

## A. MODE REGISTER FIELD TABLE TO PROGRAM MODES

Register Programmed with MRS

Address	BA <sub>0</sub> ~ BA <sub>1</sub>	A <sub>n</sub> ~ A <sub>10</sub> /AP	A <sub>9</sub>	A <sub>8</sub>	A <sub>7</sub>	A <sub>6</sub>	A <sub>5</sub>	A <sub>4</sub>	A <sub>3</sub>	A <sub>2</sub>	A <sub>1</sub>	A <sub>0</sub>
Function	RFU	RFU	W.B.L	TM		CAS Latency			BT	Burst Length		

Test Mode			CAS Latency				Burst Type		Burst Length				
A <sub>8</sub>	A <sub>7</sub>	Type	A <sub>6</sub>	A <sub>5</sub>	A <sub>4</sub>	Latency	A <sub>3</sub>	Type	A <sub>2</sub>	A <sub>1</sub>	A <sub>0</sub>	BT = 0	BT = 1
0	0	Mode Register Set	0	0	0	Reserved	0	Sequential	0	0	0	1	1
0	1	Reserved	0	0	1	Reserved	1	Interleave	0	0	1	2	2
1	0	Reserved	0	1	0	2			0	1	0	4	4
1	1	Reserved	0	1	1	3			0	1	1	8	8
<b>Write Burst Length</b>			1	0	0	Reserved			1	0	0	Reserved	Reserved
A <sub>9</sub>	Length		1	0	1	Reserved			1	0	1	Reserved	Reserved
0	Burst		1	1	0	Reserved			1	1	0	Reserved	Reserved
1	Single Bit		1	1	1	Reserved			1	1	1	Full Page	Reserved

Full Page Length : x4 (1024), x8 (512), x16 (256)

## B. POWER UP SEQUENCE

1. Apply power and start clock, Attempt to maintain CKE= "H", DQM= "H" and the other pins are NOP condition at the inputs.
  2. Maintain stable power, stable clock and NOP input condition for a minimum of 200us.
  3. Issue precharge commands for all banks of the devices.
  4. Issue 2 or more auto-refresh commands.
  5. Issue a mode register set command to initialize the mode register.
- cf.) Sequence of 4 & 5 is regardless of the order.

The device is now ready for normal operation.

- Note** :
1. If A<sub>9</sub> is high during MRS cycle, "Burst Read Single Bit Write" function will be enabled.
  2. RFU (Reserved for future use) should stay "0" during MRS cycle.

**C. BURST SEQUENCE**

**1. BURST LENGTH = 4**

Initial Address		Sequential				Interleave			
A <sub>1</sub>	A <sub>0</sub>								
0	0	0	1	2	3	0	1	2	3
0	1	1	2	3	0	1	0	3	2
1	0	2	3	0	1	2	3	0	1
1	1	3	0	1	2	3	2	1	0

**2. BURST LENGTH = 8**

Initial Address			Sequential								Interleave							
A <sub>2</sub>	A <sub>1</sub>	A <sub>0</sub>																
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

## D. DEVICE OPERATIONS

### ADDRESSES of 16Mb

#### BANK ADDRESSES (BA)

##### : In case x 4

This SDRAM is organized as two independent banks of 2,097,152 words x 4 bits memory arrays. The BA inputs are latched at the time of assertion of  $\overline{\text{RAS}}$  and  $\overline{\text{CAS}}$  to select the bank to be used for the operation. The bank addresses BA are latched at bank active, read, write, mode register set and precharge operations.

##### : In case x 8

This SDRAM is organized as two independent banks of 1,048,576 words x 8 bits memory arrays. The BA inputs are latched at the time of assertion of  $\overline{\text{RAS}}$  and  $\overline{\text{CAS}}$  to select the bank to be used for the operation. The bank addresses BA are latched at bank active, read, write, mode register set and precharge operations.

##### : In case x 16

This SDRAM is organized as two independent banks of 524,288 words x 16 bits memory arrays. The BA inputs are latched at the time of assertion of  $\overline{\text{RAS}}$  and  $\overline{\text{CAS}}$  to select the bank to be used for the operation. The bank addresses BA<sub>0</sub> ~ BA<sub>1</sub> are latched at bank active, read, write, mode register set and precharge operations.

#### ADDRESS INPUTS (A<sub>0</sub> ~ A<sub>10/AP</sub>)

##### : In case x 4

The 21 address bits are required to decode the 2,097,152 word locations are multiplexed into 11 address input pins (A<sub>0</sub> ~ A<sub>10/AP</sub>). The 11 bit row addresses are latched along with  $\overline{\text{RAS}}$  and BA during bank activate command. The 10 bit column addresses are latched along with  $\overline{\text{CAS}}$ ,  $\overline{\text{WE}}$  and BA during read or write command.

##### : In case x 8

The 20 address bits are required to decode the 1,048,576 word locations are multiplexed into 11 address input pins (A<sub>0</sub> ~ A<sub>10/AP</sub>). The 11 bit row addresses are latched along with  $\overline{\text{RAS}}$  and BA during bank activate command. The 9 bit column addresses are latched along with  $\overline{\text{CAS}}$ ,  $\overline{\text{WE}}$  and BA during read or write command.

##### : In case x 16

The 19 address bits are required to decode the 524,288 word locations are multiplexed into 11 address input pins (A<sub>0</sub> ~ A<sub>10/AP</sub>). The 11 bit row addresses are latched along with  $\overline{\text{RAS}}$  and BA during bank activate command. The 8 bit column addresses are latched along with  $\overline{\text{CAS}}$ ,  $\overline{\text{WE}}$  and BA during read or write command.

### ADDRESSES of 64Mb

#### BANK ADDRESSES (BA<sub>0</sub> ~ BA<sub>1</sub>)

##### : In case x 4

This SDRAM is organized as four independent banks of 4,194,304 words x 4 bits memory arrays. The BA<sub>0</sub> ~ BA<sub>1</sub> inputs are latched at the time of assertion of  $\overline{\text{RAS}}$  and  $\overline{\text{CAS}}$  to select the bank to be used for the operation. The bank addresses BA<sub>0</sub> ~ BA<sub>1</sub> are latched at bank active, read, write, mode register set and precharge operations.

##### : In case x 8

This SDRAM is organized as four independent banks of 2,097,152 words x 8 bits memory arrays. The BA<sub>0</sub> ~ BA<sub>1</sub> inputs are latched at the time of assertion of  $\overline{\text{RAS}}$  and  $\overline{\text{CAS}}$  to select the bank to be used for the operation. The bank addresses BA<sub>0</sub> ~ BA<sub>1</sub> are latched at bank active, read, write, mode register set and precharge operations.

##### : In case x 16

This SDRAM is organized as four independent banks of 1,048,576 words x 16 bits memory arrays. The BA<sub>0</sub> ~ BA<sub>1</sub> inputs are latched at the time of assertion of  $\overline{\text{RAS}}$  and  $\overline{\text{CAS}}$  to select the bank to be used for the operation. The bank addresses BA<sub>0</sub> ~ BA<sub>1</sub> are latched at bank active, read, write, mode register set and precharge operations.

#### ADDRESS INPUTS (A<sub>0</sub> ~ A<sub>11</sub>)

##### : In case x 4

The 22 address bits are required to decode the 4,194,304 word locations are multiplexed into 12 address input pins (A<sub>0</sub> ~ A<sub>11</sub>). The 12 bit row addresses are latched along with  $\overline{\text{RAS}}$  and BA<sub>0</sub> ~ BA<sub>1</sub> during bank activate command. The 10 bit column addresses are latched along with  $\overline{\text{CAS}}$ ,  $\overline{\text{WE}}$  and BA<sub>0</sub> ~ BA<sub>1</sub> during read or write command.

##### : In case x 8

The 21 address bits are required to decode the 2,097,152 word locations are multiplexed into 12 address input pins (A<sub>0</sub> ~ A<sub>11</sub>). The 12 bit row addresses are latched along with  $\overline{\text{RAS}}$  and BA<sub>0</sub> ~ BA<sub>1</sub> during bank activate command. The 9 bit column addresses are latched along with  $\overline{\text{CAS}}$ ,  $\overline{\text{WE}}$  and BA<sub>0</sub> ~ BA<sub>1</sub> during read or write command.

##### : In case x 16

The 20 address bits are required to decode the 1,048,576 word locations are multiplexed into 12 address input pins (A<sub>0</sub> ~ A<sub>11</sub>). The 12 bit row addresses are latched along with  $\overline{\text{RAS}}$  and BA<sub>0</sub> ~ BA<sub>1</sub> during bank activate command. The 8 bit column addresses are latched along with  $\overline{\text{CAS}}$ ,  $\overline{\text{WE}}$  and BA<sub>0</sub> ~ BA<sub>1</sub> during read or write command.

## D. DEVICE OPERATIONS (continued)

### ADDRESSES of 128Mb

#### BANK ADDRESSES (BA0 ~ BA1)

##### : In case x 4

This SDRAM is organized as four independent banks of 8,388,608 words x 4 bits memory arrays. The BA0 ~ BA1 inputs are latched at the time of assertion of  $\overline{\text{RAS}}$  and  $\overline{\text{CAS}}$  to select the bank to be used for the operation. The bank addresses BA0 ~ BA1 are latched at bank active, read, write, mode register set and pre-charge operations.

##### : In case x 8

This SDRAM is organized as four independent banks of 4,194,304 words x 8 bits memory arrays. The BA0 ~ BA1 inputs are latched at the time of assertion of  $\overline{\text{RAS}}$  and  $\overline{\text{CAS}}$  to select the bank to be used for the operation. The bank addresses BA0 ~ BA1 are latched at bank active, read, write, mode register set and pre-charge operations.

##### : In case x 16

This SDRAM is organized as four independent banks of 2,097,152 words x 16 bits memory arrays. The BA0 ~ BA1 inputs are latched at the time of assertion of  $\overline{\text{RAS}}$  and  $\overline{\text{CAS}}$  to select the bank to be used for the operation. The bank addresses BA0 ~ BA1 are latched at bank active, read, write, mode register set and pre-charge operations.

### ADDRESS INPUTS (A0 ~ A11)

##### : In case x 4

The 23 address bits are required to decode the 8,388,608 word locations are multiplexed into 12 address input pins (A0 ~ A11). The 12 bit row addresses are latched along with  $\overline{\text{RAS}}$  and BA0 ~ BA1 during bank activate command. The 11 bit column addresses are latched along with  $\overline{\text{CAS}}$ ,  $\overline{\text{WE}}$  and BA0 ~ BA1 during read or write command.

##### : In case x 8

The 22 address bits are required to decode the 4,194,304 word locations are multiplexed into 11 address input pins (A0 ~ A11). The 12 bit row addresses are latched along with  $\overline{\text{RAS}}$  and BA0 ~ BA1 during bank activate command. The 10 bit column addresses are latched along with  $\overline{\text{CAS}}$ ,  $\overline{\text{WE}}$  and BA0 ~ BA1 during read or write command.

##### : In case x 16

The 21 address bits are required to decode the 2,097,152 word locations are multiplexed into 12 address input pins (A0 ~ A11). The 12 bit row addresses are latched along with  $\overline{\text{RAS}}$  and BA0 ~ BA1 during bank activate command. The 9 bit column addresses are latched along with  $\overline{\text{CAS}}$ ,  $\overline{\text{WE}}$  and BA0 ~ BA1 during read or write command.

### ADDRESSES of 256Mb

#### BANK ADDRESSES (BA0 ~ BA1)

##### : In case x 4

This SDRAM is organized as four independent banks of 16,777,216 words x 4 bits memory arrays. The BA0 ~ BA1 inputs are latched at the time of assertion of  $\overline{\text{RAS}}$  and  $\overline{\text{CAS}}$  to select the bank to be used for the operation. The bank addresses BA0 ~ BA1 are latched at bank active, read, write, mode register set and pre-charge operations.

##### : In case x 8

This SDRAM is organized as four independent banks of 8,388,608 words x 8 bits memory arrays. The BA0 ~ BA1 inputs are latched at the time of assertion of  $\overline{\text{RAS}}$  and  $\overline{\text{CAS}}$  to select the bank to be used for the operation. The bank addresses BA0 ~ BA1 are latched at bank active, read, write, mode register set and pre-charge operations.

##### : In case x 16

This SDRAM is organized as four independent banks of 4,194,304 words x 16 bits memory arrays. The BA0 ~ BA1 inputs are latched at the time of assertion of  $\overline{\text{RAS}}$  and  $\overline{\text{CAS}}$  to select the bank to be used for the operation. The bank addresses BA0 ~ BA1 are latched at bank active, read, write, mode register set and pre-charge operations.

### ADDRESS INPUTS (A0 ~ A12)

##### : In case x 4

The 24 address bits are required to decode the 16,777,216 word locations are multiplexed into 13 address input pins (A0 ~ A12). The 13 bit row addresses are latched along with  $\overline{\text{RAS}}$  and BA0 ~ BA1 during bank activate command. The 11 bit column addresses are latched along with  $\overline{\text{CAS}}$ ,  $\overline{\text{WE}}$  and BA0 ~ BA1 during read or write command.

##### : In case x 8

The 23 address bits are required to decode the 8,388,608 word locations are multiplexed into 13 address input pins (A0 ~ A12). The 13 bit row addresses are latched along with  $\overline{\text{RAS}}$  and BA0 ~ BA1 during bank activate command. The 10 bit column addresses are latched along with  $\overline{\text{CAS}}$ ,  $\overline{\text{WE}}$  and BA0 ~ BA1 during read or write command.

##### : In case x 16

The 22 address bits are required to decode the 4,194,304 word locations are multiplexed into 13 address input pins (A0 ~ A12). The 13 bit row addresses are latched along with  $\overline{\text{RAS}}$  and BA0 ~ BA1 during bank activate command. The 9 bit column addresses are latched along with  $\overline{\text{CAS}}$ ,  $\overline{\text{WE}}$  and BA0 ~ BA1 during read or write command.

## D. DEVICE OPERATIONS (continued)

### CLOCK (CLK)

The clock input is used as the reference for all SDRAM operations. All operations are synchronized to the positive going edge of the clock. The clock transitions must be monotonic between  $V_{IL}$  and  $V_{IH}$ . During operation with CKE high all inputs are assumed to be in a valid state (low or high) for the duration of set-up and hold time around positive edge of the clock in order to function well Q perform and lcc specifications.

### CLOCK ENABLE (CKE)

The clock enable(CKE) gates the clock onto SDRAM. If CKE goes low synchronously with clock (set-up and hold time are the same as other inputs), 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. All other inputs are ignored from the next clock cycle after CKE goes low. When all banks are in the idle state and CKE goes low synchronously with clock, the SDRAM enters the power down mode from the next clock cycle. The SDRAM remains in the power down mode ignoring the other inputs as long as CKE remains low. The power down exit is synchronous as the internal clock is suspended. When CKE goes high at least "1CLK + tss" before the high going edge of the clock, then the SDRAM becomes active from the same clock edge accepting all the input commands.

### NOP and DEVICE DESELECT

When  $\overline{RAS}$ ,  $\overline{CAS}$  and  $\overline{WE}$  are high, the SDRAM performs no operation (NOP). NOP does not initiate any new operation, but is needed to complete operations which require more than single clock cycle like bank activate, burst read, auto refresh, etc. The device deselect is also a NOP and is entered by asserting  $\overline{CS}$  high.  $\overline{CS}$  high disables the command decoder so that  $\overline{RAS}$ ,  $\overline{CAS}$ ,  $\overline{WE}$  and all the address inputs are ignored.

### DQM OPERATION

The DQM is used to mask input and output operations. It works similar to  $\overline{OE}$  during read operation and inhibits writing during write operation. The read latency is two cycles from DQM and zero cycle for write, which means DQM masking occurs two cycles later in read cycle and occurs in the same cycle during write cycle. DQM operation is synchronous with the clock. The DQM signal is important during burst interruptions of write with read or precharge in the SDRAM. Due to asynchronous nature of the internal write, the DQM operation is critical to avoid unwanted or incomplete writes when the complete burst write is not required. Please refer to DQM timing diagram also.

### MODE REGISTER SET (MRS)

The mode register stores the data for controlling the various operating modes of SDRAM. It programs the CAS latency, burst type, burst length, test mode and various vendor specific options to make SDRAM useful for variety of different applications. The default value of the mode register is not defined, therefore the mode register must be written after power up to operate the SDRAM. The mode register is written by asserting low on  $\overline{CS}$ ,  $\overline{RAS}$ ,  $\overline{CAS}$  and  $\overline{WE}$  (The SDRAM should be in active mode with CKE already high prior to writing the mode register). The state of address pins  $A_0 \sim A_n$  and  $BA_0 \sim BA_1$  in the same cycle as  $\overline{CS}$ ,  $\overline{RAS}$ ,  $\overline{CAS}$  and  $\overline{WE}$  going low is the data written in the mode register. Two clock cycles is required to complete the write in the 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. The mode register is divided into various fields depending on the fields of functions. The burst length field uses  $A_0 \sim A_2$ , burst type uses  $A_3$ , CAS latency (read latency from column address) use  $A_4 \sim A_6$ , vendor specific options or test mode use  $A_7 \sim A_8$ ,  $A_{10}/AP \sim A_n$  and  $BA_0 \sim BA_1$ . The write burst length is programmed using  $A_9$ .  $A_7 \sim A_8$ ,  $A_{10}/AP \sim A_n$  and  $BA_0 \sim BA_1$  must be set to low for normal SDRAM operation. Refer to the table for specific codes for various burst length, burst type and CAS latencies.

## D. DEVICE OPERATIONS (continued)

### **BANK ACTIVATE**

The bank activate command is used to select a random row in an idle bank. By asserting low on  $\overline{\text{RAS}}$  and  $\overline{\text{CS}}$  with desired row and bank address, a row access is initiated. The read or write operation can occur after a time delay of  $t_{\text{RCD}}(\text{min})$  from the time of bank activation.  $t_{\text{RCD}}$  is an internal timing parameter of SDRAM, therefore it is dependent on operating clock frequency. The minimum number of clock cycles required between bank activate and read or write command should be calculated by dividing  $t_{\text{RCD}}(\text{min})$  with cycle time of the clock and then rounding off the result to the next higher integer. The SDRAM has four internal banks in the same chip and shares part of the internal circuitry to reduce chip area, therefore it restricts the activation of four banks simultaneously. Also the noise generated during sensing of each bank of SDRAM is high, requiring some time for power supplies to recover before another bank can be sensed reliably.  $t_{\text{RRD}}(\text{min})$  specifies the minimum time required between activating different bank. The number of clock cycles required between different bank activation must be calculated similar to  $t_{\text{RCD}}$  specification. The minimum time required for the bank to be active to initiate sensing and restoring the complete row of dynamic cells is determined by  $t_{\text{RAS}}(\text{min})$ . Every SDRAM bank activate command must satisfy  $t_{\text{RAS}}(\text{min})$  specification before a precharge command to that active bank can be asserted. The maximum time any bank can be in the active state is determined by  $t_{\text{RAS}}(\text{max})$ . The number of cycles for both  $t_{\text{RAS}}(\text{min})$  and  $t_{\text{RAS}}(\text{max})$  can be calculated similar to  $t_{\text{RCD}}$  specification.

### **BURST READ**

The burst read command is used to access burst of data on consecutive clock cycles from an active row in an active bank. The burst read command is issued by asserting low on  $\overline{\text{CS}}$  and  $\overline{\text{CAS}}$  with  $\overline{\text{WE}}$  being high on the positive edge of the clock. The bank must be active for at least  $t_{\text{RCD}}(\text{min})$  before the burst read command is issued. The first output appears in CAS latency number of clock cycles after the issue of burst read command. The burst length, burst sequence and latency from the burst read command is determined by the mode register which is already programmed.

The burst read can be initiated on any column address of the active row. The address wraps around if the initial address does not start from a boundary such that number of outputs from each I/O are equal to the burst length programmed in the mode register. The output goes into high-impedance at the end of the burst, unless a new burst read was initiated to keep the data output gapless. The burst read can be terminated by issuing another burst read or burst write in the same bank or the other active bank or a precharge command to the same bank. The burst stop command is valid at every page burst length.

### **BURST WRITE**

The burst write command is similar to burst read command and is used to write data into the SDRAM on consecutive clock cycles in adjacent addresses depending on burst length and burst sequence. By asserting low on  $\overline{\text{CS}}$ ,  $\overline{\text{CAS}}$  and  $\overline{\text{WE}}$  with valid column address, a write burst is initiated. The data inputs are provided for the initial address in the same clock cycle as the burst write command. The input buffer is deselected at the end of the burst length, even though the internal writing can be completed yet. The writing can be completed by issuing a burst read and DQM for blocking data inputs or burst write in the same or another active bank. The burst stop command is valid at every burst length. The write burst can also be terminated by using DQM for blocking data and precharging the bank  $t_{\text{RD}}$  after the last data input to be written into the active row. See DQM OPERATION also.

### **BOTH BANKS PRECHARGE**

Both banks can be precharged at the same time by using Precharge all command. Asserting low on  $\overline{\text{CS}}$ ,  $\overline{\text{RAS}}$ , and  $\overline{\text{WE}}$  with high on  $A_{10}/\text{AP}$  after all banks have satisfied  $t_{\text{RAS}}(\text{min})$  requirement, performs precharge on all banks. At the end of  $t_{\text{RP}}$  after performing precharge to all the banks, both banks are in idle state.

**D. DEVICE OPERATIONS (continued)****PRECHARGE**

The precharge operation is performed on an active bank by asserting low on  $\overline{CS}$ ,  $\overline{RAS}$ ,  $\overline{WE}$  and  $A_{10}/AP$  with valid  $BA_0 \sim BA_1$  of the bank to be precharged. The precharge command can be asserted anytime after  $t_{RAS}(\min)$  is satisfied from the bank active command in the desired bank.  $t_{RP}$  is defined as the minimum number of clock cycles required to complete row precharge is calculated by dividing  $t_{RP}$  with clock cycle time and rounding up to the next higher integer. Care should be taken to make sure that burst write is completed or DQM is used to inhibit writing before precharge command is asserted. The maximum time any bank can be active is specified by  $t_{RAS}(\max)$ . Therefore, each bank activate command. At the end of precharge, the bank enters the idle state and is ready to be activated again. Entry to Power down, Auto refresh, Self refresh and Mode register set etc. is possible only when all banks are in idle state.

**AUTO PRECHARGE**

The precharge operation can also be performed by using auto precharge. The SDRAM internally generates the timing to satisfy  $t_{RAS}(\min)$  and "tRP" for the programmed burst length and  $\overline{CAS}$  latency. The auto precharge command is issued at the same time as burst read or burst write by asserting high on  $A_{10}/AP$ . If burst read or burst write by asserting high on  $A_{10}/AP$ , the bank is left active until a new command is asserted. Once auto precharge command is given, no new commands are possible to that particular bank until the bank achieves idle state.

**AUTO REFRESH**

The storage cells of 64Mb, 128Mb and 256Mb SDRAM need to be refreshed every 64ms to maintain data and 16Mb SDRAM need to be refreshed every 32ms to maintain data. An auto refresh cycle accomplishes refresh of a single row of storage cells. The internal counter increments automatically on every auto refresh cycle to refresh all the rows. An auto refresh command is issued by asserting low on  $\overline{CS}$ ,  $\overline{RAS}$  and  $\overline{CAS}$  with high on  $\overline{CKE}$  and  $\overline{WE}$ . The auto refresh command can only be asserted with both banks being in idle state and the device is not in power down mode ( $\overline{CKE}$  is high in the previous cycle).

The time required to complete the auto refresh operation is specified by  $t_{RC}(\min)$ . The minimum number of clock cycles required can be calculated by driving  $t_{RC}$  with clock cycle time and then rounding up to the next higher integer. The auto refresh command must be followed by NOP's until the auto refresh operation is completed. All banks will be in the idle state at the end of auto refresh operation. The auto refresh is the preferred refresh mode when the SDRAM is being used for normal data transactions. The 16Mb SDRAM's auto refresh cycle can be performed once in 15.6us or a burst of 2048 auto refresh cycles once in 32ms. The 64Mb and 128Mb SDRAM's auto refresh cycle can be performed once in 15.6us or a burst of 4096 auto refresh cycles once in 64ms. The 256Mb SDRAM's auto refresh cycle can be performed once in 7.8us or a burst of 8192 auto refresh cycles once in 64ms.

**SELF REFRESH**

The self refresh is another refresh mode available in the SDRAM. The self refresh is the preferred refresh mode for data retention and low power operation of SDRAM. In self refresh mode, the SDRAM disables the internal clock and all the input buffers except  $\overline{CKE}$ . The refresh addressing and timing are internally generated to reduce power consumption.

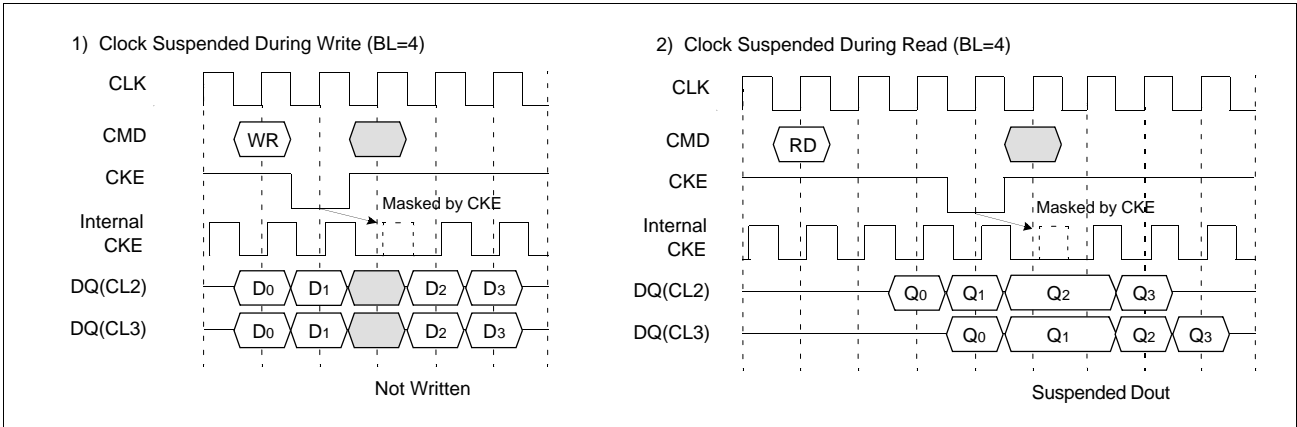
The self refresh mode is entered from all banks idle state by asserting low on  $\overline{CS}$ ,  $\overline{RAS}$ ,  $\overline{CAS}$  and  $\overline{CKE}$  with high on  $\overline{WE}$ . Once the self refresh mode is entered, only  $\overline{CKE}$  state being low matters, all the other inputs including the clock are ignored in order to remain in the self refresh mode.

The self refresh is exited by restarting the external clock and then asserting high on  $\overline{CKE}$ . This must be followed by NOP's for a minimum time of  $t_{RC}$  before the SDRAM reaches idle state to begin normal operation. If the system uses burst auto refresh during normal operation, it is recommended to use burst 8192 auto refresh cycles for 256Mb and burst 4096 auto refresh cycles for 128Mb/64Mb and burst 2048 auto refresh cycles for 16Mb immediately after exiting in self refresh mode.

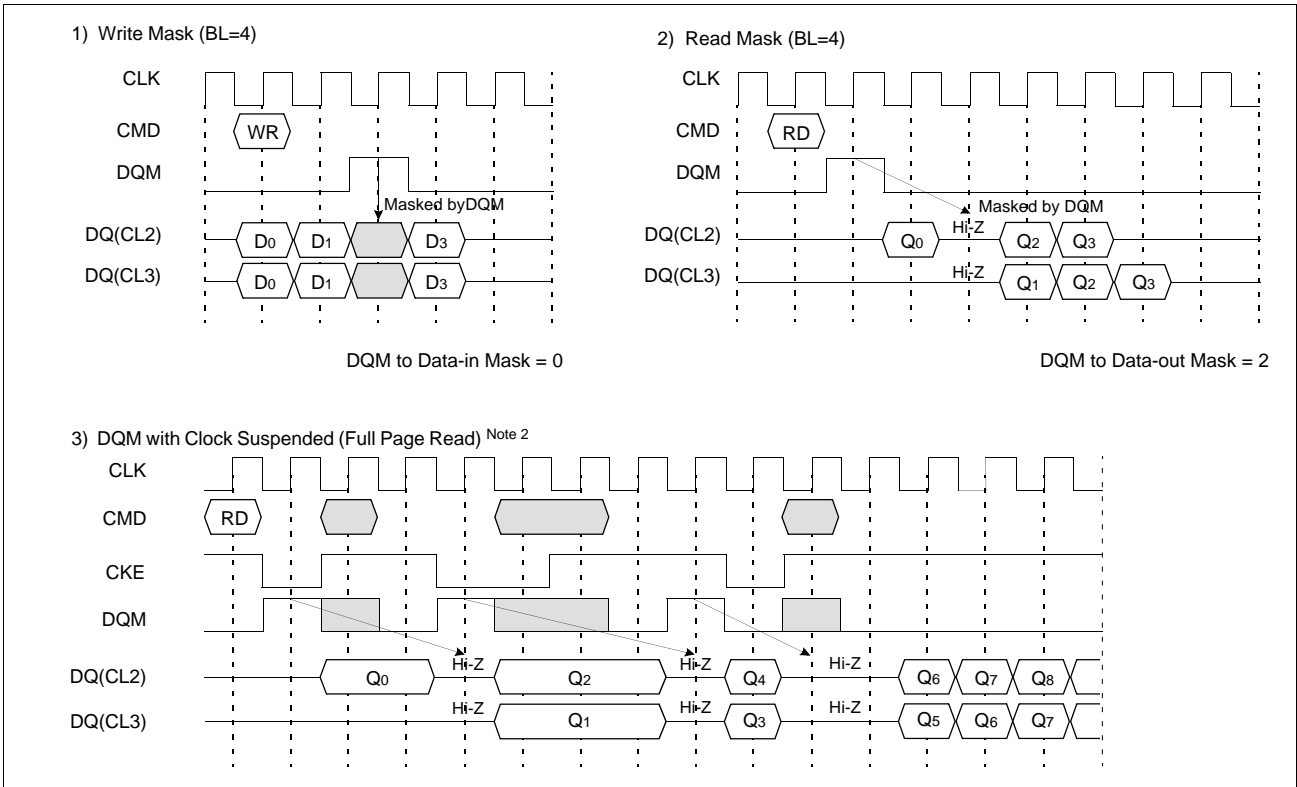


## E. BASIC FEATURE AND FUNCTION DESCRIPTIONS

### 1. CLOCK Suspend



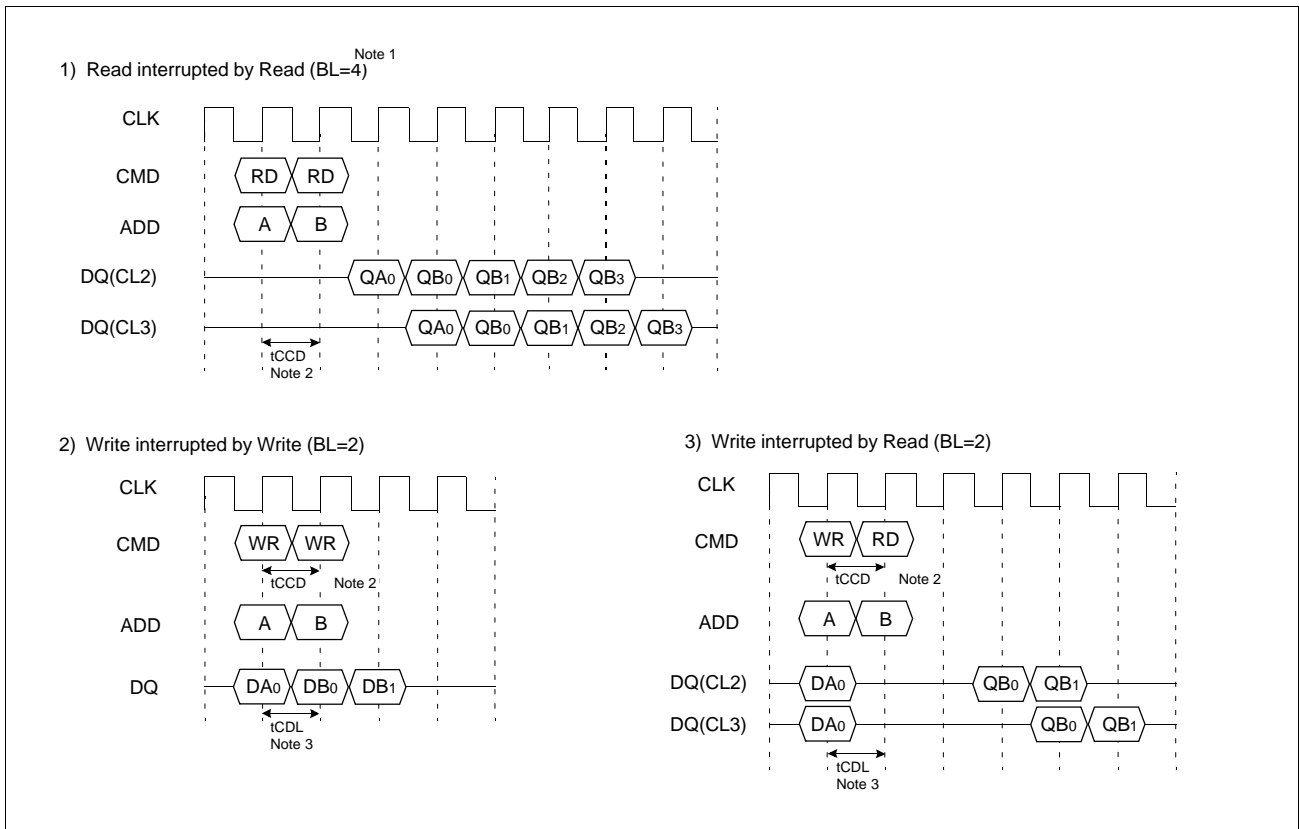
### 2. DQM Operation



- \*Note : 1. CKE to CLK disable/enable = 1CLK.
- 2. DQM makes data out Hi-Z after 2CLKs which should be masked by CKE " L"
- 3. DQM masks both data-in and data-out.

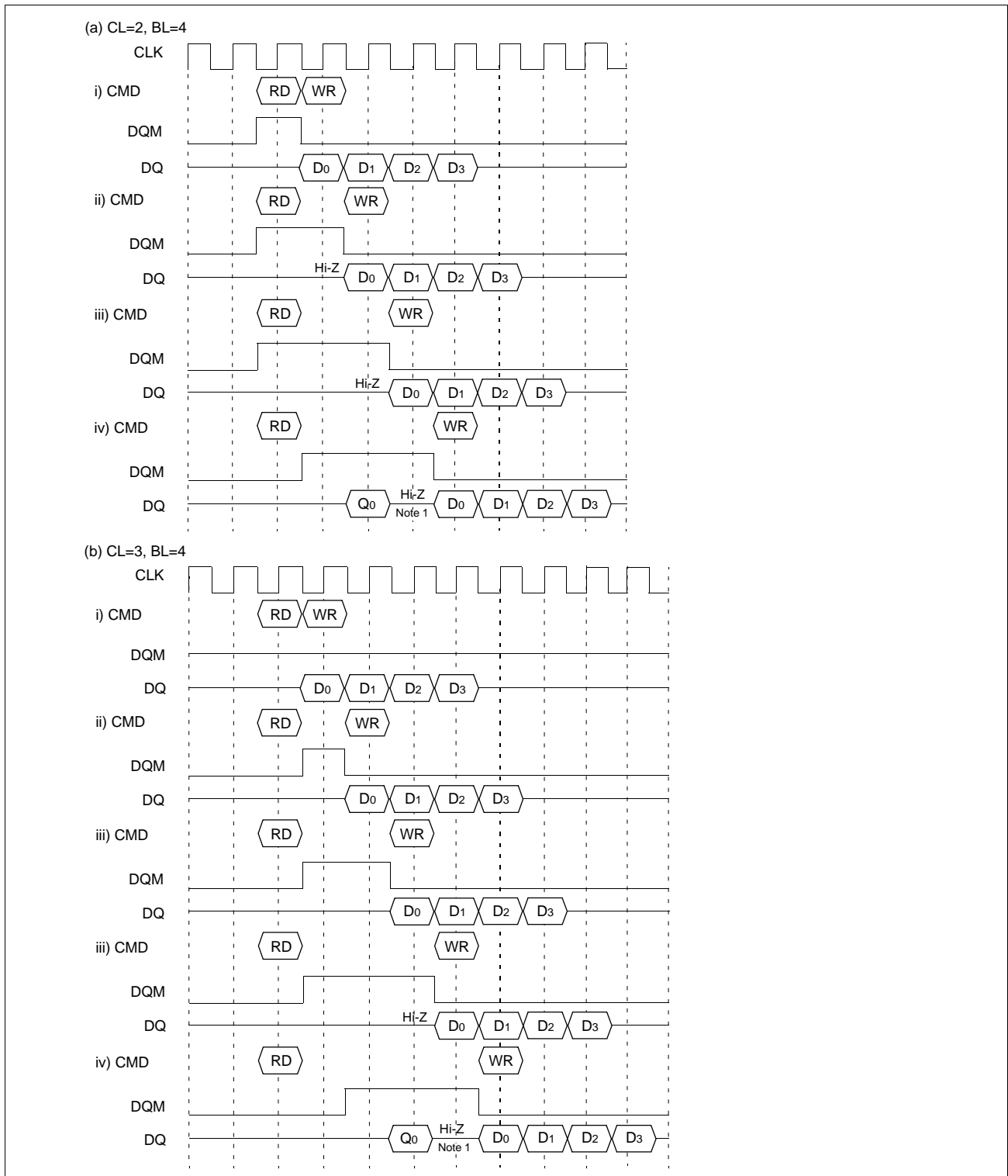


3. CAS Interrupt (I)



- \*Note :** 1. By "Interrupt", It is meant to stop burst read/write by external command before the end of burst.  
 By "CAS Interrupt", to stop burst read/write by CAS access ; read and write.  
 2.  $t_{CCD}$  :  $\overline{CAS}$  to  $\overline{CAS}$  delay. (=1CLK)  
 3.  $t_{CDL}$  : Last data in to new column address delay. (=1CLK)

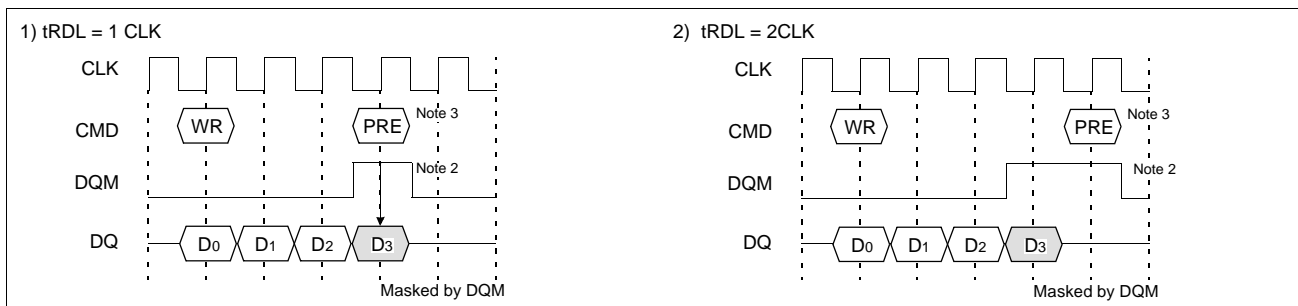
4. CAS Interrupt (II) : Read Interrupted by Write & DQM



\*Note : 1. To prevent bus contention, there should be at least one gap between data in and data out.

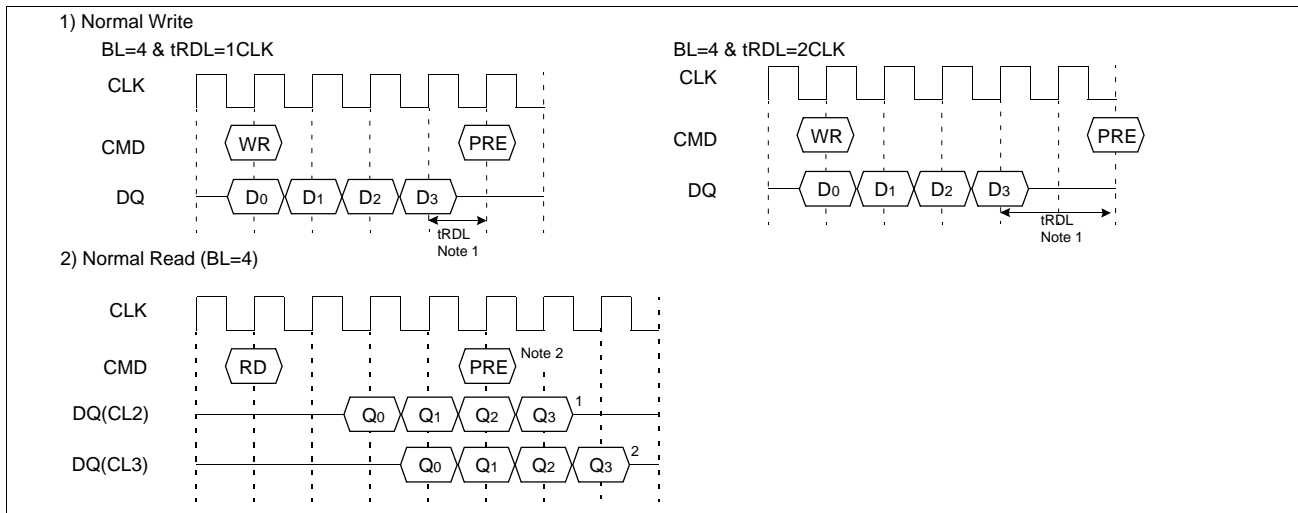


## 5. Write Interrupted by Precharge & DQM

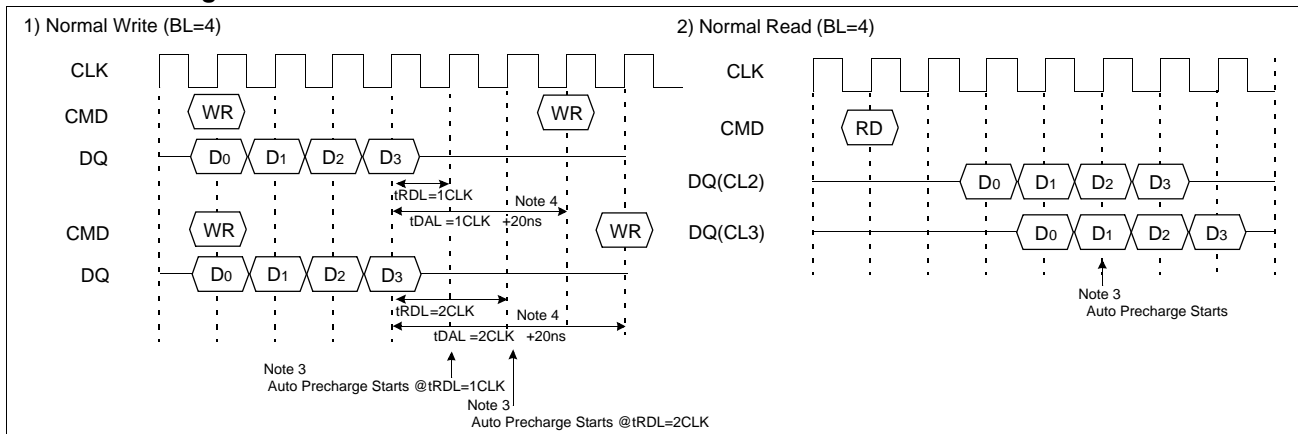


- \*Note :**
- To prevent bus contention, DQM should be issued which makes at least one gap between data in and data out.
  - To inhibit invalid write, DQM should be issued.
  - This precharge command and burst write command should be of the same bank, otherwise it is not precharge interrupt but only another bank precharge of four banks operation.

## 6. Precharge

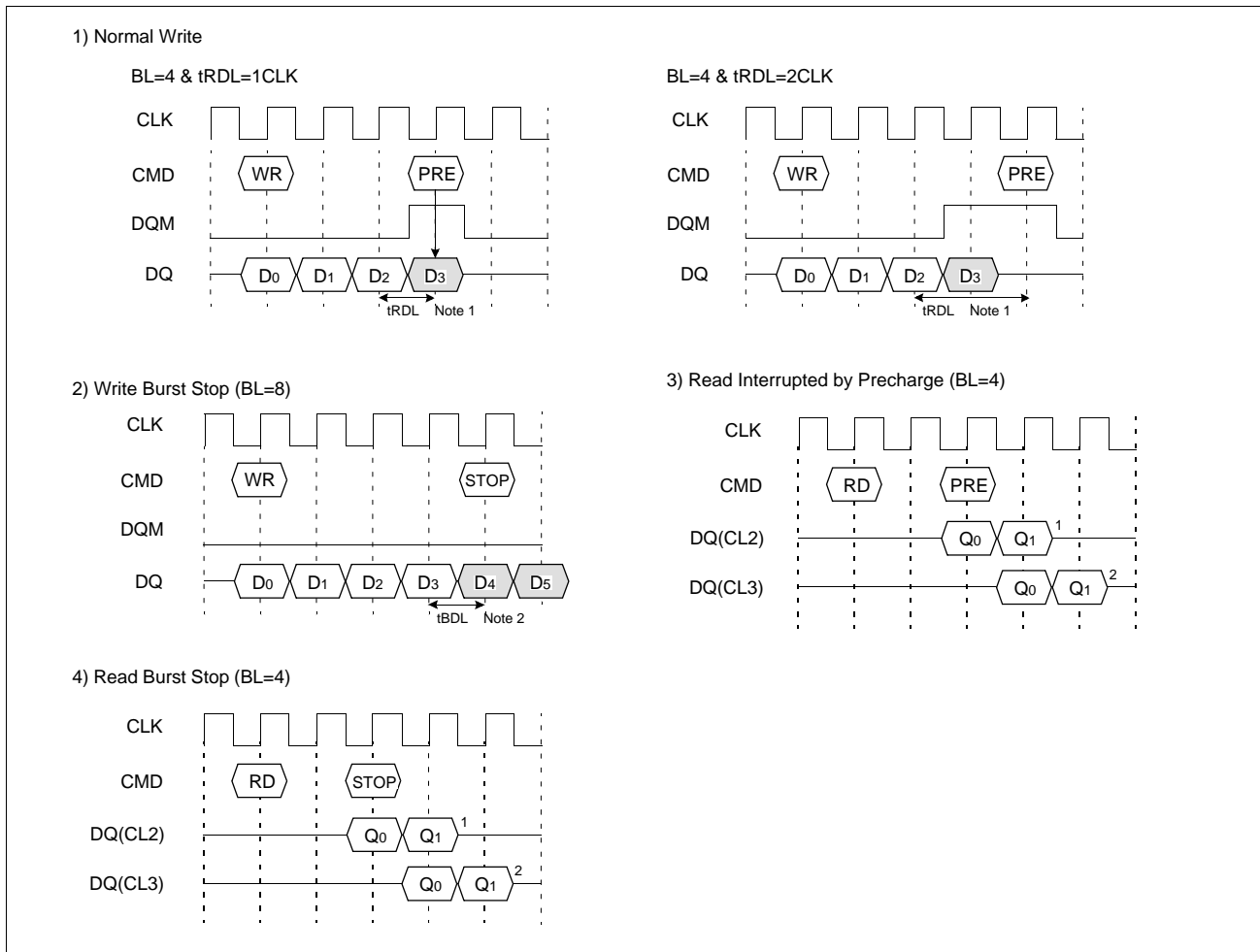


## 7. Auto Precharge

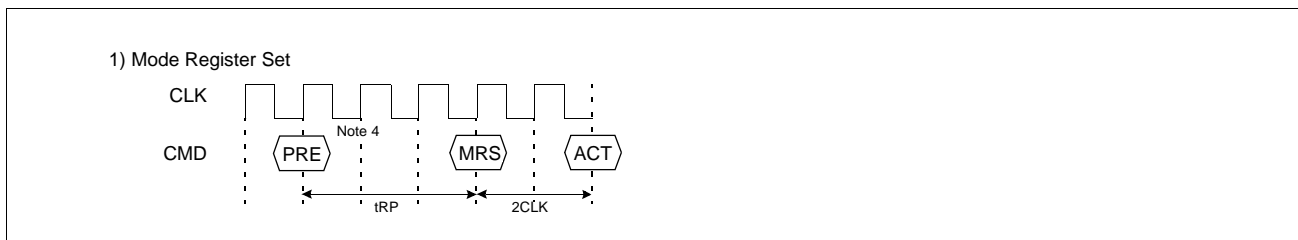


- \*Note :**
- SAMSUNG can support  $t_{RDL}=1 \text{ CLK}$  and  $t_{RDL}=2 \text{ CLK}$  for all memory devices. SAMSUNG recommends  $t_{RDL}=2 \text{ CLK}$ .
  - Number of valid output data after row precharge : 1, 2 for CAS Latency = 2, 3 respectively.
  - The row active command of the precharge bank can be issued after  $t_{RP}$  from this point.  
The new read/write command of other activated bank can be issued from this point.  
At burst read/write with auto precharge, CAS interrupt of the same bank is illegal
  - $t_{DAL}$  defined Last data in to Active delay. SAMSUNG can support  $t_{DAL}=1 \text{ CLK}+20 \text{ ns}$  and  $2 \text{ CLK}+20 \text{ ns}$ , recommends  $t_{DAL}=2 \text{ CLK}+20 \text{ ns}$ .

8. Burst Stop & Interrupted by Precharge



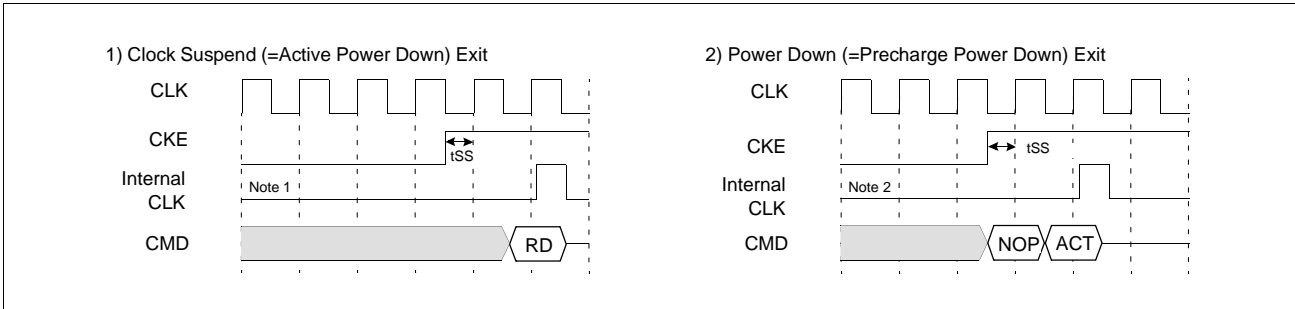
9. MRS



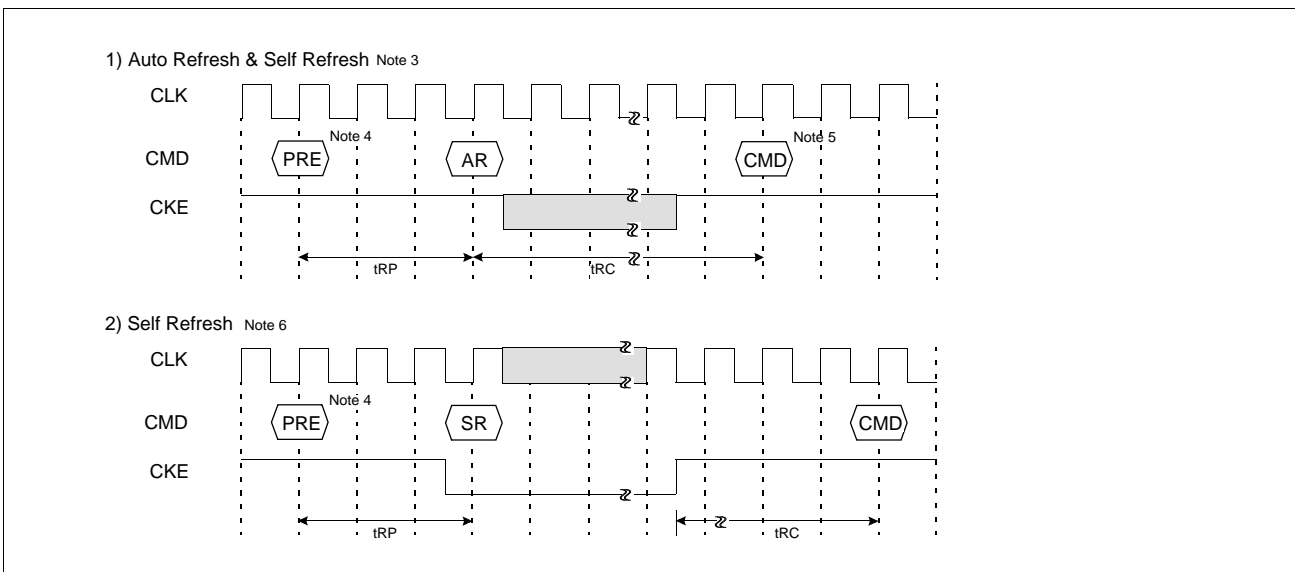
- \*Note : 1. SAMSUNG can support tRDL=1CLK and tRDL=2CLK for all memory devices. SAMSUNG recommends tRDL=2 CLK.
- 2. tBDL : 1 CLK ; Last data in to burst stop delay.  
Read or write burst stop command is valid at every burst length.
- 3. Number of valid output data after row precharge or burst stop : 1, 2 for CAS latency= 2, 3 respectively.
- 4. PRE : All banks precharge if necessary.  
MRS can be issued only at all banks precharge state.



10. Clock Suspend Exit & Power Down Exit



11. Auto Refresh & Self Refresh



- \*Note :**
1. Active power down : one or more banks active state.
  2. Precharge power down : all banks precharge state.
  3. The auto refresh is the same as CBR refresh of conventional DRAM.  
No precharge commands are required after auto refresh command.  
During t<sub>rc</sub> from auto refresh command, any other command can not be accepted.
  4. Before executing auto/self refresh command, all banks must be idle state.
  5. MRS, Bank Active, Auto/Self Refresh, Power Down Mode Entry.
  6. During self refresh mode, refresh interval and refresh operation are performed internally.  
After self refresh entry, self refresh mode is kept while CKE is low.  
During self refresh mode, all inputs except CKE will be don't cared, and outputs will be in Hi-Z state.  
For the time interval of t<sub>rc</sub> from self refresh exit command, any other command can not be accepted.  
Before/After self refresh mode, burst auto refresh cycle is recommended.

**12. About Burst Type Control**

Basic MODE	Sequential Counting	At MRS A <sub>3</sub> = "0". See the BURST SEQUENCE TABLE. (BL=4, 8) BL=1, 2, 4, 8 and full page.
	Interleave Counting	At MRS A <sub>3</sub> = "1". See the BURST SEQUENCE TABLE. (BL=4, 8) BL=4, 8. At BL=1, 2 Interleave Counting = Sequential Counting
Random MODE	Random column Access t <sub>CCD</sub> = 1 CLK	Every cycle Read/Write Command with random column address can realize Random Column Access. That is similar to Extended Data Out (EDO) Operation of conventional DRAM.

**13. About Burst Length Control**

Basic MODE	1	At MRS A <sub>2,1,0</sub> = "000". At auto precharge, t <sub>RAS</sub> should not be violated.
	2	At MRS A <sub>2,1,0</sub> = "001". At auto precharge, t <sub>RAS</sub> should not be violated.
	4	At MRS A <sub>2,1,0</sub> = "010".
	8	At MRS A <sub>2,1,0</sub> = "011".
	Full Page	At MRS A <sub>2,1,0</sub> = "111". Wrap around mode(infinite burst length) should be stopped by burst stop. RAS interrupt or CAS interrupt
Special MODE	BRSW	At MRS A <sub>9</sub> = "1". Read burst =1, 2, 4, 8, full page write Burst =1 At auto precharge of write, t <sub>RAS</sub> should not be violated.
Random MODE	Burst Stop	t <sub>BDL</sub> = 1, Valid DQ after burst stop is 1, 2 for CAS latency 2, 3 respectively Using burst stop command, any burst length control is possible.
Interrupt MODE	RAS Interrupt (Interrupted by Precharge)	Before the end of burst, Row precharge command of the same bank stops read/write burst with Row precharge. t <sub>RDL</sub> = 2 with DQM, valid DQ after burst stop is 1, 2 for CAS latency 2, 3 respectively. During read/write burst with auto precharge, RAS interrupt can not be issued.
	CAS Interrupt	Before the end of burst, new read/write stops read/write burst and starts new read/write burst. During read/write burst with auto precharge, CAS interrupt can not be issued.

# DEVICE OPERATIONS

# CMOS SDRAM

FUNCTION TRUTH TABLE (TABLE 1)

Current State	$\overline{CS}$	$\overline{RAS}$	$\overline{CAS}$	$\overline{WE}$	BA	ADDR	ACTION	Note
IDLE	H	X	X	X	X	X	NOP	
	L	H	H	H	X	X	NOP	
	L	H	H	L	X	X	ILLEGAL	2
	L	H	L	X	BA	CA, A <sub>10</sub> /AP	ILLEGAL	2
	L	L	H	H	BA	RA	Row (& Bank) Active ; Latch RA	
	L	L	H	L	BA	A <sub>10</sub> /AP	NOP	4
	L	L	L	H	X	X	Auto Refresh or Self Refresh	5
Row Active	L	L	L	L	OP code	OP code	Mode Register Access	5
	H	X	X	X	X	X	NOP	
	L	H	H	H	X	X	NOP	
	L	H	H	L	X	X	ILLEGAL	2
	L	H	L	H	BA	CA, A <sub>10</sub> /AP	Begin Read ; latch CA ; determine AP	
	L	H	L	L	BA	CA, A <sub>10</sub> /AP	Begin Write ; latch CA ; determine AP	
	L	L	H	H	BA	RA	ILLEGAL	2
Read	L	L	H	L	BA	A <sub>10</sub> /AP	Precharge	
	L	L	L	X	X	X	ILLEGAL	
	H	X	X	X	X	X	NOP (Continue Burst to End --> Row Active)	
	L	H	H	H	X	X	NOP (Continue Burst to End --> Row Active)	
	L	H	H	L	X	X	Term burst --> Row active	
	L	H	L	H	BA	CA, A <sub>10</sub> /AP	Term burst, New Read, Determine AP	
	L	H	L	L	BA	CA, A <sub>10</sub> /AP	Term burst, New Write, Determine AP	3
Write	L	L	H	H	BA	RA	ILLEGAL	2
	L	L	H	L	BA	A <sub>10</sub> /AP	Term burst, Precharge timing for Reads	
	L	L	L	X	X	X	ILLEGAL	
	H	X	X	X	X	X	NOP (Continue Burst to End --> Row Active)	
	L	H	H	H	X	X	NOP (Continue Burst to End --> Row Active)	
	L	H	H	L	X	X	Term burst --> Row active	
	L	H	L	H	BA	CA, A <sub>10</sub> /AP	Term burst, New read, Determine AP	3
Read with Auto Precharge	L	H	L	L	BA	CA, A <sub>10</sub> /AP	Term burst, New Write, Determine AP	3
	L	L	H	H	BA	RA	ILLEGAL	2
	L	L	H	L	BA	A <sub>10</sub> /AP	Term burst, precharge timing for Writes	3
	L	L	L	X	X	X	ILLEGAL	
	H	X	X	X	X	X	NOP (Continue Burst to End --> Precharge)	
	L	H	H	H	X	X	NOP (Continue Burst to End --> Precharge)	
	L	H	H	L	X	X	ILLEGAL	
Write with Auto Precharge	L	H	L	X	BA	CA, A <sub>10</sub> /AP	ILLEGAL	
	L	L	H	X	BA	RA, RA <sub>10</sub>	ILLEGAL	2
	L	L	L	X	X	X	ILLEGAL	
	H	X	X	X	X	X	NOP (Continue Burst to End --> Precharge)	
	L	H	H	H	X	X	NOP (Continue Burst to End --> Precharge)	
	L	H	H	L	X	X	ILLEGAL	
Pre-charging	L	L	L	X	X	X	ILLEGAL	
	L	L	H	X	BA	CA	ILLEGAL	2
	L	L	H	H	BA	RA	ILLEGAL	2
	L	L	L	X	X	X	ILLEGAL	
	H	X	X	X	X	X	NOP --> Idle after t <sub>RP</sub>	
	L	H	H	H	X	X	NOP --> Idle after t <sub>RP</sub>	
Pre-charging	L	H	H	L	X	X	ILLEGAL	2
	L	H	L	X	BA	CA	ILLEGAL	2
	L	L	H	H	BA	RA	ILLEGAL	2
	L	L	L	X	X	X	ILLEGAL	
	L	L	H	L	BA	A <sub>10</sub> /AP	NOP --> Idle after t <sub>RP</sub>	4
	L	L	L	X	X	X	ILLEGAL	





**FUNCTION TRUTH TABLE (TABLE 1)**

Current State	$\overline{CS}$	$\overline{RAS}$	$\overline{CAS}$	$\overline{WE}$	BA	ADDR	ACTION	Note
Row Activating	L	L	L	X	X	X	ILLEGAL	
	H	X	X	X	X	X	NOP --> Row Active after $trcd$	
	L	H	H	H	X	X	NOP --> Row Active after $trcd$	
	L	H	H	L	X	X	ILLEGAL	2
	L	H	L	X	BA	CA	ILLEGAL	2
	L	L	H	H	BA	RA	ILLEGAL	2
	L	L	H	L	BA	A10/AP	ILLEGAL	2
Refreshing	L	L	L	X	X	X	ILLEGAL	
	H	X	X	X	X	X	NOP --> Idle after $trc$	
	L	H	H	X	X	X	NOP --> Idle after $trc$	
	L	H	L	X	X	X	ILLEGAL	
	L	L	H	X	X	X	ILLEGAL	
Mode Register Accessing	L	L	L	X	X	X	ILLEGAL	
	H	X	X	X	X	X	NOP --> Idle after 2 clocks	
	L	H	H	H	X	X	NOP --> Idle after 2 clocks	
	L	H	H	L	X	X	ILLEGAL	
	L	H	L	X	X	X	ILLEGAL	
L	L	X	X	X	X	ILLEGAL		

Abbreviations : RA = Row Address                      BA = Bank Address  
 NOP = No Operation Command                      CA = Column Address                      AP = Auto Precharge

- \*Note :**
1. All entries assume the CKE was active (High) during the precharge clock and the current clock cycle.
  2. Illegal to bank in specified state ; Function may be legal in the bank indicated by BA, depending on the state of that bank.
  3. Must satisfy bus contention, bus turn around, and/or write recovery requirements.
  4. NOP to bank precharging or in idle state. May precharge bank indicated by BA (and A10/AP).
  5. Illegal if any bank is not idle.

# DEVICE OPERATIONS

# CMOS SDRAM

FUNCTION TRUTH TABLE (TABLE 2)

Current State	CKE (n-1)	CKE n	$\overline{CS}$	$\overline{RAS}$	$\overline{CAS}$	$\overline{WE}$	ADDR	ACTION	Note
Self Refresh	H	X	X	X	X	X	X	INVALID	
	L	H	H	X	X	X	X	Exit Self Refresh --> Idle after trFC (ABI)	6
	L	H	L	H	H	H	X	Exit Self Refresh --> Idle after trFC (ABI)	6
	L	H	L	H	H	L	X	ILLEGAL	
	L	H	L	H	L	X	X	ILLEGAL	
	L	L	X	X	X	X	X	NOP (Maintain Self Refresh)	
All Banks Precharge Power Down	H	X	X	X	X	X	X	INVALID	
	L	H	H	X	X	X	X	Exit Power Down --> ABI	
	L	H	L	H	H	H	X	Exit Power Down --> ABI	7
	L	H	L	H	H	L	X	ILLEGAL	7
	L	H	L	L	L	X	X	ILLEGAL	
	L	L	X	X	X	X	X	NOP (Maintain Low Power Mode)	
All Banks Idle	H	H	X	X	X	X	X	Refer to Table 1	
	H	L	H	X	X	X	X	Enter Power Down	
	H	L	L	H	H	H	X	Enter Power Down	8
	H	L	L	H	H	L	X	ILLEGAL	8
	H	L	L	H	L	X	X	ILLEGAL	
	H	L	L	L	H	H	RA	Row (& Bank) Active	
	H	L	L	L	L	H	X	Enter Self Refresh	8
	L	L	X	X	X	X	OP Code	Mode Register Access	
Any State other than Listed above	L	L	X	X	X	X	X	NOP	
	H	H	X	X	X	X	X	Refer to Operations in Table 1	
	H	L	X	X	X	X	X	Begin Clock Suspend next cycle	9
	L	H	X	X	X	X	X	Exit Clock Suspend next cycle	9
L	L	X	X	X	X	X	Maintain Clock Suspend		

Abbreviations : ABI = All Banks Idle, RA = Row Address

**\*Note** : 6. CKE low to high transition is asynchronous.

7. CKE low to high transition is asynchronous if restarts internal clock.

A minimum setup time 1CLK + tss must be satisfied before any command other than exit.

8. Power down and self refresh can be entered only from the both banks idle state.

9. Must be a legal command.

