2M x 32 SDRAM

86 TSOP-II with Pb-Free

(RoHS compliant)

Revision 1.2

April 2006

Revision History

Revision	Month	Year	History
0.0	October	2003	- Preliminary spec First release.
0.1	November	2003	- Final spec release.
1.1	August	2004	- Corrected typo.
1.2	April	2006	- Applied now format and corrected typo.

512K x 32Bit x 4 Banks

FEATURES

- JEDEC standard 3.3V power supply
- LVTTL compatible with multiplexed address
- Four banks operation
- MRS cycle with address key programs
  - -. CAS latency (2 & 3)
  - -. Burst length (1, 2, 4, 8 & Full page)
  - -. Burst type (Sequential & Interleave)
- All inputs are sampled at the positive going edge of the system clock.
- Burst read single-bit write operation
- DQM (x4,x8) & L(U)DQM (x16) for masking
- Auto & self refresh
- 15.6us refresh duty cycle
- **Pb-free Package**
- **RoHS compliant**

GENERAL DESCRIPTION

The K4S643232H is 67,108,864 bits synchronous high data rate Dynamic RAM organized as 4 x 524,288 words by 32 bits, fabricated with SAMSUNG′s high performance CMOS technology. Synchronous design allows precise cycle control with the use of system clock. I/O transactions are possible on every clock cycle. Range of operating frequencies, programmable burst length and programmable latencies allow the same device to be useful for a variety of high bandwidth, high performance memory system applications.

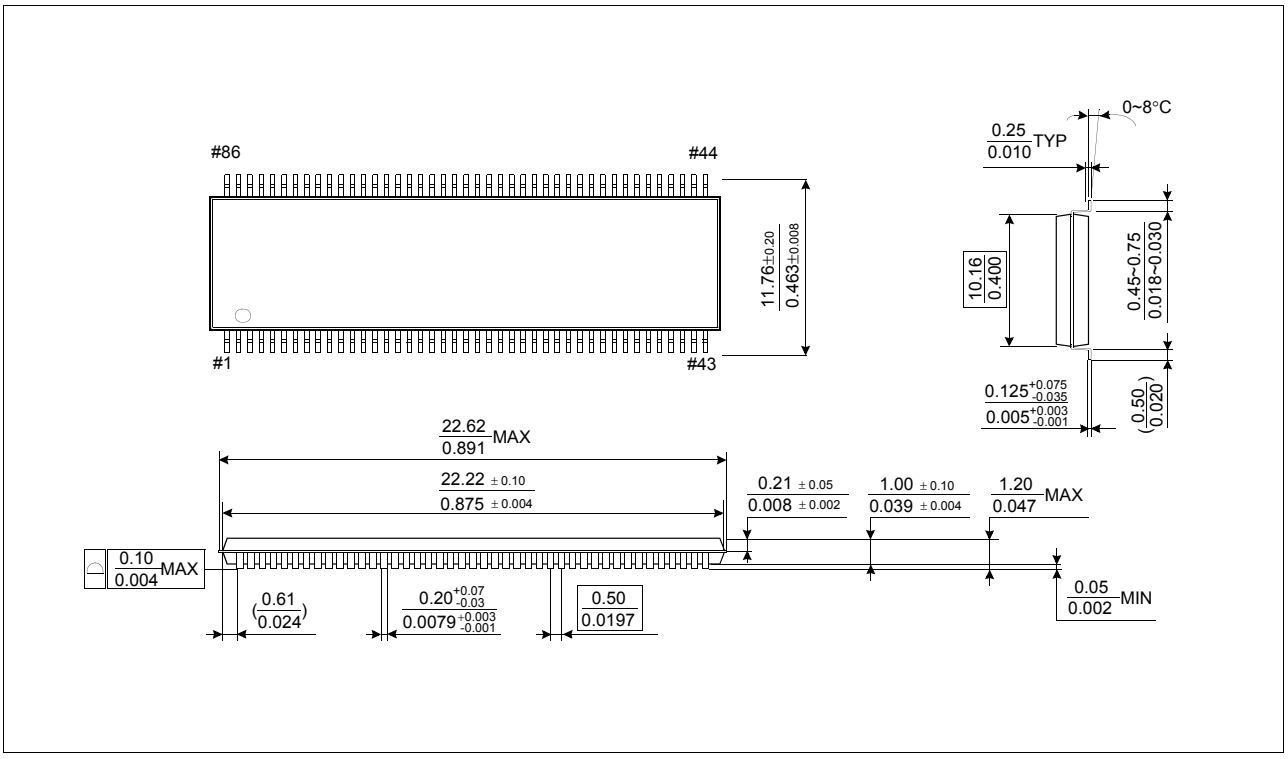
Ordering Information

Part No.	Orgainization	Max Freq.	Interface	Package
K4S643232H-UC/L70	2Mbx32	143MHz	LVTTL	86pin TSOP(II)
K4S643232H-UC/L60		166MHz	LVTTL	86pin TSOP(II)
K4S643232H-UC/L55		183MHz	LVTTL	86pin TSOP(II)
K4S643232H-UC/L50		200MHz	LVTTL	86pin TSOP(II)

Organization	Row Address	Column Address
2Mx32	A0~A10	A0-A7

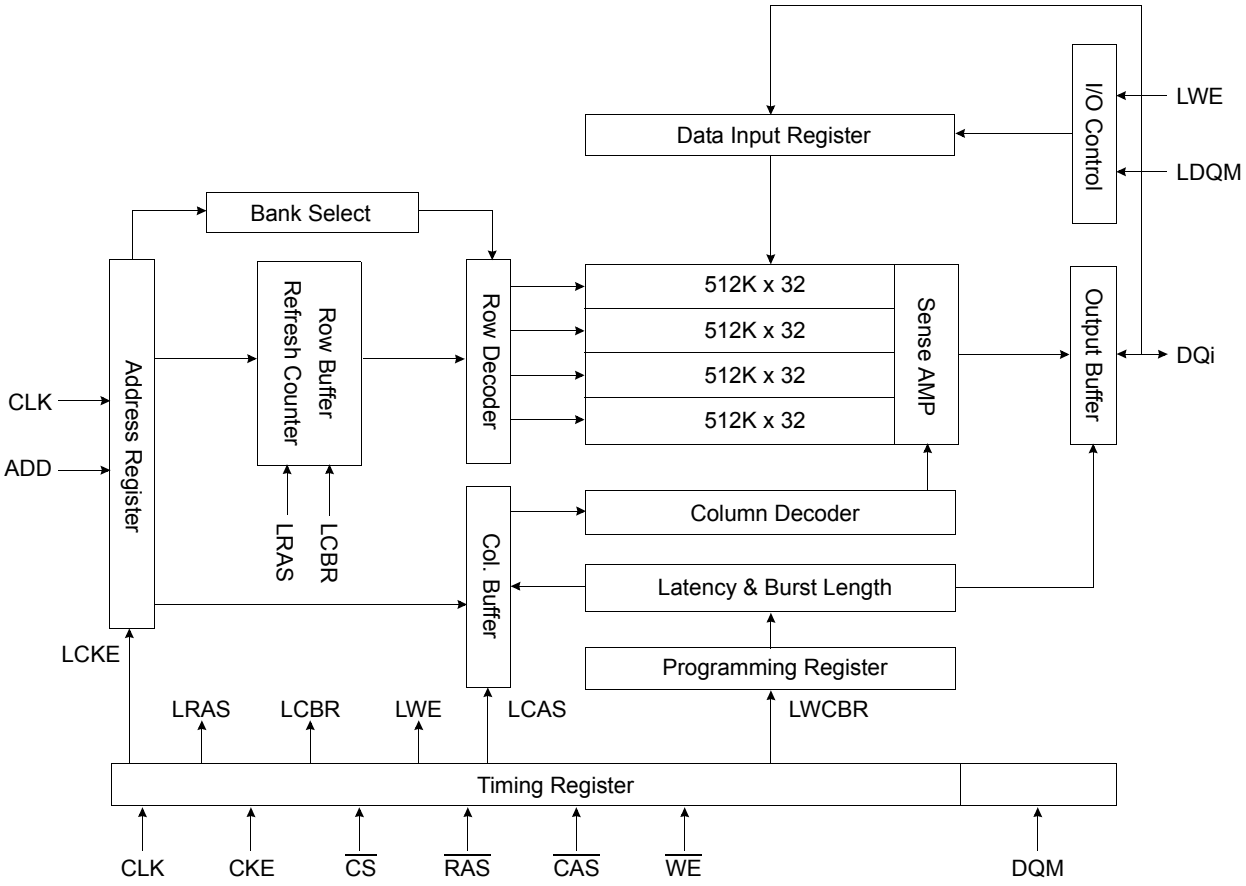
Row & Column address configuration

Package Physical Dimension

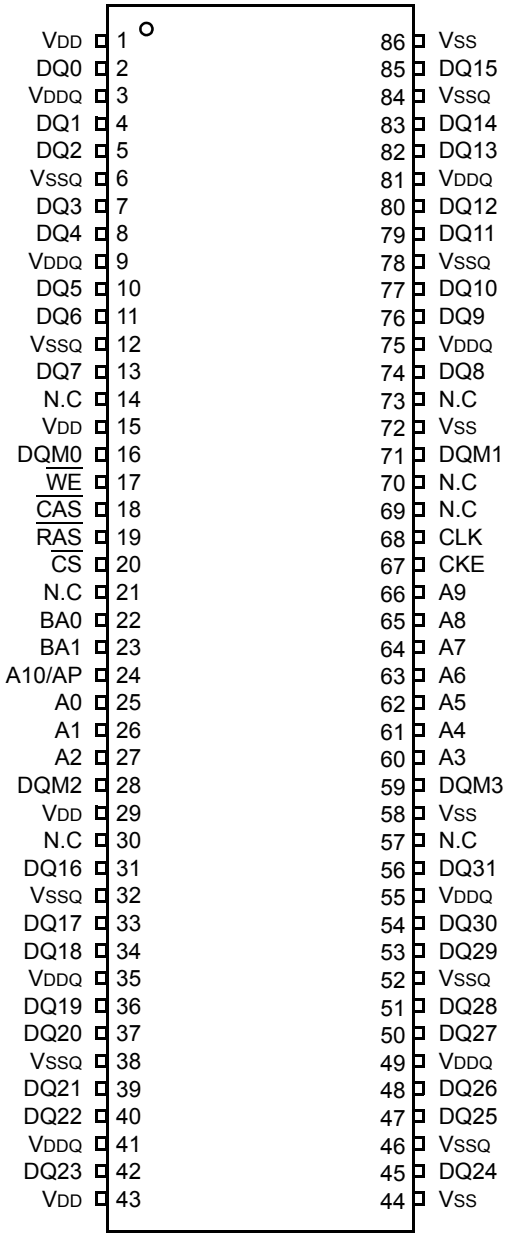


86Pin TSOP Package Dimension

FUNCTIONAL BLOCK DIAGRAM



PIN CONFIGURATION (Top view)



86Pin TSOP (II)
(400mil x 875mil)
(0.5 mm Pin pitch)

PIN FUNCTION DESCRIPTION

Pin	Name	Input Function
CLK	*System clock*	Active on the positive going edge to sample all inputs.
$\overline{CS}$	*Chip select*	Disables or enables device operation by masking or enabling all inputs except CLK, CKE and DQM.
CKE	*Clock enable*	Masks system clock to freeze operation from the next clock cycle. CKE should be enabled at least one cycle prior to new command. Disables input buffers for power down mode.
A_0 ~ A_{10}	*Address*	Row/column addresses are multiplexed on the same pins. Row address : RA_0 ~ RA_{10}, Column address : CA_0 ~ CA_7
BA0,1	*Bank select address*	Selects bank to be activated during row address latch time. Selects bank for read/write during column address latch time.
$\overline{RAS}$	*Row address strobe*	Latches row addresses on the positive going edge of the CLK with $\overline{RAS}$ low. Enables row access & precharge.
$\overline{CAS}$	*Column address strobe*	Latches column addresses on the positive going edge of the CLK with $\overline{CAS}$ low. Enables column access.
$\overline{WE}$	*Write enable*	Enables write operation and row precharge. Latches data in starting from $\overline{CAS}$, $\overline{WE}$ active.
DQM0 ~ 3	*Data input/output mask*	Makes data output Hi-Z, t_{SHZ} after the clock and masks the output. Blocks data input when DQM active.
$DQ_{0 \sim 31}$	*Data input/output*	Data inputs/outputs are multiplexed on the same pins.
V_{DD}/V_{SS}	*Power supply/ground*	Power and ground for the input buffers and the core logic.
V_{DDQ}/V_{SSQ}	*Data output power/ground*	Isolated power supply and ground for the output buffers to provide improved noise immunity.
NC	*No Connection*	This pin is recommended to be left No connection on the device.

ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Value	Unit
Voltage on any pin relative to Vss	V_{IN}, V_{OUT}	-1.0 ~ 4.6	V
Voltage on V_{DD} supply relative to Vss	V_{DD}, V_{DDQ}	-1.0 ~ 4.6	V
Storage temperature	T_{STG}	-55 ~ +150	°C
Short circuit current	I_{OS}	50	mA

Note : Permanent device damage may occur if "ABSOLUTE MAXIMUM RATINGS" are exceeded.
Functional operation should be restricted to recommended operating condition.
Exposure to higher than recommended voltage for extended periods of time could affect device reliability.

DC OPERATING CONDITIONS

Recommended operating conditions (Voltage referenced to V_{SS} = 0V, T_A = 0 to 70°C)

Parameter	Symbol	Min	Typ	Max	Unit	Note
Supply voltage	V_{DD}, V_{DDQ}	3.0	3.3	3.6	V	
Input logic high voltage	V_{IH}	2.0	3.0	V_{DDQ}+0.3	V	1
Input logic low voltage	V_{IL}	-0.3	0	0.8	V	2
Output logic high voltage	V_{OH}	2.4	-	-	V	I_{OH} = -2mA
Output logic low voltage	V_{OL}	-	-	0.4	V	I_{OL} = 2mA
Input leakage current	I_{LI}	-10	-	10	uA	3

Notes : 1. V_{IH} (max) = 5.6V AC.The overshoot voltage duration is ≤ 3ns.
2. V_{IL} (min) = -2.0V AC. The undershoot voltage duration is ≤ 3ns.
3. Any input 0V ≤ V_{IN} ≤ V_{DDQ},
Input leakage currents include Hi-Z output leakage for all bi-directional buffers with Tri-State outputs.

CAPACITANCE (V_{DD} = 3.3V, T_A = 23°C, f = 1MHz, V_{REF} = 1.4V ± 200 mV)

Pin	Symbol	Min	Max	Unit
Clock	C_{CLK}	-	4	pF
$\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$, $\overline{CS}$, CKE, DQM	C_{IN}	-	4.5	pF
Address	C_{ADD}	-	4.5	pF
DQ_0 ~ DQ_{31}	C_{OUT}	-	6.5	pF

DC CHARACTERISTICS

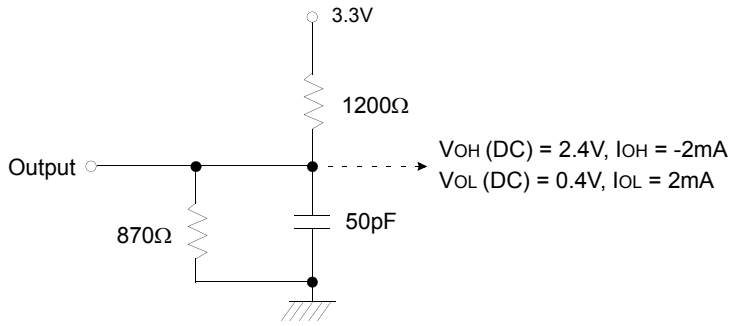
(Recommended operating condition unless otherwise noted, T_A = 0 to 70°C, $V_{IH(min)}/V_{IL(max)}$=2.0V/0.8V)

Parameter	Symbol	Test Condition	CAS Latency	Speed				Unit	Note
				-50	-55	-60	-70		
Operating Current (One Bank Active)	ICC1	Burst Length =1 tRC ≥ tRC(min), tCC ≥ tCC(min), Io = 0mA	3	140	140	130	130	mA	2
			2	110					
Precharge Standby Current in power-down mode	ICC2P	CKE ≤ VIL(max), tCC = 15ns		2				mA	
	ICC2PS	CKE & CLK ≤ VIL(max), tCC = ∞		2					
Precharge Standby Current in non power-down mode	ICC2N	CKE ≥ VIH(min), $\overline{CS}$ ≥ VIH(min), tCC = 15ns Input signals are changed one time during 30ns		12				mA	
	ICC2NS	CKE ≥ VIH(min), CLK ≤ VIL(max), tCC = ∞ Input signals are stable		7					
Active Standby Current in power-down mode	ICC3P	CKE ≤ VIL(max), tCC = 15ns		4				mA	
	ICC3PS	CKE ≤ VIL(max), tCC = ∞		4					
Active Standby Current in non power-down mode (One Bank Active)	ICC3N	CKE ≥ VIH(min), $\overline{CS}$ ≥ VIH(min), tCC = 15ns Input signals are changed one time during 30ns		40				mA	
	ICC3NS	CKE ≥ VIH(min), CLK ≤ VIL(max), tCC = ∞ Input signals are stable		35					
Operating Current (Burst Mode)	ICC4	Io = 0 mA, Page Burst All bank Activated, tCCD = tCCD(min)	3	170	160	150	140	mA	2
			2	120					
Refresh Current	ICC5	tRC ≥ tRC(min)	3	150	150	140	120	mA	3
			2	120					
Self Refresh Current	ICC6	CKE ≤ 0.2V		2				mA	4
				450				uA	5

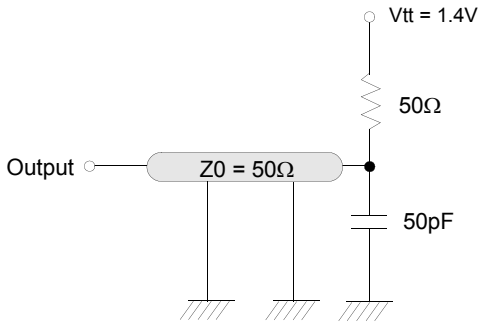
Notes : 1. Unless otherwise notes, Input level is CMOS(V_{IH}/V_{IL}=V_{DDQ}/V_{SSQ}) in LVTTL.
2. Measured with outputs open.
3. Refresh period is 64ms.
4. K4S643232H-UC
5. K4S643232H-UL

AC OPERATING TEST CONDITIONS (V_{DD} = 3.3V ± 0.3V, T_A = 0 to 70°C)

Parameter	Value	Unit
AC input levels (Vih/Vil)	2.4/0.4	V
Input timing measurement reference level	1.4	V
Input rise and fall time	tr/tf = 1/1	ns
Output timing measurement reference level	1.4	V
Output load condition	See Fig. 2	



(Fig. 1) DC output load circuit



(Fig. 2) AC output load circuit

OPERATING AC PARAMETER

(AC operating conditions unless otherwise noted)

Parameter		Symbol	Version				Unit	Note
			50	55	60	70		
Row active to row active delay		$t_{RRD(min)}$	2				CLK	1
$\overline{RAS}$ to $\overline{CAS}$ delay		$t_{RCD(min)}$	3	3	3	3	CLK	1
Row precharge time		$t_{RP(min)}$	3	3	3	3	CLK	1
Row active time		$t_{RAS(min)}$	8	7	7	7	CLK	1
		$t_{RAS(max)}$	100				us	
Row cycle time		$t_{RC(min)}$	11	10	10	10	CLK	1
Last data in to row precharge		$t_{RDL(min)}$	2				CLK	2
Last data in to new col.address delay		$t_{CDL(min)}$	1				CLK	2
Last data in to burst stop		$t_{BDL(min)}$	1				CLK	2
Col. address to col. address delay		$t_{CCD(min)}$	1				CLK	3
Mode Register Set cycle time		$t_{MRS(min)}$	2				CLK	
Number of valid output data	CAS Latency=3		2				ea	4
	CAS Latency=2		1					

Note : 1. The minimum number of clock cycles is determined by dividing the minimum time required with clock cycle time and then rounding off to the next higher integer. Refer to the following ns-unit based AC table.
2. Minimum delay is required to complete write.
3. All parts allow every cycle column address change.
4. In case of row precharge interrupt, auto precharge and read burst stop.

AC CHARACTERISTICS (AC operating conditions unless otherwise noted)

Parameter		Symbol	-50		-55		-60		-70		Unit	Note
			Min	Max	Min	Max	Min	Max	Min	Max		
CLK cycle time	CAS Latency=3	tCC	5	1000	5.5	1000	6	1000	7	1000	ns	1
	CAS Latency=2		10		10		10		10			
CLK to valid output delay	CAS Latency=3	tSAC	-	4.5	-	5.0	-	5.5	-	5.5	ns	1, 2
	CAS Latency=2		-	6	-	6	-	6	-	6		
Output data hold time		tOH	2	-	2	-	2	-	2	-	ns	2
CLK high pulse width	CAS Latency=3	tCH	2	-	2	-	2.5	-	3	-	ns	3
	CAS Latency=2		3	-	3	-	3	-	3	-		
CLK low pulse width	CAS Latency=3	tCL	2	-	2	-	2.5	-	3	-	ns	3
	CAS Latency=2		3	-	3	-	3	-	3	-		
Input setup time	CAS Latency=3	tSS	1.5	-	1.5	-	1.5	-	1.75	-	ns	3
	CAS Latency=2		2.5	-	2.5	-	2.5	-	2.5	-		
Input hold time		tSH	1	-	1	-	1	-	1	-	ns	3
CLK to output in Low-Z		tSLZ	1	-	1	-	1	-	1	-	ns	2
CLK to output in Hi-Z	CAS latency=3	tSHZ	-	4.5	-	5.0	-	5.5	-	5.5	ns	-
	CAS latency=2		-	6	-	6	-	6	-	6		

Note : 1. Parameters depend on programmed CAS latency.
2. If clock rising time is longer than 1ns, (tr/2-0.5)ns should be added to the parameter.
3. Assumed input rise and fall time (tr & tf)=1ns.
If tr & tf is longer than 1ns, transient time compensation should be considered,
i.e., [(tr + tf)/2-1]ns should be added to the parameter.

SIMPLIFIED TRUTH TABLE

(V=Valid, X=Don't care, H=Logic high, L=Logic low)

Command			CKEn-1	CKEn	$\overline{CS}$	$\overline{RAS}$	$\overline{CAS}$	$\overline{WE}$	DQM	$BA_{0,1}$	A_{10}/AP	A_9 ~ A_0	Note
Register	Mode register set		H	X	L	L	L	L	X	OP code			1,2
Refresh	Auto refresh		H	H	L	L	L	H	X	X			3
	Self refresh	Entry		L									3
		Exit	L	H	L	H	H	H	X	X			3
					H	X	X	X					3
Bank active & row addr.			H	X	L	L	H	H	X	V	Row address		
Read & column address	Auto precharge disable		H	X	L	H	L	H	X	V	L	Column address (A_0 ~ A_7)	4
	Auto precharge enable										H		4,5
Write & column address	Auto precharge disable		H	X	L	H	L	L	X	V	L	Column address (A_0 ~ A_7)	4
	Auto precharge enable										H		4,5
Burst Stop			H	X	L	H	H	L	X	X			6
Precharge	Bank selection		H	X	L	L	H	L	X	V	L	X	
	All banks									X	H		
Clock suspend or active power down		Entry	H	L	H	X	X	X	X	X			
					L	V	V	V					
		Exit	L	H	X	X	X	X	X				
Precharge power down mode		Entry	H	L	H	X	X	X	X	X			
					L	H	H	H					
		Exit	L	H	H	X	X	X	X				
					L	V	V	V					
DQM			H	X					V	X			7
No operation command			H	X	H	X	X	X	X	X			
					L	H	H	H					

Notes : 1. OP Code : Operand code
A_0 ~ A_{10} & BA_0 ~ BA_1 : Program keys. (@ MRS)

2. MRS can be issued only at all banks precharge state.
A new command can be issued after 2 CLK cycles of MRS.

3. Auto refresh functions are as same as CBR refresh of DRAM.
The automatical precharge without row precharge command is meant by "Auto".
Auto/self refresh can be issued only at all banks precharge state.

4. BA_0 ~ BA_1 : Bank select addresses.
If both BA_0 and BA_1 are "Low" at read, write, row active and precharge, bank A is selected.
If both BA_0 is "Low" and BA_1 is "High" at read, write, row active and precharge, bank B is selected.
If both BA_0 is "High" and BA_1 is "Low" at read, write, row active and precharge, bank C is selected.
If both BA_0 and BA_1 are "High" at read, write, row active and precharge, bank D is selected.
If A_{10}/AP is "High" at row precharge, BA_0 and BA_1 is ignored and all banks are selected.

5. During burst read or write with auto precharge, new read/write command can not be issued.
Another bank read/write command can be issued after the end of burst.
New row active of the associated bank can be issued at t_{RP} after the end of burst.

6. Burst stop command is valid at every burst length.

7. DQM sampled at positive going edge of a CLK and masks the data-in at the very CLK (Write DQM latency is 0), but makes Hi-Z state the data-out of 2 CLK cycles after. (Read DQM latency is 2)

MODE REGISTER FIELD TABLE TO PROGRAM MODES

Register Programmed with MRS

Address	BA_0 ~ BA_1	A_{10}/AP	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1	A_0
Function	RFU	RFU	W.B.L	TM		CAS Latency			BT	Burst Length		

Test Mode			CAS Latency				Burst Type		Burst Length				
A_8	A_7	Type	A_6	A_5	A_4	Latency	A_3	Type	A_2	A_1	A_0	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
Write Burst Length			1	0	0	Reserved			1	0	0	Reserved	Reserved
A_9	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 : x32 (256)

POWER UP SEQUENCE

SDRAMs must be powered up and initialized in a predefined manner to prevent undefined operations.

1. Apply power and start clock. Must 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_9 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.

BURST SEQUENCE (BURST LENGTH = 4)

Initial Address		Sequential				Interleave			
A_1	A_0								
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

BURST SEQUENCE (BURST LENGTH = 8)

Initial Address			Sequential								Interleave							
A_2	A_1	A_0																
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

DEVICE OPERATIONS

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 I_{CC} 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 + t_{SS}" before the high going edge of the clock, then the SDRAM becomes active from the same clock edge accepting all the input commands.

BANK ADDRESSES (BA0 ~ BA1)

This SDRAM is organized as four independent banks of 524,288 words x 32 bits memory arrays. The BA_0 ~ BA_1 inputs are latched at the time of assertion of $\overline{RAS}$ and $\overline{CAS}$ to select the bank to be used for the operation. The bank addresses BA_0 ~ BA_1 are latched at bank active, read, write, mode register set and precharge operations.

ADDRESS INPUTS (A0 ~ A10)

The 19 address bits are required to decode the 524,288 word locations are multiplexed into 11 address input pins (A_0 ~ A_{10}). The 11 bit row addresses are latched along with $\overline{RAS}$ and BA_0 ~ BA_1 during bank activate command. The 8 bit column addresses are latched along with $\overline{CAS}$, $\overline{WE}$ and BA_0 ~ BA_1 during read or write command.

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.

POWER-UP

SDRAMs must be powered up and initialized in a predefined manner to prevent undefined operations.

1. Apply power and start clock. Must 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 both 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.

DEVICE OPERATIONS (Continued)

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 ~ A_{10} and BA_0 ~ 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 ~ A_2, burst type uses A_3, CAS latency (read latency from column address) use A_4 ~ A_6, vendor specific options or test mode use A_7 ~ A_8, A_{10}/AP and BA_0 ~ BA_1. The write burst length is programmed using A_9. A_7 ~ A_8, A_{10}/AP and BA_0 ~ 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.

BANK ACTIVATE

The bank activate command is used to select a random row in an idle bank. By asserting low on $\overline{RAS}$ and $\overline{CS}$ with desired row and bank address, a row access is initiated. The read or write operation can occur after a time delay of t_{RCD}(min) from the time of bank activation. t_{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_{RCD}(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_{RRD}(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_{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_{RAS}(min). Every SDRAM bank activate command must satisfy t_{RAS}(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_{RAS}(max). The number of cycles for both t_{RAS}(min) and t_{RAS}(max) can be calculated similar to t_{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 $\overline{CS}$ and $\overline{CAS}$ with $\overline{WE}$ being high on the positive edge of the clock. The bank must be active for at least t_{RCD}(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 $\overline{CS}$, $\overline{CAS}$ and $\overline{WE}$ 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 procreating the bank t_{RDL} after the last data input to be written into the active row. See DQM OPERATION also.

DEVICE OPERATIONS (Continued)

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.

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 ~ 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 "t_{RP}" 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 precahrge command is given, no new commands are possible to that particular bank until the bank achieves idle state.

BOTH BANKS PRECHARGE

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

AUTO REFRESH

The storage cells of SDRAM need to be refreshed every 64ms 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 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 (CKE is high in the previous cycle). The time required to complete the auto refresh operation is specified by t_{RFC}(min). The minimum number of clock cycles required can be calculated by driving t_{RFC} with clock cycle time and them 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 auto refresh cycle can be performed once in 15.6us or a burst of 4096 auto refresh cycles once in 64ms.

SELF REFRESH

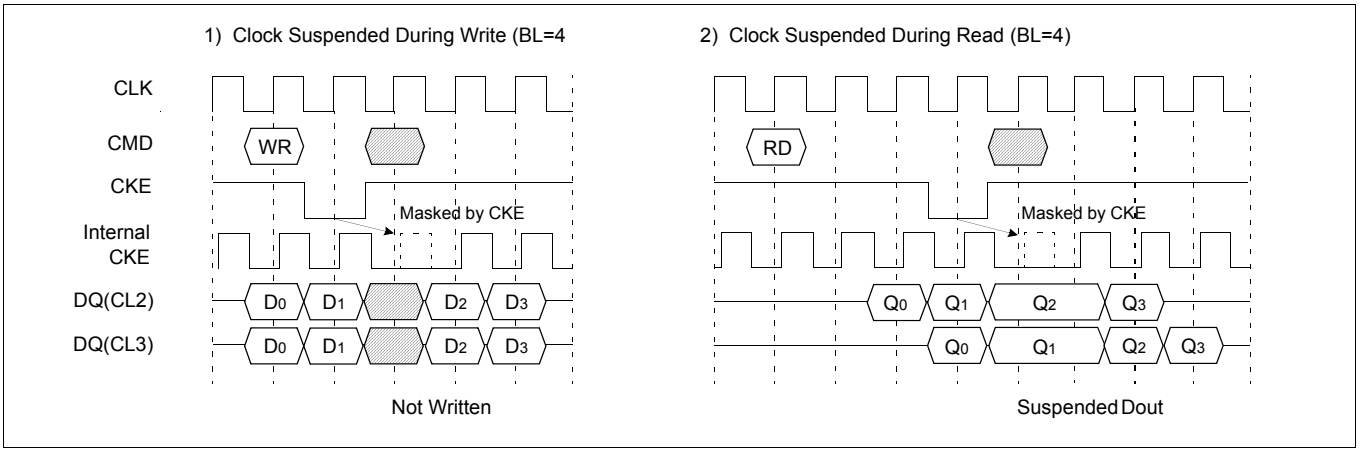
The self refresh is another refresh mode available in the SDRAM. The self refresh is the preferred refresh mode for data retention and low power operation of SDRAM. In self refresh mode, the SDRAM disables the internal clock and all the input buffers except CKE. The refresh addressing and timing are 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 CKE with high on $\overline{WE}$. Once the self refresh mode is entered, only CKE state being low matters, all the other inputs including the clock are ignored in order to remain in the self refresh mode.

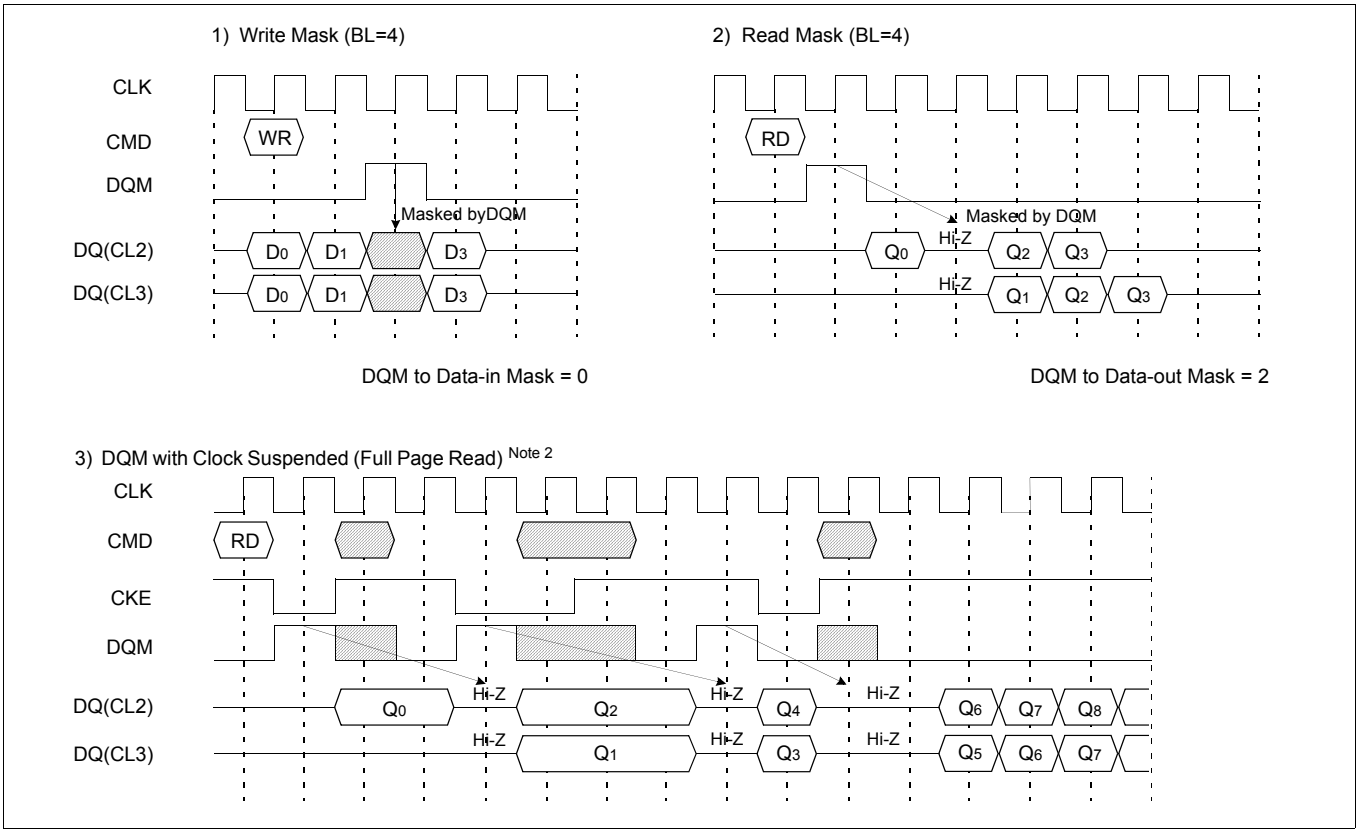
The self refresh is exited by restarting the external clock and then asserting high on CKE. This must be followed by NOP's for a minimum time of t_{RFC} before the SDRAM reaches idle state to begin normal operation. If the system uses burst auto refresh during normal operation, it is recommended to use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

BASIC FEATURE AND FUNCTION DESCRIPTIONS

1. CLOCK Suspend



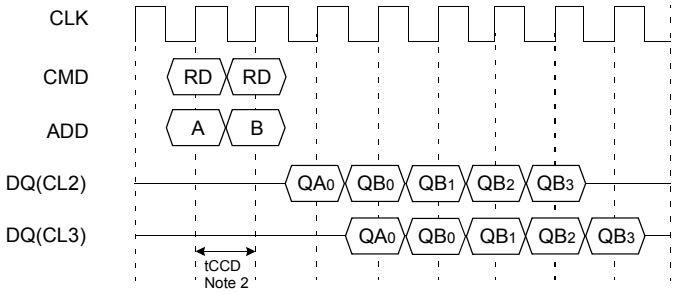
2. DQM Operation



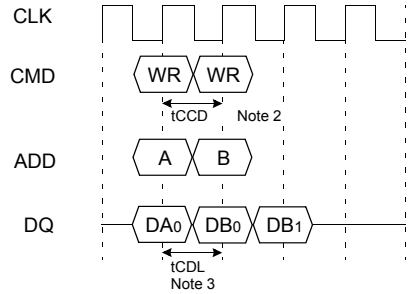
***Note :** 1. CKE to CLK disable/enable = 1CLK.
2. DQM makes data out Hi-Z after 2CLKs which should masked by CKE " L"
3. DQM masks both data-in and data-out.

3. $\overline{CAS}$ Interrupt (I)

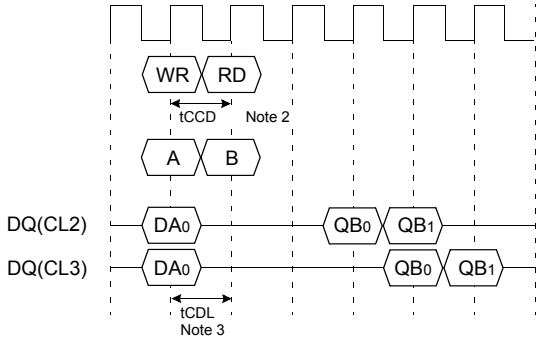
1) Read interrupted by Read (BL=4) Note 1



2) Write interrupted by Write (BL=2)

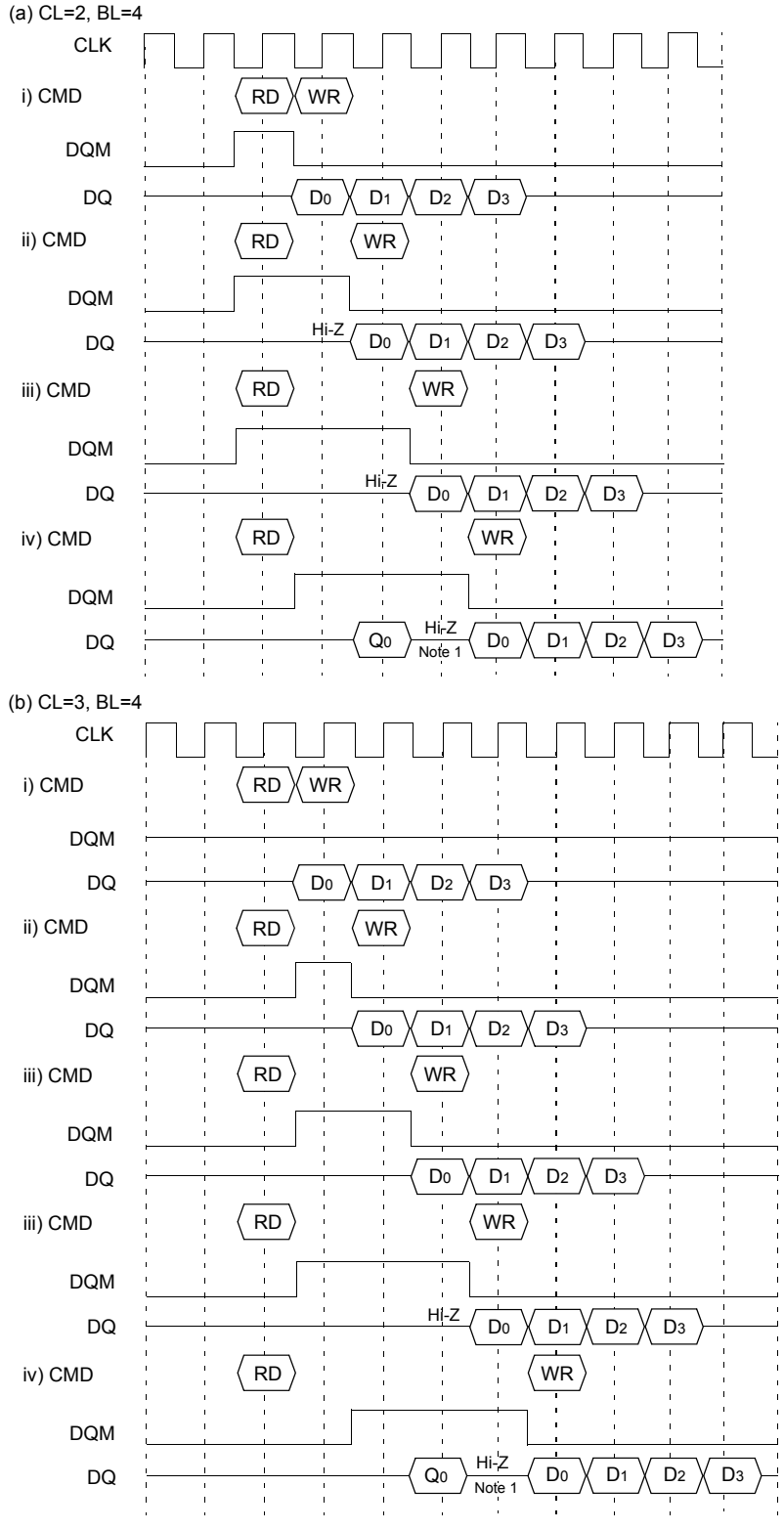


3) Write interrupted by Read (BL=2)



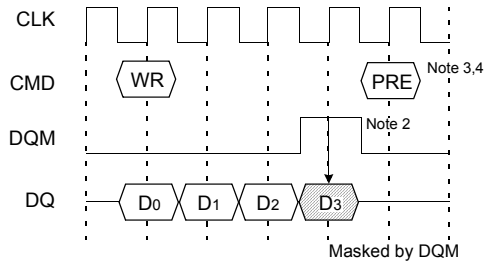
***Note :** 1. By " Interrupt", It is meant to stop burst read/write by external command before the end of burst.
By "$\overline{CAS}$ Interrupt", to stop burst read/write by $\overline{CAS}$ access ; read and write.
2. t_{CCD} : $\overline{CAS}$ to $\overline{CAS}$ delay. (=1CLK)
3. t_{CDL} : Last data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

4. $\overline{CAS}$ Interrupt (II) : Read Interrupted by Write & DQM



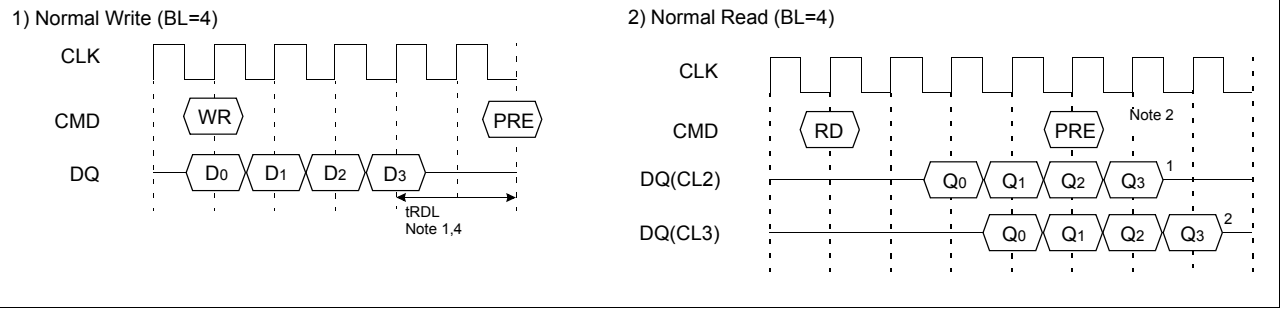
***Note :** 1. To prevent bus contention, there should be at least one gap between data in and data out.

5. Write Interrupted by Precharge & DQM

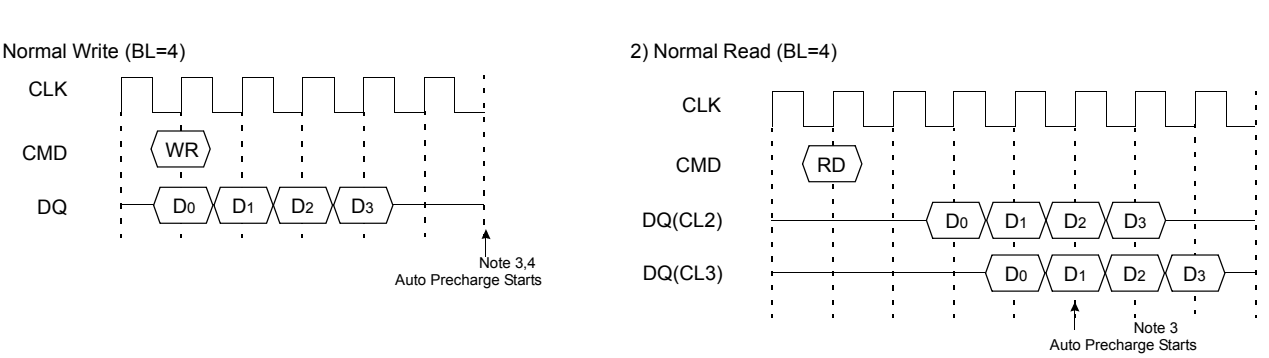


***Note :** 1. To prevent bus contention, DQM should be issued which makes at least one gap between data in and data out.
2. To inhibit invalid write, DQM should be issued.
3. This precharge command and burst write command should be of the same bank, otherwise it is not precharge interrupt but only another bank precharge of four banks operation.
4. For -55/60/70/80/10, tRDL=1CLK product can be supported within restricted amounts and it will be distinguished by bucket code "NV" . From the next generation, tRDL will be only 2CLK for every clock frequency.

6. Precharge



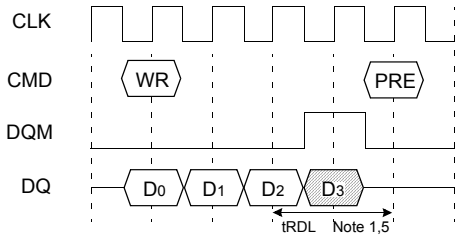
7. Auto Precharge



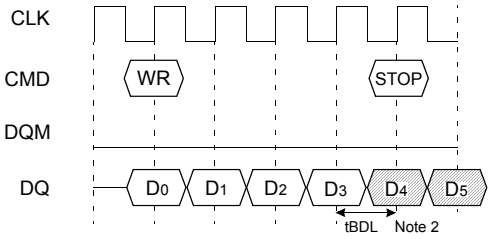
***Note :** 1. t_{RDL} : Last data in to row precharge delay
2. Number of valid output data after row precharge : 1, 2 for CAS Latency = 2, 3 respectively.
3. The row active command of the precharge bank can be issued after t_{RP} from this point.
The new read/write command of other activated bank can be issued from this point.
At burst read/write with auto precharge, CAS interrupt of the same/another bank is illegal.
4. For -55/60/70/80/10, tRDL=1CLK product can be supported within restricted amounts and it will be distinguished by bucket code "NV" . From the next generation, tRDL will be only 2CLK for every clock frequency

8. Burst Stop & Interrupted by Precharge

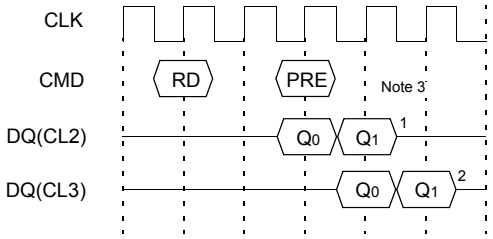
1) Normal Write (BL=4)



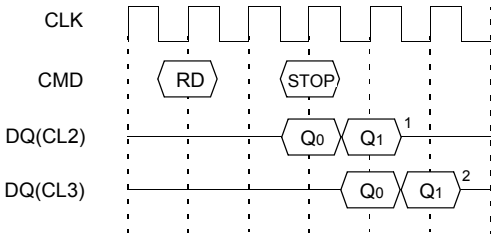
2) Write Burst Stop (BL=8)



3) Read Interrupted by Precharge (BL=4)

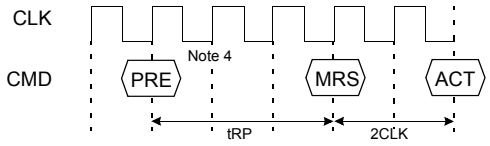


4) Read Burst Stop (BL=4)



9. MRS

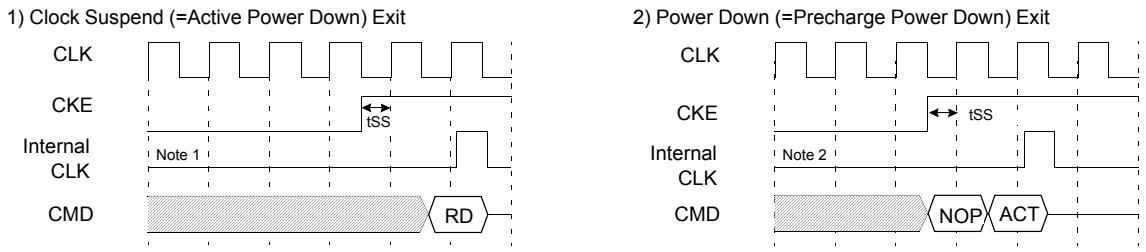
1) Mode Register Set



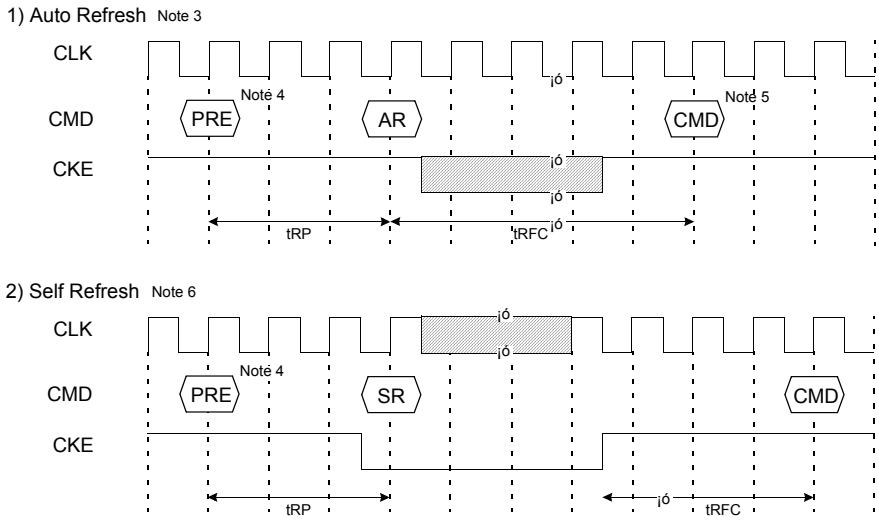
***Note :** 1. t_{RDL} : 1 CLK

2. t_{BDL} : 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 respectiviely.
4. PRE : All banks precharge if necessary.
   MRS can be issued only at all banks precharge state.
5. For -55/60/70/80/10, tRDL=1CLK product can be supported within restricted amounts and it will be distinguished by bucket code "NV"
   . From the next generation, tRDL will be only 2CLK for every clock frequency

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_{RFC} 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 perfomed internally.
After self refresh entry, self refresh mode is kept while CKE is low.
During self refresh mode, all inputs expect CKE will be don't cared, and outputs will be in Hi-Z state.
For the time interval of t_{RFC} from self refresh exit command, any other command can not be accepted.
Before/After self refresh mode, burst auto refresh cycle (4096 cycles) is recommended.

12. About Burst Type Control

Basic MODE	Sequential Counting	At MRS A_3 = "0". See the BURST SEQUENCE TABLE. (BL=4, 8) BL=1, 2, 4, 8 and full page.
	Interleave Counting	At MRS A_3 = "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_{CCD} = 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 $A_{2,1,0}$ = "000". At auto precharge, t_{RAS} should not be violated.
	2	At MRS $A_{2,1,0}$ = "001". At auto precharge, t_{RAS} should not be violated.
	4	At MRS $A_{2,1,0}$ = "010".
	8	At MRS $A_{2,1,0}$ = "011".
	Full Page	At MRS $A_{2,1,0}$ = "111". Wrap around mode(Infinite burst length) should be stopped by burst stop Ras interrupt or CAS interrupt
Special MODE	BRSW	At MRS A_9 = "1". Read burst =1, 2, 4, 8, full page write Burst =1 At auto precharge of write, t_{RAS} should not be violated.
Random MODE	Burst Stop	t_{BDL}= 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	$\overline{RAS}$ Interrupt (Interrupted by Precharge)	Before the end of burst, Row precharge command of the same bank stops read/write burst with Row precharge. t_{RDL}= 2 with DQM, valid DQ after burst stop is 1, 2 for CAS latency 2, 3 respectively. During read/write burst with auto precharge, $\overline{RAS}$ interrupt can not be issued.
	$\overline{CAS}$ 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, $\overline{CAS}$ interrupt can not be issued.

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_{10}/AP	ILLEGAL	2
	L	L	H	H	BA	RA	Row (& Bank) Active ; Latch RA	
	L	L	H	L	BA	A_{10}/AP	NOP	4
	L	L	L	H	X	X	Auto Refresh or Self Refresh	5
	L	L	L	L	OP code	OP code	Mode Register Access	5
Row Active	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_{10}/AP	Begin Read ; latch CA ; determine AP	
	L	H	L	L	BA	CA, A_{10}/AP	Begin Write ; latch CA ; determine AP	
	L	L	H	H	BA	RA	ILLEGAL	2
	L	L	H	L	BA	A_{10}/AP	Precharge	
	L	L	L	X	X	X	ILLEGAL	
Read	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_{10}/AP	Term burst, New Read, Determine AP	
	L	H	L	L	BA	CA, A_{10}/AP	Term burst, New Write, Determine AP	3
	L	L	H	H	BA	RA	ILLEGAL	2
	L	L	H	L	BA	A_{10}/AP	Term burst, Precharge timing for Reads	
	L	L	L	X	X	X	ILLEGAL	
Write	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_{10}/AP	Term burst, New read, Determine AP	3
	L	H	L	L	BA	CA, A_{10}/AP	Term burst, New Write, Determine AP	3
	L	L	H	H	BA	RA	ILLEGAL	2
	L	L	H	L	BA	A_{10}/AP	Term burst, precharge timing for Writes	3
	L	L	L	X	X	X	ILLEGAL	
Read with Auto Precharge	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	
	L	H	L	X	BA	CA, A_{10}/AP	ILLEGAL	
	L	L	H	X	BA	RA, RA_{10}	ILLEGAL	2
	L	L	L	X	X	X	ILLEGAL	
Write with Auto Precharge	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	
	L	H	L	X	BA	CA, A_{10}/AP	ILLEGAL	
	L	L	H	X	BA	RA, RA_{10}	ILLEGAL	2
	L	L	L	X	X	X	ILLEGAL	
Pre-charging	H	X	X	X	X	X	NOP --> Idle after t_{RP}	
	L	H	H	H	X	X	NOP --> Idle after t_{RP}	
	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	A_{10}/AP	NOP --> Idle after t_{RP}L	4

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 t_{RCD}	
	L	H	H	H	X	X	NOP --> Row Active after t_{RCD}	
	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	A_{10}/AP	ILLEGAL	2
	L	L	L	X	X	X	ILLEGAL	
Refreshing	H	X	X	X	X	X	NOP --> Idle after t_{RFC}	
	L	H	H	X	X	X	NOP --> Idle after t_{RFC}	
	L	H	L	X	X	X	ILLEGAL	
	L	L	H	X	X	X	ILLEGAL	
	L	L	L	X	X	X	ILLEGAL	
Mode Register Accessing	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 clcok 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 A_{10}/AP).
5. Illegal if any bank is not idle.

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 t_{RFC} (ABI)	6
	L	H	L	H	H	H	X	Exit Self Refresh --> Idle after t_{RFC} (ABI)	6
	L	H	L	H	H	L	X	ILLEGAL	
	L	H	L	H	L	X	X	ILLEGAL	
	L	H	L	L	X	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	H	L	X	X	ILLEGAL	
	L	H	L	L	X	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
	H	L	L	L	L	L	OP Code	Mode Register Access	
	L	L	X	X	X	X	X	NOP	
Any State other than Listed above	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 Clcok 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 + t_{SS} 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.

Single Bit Read-Write-Read Cycle(Same Page) @CAS Latency=3, Burst Length=1