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Revision History
AS4C8M16D1 - 60-ball FBGA PACKAGE

Revision	Details	Date
Rev 1.0	Preliminary datasheet	May 2015

Features

- Fast clock rate: 250/200MHz
- Operating temperature:
  - Commercial (0°C~70°C)
  - Industrial (-40°C~85°C)
- Differential Clock CK & $\overline{CK}$ input
- Bi-directional DQS
- DLL enable/disable by EMRS
- Fully synchronous operation
- Internal pipeline architecture
- Four internal banks, 2M x 16-bit for each bank
- Programmable Mode and Extended Mode registers
  - CAS Latency: 2, 2.5, 3
  - Burst length: 2, 4, 8
  - Burst Type: Sequential & Interleaved
- Individual byte write mask control
- DM Write Latency = 0
- Auto Refresh and Self Refresh
- 4096 refresh cycles / 64ms
- Precharge & active power down
- Power supplies: VDD & VDDQ = 2.5V ± 0.2V
- Interface: SSTL_2 I/O Interface
- Package: 60-Ball, 8x13x1.2 mm (max) FBGA
  - Pb free and Halogen free

Overview

The 128Mb DDR SDRAM is a high-speed CMOS double data rate synchronous DRAM containing 128 Mbits. It is internally configured as a quad 2M x 16 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 $\overline{CK}$.

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 device provides programmable Read or Write burst lengths of 2, 4, or 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, 128Mb DDR 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 and high performance.

Table 1. Ordering Information

Part Number	Org	Max Clock (MHz)	Temperature	Package
AS4C8M16D1-5BCN	8 x 16	200	Commercial 0°C to 70°C	60ball FBGA
AS4C8M16D1-5BIN	8 x 16	200	Industrial -40°C to 85°C	60ball FBGA

Figure 1. Ball Assignment (Top View)

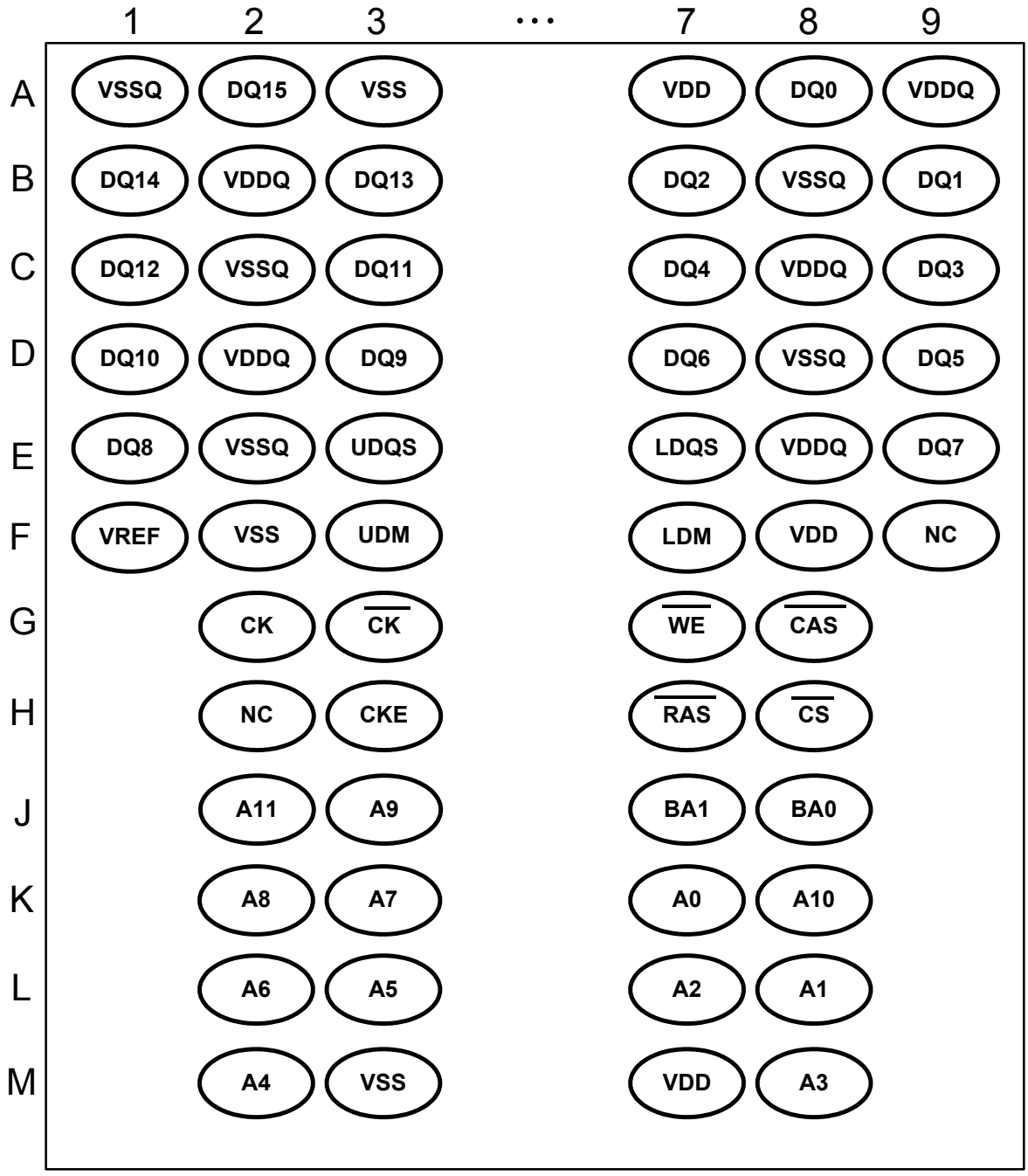
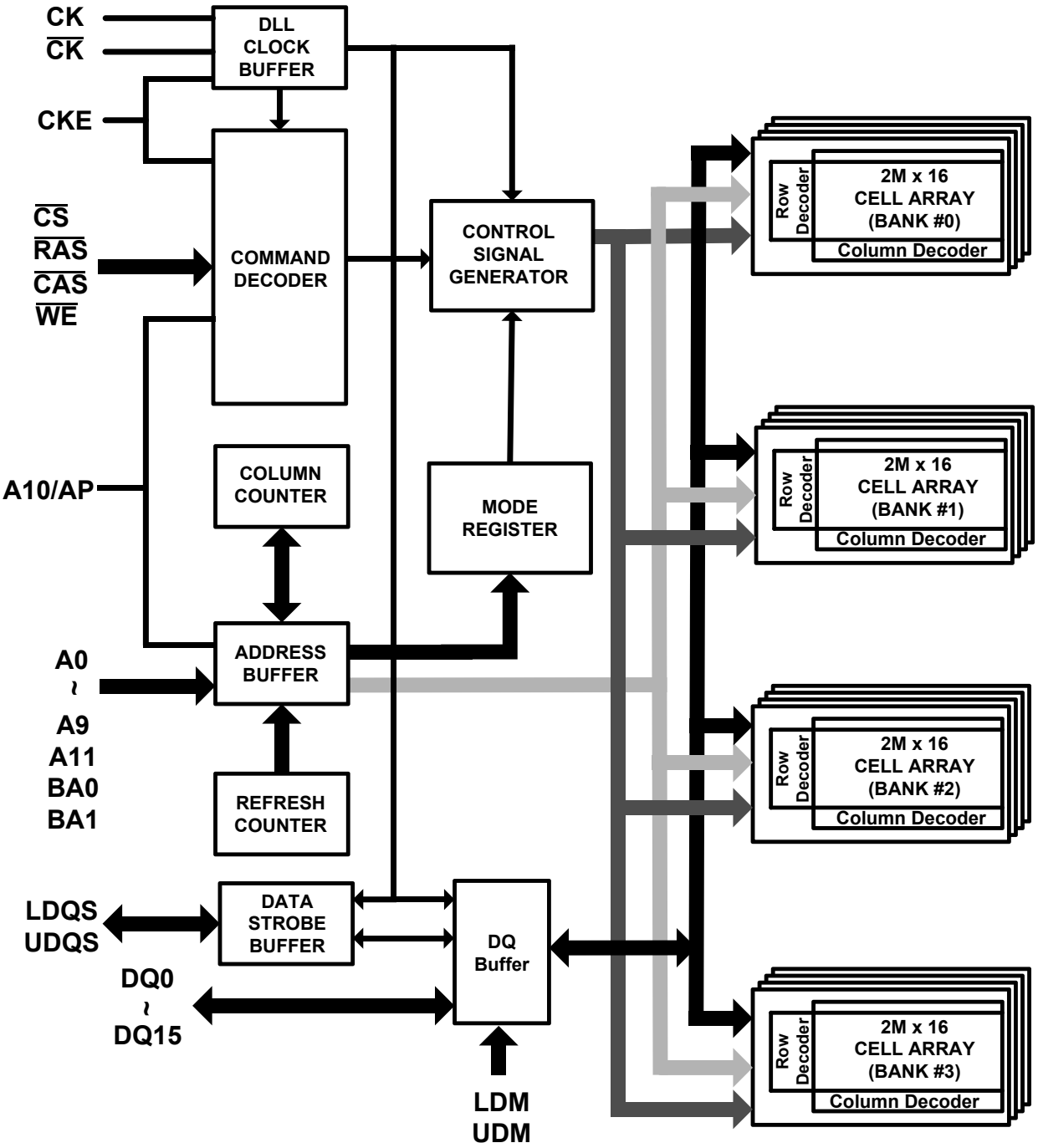


Figure 2. Block Diagram



Pin Descriptions

Table 2. Pin Details

Symbol	Type	Description
CK, $\overline{CK}$	Input	**Differential Clock:** CK, $\overline{CK}$ are driven by the system clock. All SDRAM input signals are sampled on the positive edge of CK. Both CK and $\overline{CK}$ increment the internal burst counter and controls the output registers.
CKE	Input	**Clock Enable:** 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	**Bank Activate:** BA0 and BA1 define to which bank the BankActivate, Read, Write, or BankPrecharge command is being applied.
A0-A11	Input	**Address Inputs:** A0-A11 are sampled during the BankActivate command (row address A0-A11) and Read/Write command (column address A0-A8 with A10 defining Auto Precharge).
$\overline{CS}$	Input	**Chip Select:** $\overline{CS}$ enables (sampled LOW) and disables (sampled HIGH) the command decoder. All commands are masked when $\overline{CS}$ is sampled HIGH. $\overline{CS}$ provides for external bank selection on systems with multiple banks. It is considered part of the command code.
$\overline{RAS}$	Input	**Row Address Strobe:** The $\overline{RAS}$ signal defines the operation commands in conjunction with the $\overline{CAS}$ and $\overline{WE}$ signals and is latched at the positive edges of CK. When $\overline{RAS}$ and $\overline{CS}$ are asserted "LOW" and $\overline{CAS}$ is asserted "HIGH," either the BankActivate command or the Precharge command is selected by the $\overline{WE}$ signal. When the $\overline{WE}$ is asserted "HIGH," the BankActivate command is selected and the bank designated by BA is turned on to the active state. When the $\overline{WE}$ is asserted "LOW," the Precharge command is selected and the bank designated by BA is switched to the idle state after the precharge operation.
$\overline{CAS}$	Input	**Column Address Strobe:** The $\overline{CAS}$ signal defines the operation commands in conjunction with the $\overline{RAS}$ and $\overline{WE}$ signals and is latched at the positive edges of CK. When $\overline{RAS}$ is held "HIGH" and $\overline{CS}$ is asserted "LOW," the column access is started by asserting $\overline{CAS}$ "LOW." Then, the Read or Write command is selected by asserting $\overline{WE}$ "HIGH" or "LOW".
$\overline{WE}$	Input	**Write Enable:** The $\overline{WE}$ signal defines the operation commands in conjunction with the $\overline{RAS}$ and $\overline{CAS}$ signals and is latched at the positive edges of CK. The $\overline{WE}$ input is used to select the BankActivate or Precharge command and Read or Write command.
LDQS, UDQS	Input / Output	**Bidirectional Data Strobe:** Specifies timing for Input and Output data. Read Data Strobe is edge triggered. Write Data Strobe provides a setup and hold time for data and DQM. LDQS is for DQ0~7, UDQS is for DQ8~15.
LDM, UDM	Input	**Data Input Mask:** Input data is masked when DM is sampled HIGH during a write cycle. LDM masks DQ0-DQ7, UDM masks DQ8-DQ15.
DQ0 - DQ15	Input / Output	**Data I/O:** The DQ0-DQ15 input and output data are synchronized with positive and negative edges of LDQS and UDQS. The I/Os are byte-maskable during Writes.
VDD	Supply	**Power Supply:** +2.5V ± 0.2V
VSS	Supply	**Ground**
VDDQ	Supply	**DQ Power:** +2.5V ± 0.2V. Provide isolated power to DQs for improved noise immunity.
VSSQ	Supply	**DQ Ground:** Provide isolated ground to DQs for improved noise immunity.
VREF	Supply	**Reference Voltage for Inputs:** +0.5*V_{DDQ}
NC	-	**No Connect:** No internal connection, these pins suggest to be left unconnected.

Operation Mode

Fully synchronous operations are performed to latch the commands at the positive edges of CK. Table 3 shows the truth table for the operation commands.

Table 3. Truth Table (Note (1), (2))

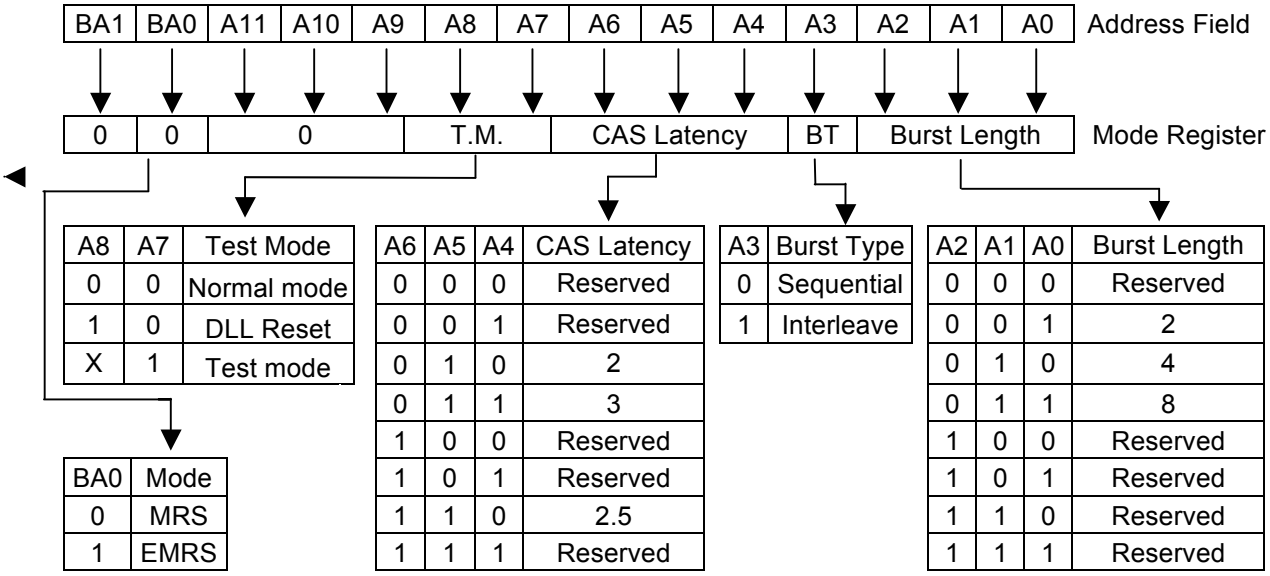
Command	State	CKE_{n-1}	CKE_n	DM	BA0,1	A10	A0-9,11	$\overline{CS}$	$\overline{RAS}$	$\overline{CAS}$	$\overline{WE}$
BankActivate	Idle(3)	H	X	X	V	Row address		L	L	H	H
BankPrecharge	Any	H	X	X	V	L	X	L	L	H	L
PrechargeAll	Any	H	X	X	X	H	X	L	L	H	L
Write	Active(3)	H	X	X	V	L	Column address (A0 ~ A8)	L	H	L	L
Write and AutoPrecharge	Active(3)	H	X	X	V	H		L	H	L	L
Read	Active(3)	H	X	X	V	L	Column address (A0 ~ A8)	L	H	L	H
Read and Autoprecharge	Active(3)	H	X	X	V	H		L	H	L	H
Mode Register Set	Idle	H	X	X	OP code			L	L	L	L
Extended MRS	Idle	H	X	X	OP code			L	L	L	L
No-Operation	Any	H	X	X	X	X	X	L	H	H	H
Burst Stop	Active(4)	H	X	X	X	X	X	L	H	H	L
Device Deselect	Any	H	X	X	X	X	X	H	X	X	X
AutoRefresh	Idle	H	H	X	X	X	X	L	L	L	H
SelfRefresh Entry	Idle	H	L	X	X	X	X	L	L	L	H
SelfRefresh Exit	Idle (SelfRefresh)	L	H	X	X	X	X	H	X	X	X
								L	H	H	H
Precharge Power Down Mode Entry	Idle	H	L	X	X	X	X	H	X	X	X
								L	H	H	H
Precharge Power Down Mode Exit	Any (PowerDown)	L	H	X	X	X	X	H	X	X	X
								L	H	H	H
Active Power Down Mode Entry	Active	H	L	X	X	X	X	H	X	X	X
								L	V	V	V
Active Power Down Mode Exit	Any (PowerDown)	L	H	X	X	X	X	H	X	X	X
								L	H	H	H
Data Input Mask Disable	Active	H	X	L	X	X	X	X	X	X	X
Data Input Mask Enable(5)	Active	H	X	H	X	X	X	X	X	X	X

Note: 1. V=Valid data, X=Don't Care, L=Low level, H=High level
2. CKE_n signal is input level when commands are provided.
CKE_{n-1} signal is input level one clock cycle before the commands are provided.
3. These are states of bank designated by BA signal.
4. Device state is 2, 4, and 8 burst operation.
5. LDM and UDM can be enabled respectively.

Mode Register Set (MRS)

The Mode Register stores the data for controlling various operating modes of a DDR SDRAM. It programs CAS Latency, Burst Type, and Burst Length to make the DDR SDRAM useful for a variety of applications. The default value of the Mode Register is not defined; therefore the Mode Register must be written by the user. Values stored in the register will be retained until the register is reprogrammed. The Mode Register is written by asserting Low on $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$, BA1 and BA0 (the device should have all banks idle with no bursts in progress prior to writing into the mode register, and CKE should be High). The state of address pins A0~A11 and BA0, BA1 in the same cycle in which $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$ and $\overline{WE}$ are asserted Low is written into the Mode Register. A minimum of two clock cycles, tMRD, are required to complete the write operation in the Mode Register. The Mode Register is divided into various fields depending on functionality. The Burst Length uses A0~A2, Burst Type uses A3, and CAS Latency (read latency from column address) uses A4~A6. A logic 0 should be programmed to all the undefined addresses to ensure future compatibility. Reserved states should not be used to avoid unknown device operation or incompatibility with future versions. Refer to the table for specific codes for various burst lengths, burst types and CAS latencies.

Table 4. Mode Register Bitmap



A8	A7	Test Mode
0	0	Normal mode
1	0	DLL Reset
X	1	Test mode

BA0	Mode
0	MRS
1	EMRS

A6	A5	A4	CAS Latency
0	0	0	Reserved
0	0	1	Reserved
0	1	0	2
0	1	1	3
1	0	0	Reserved
1	0	1	Reserved
1	1	0	2.5
1	1	1	Reserved

A3	Burst Type
0	Sequential
1	Interleave

A2	A1	A0	Burst Length
0	0	0	Reserved
0	0	1	2
0	1	0	4
0	1	1	8
1	0	0	Reserved
1	0	1	Reserved
1	1	0	Reserved
1	1	1	Reserved

- Burst Length Field (A2~A0)

  This field specifies the data length of column access using the A2~A0 pins and selects the Burst Length to be 2, 4, and 8.

Table 5. Burst Length

A2	A1	A0	Burst Length
0	0	0	Reserved
0	0	1	2
0	1	0	4
0	1	1	8
1	0	0	Reserved
1	0	1	Reserved
1	1	0	Reserved
1	1	1	Reserved

- Addressing Mode Select Field (A3)

  The Addressing Mode can be one of two modes, either Interleave Mode or Sequential Mode. Both Sequential Mode and Interleave Mode support burst length of 2, 4, and 8.

Table 6. Addressing Mode

A3	Addressing Mode
0	Sequential
1	Interleave

- Burst Definition, Addressing Sequence of Sequential and Interleave Mode

Table 7. Burst Address ordering

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

- CAS Latency Field (A6~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.

  $t_{CAC}(min) \leq$ CAS Latency X t_{CK}

Table 8. CAS Latency

A6	A5	A4	CAS Latency
0	0	0	Reserved
0	0	1	Reserved
0	1	0	2 clocks
0	1	1	3 clocks
1	0	0	Reserved
1	0	1	Reserved
1	1	0	2.5 clocks
1	1	1	Reserved

• Test Mode field (A8~A7)

These two bits are used to enter the test mode and must be programmed to "00" in normal operation.

Table 9. Test Mode

A8	A7	Test Mode
0	0	Normal mode
1	0	DLL Reset
X	1	Test mode

• (BA0, BA1)

Table 10. MRS/EMRS

BA1	BA0	A11 ~ A0
RFU	0	MRS Cycle
RFU	1	Extended Functions (EMRS)

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 $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, and $\overline{WE}$. The state of A0, A2 ~ A5, A7 ~ A11and BA1 is written in the mode register in the same cycle as $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, and $\overline{WE}$ 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.

Table 11. Extended Mode Register Bitmap

BA1	BA0	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0	Address Field
0	1	RFU must be set to “0”					DS1	RFU must be set to “0”				DS0	DLL	Extended Mode Register

BA0	Mode
0	MRS
1	EMRS

A6	A1	Drive Strength	Comment
0	0	Full	
0	1	Weak	
1	0	RFU	Reserved For Future
1	1	Matched impedance	Output driver matches impedance

A0	DLL
0	Enable
1	Disable

Table 12. Absolute Maximum Rating

Symbol	Item		Rating	Unit
			-4/5	
V_{IN}, V_{OUT}	I/O Pins Voltage		- 0.5~V_{DDQ} + 0.5	V
V_{IN}	VREF and Inputs Voltage		- 1~3.6	V
V_{DD}, V_{DDQ}	Power Supply Voltage		- 1~3.6	V
T_A	Ambient Temperature	Commercial	0~70	∞C
		Industrial	-40~85	∞C
T_{STG}	Storage Temperature		- 55~150	∞C
P_D	Power Dissipation		1	W
I_{OS}	Short Circuit Output Current		50	mA

Note1: Stress greater than those listed under “Absolute Maximum Ratings” may cause permanent damage of the devices

Note2: These voltages are relative to Vss

Table 13. Recommended D.C. Operating Conditions

Symbol	Parameter	Min.	Max.	Unit
V_{DD}	Power Supply Voltage	2.3	2.7	V
V_{DDQ}	Power Supply Voltage (for I/O Buffer)	2.3	2.7	V
V_{REF}	Input Reference Voltage	0.49 * V_{DDQ}	0.51 * V_{DDQ}	V
V_{TT}	Termination Voltage	V_{REF} - 0.04	V_{REF} + 0.04	V
V_{IH} (DC)	Input High Voltage (DC)	V_{REF} + 0.15	V_{DDQ} + 0.3	V
V_{IL} (DC)	Input Low Voltage (DC)	-0.3	V_{REF} - 0.15	V
V_{IN} (DC)	Input Voltage Level, CK and $\overline{CK}$ inputs	-0.3	V_{DDQ} + 0.3	V
I_I	Input Leakage current, Any input 0V ≤ V_{IN} ≤ V_{DD} (All other pins not under test = 0 V)	-2	2	μA
I_{OZ}	Output Leakage current	-5	5	μA
I_{OH}	Output High Current (V_{OUT} = 1.95V)	-16.2	-	mA
I_{OL}	Output Low Current (V_{OUT} = 0.35V)	16.2	-	mA

Table 14. Capacitance (V_{DD} = 2.5V, f = 1MHz, T_A = 25 °C)

Symbol	Parameter	Min.	Max.	Unit
C_{IN1}	Input Capacitance (CK, $\overline{CK}$)	2	3	pF
C_{IN2}	Input Capacitance (All other input-only pins)	2	3	pF
$C_{I/O}$	DQ, DQS, DM Input/Output Capacitance	4	5	pF

Note: These parameters are guaranteed by design, periodically sampled and are not 100% tested

Table 15. D.C. Characteristics (V_{DD} = 2.5V±0.2V, T_A = -40~85°C)

Parameter & Test Condition	Symbol	-4	-5	Unit
		Max.		
OPERATING CURRENT: 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	60	55	mA
OPERATING CURRENT : One bank; Active-Read-Precharge; BL=4; tRC=tRC(min); tCK=tCK(min); Iout=0mA; Address and control inputs changing once per clock cycle	IDD1	75	65	mA
PRECHARGE POWER-DOWN STANDBY CURRENT: All banks idle; power-down mode; tCK=tCK(min); CKE=LOW	IDD2P	5	5	mA
IDLE STANDLY CURRENT : CKE = HIGH; $\overline{CS}$=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	30	30	mA
ACTIVE POWER-DOWN STANDBY CURRENT : one bank active; power-down mode; CKE=LOW; tCK=tCK(min)	IDD3P	17	17	mA
ACTIVE STANDBY CURRENT : $\overline{CS}$=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	40	40	mA
OPERATING CURRENT BURST READ : 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	120	100	mA
OPERATING CURRENT BURST Write : 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	120	100	mA
AUTO REFRESH CURRENT : tRC=tRFC(min); tCK=tCK(min)	IDD5	80	70	mA
SELF REFRESH CURRENT: Self Refresh Mode ; CKE≦0.2V;tCK=tCK(min)	IDD6	2	2	mA
BURST OPERATING CURRENT 4 bank operation: Four bank interleaving READs; BL=4; with Auto Precharge; tRC=tRC(min); tCK=tCK(min); Address and control inputs change only during Active, READ , or WRITE command	IDD7	160	140	mA

Figure 3: Timing Waveform for IDD7 Measurement at 200 MHz CK Operation

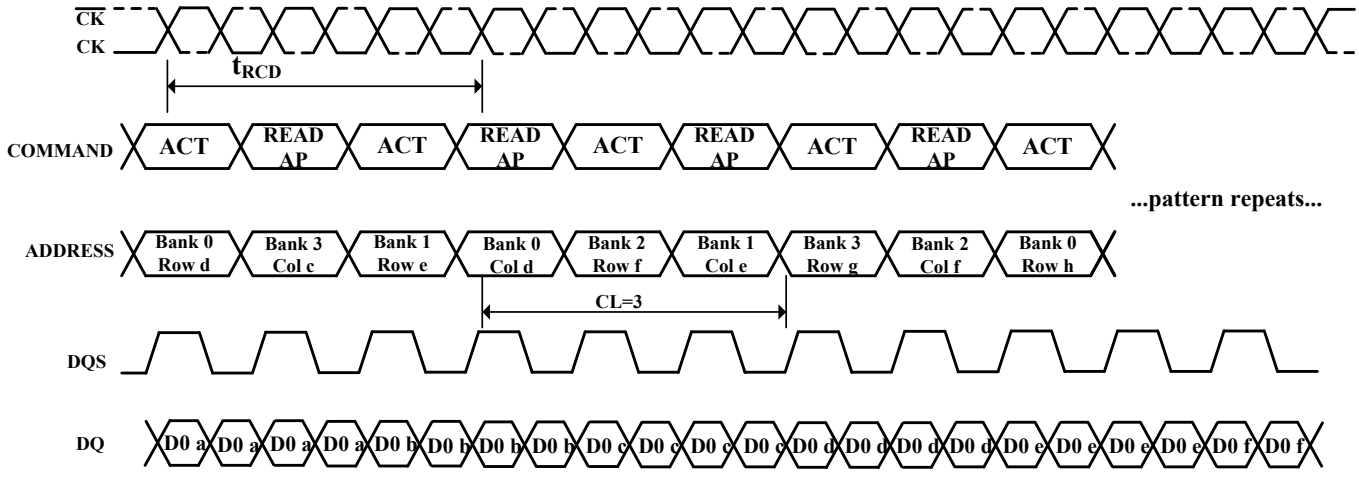


Table 16. Electrical AC Characteristics (V_{DD} = 2.5V±0.2V, T_A = -40~85°C)

Symbol	Parameter		-4		-5		Unit
			Min	Max	Min	Max	
t_{CK}	Clock cycle time	CL=2	-	-	7.5	12	ns
		CL=2.5	-	-	6	12	ns
		CL = 3	4	12	5	12	ns
t_{CH}	Clock high level width		0.45	0.55	0.45	0.55	t_{CK}
t_{CL}	Clock low level width		0.45	0.55	0.45	0.55	t_{CK}
t_{DQSCK}	DQS-out access time from CK, $\overline{CK}$		-0.7	0.7	-0.6	0.6	ns
t_{AC}	Output access time from CK, $\overline{CK}$		-0.7	0.7	-0.7	0.7	ns
t_{DQSQ}	DQS-DQ Skew		-	0.4	-	0.4	ns
t_{RPRE}	Read preamble		0.9	1.1	0.9	1.1	t_{CK}
t_{RPST}	Read postamble		0.4	0.6	0.4	0.6	t_{CK}
t_{DQSS}	CK to valid DQS-in		0.8	1.2	0.72	1.25	t_{CK}
t_{WPRES}	DQS-in setup time		0	-	0	-	ns
t_{WPRE}	DQS write preamble		0.25	-	0.25	-	t_{CK}
t_{WPST}	DQS write postamble		0.4	0.6	0.4	0.6	t_{CK}
t_{DQSH}	DQS in high level pulse width		0.35	-	0.35	-	t_{CK}
t_{DQSL}	DQS in low level pulse width		0.35	-	0.35	-	t_{CK}
t_{IS}	Address and Control input setup time		0.7	-	0.7	-	ns
t_{IH}	Address and Control input hold time		0.7	-	0.7	-	ns
t_{DS}	DQ & DM setup time to DQS		0.4	-	0.4	-	ns
t_{DH}	DQ & DM hold time to DQS		0.4	-	0.4	-	ns
t_{HP}	Clock half period		t_{CLMIN} or t_{CHMIN}	-	t_{CLMIN} or t_{CHMIN}	-	ns
t_{QH}	DQ/DQS output hold time from DQS		t_{HP} - t_{QHS}	-	t_{HP} - t_{QHS}	-	ns
t_{RC}	Row cycle time		52	-	55	-	ns
t_{RFC}	Refresh row cycle time		70	-	70	-	ns
t_{RAS}	Row active time		36	70K	40	70K	ns
t_{RCD}	Active to Read or Write delay		16	-	15	-	ns
t_{RP}	Row precharge time		16	-	15	-	ns
t_{RRD}	Row active to Row active delay		8	-	10	-	ns
t_{WR}	Write recovery time		12	-	15	-	ns
t_{MRD}	Mode register set cycle time		2	-	2	-	t_{CK}
t_{DAL}	Auto precharge write recovery + Precharge time		t_{WR} + t_{RP}	-	t_{WR} + t_{RP}	-	t_{CK}
t_{XSRD}	Self refresh exit to read command delay		200	-	200	-	t_{CK}
t_{REFI}	Refresh interval time		-	15.6	-	15.6	µs
t_{IPW}	Control and Address input pulse width		2.2	-	2.2	-	ns
t_{DIPW}	DQ & DM input pulse width (for each input)		1.75	-	1.75	-	ns
t_{HZ}	Data-out high-impedance window from CK, $\overline{CK}$		-	0.7	-	0.7	ns
t_{LZ}	Data-out low-impedance window from CK, $\overline{CK}$		-0.7	0.7	-0.7	0.7	ns
t_{QHS}	Data Hold Skew Factor		-	0.5	-	0.5	ns
t_{DSS}	DQS falling edge to CK rising – setup time		0.2	-	0.2	-	t_{CK}
t_{DSH}	DQS falling edge to CK rising – hold time		0.2	-	0.2	-	t_{CK}
t_{WTR}	Internal Write to Read command delay		2	-	2	-	t_{CK}
t_{XSNR}	Exit Self-Refresh to non-Read command		75	-	75	-	ns

Table 17. Recommended A.C. Operating Conditions (V_{DD} = 2.5V±0.2V, T_A = -40~85°C)

Symbol	Parameter	Min.	Max.	Unit
V_{IH} (AC)	Input High Voltage (AC)	V_{REF} + 0.31	-	V
V_{IL} (AC)	Input Low Voltage (AC)	-	V_{REF} – 0.31	V
V_{ID} (AC)	Input Different Voltage, CK and $\overline{CK}$ inputs	0.7	V_{DDQ} + 0.6	V
V_{IX} (AC)	Input Crossing Point Voltage, CK and $\overline{CK}$ inputs	0.5 * V_{DDQ}-0.2	0.5 * V_{DDQ}+0.2	V

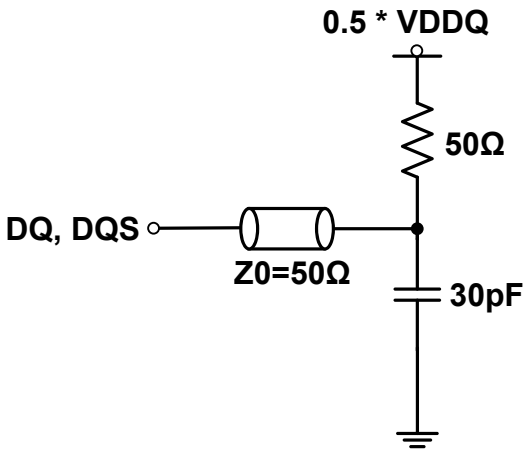
Note:

1. All voltages are referenced to V_{SS}.
2. These parameters depend on the cycle rate and these values are measured by the cycle rate under the minimum value of t_{CK} and t_{RC}. Input signals are changed one time during t_{CK}.
3. Power-up sequence is described in Note 5.
4. A.C. Test Conditions

Table 18. SSTL _2 Interface

Reference Level of Output Signals (V_{REF})	0.5 * V_{DDQ}
Output Load	Reference to the Test Load
Input Signal Levels(V_{IH} / V_{IL})	V_{REF}+0.31 V / V_{REF}-0.31V
Input Signals Slew Rate	1 V/ns
Reference Level of Input Signals	0.5 * V_{DDQ}

Figure 4. SSTL_2 A.C. Test Load



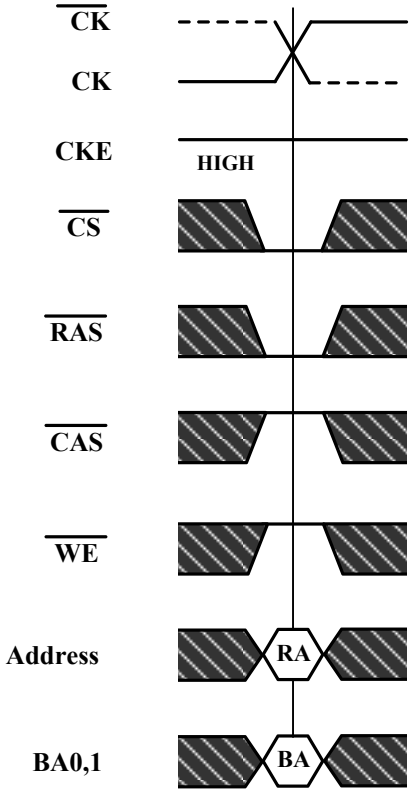
5. **Power up Sequence**

Power up must be performed in the following sequence.

1) Apply power to V_{DD} before or at the same time as V_{DDQ}, V_{TT} and V_{REF} when all input signals are held "NOP" state and maintain CKE “LOW”.
2) Start clock and maintain stable condition for minimum 200μs.
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.

Timing Waveforms

Figure 5. Activating a Specific Row in a Specific Bank



RA=Row Address

BA=Bank Address

Don't Care

Figure 6. tRCD and tRRD Definition

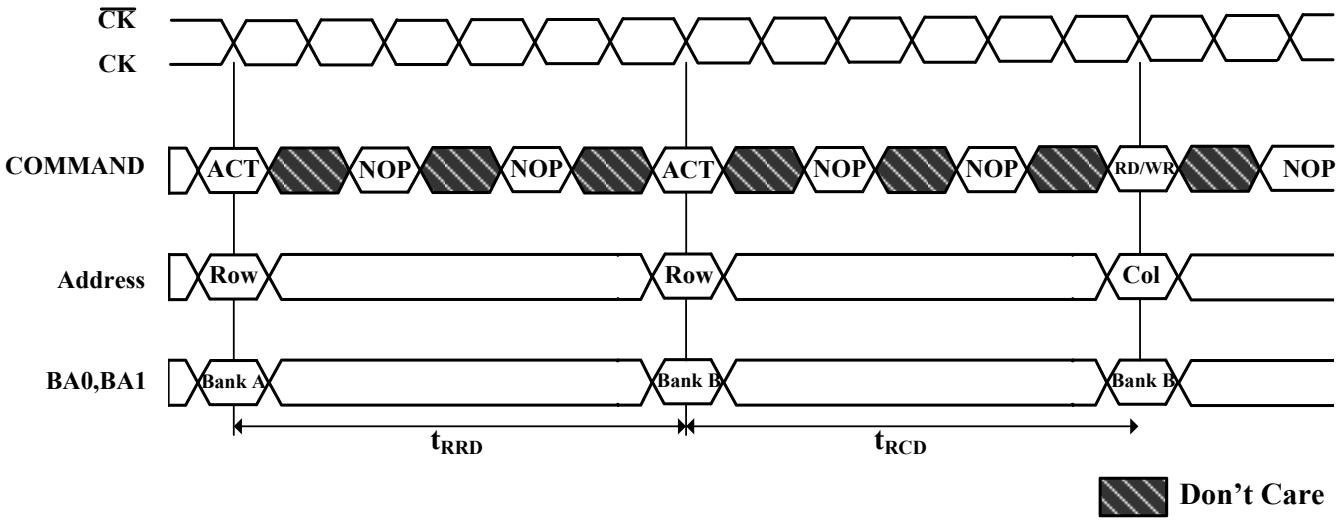
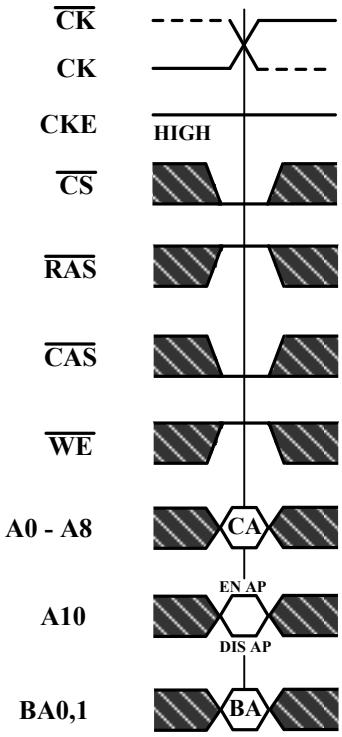


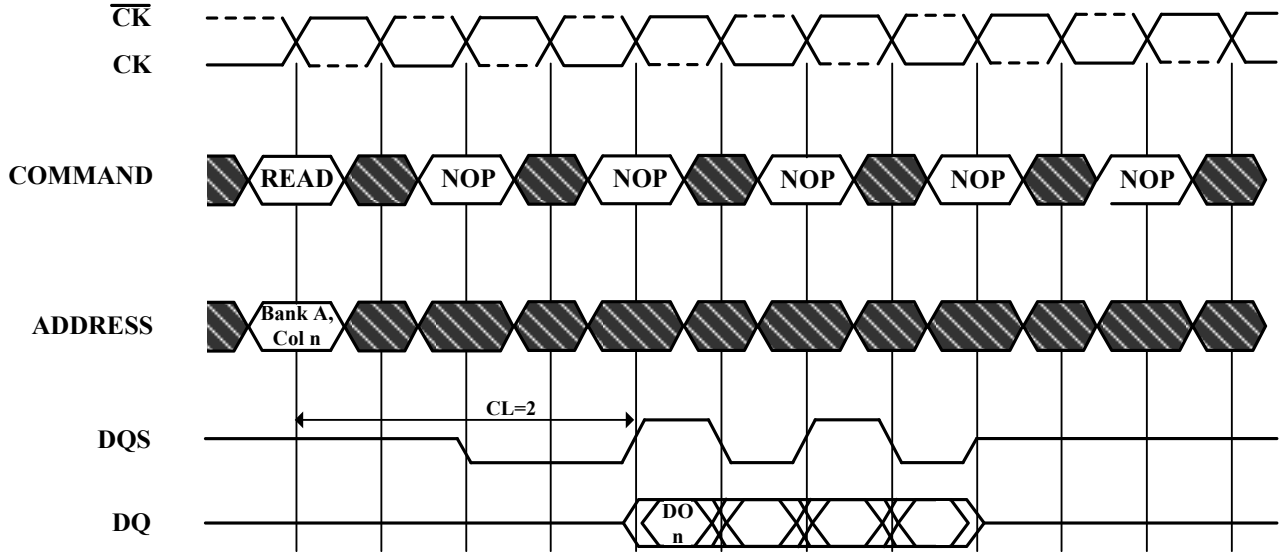
Figure 7. READ Command



CA=Column Address
BA=Bank Address
EN AP=Enable Autoprecharge
DIS AP=Disable Autoprecharge

Don't Care

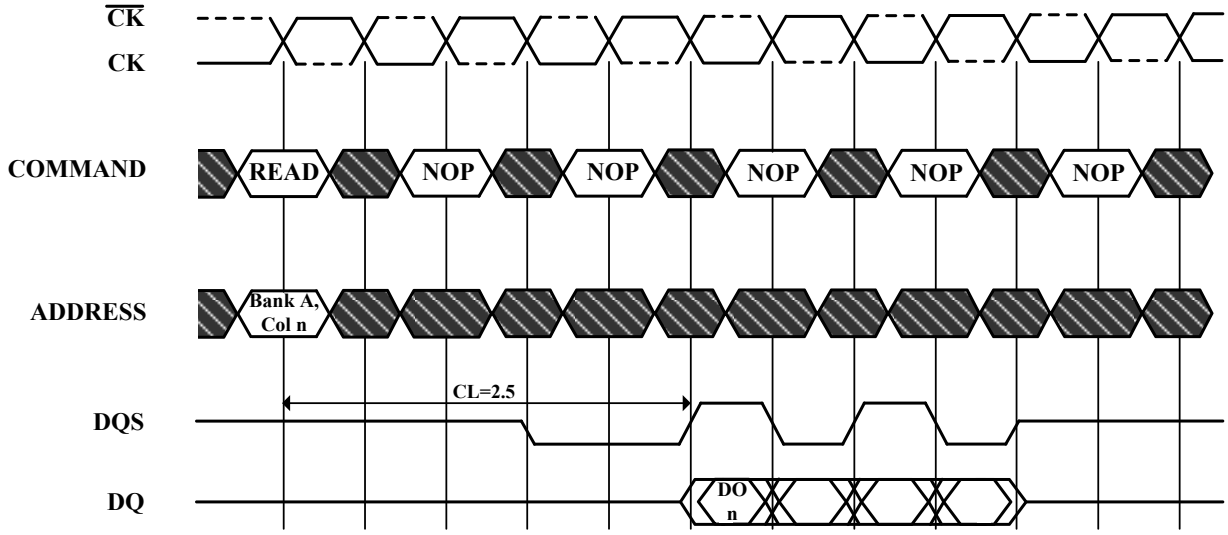
Figure 8. Read Burst Required CAS Latencies (CL=2)



DO n=Data Out from column n
Burst Length=4
3 subsequent elements of Data Out appear in the programmed order following DO n

Don't Care

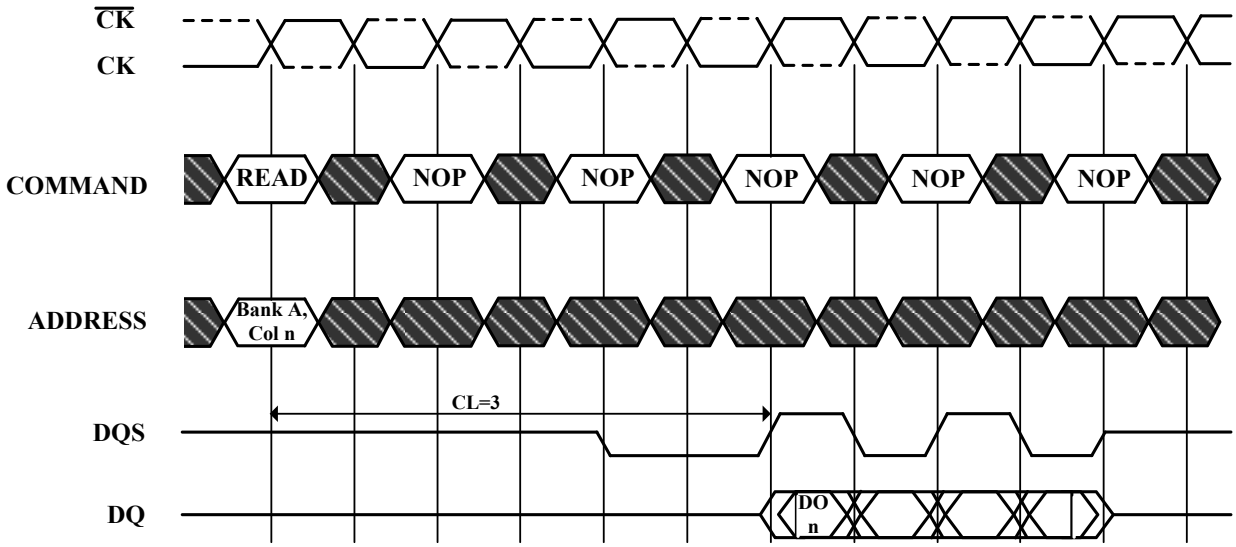
Read Burst Required CAS Latencies (CL=2.5)



DO n=Data Out from column n

Don't Care

Read Burst Required CAS Latencies (CL=3)



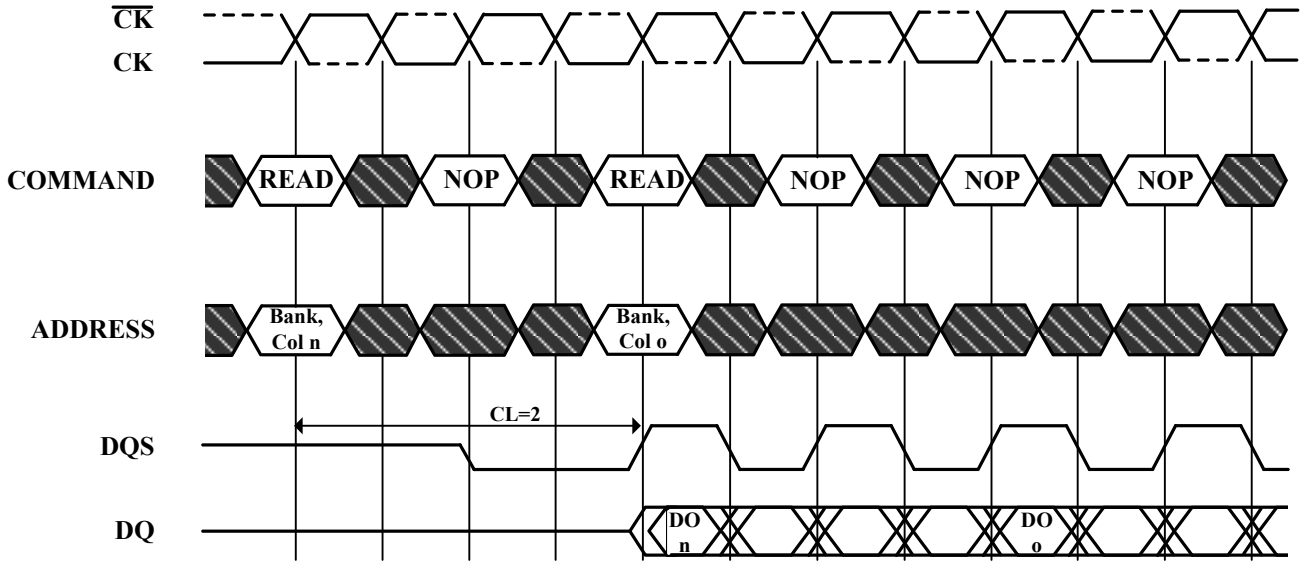
DO n=Data Out from column n

Burst Length=4

3 subsequent elements of Data Out appear in the programmed order following DO n

Don't Care

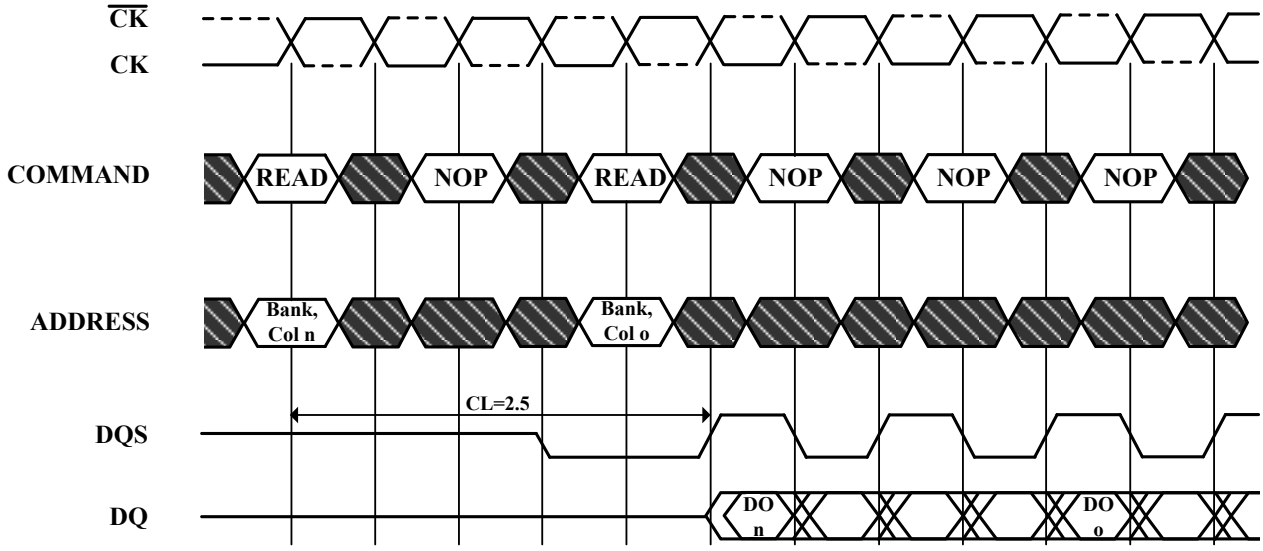
Figure 9. Consecutive Read Bursts Required CAS Latencies (CL=2)



DO n (or o)=Data Out from column n (or column o)
Burst Length=4 or 8 (if 4, the bursts are concatenated; if 8, the second burst interrupts the first)
3 subsequent elements of Data Out appear in the programmed order following DO n
3 (or 7) subsequent elements of Data Out appear in the programmed order following DO o
Read commands shown must be to the same device

Don't Care

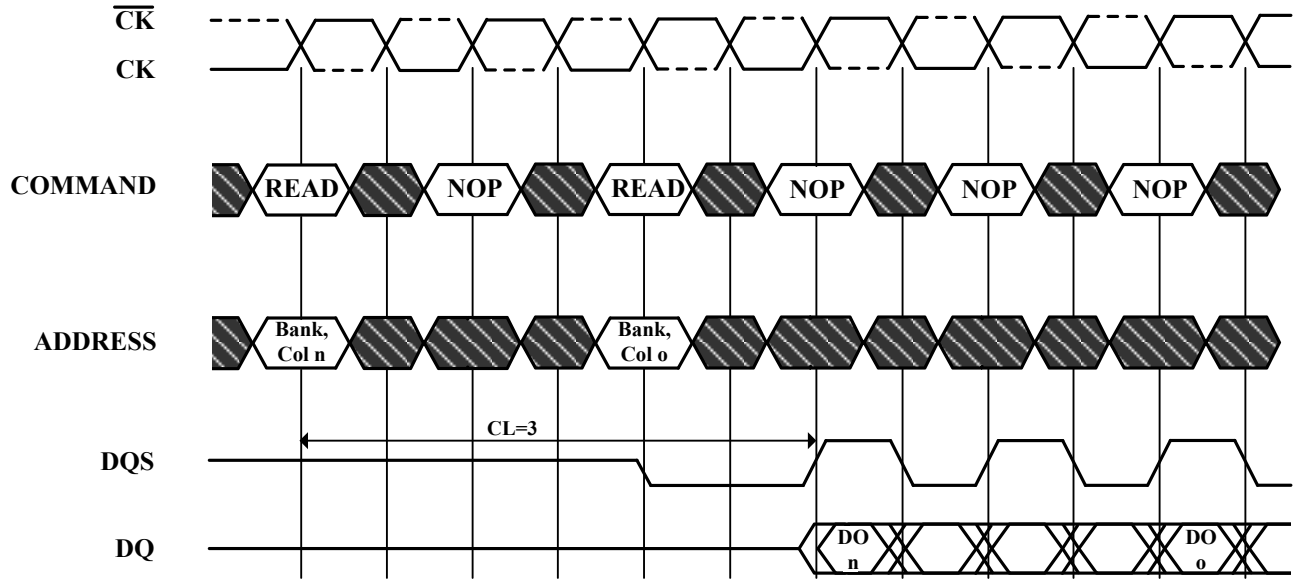
Consecutive Read Bursts Required CAS Latencies (CL=2.5)



DO n (or o)=Data Out from column n (or column o)
Burst Length=4 or 8 (if 4, the bursts are concatenated; if 8, the second burst interrupts the first)
3 subsequent elements of Data Out appear in the programmed order following DO n
3 (or 7) subsequent elements of Data Out appear in the programmed order following DO o
Read commands shown must be to the same device

Don't Care

Consecutive Read Bursts Required CAS Latencies (CL=3)



DO n (or o)=Data Out from column n (or column o)

Burst Length=4 or 8 (if 4, the bursts are concatenated; if 8, the second burst interrupts the first)

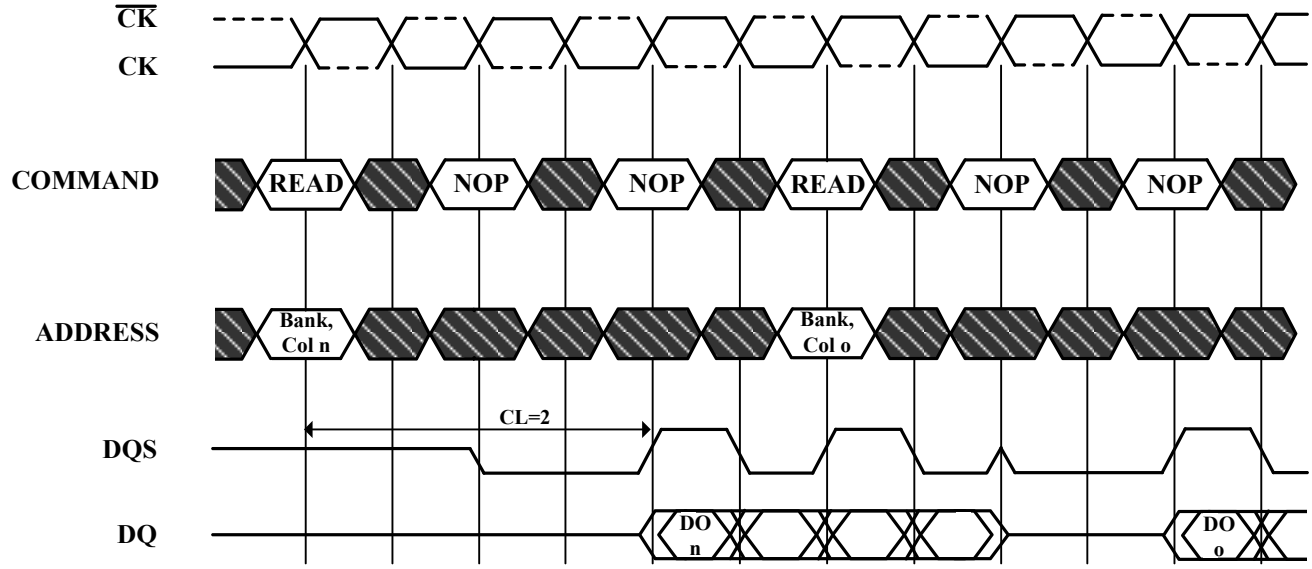
3 subsequent elements of Data Out appear in the programmed order following DO n

3 (or 7) subsequent elements of Data Out appear in the programmed order following DO o

Read commands shown must be to the same device

Don't Care

Figure 10. Non-Consecutive Read Bursts Required CAS Latencies (CL=2)



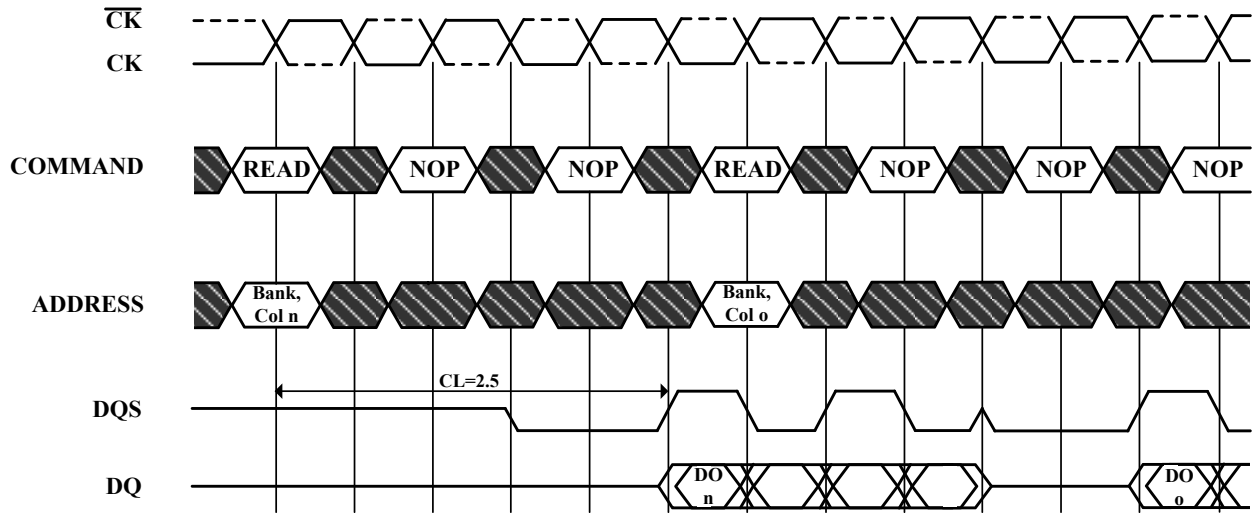
DO n (or o)=Data Out from column n (or column o)

Burst Length=4

3 subsequent elements of Data Out appear in the programmed order following DO n (and following DO o)

Don't Care

Non-Consecutive Read Bursts Required CAS Latencies (CL=2.5)



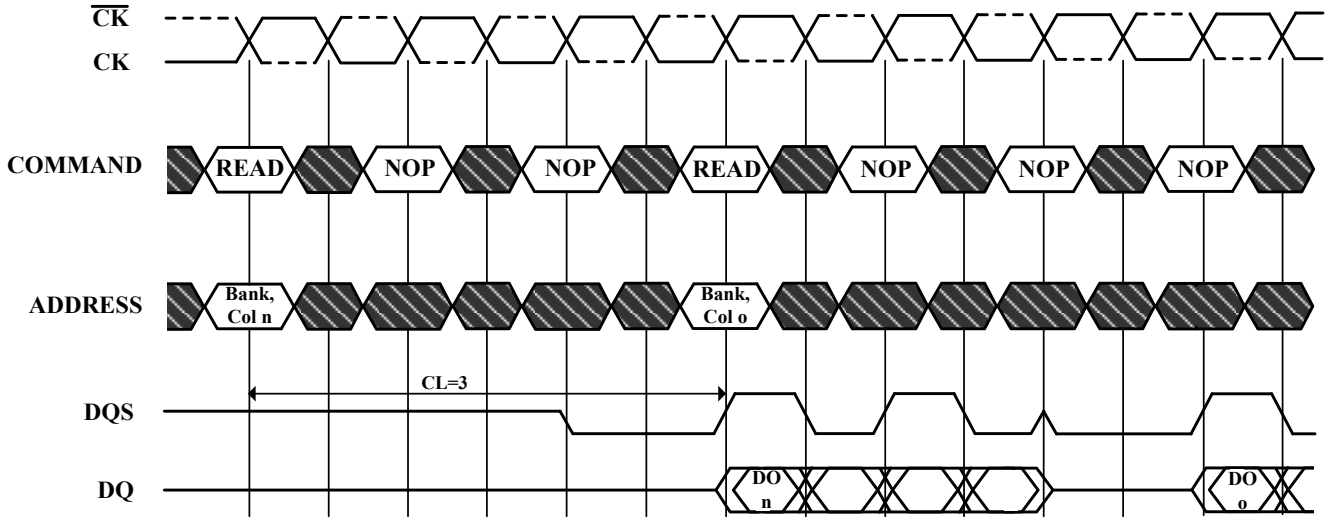
DO n (or o)=Data Out from column n (or column o)

Burst Length=4

3 subsequent elements of Data Out appear in the programmed order following DO n (and following DO o)

Don't Care

Non-Consecutive Read Bursts Required CAS Latencies (CL=3)



DO n (or o)=Data Out from column n (or column o)

Burst Length=4

3 subsequent elements of Data Out appear in the programmed order following DO n (and following DO o)

Don't Care