- Differential Clock CK & CK# input
- 4 Bi-directional DQS. Data transactions on both edges of DQS (1DQS / Byte)
- DLL aligns DQ and DQS transitions
- Edge aligned data & DQS output
- Center aligned data & DQS input
- 4 banks operation
- Programmable mode and extended mode registers
  - CAS# Latency: 3, 4, 5
  - Burst length: 2, 4, 8
  - Burst Type: Sequential & Interleave
- Full page burst length for sequential type only
- Start address of full page burst should be even
- All inputs except DQ's & DM are at the positive edge of the system clock
- No Write-Interrupted by Read function
- 4 individual DM control for write masking only
- Auto Refresh and Self Refresh
- 4096 refresh cycles / 32ms
- Power supplies :
  - $V_{DD} = 2.8V \pm 5\%$
  - $V_{DDQ} = 2.8V \pm 5\%$
- Interface : SSTL\_2 I/O compatible
- Standard 144-ball FBGA package

## Ordering Information

| Part Number                    | Frequency | Power Supply                    | Package |
|--------------------------------|-----------|---------------------------------|---------|
| EM6AA320BI-3.3S <sup>(*)</sup> | 300MHz    | $V_{DD} 2.8V$<br>$V_{DDQ} 2.8V$ | FBGA    |
| EM6AA320BI-3.6S <sup>(*)</sup> | 275MHz    |                                 |         |
| EM6AA320BI-4S <sup>(*)</sup>   | 250MHz    |                                 |         |
| EM6AA320BI-5S <sup>(*)</sup>   | 200MHz    |                                 |         |

\* : S indicates stack die package

## Overview

The EM6AA320 DDR SDRAM is a high-speed CMOS double data rate synchronous DRAM containing 256 Mbits. It is internally configured as a quad 2M x 32 DRAM with a synchronous interface (all signals are registered on the positive edge of the clock signal, CK).

Data outputs occur at both rising edges of CK and CK#. 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 a BankActivate command, which is then followed by a Read or Write command.

The EM6AA320 provides programmable Read or Write burst lengths of 2, 4, 8. 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 refresh functions, either Auto or Self Refresh are easy to use.

In addition, EM6AA320 features programmable DLL option. By having a programmable mode register and extended mode register, the system can choose the most suitable modes to maximize its performance.

These devices are well suited for applications requiring high memory bandwidth, result in a device particularly well suited to high performance main memory and graphics applications.

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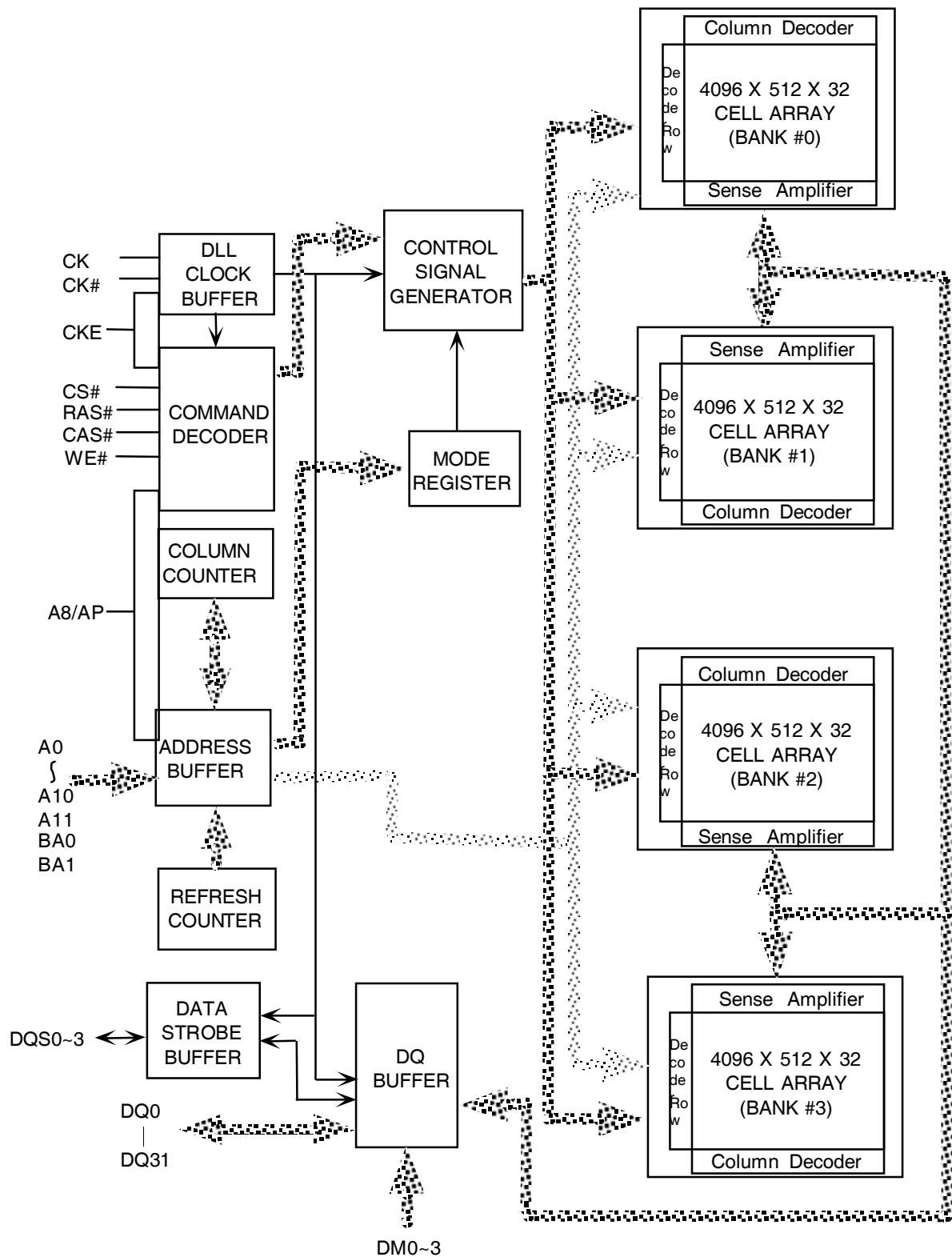
### Pin Assignment (FBGA 144Ball Top View)

|   | 1    | 2    | 3    | 4    | 5           | 6           | 7           | 8           | 9    | 10    | 11   | 12   |
|---|------|------|------|------|-------------|-------------|-------------|-------------|------|-------|------|------|
| A | DQS0 | DM0  | VSSQ | DQ3  | DQ2         | DQ0         | DQ31        | DQ29        | DQ28 | VSSQ  | DM3  | DQS3 |
| B | DQ4  | VDDQ | NC   | VDDQ | DQ1         | VDDQ        | VDDQ        | DQ30        | VDDQ | NC    | VDDQ | DQ27 |
| C | DQ6  | DQ5  | VSSQ | VSSQ | VSSQ        | VDD         | VDD         | VSSQ        | VSSQ | VSSQ  | DQ26 | DQ25 |
| D | DQ7  | VDDQ | VDD  | VSS  | VSSQ        | VSS         | VSS         | VSSQ        | VSS  | VDD   | VDDQ | DQ24 |
| E | DQ17 | DQ16 | VDDQ | VSSQ | VSS Thermal | VSS Thermal | VSS Thermal | VSS Thermal | VSSQ | VDDQ  | DQ15 | DQ14 |
| F | DQ19 | DQ18 | VDDQ | VSSQ | VSS Thermal | VSS Thermal | VSS Thermal | VSS Thermal | VSSQ | VDDQ  | DQ13 | DQ12 |
| G | DQS2 | DM2  | NC   | VSSQ | VSS Thermal | VSS Thermal | VSS Thermal | VSS Thermal | VSSQ | NC    | DM1  | DQS1 |
| H | DQ21 | DQ20 | VDDQ | VSSQ | VSS Thermal | VSS Thermal | VSS Thermal | VSS Thermal | VSSQ | VDDQ  | DQ11 | DQ10 |
| J | DQ22 | DQ23 | VDDQ | VSSQ | VSS         | VSS         | VSS         | VSS         | VSSQ | VDDQ  | DQ9  | DQ8  |
| K | CAS# | WE#  | VDD  | VSS  | A10         | VDD         | VDD         | NC          | VSS  | VDD   | NC   | NC   |
| L | RAS# | NC   | NC   | BA1  | A2          | A11         | A9          | A5          | NC   | CK    | CK#  | NC   |
| M | CS#  | NC   | BA0  | A0   | A1          | A3          | A4          | A6          | A7   | A8/AP | CKE  | VREF |

### Pin Assignment by Name (FBGA 144Ball)

| Symbol | Location | Symbol | Location | Symbol | Location | Symbol | Location | Symbol | Location | Symbol | Location | Symbol | Location | Symbol | Location |
|--------|----------|--------|----------|--------|----------|--------|----------|--------|----------|--------|----------|--------|----------|--------|----------|
| A0     | M4       | DQ6    | C1       | DQ24   | D12      | CK     | L10      | VDDQ   | B6       | VSS    | E5       | VSS    | J7       | VSSQ   | G4       |
| A1     | M5       | DQ7    | D1       | DQ25   | C12      | CK#    | L11      | VDDQ   | B7       | VSS    | E6       | VSS    | J8       | VSSQ   | G9       |
| A2     | L5       | DQ8    | J12      | DQ26   | C11      | CKE    | M11      | VDDQ   | B9       | VSS    | E7       | VSS    | K4       | VSSQ   | H4       |
| A3     | M6       | DQ9    | J11      | DQ27   | B12      | CS#    | M1       | VDDQ   | B11      | VSS    | E8       | VSS    | K9       | VSSQ   | H9       |
| A4     | M7       | DQ10   | H12      | DQ28   | A9       | RAS#   | L1       | VDDQ   | D2       | VSS    | F5       | VSSQ   | A3       | VSSQ   | J4       |
| A5     | L8       | DQ11   | H11      | DQ29   | A8       | CAS#   | K1       | VDDQ   | D11      | VSS    | F6       | VSSQ   | A10      | VSSQ   | J9       |
| A6     | M8       | DQ12   | F12      | DQ30   | B8       | WE#    | K2       | VDDQ   | E3       | VSS    | F7       | VSSQ   | C3       | NC     | B3       |
| A7     | M9       | DQ13   | F11      | DQ31   | A7       | VREF   | M12      | VDDQ   | E10      | VSS    | F8       | VSSQ   | C4       | NC     | B10      |
| A8/AP  | M10      | DQ14   | E12      | DQS0   | A1       | VDD    | C6       | VDDQ   | F3       | VSS    | G5       | VSSQ   | C5       | NC     | G3       |
| A9     | L7       | DQ15   | E11      | DQS1   | G12      | VDD    | C7       | VDDQ   | F10      | VSS    | G6       | VSSQ   | C8       | NC     | G10      |
| A10    | K5       | DQ16   | E2       | DQS2   | G1       | VDD    | D3       | VDDQ   | H3       | VSS    | G7       | VSSQ   | C9       | NC     | K8       |
| A11    | L6       | DQ17   | E1       | DQS3   | A12      | VDD    | D10      | VDDQ   | H10      | VSS    | G8       | VSSQ   | C10      | NC     | K11      |
| DQ0    | A6       | DQ18   | F2       | DM0    | A2       | VDD    | K3       | VDDQ   | J3       | VSS    | H5       | VSSQ   | D5       | NC     | K12      |
| DQ1    | B5       | DQ19   | F1       | DM1    | G11      | VDD    | K6       | VDDQ   | J10      | VSS    | H6       | VSSQ   | D8       | NC     | L2       |
| DQ2    | A5       | DQ20   | H2       | DM2    | G2       | VDD    | K7       | VSS    | D4       | VSS    | H7       | VSSQ   | E4       | NC     | L3       |
| DQ3    | A4       | DQ21   | H1       | DM3    | A11      | VDD    | K10      | VSS    | D6       | VSS    | H8       | VSSQ   | E9       | NC     | L9       |
| DQ4    | B1       | DQ22   | J1       | BA0    | M3       | VDDQ   | B2       | VSS    | D7       | VSS    | J5       | VSSQ   | F4       | NC     | L12      |
| DQ5    | C2       | DQ23   | J2       | BA1    | L4       | VDDQ   | B4       | VSS    | D9       | VSS    | J6       | VSSQ   | F9       | NC     | M2       |

### Block Diagram



### Pin Descriptions

Table 1. Pin Details of EM6AA320

| Symbol          | Type           | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|-----------------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CK, CK#         | Input          | <b>Differential Clock:</b> CK, CK# are driven by the system clock. All SDRAM input commands are sampled on the positive edge of CK. Both CK and CK# increment the internal burst counter and controls the output registers.                                                                                                                                                                                                                                                                                                                                                                                                    |
| CKE             | Input          | <b>Clock Enable:</b> CKE activates (HIGH) and deactivates (LOW) the CK signal. If CKE goes low synchronously with clock, the internal clock is suspended from the next clock cycle and the state of output and burst address is frozen as long as the CKE remains low. When all banks are in the idle state, deactivating the clock controls the entry to the Power Down and Self Refresh modes.                                                                                                                                                                                                                               |
| BA0, BA1        | Input          | <b>Bank Select:</b> BA0 and BA1 defines to which bank the BankActivate, Read, Write, or BankPrecharge command is being applied. They also define which Mode Register or Extended Mode Register is loaded during a Mode Register Set command.                                                                                                                                                                                                                                                                                                                                                                                   |
| A0-A11          | Input          | <b>Address Inputs:</b> A0-A11 are sampled during the Bank Activate command (row address A0-A11) and Read/Write command (column address A0-A7, and A9 with A8 defining Auto Precharge) to select one location out of the memory array in the respective bank. During a Precharge command, A8 is sampled to determine if all banks are to be precharged (A8 = HIGH). The address inputs also provide the op-code during a Mode Register Set or Extended Mode Register Set command.                                                                                                                                               |
| CS#             | Input          | <b>Chip Select:</b> CS# enables (sampled LOW) and disables (sampled HIGH) the command decoder. All commands are masked when CS# is sampled HIGH. CS# provides for external bank selection on systems with multiple banks. It is considered part of the command code.                                                                                                                                                                                                                                                                                                                                                           |
| RAS#            | Input          | <b>Row Address Strobe:</b> The RAS# signal defines the operation commands in conjunction with the CAS# and WE# signals and is latched at the positive edges of CK. When RAS# and CS# are asserted "LOW" and CAS# is asserted "HIGH" either the BankActivate command or the Precharge command is selected by the WE# signal. When the WE# is asserted "HIGH," the BankActivate command is selected and the bank designated by BS is turned on to the active state. When the WE# is asserted "LOW," the Precharge command is selected and the bank designated by BS is switched to the idle state after the precharge operation. |
| CAS#            | Input          | <b>Column Address Strobe:</b> The CAS# signal defines the operation commands in conjunction with the RAS# and WE# signals and is latched at the positive edges of CK. When RAS# is held "HIGH" and CS# is asserted "LOW" the column access is started by asserting CAS# "LOW" Then, the Read or Write command is selected by asserting WE# "HIGH" or "LOW".                                                                                                                                                                                                                                                                    |
| WE#             | Input          | <b>Write Enable:</b> The WE# signal defines the operation commands in conjunction with the RAS# and CAS# signals and is latched at the positive edges of CK. The WE# input is used to select the BankActivate or Precharge command and Read or Write command.                                                                                                                                                                                                                                                                                                                                                                  |
| DQS0-DQS3       | Input / Output | <b>Bidirectional Data Strobe:</b> The DQSx signals are mapped to the following data bytes: DQS0 to DQ0-DQ7, DQS1 to DQ8-DQ15, DQS2 to DQ16-DQ23, DQS3 to DQ24-DQ31.                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| DM0 - DM3       | Input          | <b>Data Input Mask:</b> DM0-DM3 are byte specific. Input data is masked when DM is sampled HIGH during a write cycle. DM3 masks DQ31-DQ24, DM2 masks DQ23-DQ16, DM1 masks DQ15-DQ8, and DM0 masks DQ7-DQ0.                                                                                                                                                                                                                                                                                                                                                                                                                     |
| DQ0 - DQ31      | Input / Output | <b>Data I/O:</b> The DQ0-DQ31 input and output data are synchronized with the positive edges of CK and CK#. The I/Os are byte-maskable during Writes.                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| V <sub>DD</sub> | Supply         | <b>Power Supply:</b> Power for the input buffers and core logic.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

|                  |        |                                                                               |
|------------------|--------|-------------------------------------------------------------------------------|
| V <sub>SS</sub>  | Supply | <b>Ground:</b> Ground for the input buffers and core logic.                   |
| V <sub>DDQ</sub> | Supply | <b>DQ Power:</b> Provide isolated power to DQs for improved noise immunity.   |
| V <sub>SSQ</sub> | Supply | <b>DQ Ground:</b> Provide isolated ground to DQs for improved noise immunity. |
| V <sub>REF</sub> | Supply | <b>Reference Voltage for Inputs:</b> +0.5 x V <sub>DDQ</sub>                  |
| NC               | -      | <b>No Connect:</b> These pins should be left unconnected.                     |

Note: The timing reference point for the differential clocking is the cross point of the CK and CK#. For any applications using the single ended clocking, apply V<sub>REF</sub> to CK# pin.

## Operation Mode

Fully synchronous operations are performed to latch the commands at the positive edges of CK . Table 2 shows the truth table for the operation commands.

**Table 2. Truth Table (Note (1), (2) )**

| Command                    | State                      | CKEn-1 | CKEn | DM | BA1 | BA0 | A8          | A11-A9, A7-0                | CS# | RAS# | CAS# | WE# |
|----------------------------|----------------------------|--------|------|----|-----|-----|-------------|-----------------------------|-----|------|------|-----|
| BankActivate               | Idle <sup>(3)</sup>        | H      | X    | X  | V   | V   | Row Address |                             | L   | L    | H    | H   |
| BankPrecharge              | Any                        | H      | X    | X  | V   | V   | L           | X                           | L   | L    | H    | L   |
| PrechargeAll               | Any                        | H      | X    | X  | X   | X   | H           | X                           | L   | L    | H    | L   |
| Write                      | Active <sup>(3)</sup>      | H      | X    | V  | V   | V   | L           | Column Address<br>A0~A7, A9 | L   | H    | L    | L   |
| Write and AutoPrecharge    | Active <sup>(3)</sup>      | H      | X    | V  | V   | V   | H           |                             | L   | H    | L    | L   |
| Read                       | Active <sup>(3)</sup>      | H      | X    | X  | V   | V   | L           |                             | L   | H    | L    | H   |
| Read and Autoprecharge     | Active <sup>(3)</sup>      | H      | X    | X  | V   | V   | H           |                             | L   | H    | L    | H   |
| Mode Register Set          | Idle                       | H      | X    | X  | L   | L   | OP code     |                             | L   | L    | L    | L   |
| Extended Mode Register Set | Idle                       | H      | X    | X  | L   | H   |             |                             | L   | L    | L    | L   |
| No-Operation               | Any                        | H      | X    | X  | X   | X   | X           | X                           | L   | H    | H    | H   |
| Device Deselect            | Any                        | H      | X    | X  | X   | X   | X           | X                           | H   | X    | X    | X   |
| Burst Stop                 | Active <sup>(4)</sup>      | H      | X    | X  | X   | X   | X           | X                           | L   | H    | H    | L   |
| AutoRefresh                | Idle                       | H      | H    | X  | X   | X   | X           | X                           | L   | L    | L    | H   |
| SelfRefresh Entry          | Idle                       | H      | L    | X  | X   | X   | X           | X                           | L   | L    | L    | H   |
| SelfRefresh Exit           | Idle<br>(Self Refresh)     | L      | H    | X  | X   | X   | X           | X                           | H   | X    | X    | X   |
|                            |                            |        |      |    |     |     |             |                             | L   | H    | H    | H   |
| Power Down Mode Entry      | Idle/Active <sup>(5)</sup> | H      | L    | X  | X   | X   | X           | X                           | H   | X    | X    | X   |
|                            |                            |        |      |    |     |     |             |                             | L   | H    | H    | H   |
| Power Down Mode Exit       | Any<br>(Power Down)        | L      | H    | X  | X   | X   | X           | X                           | H   | X    | X    | X   |
|                            |                            |        |      |    |     |     |             |                             | L   | H    | H    | H   |
| Data Write/Output Enable   | Active                     | H      | X    | L  | X   | X   | X           | X                           | X   | X    | X    | X   |
| Data Mask/Output Disable   | Active                     | H      | X    | H  | X   | X   | X           | X                           | X   | X    | X    | X   |

- Note:**
1. V = Valid data, X = Don't Care, L = Low level, H = High level
  2. CKEn signal is input level when commands are provided.  
CKEn-1 signal is input level one clock cycle before the commands are provided.
  3. These are states of bank designated by BA0, BA1 signals.
  4. Read burst stop with BST command for all burst types.
  5. Power Down Mode can not enter in the burst operation.  
When this command is asserted in the burst cycle, device state is clock suspend mode.

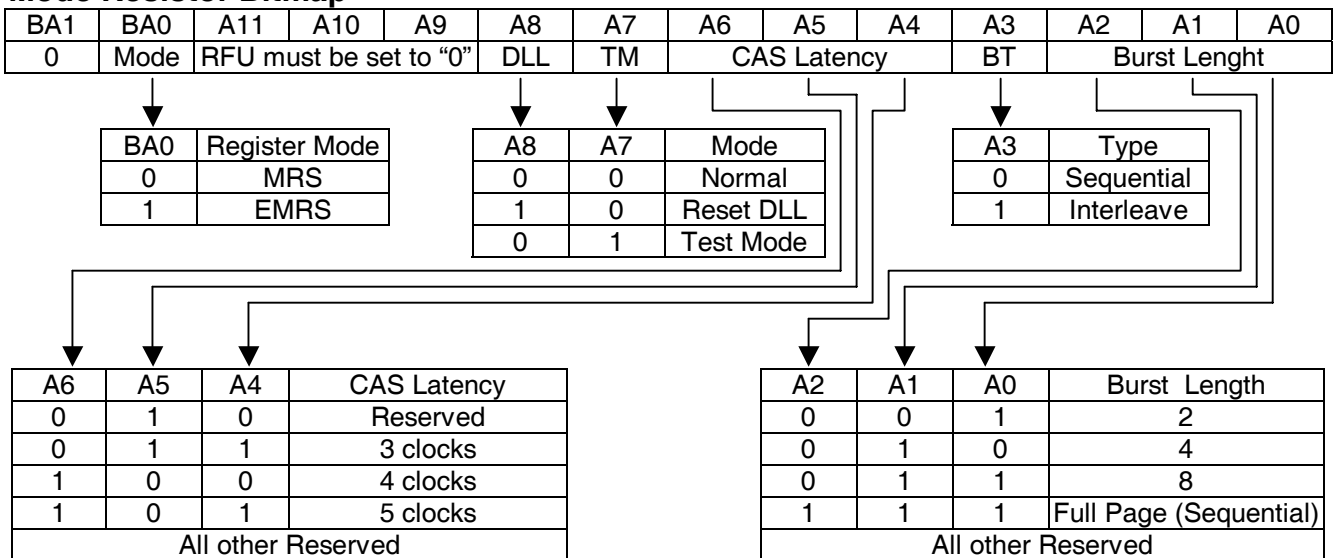
### Mode Register Set (MRS)

The mode register is divided into various fields depending on functionality.

- Burst Length Field (A2, A1, A0)  
This field specifies the data length of column access and selects the Burst Length.
- Addressing Mode Select Field (A3)  
The Addressing Mode can be Interleave Mode or Sequential Mode. Both Sequential Mode and Interleave Mode support burst length of 2, 4 and 8. Full page burst length is only for Sequential mode.
- CAS# Latency Field (A6, A5, A4)  
This field specifies the number of clock cycles from the assertion of the Read command to the first read data. The minimum whole value of CAS# Latency depends on the frequency of CK. The minimum whole value satisfying the following formula must be programmed into this field.  

$$t_{CAC(min)} \leq \text{CAS\# Latency} \times t_{CK}$$
- Test Mode field :A7; DLL Reset Mode field : A8  
These two bits must be programmed to "00" in normal operation.
- (BA0, BA1)

### Mode Resistor Bitmap



### Burst Definition, Addressing Sequence of Sequential and Interleave Mode

| Burst Length | Start Address |    |    | Sequential             | Interleave             |
|--------------|---------------|----|----|------------------------|------------------------|
|              | A2            | A1 | A0 |                        |                        |
| 2            | X             | X  | 0  | 0, 1                   | 0, 1                   |
|              | X             | X  | 1  | 1, 0                   | 1, 0                   |
| 4            | X             | 0  | 0  | 0, 1, 2, 3             | 0, 1, 2, 3             |
|              | X             | 0  | 1  | 1, 2, 3, 0             | 1, 0, 3, 2             |
|              | X             | 1  | 0  | 2, 3, 0, 1             | 2, 3, 0, 1             |
|              | X             | 1  | 1  | 3, 0, 1, 2             | 3, 2, 1, 0             |
| 8            | 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 |

### Extended Mode Register Set (EMRS)

The Extended Mode Register Set stores the data for enabling or disabling DLL and selecting output driver strength. The default value of the extended mode register is not defined, therefore must be written after power up for proper operation. The extended mode register is written by asserting low on CS#, RAS#, CAS#, and WE#. The state of A0, A2 ~ A5, A7 ~ A11 and BA1 is written in the mode register in the same cycle as CS#, RAS#, CAS#, and WE# going low. The DDR SDRAM should be in all bank precharge with CKE already high prior to writing into the extended mode register. A1 and A6 are used for setting driver strength to normal, weak or matched impedance. Two clock cycles are required to complete the write operation in the extended mode register. The mode register contents can be changed using the same command and clock cycle requirements during operation as long as all banks are in the idle state. A0 is used for DLL enable or disable. "High" on BA0 is used for EMRS. Refer to the table for specific codes.

### Extended Mode Resistor Bitmap

| BA1 | BA0 | A11                    | A10 | A9 | A8 | A7 | A6  | A5                     | A4 | A3 | A2 | A1 | A0  |     |
|-----|-----|------------------------|-----|----|----|----|-----|------------------------|----|----|----|----|-----|-----|
| 0   | 1   | RFU must be set to "0" |     |    |    |    | DS1 | RFU must be set to "0" |    |    |    |    | DS0 | DLL |

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### Power up Sequence

Power up must be performed in the following sequence.

- 1) Apply power to V<sub>DD</sub> before or at the same time as V<sub>DDQ</sub>, V<sub>TT</sub> and V<sub>REF</sub> when all input signals are held "NOP" state and maintain CKE "LOW".
- 2) Start clock and maintain stable condition for minimum 200us.
- 3) Issue a "NOP" command and keep CKE "HIGH"
- 4) Issue a "Precharge All" command.
- 5) Issue EMRS – enable DLL.
- 6) Issue MRS – reset DLL. (An additional 200 clock cycles are required to lock the DLL).
- 7) Precharge all banks of the device.
- 8) Issue two or more Auto Refresh commands.
- 9) Issue MRS – with A8 to low to initialize the mode register.

**Absolute Maximum Rating**

| Symbol                             | Item                         | Rating                        | Unit |
|------------------------------------|------------------------------|-------------------------------|------|
| V <sub>IN</sub> , V <sub>OUT</sub> | Input, Output Voltage        | - 0.3 ~ V <sub>DDQ</sub> +0.3 | V    |
| V <sub>DD</sub> , V <sub>DDQ</sub> | Power Supply Voltage         | -0.3 ~ 3.6                    | V    |
| T <sub>A</sub>                     | Ambient Temperature          | 0~70                          | °C   |
| T <sub>STG</sub>                   | Storage Temperature          | - 55~150                      | °C   |
| T <sub>SOLDER</sub>                | Soldering Temperature (10s)  | 240                           | °C   |
| P <sub>D</sub>                     | Power Dissipation            | 2.0                           | W    |
| I <sub>OUT</sub>                   | Short Circuit Output Current | 50                            | mA   |

**Recommended D.C. Operating Conditions (SSTL\_2 In/Out, T<sub>A</sub> = 0 ~ 70 °C)**

| Symbol              | Parameter                      | Min.                    | Typ.             | Max.                    | Unit | Note                       |
|---------------------|--------------------------------|-------------------------|------------------|-------------------------|------|----------------------------|
| V <sub>DD</sub>     | Power Supply Voltage           | 2.66                    | 2.8              | 2.94                    | V    |                            |
| V <sub>DDQ</sub>    | Power Supply Voltage(for I/O ) | 2.66                    | 2.8              | 2.94                    | V    |                            |
| V <sub>REF</sub>    | Input Reference Voltage        | 0.49 x V <sub>DDQ</sub> | -                | 0.51 x V <sub>DDQ</sub> | V    |                            |
| V <sub>TT</sub>     | Termination Voltage            | V <sub>REF</sub> - 0.04 | V <sub>REF</sub> | V <sub>REF</sub> + 0.04 | V    |                            |
| V <sub>IH(DC)</sub> | Input High Voltage             | V <sub>REF</sub> + 0.15 | -                | V <sub>DDQ</sub> + 0.3  | V    |                            |
| V <sub>IL(DC)</sub> | Input Low Voltage              | V <sub>ssq</sub> - 0.3  | -                | V <sub>REF</sub> - 0.15 | V    |                            |
| V <sub>OH</sub>     | Output High Voltage            | V <sub>tt</sub> + 0.76  | -                | -                       | V    | I <sub>OH</sub> = -15.2 mA |
| V <sub>OL</sub>     | Output Low Voltage             | -                       | -                | V <sub>tt</sub> - 0.76  | V    | I <sub>OL</sub> = +15.2 mA |
| I <sub>IL</sub>     | Input Leakage Current          | - 5                     | -                | 5                       | uA   |                            |
| I <sub>OL</sub>     | Output Leakage Current         | - 5                     | -                | 5                       | uA   |                            |

Note : Under all conditions V<sub>DDQ</sub> must be less than or equal to V<sub>DD</sub>.

**Capacitance (V<sub>DD</sub> = 2.8V, f = 1MHz, T<sub>A</sub> = 25 °C)**

| Parameter                                             | Symbol           | Min. | Max. | Unit |
|-------------------------------------------------------|------------------|------|------|------|
| Input Capacitance (A0~A11, BA0, BA1)                  | C <sub>IN1</sub> | 8    | 10   | pF   |
| Input Capacitance (CK, CK#, CE, CS#, RAS#, CAS#, WE#) | C <sub>IN2</sub> | 6    | 10   | pF   |
| DQ & DQS input/output capacitance                     | C <sub>OUT</sub> | 6    | 9    | pF   |
| DM0~DM3 input/output capacitance                      | C <sub>IN3</sub> | 6    | 9    | pF   |

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

### D.C. Characteristics

( $V_{DD} = 2.8V \pm 5\%$ ,  $T_A = 0 \sim 70^\circ C$ )

| Parameter & Test Condition                                                                                                                                                                                                                           | Symbol | 3.3  | 3.6  | 4    | 5   | Unit |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|------|------|-----|------|
|                                                                                                                                                                                                                                                      |        | Max  |      |      |     |      |
| <b>OPERATING CURRENT</b> : One bank; Active-Precharge; trc=trc(min); tck=tck(min); DQ,DM and DQS inputs changing once per clock cycle; Address and control inputs changing once every two clock cycles.                                              | IDD0   | 500  | 460  | 350  | 310 | mA   |
| <b>OPERATING CURRENT</b> : One bank; Active-Read-Precharge; BL=4; CL=4; tRCDRD=4*tck; trc=trc(min); tck=tck(min); Iout=0mA; Address and control inputs changing once per clock cycle                                                                 | IDD1   | 600  | 540  | 480  | 440 | mA   |
| <b>PRECHARGE POWER-DOWN STANDBY CURRENT:</b><br>All banks idle; power-down mode; tck=tck(min); CKE=LOW                                                                                                                                               | IDD2P  | 120  | 120  | 100  | 80  | mA   |
| <b>IDLE STANDLY CURRENT</b> : CKE = HIGH; CS#=HIGH(DESELECT); All banks idle; tck=tck(min); Address and control inputs changing once per clock cycle; VIN=VREF for DQ, DQS and DM                                                                    | IDD2N  | 210  | 200  | 175  | 170 | mA   |
| <b>ACTIVE POWER-DOWN STANDBY CURRENT</b> : one bank active; power-down mode; CKE=LOW; tck=tck(min)                                                                                                                                                   | IDD3P  | 120  | 120  | 100  | 80  | mA   |
| <b>ACTIVE STANDBY CURRENT</b> : CS#=HIGH;CKE=HIGH; one bank active ; trc=trc(max);tck=tck(min);Address and control inputs changing once per clock cycle; DQ,DQS,and DM inputs changing twice per clock cycle                                         | IDD3N  | 300  | 280  | 260  | 240 | mA   |
| <b>OPERATING CURRENT BURST READ</b> : BL=2; READS; Continuous burst; one bank active; Address and control inputs changing once per clock cycle; tck=tck(min); Iout=0mA;50% of data changing on every transfer                                        | IDD4R  | 640  | 610  | 580  | 550 | mA   |
| <b>OPERATING CURRENT BURST Write</b> : BL=2; WRITES; Continuous Burst ;one bank active; address and control inputs changing once per clock cycle; tck=tck(min); DQ,DQS,and DM changing twice per clock cycle; 50% of data changing on every transfer | IDD4W  | 550  | 525  | 500  | 480 | mA   |
| <b>AUTO REFRESH CURRENT</b> : trc=trFC(min); tck=tck(min)                                                                                                                                                                                            | IDD5   | 750  | 720  | 650  | 610 | mA   |
| <b>SELF REFRESH CURRENT:</b> Sell Refresh Mode ; CKE<=0.2V;tck=tck(min)                                                                                                                                                                              | IDD6   | 8    | 8    | 5    | 5   | mA   |
| <b>BURST OPERATING CURRENT 4 bank operation:</b><br>Four bank interleaving READs; BL=4;with Auto Precharge; trc=trc(min); tck=tck(min); Address and control inputschang only during Active, READ , or WRITE command                                  | IDD7   | 1100 | 1050 | 1000 | 950 | mA   |

#### Note:

1. Stress greater than those listed under "Absolute Maximum Ratings" may cause permanent damage of the device.
2. All voltages are referenced to Vss.
3. Power-up sequence is described in previous page.

### Decoupling Capacitance Guide Line

| Symbol           | Parameter                                                            | Value    | Unit |
|------------------|----------------------------------------------------------------------|----------|------|
| C <sub>DC1</sub> | Decoupling Capacitance between V <sub>DD</sub> and V <sub>SS</sub>   | 0.1+0.01 | uF   |
| C <sub>DC2</sub> | Decoupling Capacitance between V <sub>DDQ</sub> and V <sub>SSQ</sub> | 0.1+0.01 | uF   |

### AC Input Operating Conditions

(V<sub>DD</sub> = 2.8V ± 5%, T<sub>A</sub> = 0~70 °C)

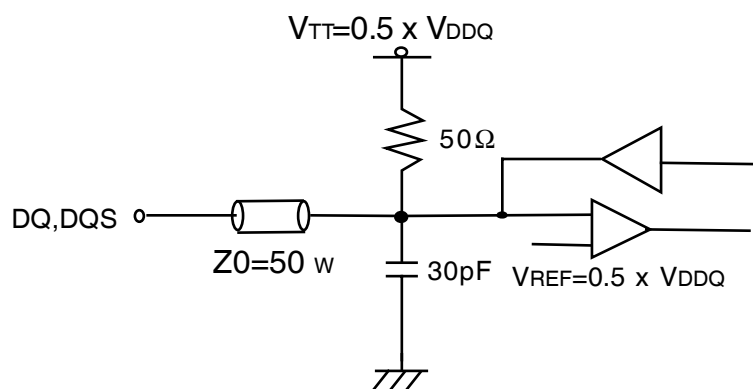
| Symbol          | Parameter                                    | Min                       | Max                       | Unit | Note |
|-----------------|----------------------------------------------|---------------------------|---------------------------|------|------|
| V <sub>IH</sub> | Input High Voltage; DQ                       | V <sub>REF</sub> +0.4     | -                         | V    |      |
| V <sub>IL</sub> | Input Low Voltage; DQ                        | -                         | V <sub>REF</sub> -0.4     | V    |      |
| V <sub>ID</sub> | Clock Input Differential Voltage; Ck & CK#   | 0.8                       | V <sub>DDQ</sub> +0.6     | V    |      |
| V <sub>IX</sub> | Clock Input Crossing Point Voltage; Ck & CK# | 0.5xV <sub>DDQ</sub> -0.2 | 0.5xV <sub>DDQ</sub> +0.2 | V    |      |

### AC Operating Test Conditions

(V<sub>DD</sub> = 2.8V ± 5%, T<sub>A</sub> = 0~70 °C)

|                                                       |                                                   |
|-------------------------------------------------------|---------------------------------------------------|
| Reference Level of Output Signals (V <sub>RFE</sub> ) | 0.5 x V <sub>DDQ</sub>                            |
| CK & CK# signal maximum peak swing                    | 1.5V                                              |
| Output Load                                           | See Figure. A Test Load                           |
| Input Signal Levels                                   | V <sub>REF</sub> +0.4 V / V <sub>REF</sub> -0.4 V |
| Input Signals Slew Rate                               | 1 V/ns                                            |
| Input timing measurement reference level              | V <sub>REF</sub>                                  |
| Output timing measurement reference level             | V <sub>TT</sub>                                   |
| Reference Level of Input Signals                      | 0.5 x V <sub>DDQ</sub>                            |

**Figure A. Test Load**



### Electrical Characteristics and Recommended A.C. Operating Conditions

(V<sub>DD</sub> = 2.8V ± 5%, T<sub>A</sub> = 0~70 °C)

| Symbol             | Parameter                                 | 3.3                                            |      | 3.6                                            |      | 4.0                                            |      | 5.0                                            |      | Unit            |
|--------------------|-------------------------------------------|------------------------------------------------|------|------------------------------------------------|------|------------------------------------------------|------|------------------------------------------------|------|-----------------|
|                    |                                           | Min                                            | Max  | Min                                            | Max  | Min                                            | Max  | Min                                            | Max  |                 |
| t <sub>CK</sub>    | Clock cycle time                          | CL = 3                                         | -    | -                                              | -    | 4                                              | 10   | 5                                              | 10   | ns              |
|                    |                                           | CL = 4                                         | 3.3  | 10                                             | 3.6  | 10                                             | 4    | 10                                             | 5    |                 |
| t <sub>CH</sub>    | Clock high level width                    | 0.45                                           | 0.55 | 0.45                                           | 0.55 | 0.45                                           | 0.55 | 0.45                                           | 0.55 | t <sub>CK</sub> |
| t <sub>CL</sub>    | Clock low level width                     | 0.45                                           | 0.55 | 0.45                                           | 0.55 | 0.45                                           | 0.55 | 0.45                                           | 0.55 | t <sub>CK</sub> |
| t <sub>DQSCK</sub> | DQS-out access time from CK,CK#           | -0.6                                           | 0.6  | -0.6                                           | 0.6  | -0.7                                           | 0.7  | -0.7                                           | 0.7  | ns              |
| t <sub>AC</sub>    | Output access time from CK,CK#            | -0.6                                           | 0.6  | -0.6                                           | 0.6  | -0.7                                           | 0.7  | -0.7                                           | 0.7  | ns              |
| t <sub>DQSQ</sub>  | DQS-DQ Skew                               | -                                              | 0.35 | -                                              | 0.4  | -                                              | 0.4  | -                                              | 0.45 | ns              |
| t <sub>RPRE</sub>  | Read preamble                             | 0.9                                            | 1.1  | 0.9                                            | 1.1  | 0.9                                            | 1.1  | 0.9                                            | 1.1  | t <sub>CK</sub> |
| t <sub>RPST</sub>  | Read postamble                            | 0.4                                            | 0.6  | 0.4                                            | 0.6  | 0.4                                            | 0.6  | 0.4                                            | 0.6  | t <sub>CK</sub> |
| t <sub>DQSS</sub>  | CK to valid DQS-in                        | 0.85                                           | 1.15 | 0.85                                           | 1.15 | 0.85                                           | 1.15 | 0.85                                           | 1.15 | t <sub>CK</sub> |
| t <sub>WPRES</sub> | DQS-in setup time                         | 0                                              | -    | 0                                              | -    | 0                                              | -    | 0                                              | -    | ns              |
| t <sub>WPREH</sub> | DQS-in hold time                          | 0.35                                           | -    | 0.35                                           | -    | 0.35                                           | -    | 0.35                                           | -    | ns              |
| t <sub>WPST</sub>  | DQS write postamble                       | 0.4                                            | 0.6  | 0.4                                            | 0.6  | 0.4                                            | 0.6  | 0.4                                            | 0.6  | t <sub>CK</sub> |
| t <sub>DQSH</sub>  | DQS in high level pulse width             | 0.4                                            | 0.6  | 0.4                                            | 0.6  | 0.4                                            | 0.6  | 0.4                                            | 0.6  | t <sub>CK</sub> |
| t <sub>DQSL</sub>  | DQS in low level pulse width              | 0.4                                            | 0.6  | 0.4                                            | 0.6  | 0.4                                            | 0.6  | 0.4                                            | 0.6  | t <sub>CK</sub> |
| t <sub>IS</sub>    | Address and Control input setup time      | 0.9                                            | -    | 0.9                                            | -    | 0.9                                            | -    | 1.0                                            | -    | ns              |
| t <sub>IH</sub>    | Address and Control input hold time       | 0.9                                            | -    | 0.9                                            | -    | 0.9                                            | -    | 1.0                                            | -    | ns              |
| t <sub>DS</sub>    | DQ & DM setup time to DQS                 | 0.35                                           | -    | 0.4                                            | -    | 0.45                                           | -    | 0.5                                            | -    | ns              |
| t <sub>DH</sub>    | DQ & DM hold time to DQS                  | 0.35                                           | -    | 0.4                                            | -    | 0.45                                           | -    | 0.5                                            | -    | ns              |
| t <sub>HP</sub>    | Clock half period                         | t <sub>CLMIN</sub><br>or<br>t <sub>CHMIN</sub> | -    | t <sub>CLMIN</sub><br>or<br>t <sub>CHMIN</sub> | -    | t <sub>CLMIN</sub><br>or<br>t <sub>CHMIN</sub> | -    | t <sub>CLMIN</sub><br>or<br>t <sub>CHMIN</sub> | -    | ns              |
| t <sub>QH</sub>    | Output DQS valid window                   | t <sub>HP</sub> -<br>0.35                      | -    | t <sub>HP</sub> -<br>0.4                       | -    | t <sub>HP</sub> -<br>0.45                      | -    | t <sub>HP</sub> -<br>0.5                       | -    | ns              |
| t <sub>RC</sub>    | Row cycle time                            | 17                                             | -    | 16                                             | -    | 15                                             | -    | 12                                             | -    | t <sub>CK</sub> |
| t <sub>RFC</sub>   | Refresh row cycle time                    | 19                                             | -    | 18                                             | -    | 17                                             | -    | 14                                             | -    | t <sub>CK</sub> |
| t <sub>RAS</sub>   | Row active time                           | 12                                             | 100K | 11                                             | 100K | 10                                             | 100K | 8                                              | 100K | t <sub>CK</sub> |
| t <sub>RCDRD</sub> | RAS# to CAS# Delay in Read                | 6                                              | -    | 5                                              | -    | 5                                              | -    | 4                                              | -    | t <sub>CK</sub> |
| t <sub>RCDWR</sub> | RAS# to CAS# Delay in Write               | 4                                              | -    | 3                                              | -    | 3                                              | -    | 2                                              | -    | t <sub>CK</sub> |
| t <sub>RP</sub>    | Row precharge time                        | 5                                              | -    | 3                                              | -    | 3                                              | -    | 3                                              | -    | t <sub>CK</sub> |
| t <sub>RRD</sub>   | Row active to Row active delay            | 3                                              | -    | 3                                              | -    | 3                                              | -    | 2                                              | -    | t <sub>CK</sub> |
| t <sub>WR</sub>    | Write recovery time                       | 3                                              | -    | 3                                              | -    | 3                                              | -    | 2                                              | -    | t <sub>CK</sub> |
| t <sub>CDLR</sub>  | Last data in to Read command              | 2                                              | -    | 2                                              | -    | 2                                              | -    | 2                                              | -    | t <sub>CK</sub> |
| t <sub>CCD</sub>   | Col. Address to Col. Address delay        | 1                                              | -    | 1                                              | -    | 1                                              | -    | 1                                              | -    | t <sub>CK</sub> |
| t <sub>MRD</sub>   | Mode register set cycle time              | 1                                              | -    | 1                                              | -    | 2                                              | -    | 2                                              | -    | t <sub>CK</sub> |
| t <sub>DAL</sub>   | Auto precharge write recovery + Precharge | 9                                              | -    | 9                                              | -    | 8                                              | -    | 7                                              | -    | t <sub>CK</sub> |
| t <sub>XSA</sub>   | Self refresh exit to read command delay   | 200                                            | -    | 200                                            | -    | 200                                            | -    | 200                                            | -    | t <sub>CK</sub> |
| t <sub>PDEX</sub>  | Power down exit time                      | t <sub>IS</sub> +<br>2t <sub>CK</sub>          | -    | t <sub>IS</sub> +<br>2t <sub>CK</sub>          | -    | t <sub>IS</sub> +<br>2t <sub>CK</sub>          | -    | t <sub>IS</sub> +<br>2t <sub>CK</sub>          | -    | ns              |
| t <sub>REF</sub>   | Refresh interval time                     | -                                              | 7.8  | -                                              | 7.8  | -                                              | 7.8  | -                                              | 7.8  | us              |

### Timing Waveforms

Figure 1. AC Parameters for Read Timing (Burst Length = 4)

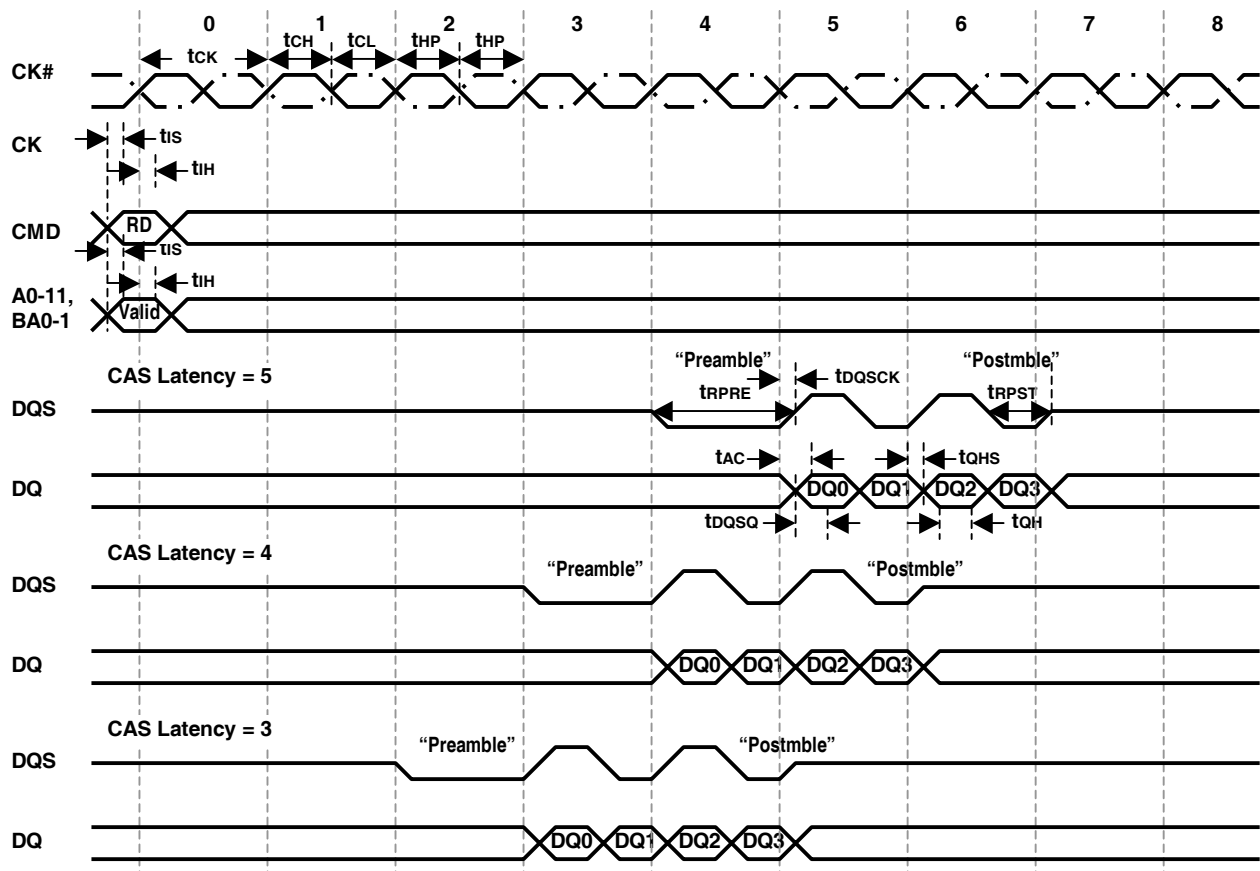
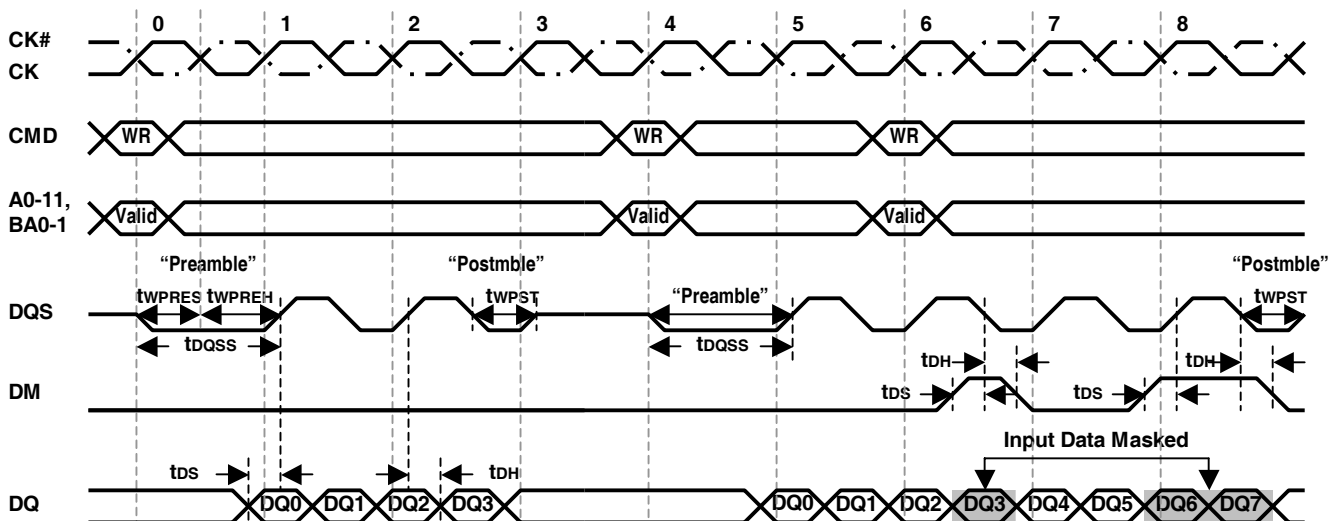
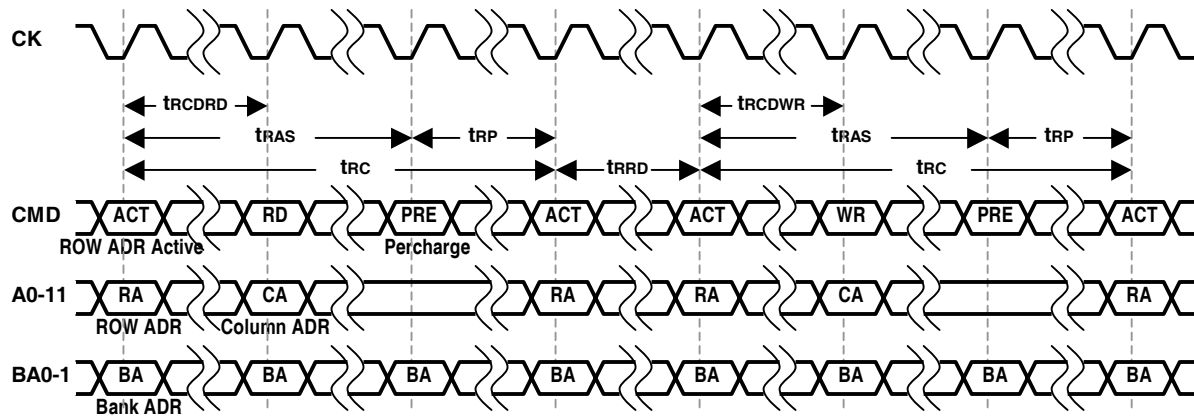


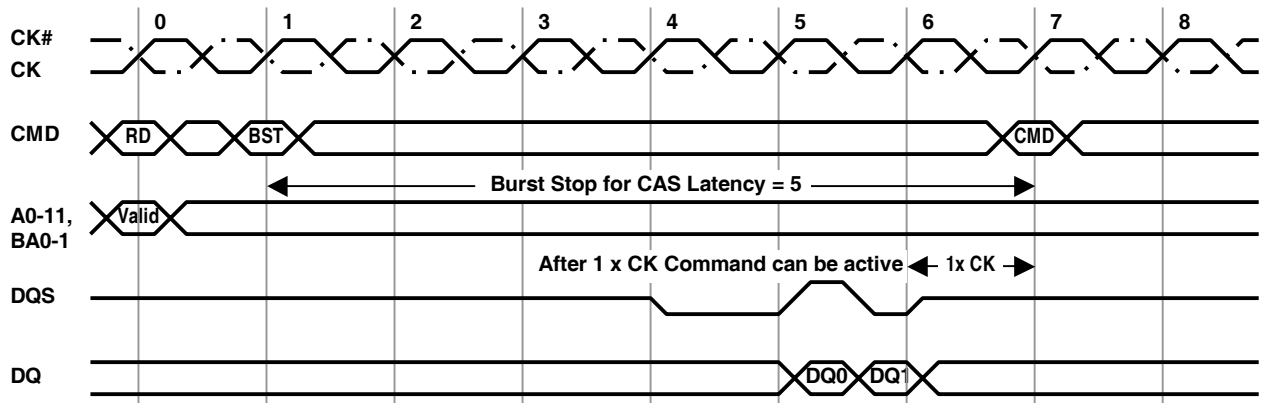
Figure 2. AC Parameters for Write Timing (Burst Length=4)



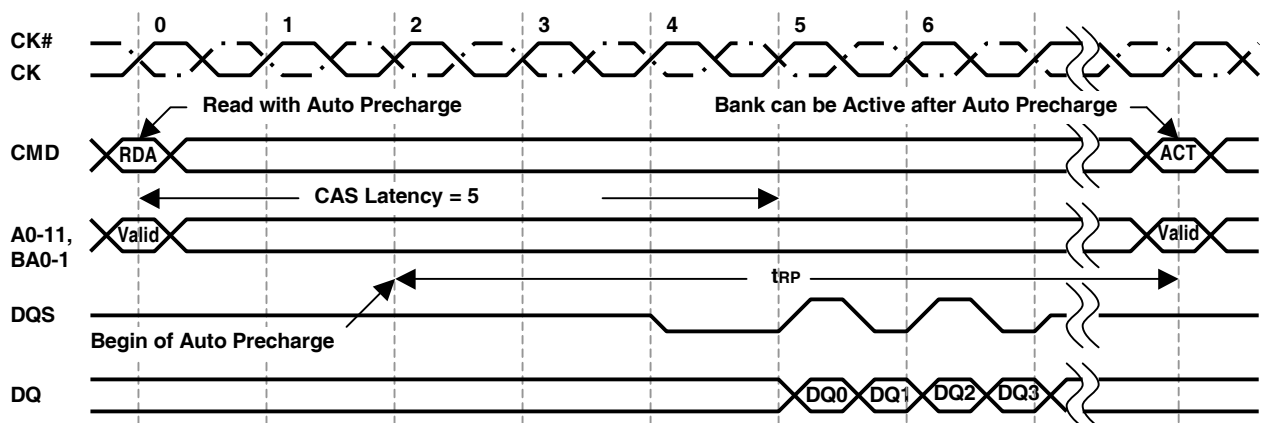
**Figure 3. Bank Activate Read or Write Command Timing**



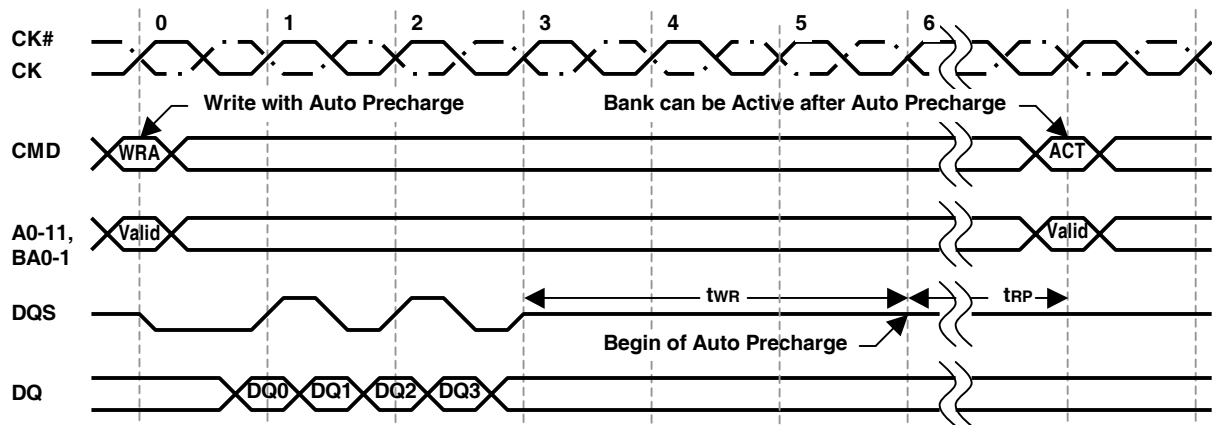
**Figure 4. Burst Stop for Read (CAS Latency = 5, Burst Length = 4)**



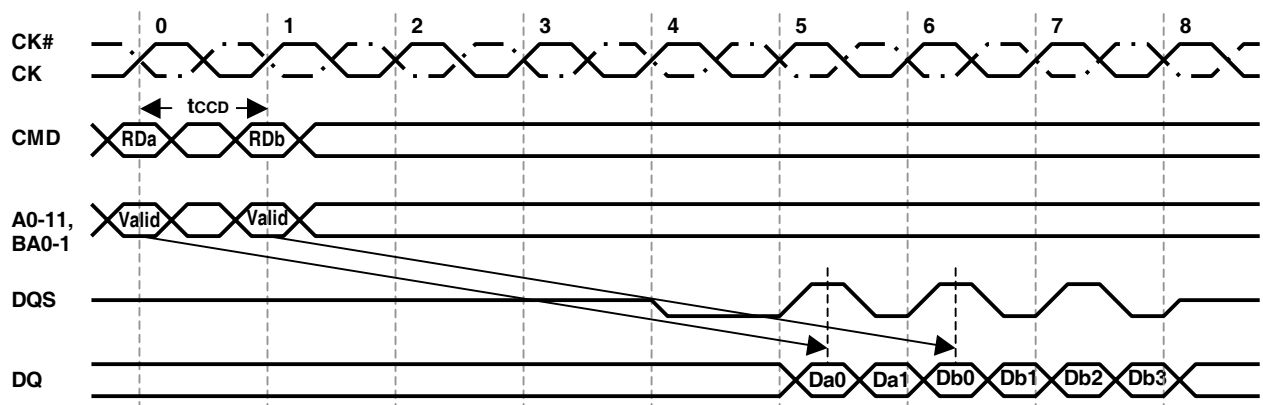
**Figure 5. Read with Auto Precharge (CAS Latency = 5, Burst Length = 4)**



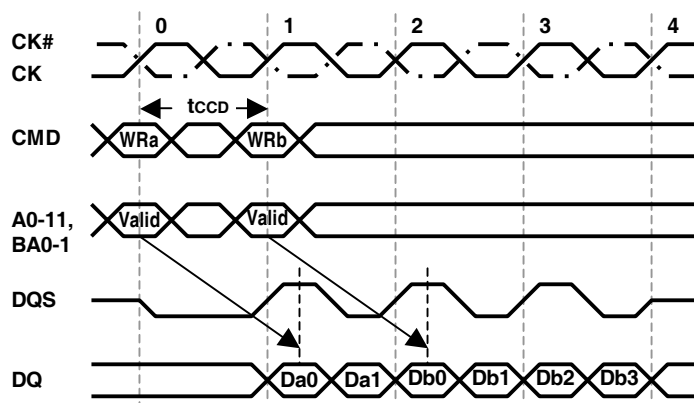
**Figure 6. Write with Auto Precharge (Burst Length = 4)**



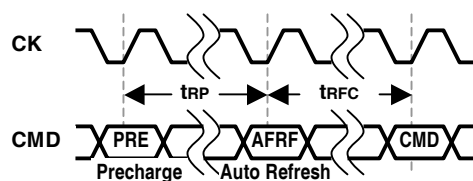
**Figure 7. Read Burst Interrupt by Read (CAS Latency = 5, Burst Length = 4)**



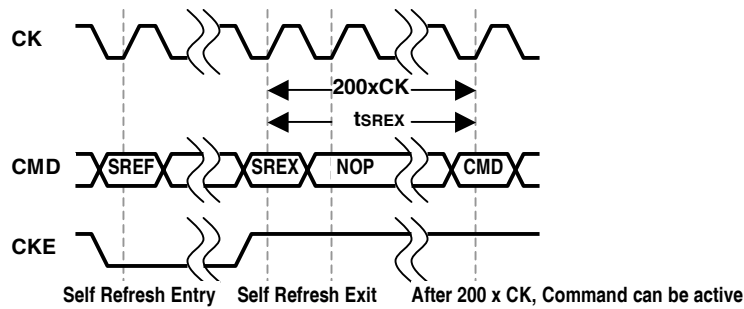
**Figure 8. Write Interrupted by Write (Burst Length = 4)**



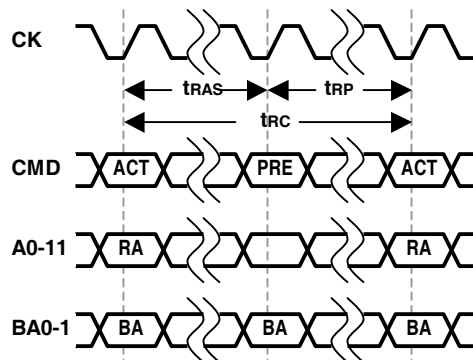
**Figure 9. Auto Refresh Timing**



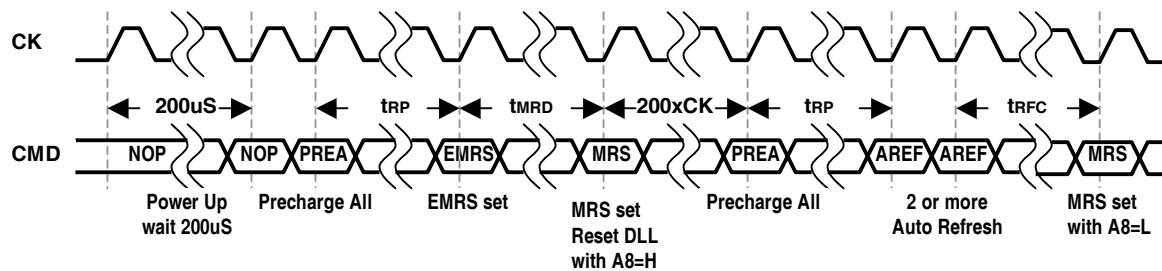
**Figure 10. Self Refresh Timing**



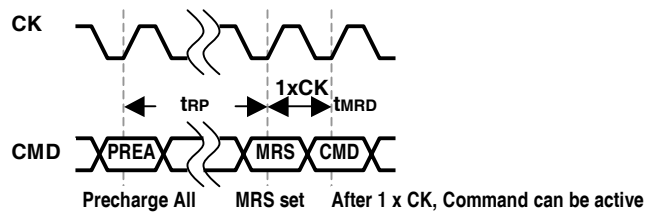
**Figure 11. Precharge Command**



**Figure 12. Power Up Sequence**



**Figure 13. Mode Register Set Timing**



**Figure 14. Power Down Mode**

