1Gb DDR3 SDRAM A-Die

Preliminary Edition

Features

- VDD=VDDQ=1.5V ± 0.075V (JEDEC Standard Power Supply)
- 8 internal banks (BA0 - BA2)
- Differential clock inputs (CK, $\overline{CK}$)
- Programmable $\overline{CAS}$ Latency: 5, 6, 7, 8, 9
- Programmable Additive Latency: 0, CL-1, CL-2
- Burst Length: 4, 8
- Programmable Sequential / Interleave Burst Type
- 8 bit prefetch architecture
- Output Driver Impedance Control
- Write Leveling
- OCD Calibration
- Dynamic ODT (Rtt_Nom & Rtt_WR)
- Auto Self-Refresh
- Self-Refresh Temperature
- Partial Array Self-Refresh
- Packages:
  78 balls wBGA for x4 / x8
  96 balls wBGA for x16
- RoHS Compliance

Ordering Informatoin

Org.	Part Number	Package	Speed		
			Clock (MHz)	Data rate (Mb/s)	CL-t_{RCD}-t_{RP}
256M x 4	NT5CB256M4AN-AC	78ball wBGA 0.8mmx0.8mm Pitch	400	DDR3-800	5-5-5
	NT5CB256M4AN-AD		400	DDR3-800	6-6-6
	NT5CB256M4AN-BE		533	DDR3-1066	7-7-7
	NT5CB256M4AN-BF		533	DDR3-1066	8-8-8
	NT5CB256M4AN-CF		667	DDR3-1333	8-8-8
	NT5CB256M4AN-CG		667	DDR3-1333	9-9-9
128M x 8	NT5CB128M8AN-AC		400	DDR3-800	5-5-5
	NT5CB128M8AN-AD		400	DDR3-800	6-6-6
	NT5CB128M8AN-BE		533	DDR3-1066	7-7-7
	NT5CB128M8AN-BF		533	DDR3-1066	8-8-8
	NT5CB128M8AN-CF		667	DDR3-1333	8-8-8
	NT5CB128M8AN-CG		667	DDR3-1333	9-9-9
64M x 16	NT5CB64M16AP-AC	96ball wBGA 0.8mmx0.8mm Pitch	400	DDR3-800	5-5-5
	NT5CB64M16AP-AD		400	DDR3-800	6-6-6
	NT5CB64M16AP-BE		533	DDR3-1066	7-7-7
	NT5CB64M16AP-BF		533	DDR3-1066	8-8-8
	NT5CB64M16AP-CF		667	DDR3-1333	8-8-8
	NT5CB64M16AP-CG		667	DDR3-1333	9-9-9

Description

The 1Gb Double-Data-Rate-3 (DDR3) DRAMs is a high-speed CMOS. Double Data Rate 3 SDRAM containing 1,073,741,824 bits. It is internally configured as a 8 bank DRAM.

The 1Gb chip is organized as either 32Mbit x 4 I/O x 8 bank, 16Mbit x 8 I/O x 8 bank or 8Mbit x 16 I/O x 8 bank device. These synchronous devices achieve high speed double-data transfer rates of up to 1333 Mb/sec/pin for general applications.

These devices operate with a single 1.5V+/-0.075V power supply and are available in wBGA packages.

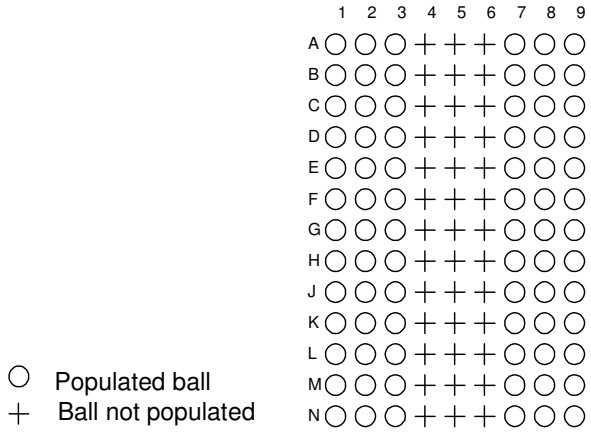
Pin Configuration - 78 balls 0.8mm x 0.8mm Pitch wBGA Package (x4)

<Top View >

See the balls through the package

X4

1	2	3		7	8	9
VSS	VDD	NC	A	NC	VSS	VDD
VSS	VSSQ	DQ0	B	DM	VSSQ	VDDQ
VDDQ	DQ2	DQS	C	DQ1	DQ3	VSSQ
VSSQ	NC	$\overline{DQS}$	D	VDD	VSS	VSSQ
VREFDQ	VDDQ	NC	E	NC	NC	VDDQ
NC	VSS	$\overline{RAS}$	F	CK	VSS	NC
ODT	VDD	$\overline{CAS}$	G	$\overline{CK}$	VDD	CKE
NC	$\overline{CS}$	$\overline{WE}$	H	A 10 / AP	ZQ	NC
VSS	BA0	BA2	J	NC	VREFCA	VSS
VDD	A3	A0	K	A 12 / $\overline{BC}$	BA1	VDD
VSS	A5	A2	L	A1	A4	VSS
VDD	A7	A9	M	A11	A6	VDD
VSS	$\overline{RESET}$	A13	N	NC	A8	VSS



○ Populated ball

＋ Ball not populated

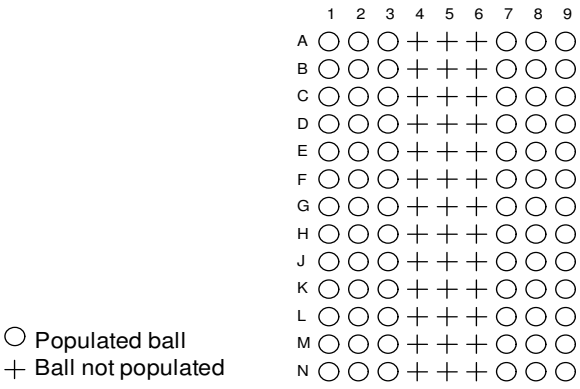
Pin Configuration - 78 balls 0.8mm x 0.8mm Pitch wBGA Package (x8)

<Top View >

See the balls through the package

X 8

1	2	3	4 5 6	7	8	9
VSS	VDD	NC	A	NU / $\overline{\text{TDQS}}$	VSS	VDD
VSS	VSSQ	DQ0	B	DM / TDQS	VSSQ	VDDQ
VDDQ	DQ2	DQS	C	DQ1	DQ3	VSSQ
VSSQ	DQ6	$\overline{\text{DQS}}$	D	VDD	VSS	VSSQ
VREFDQ	VDDQ	DQ4	E	DQ7	DQ5	VDDQ
NC	VSS	$\overline{\text{RAS}}$	F	CK	VSS	NC
ODT	VDD	$\overline{\text{CAS}}$	G	$\overline{\text{CK}}$	VDD	CKE
NC	$\overline{\text{CS}}$	$\overline{\text{WE}}$	H	A10 / AP	ZQ	NC
VSS	BA0	BA2	J	NC	VREFCA	VSS
VDD	A3	A0	K	A12 / $\overline{\text{BC}}$	BA1	VDD
VSS	A5	A2	L	A1	A4	VSS
VDD	A7	A9	M	A11	A6	VDD
VSS	$\overline{\text{RESET}}$	A13	N	NC	A8	VSS



○ Populated ball
＋ Ball not populated

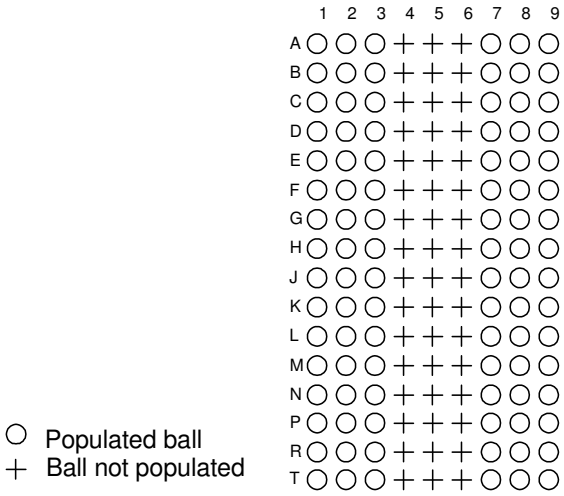
Pin Configuration - 96 balls 0.8mm x 0.8mm Pitch wBGA Package (x16)

<Top View >

See the balls through the package

X16

1	2	3		4 5 6		7	8	9
VDDQ	DQU5	DQU7		A		DQU4	VDDQ	VSS
VSSQ	VDD	VSS		B		$\overline{\text{DQSU}}$	DQU6	VSSQ
VDDQ	DQU3	DQU1		C		DQSU	DQU2	VDDQ
VSSQ	VDDQ	DMU		D		DQU0	VSSQ	VDD
VSS	VSSQ	DQL0		E		DML	VSSQ	VDDQ
VDDQ	DQL2	DQSL		F		DQL1	DQL3	VSSQ
VSSQ	DQL6	$\overline{\text{DQSL}}$		G		VDD	VSS	VSSQ
VREFDQ	VDDQ	DQL4		H		DQL7	DQL5	VDDQ
NC	VSS	$\overline{\text{RAS}}$		J		CK	VSS	NC
ODT	VDD	$\overline{\text{CAS}}$		K		$\overline{\text{CK}}$	VDD	CKE
NC	$\overline{\text{CS}}$	$\overline{\text{WE}}$		L		A10/AP	ZQ	NC
VSS	BA0	BA2		M		NC	VREFCA	VSS
VDD	A3	A0		N		A12/$\overline{\text{BC}}$	BA1	VDD
VSS	A5	A2		P		A1	A4	VSS
VDD	A7	A9		R		A11	A6	VDD
VSS	$\overline{\text{RESET}}$	NC		T		NC	A8	VSS



○ Populated ball
＋ Ball not populated

Input/Output Functional Description

Symbol	Type	Function
CK, $\overline{CK}$	Input	**Clock:** CK and $\overline{CK}$ are differential clock inputs. All address and control input signals are sampled on the crossing of the positive edge of CK and negative edge of $\overline{CK}$.
CKE	Input	**Clock Enable:** CKE high activates, and CKE low deactivates, internal clock signals ,device input buffers and output drivers. Taking CKE low provides Precharge Power-Down and Self-Refresh operation (all banks idle), or Active Power-Down (row Active in any bank). CKE is asynchronous for Self-Refresh exit. After VREFCA and VREFDQ have become stable during the power on and initialization sequence, they must be maintained for proper operation (including Self-Refresh). CKE must be maintained high throughout read and write accesses. Input buffers, excluding CK, $\overline{CK}$, ODT, and CKE are disabled during Power Down. Input buffers, excluding CKE are disabled during Self-Refresh.
$\overline{CS}$	Input	**Chip Select:** All commands are masked when $\overline{CS}$ is registered HIGH. $\overline{CS}$ provides for external rank selection on systems with multiple memory ranks. $\overline{CS}$ is considered part of the command code.
$\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$	Input	**Command Inputs:** $\overline{RAS}$, $\overline{CAS}$, and $\overline{WE}$(along with $\overline{CS}$) define the command being entered.
DM, (DML, DMU)	Input	**Input Data Mask:** DM is an input mask signal for write data. Input data is masked when DM is sampled HIGH coincident with that input data during a Write access. DM is sampled on both edges of DQS. For x8 device, the function of DM or TDQS/$\overline{TDQS}$ is enabled by Mode Register A11 setting in MR1.
BA0 - BA2	Input	**Bank Address Inputs:** BA0 - BA2 define to which bank an Active, Read, Write or Precharge command is being applied. Bank address also determines which mode register is to be accessed during a MRS cycle.
A0 - A12/13	Input	**Address Inputs:** Provide the row address for Activate commands and the column address for Read/Write commands to select one location out of the memory array in the respective bank. (A10/AP and A12/$\overline{BC}$ have additional function as below. The address inputs also provide the opcode during Mode Register Set commands. A13 did not apply on x16 device.
A10 / AP	Input	**Auto-precharge:** A10 is sampled during Read/Write commands to determine whether Auto-precharge should be performed to the accessed bank after the Read/Write operation. (HIGH: Auto-precharge; LOW: no Auto-precharge). A10 is sampled during a Precharge command to determine whether the Pre-charge applies to one bank (A10 - Low) or all banks (A10 - HIGH). If only one bank is to precharged, the bank is selected by bank addresses.
A12 / $\overline{BC}$	Input	**Burst Chop:** A12/$\overline{BC}$ is sampled during Read and Write commands to determine if burst chop (on the fly) will be performed. (HIGH - no burst chop; LOW - burst chopped).
DQ	Input / Output	**Data Inputs/Output:** Bi-directional data bus.
DQU, DQL DQS, $\overline{DQS}$ DQSL, $\overline{DQSL}$ DQSU, $\overline{DQSU}$	Input / Output	**Data Strobe:** output with read data, input with write data. Edge aligned with read data, centered with write data. For the x16, DQSL corresponds to the data on DQL0 - DQL7; DQSU corresponds to the data on DQU0-DQU7. The data strobes DQS, DQSL, DQSU are paired with differential signals DQS, DQSL, DQSU, respectively, to provide differential pair signaling to the system during both reads and writes. DDR3 SDRAM supports differential data strobe only and does not support single-ended.
TDQS, $\overline{TDQS}$	Output	**Termination Data Strobe:** TDQS/$\overline{TDQS}$ is applicable for x8 DRAMs only. When enabled via Mode Register A11 = 1 in MR1, the DRAM will enable the same termination resistance function on TDQS/$\overline{TDQS}$ that is applied to DQS/$\overline{DQS}$. When disabled via mode register A11 = 0 in MR1, DM/TDQS will provide the data mask function and $\overline{TDQS}$ is not used. x4/x16 DRAMs must disable the TDQS function via mode register A11 = 0 in MR1.
ODT	Input	**On Die Termination:** ODT (registered HIGH) enables termination resistance internal to the DDR3 SDRAM. When enabled, ODT is applied to each DQ, DQS, $\overline{DQS}$ and DM/TDQS, NU/$\overline{TDQS}$ (when TDQS is enabled via Mode Register A11=1 in MR1) signal for x4 and x8 configurations. For x16 configuration ODT is applied to each DQ, DQSU, $\overline{DQSU}$, DQSL, $\overline{DQSL}$, DMU and DML signal. The ODT pin will be ignored if MR1and MR2 are programmed to disable RTT.
$\overline{RESET}$	Input	**Active Low Asynchronous Reset:** Reset is active when $\overline{RESET}$ is LOW, and inactive when $\overline{RESET}$ is HIGH. $\overline{RESET}$ must be HIGH during normal operation. $\overline{RESET}$ is a CMOS rail to rail signal with DC high and low at 80% and 20% of VDD, i.e. 1.20V for DC high and 0.30V for DC low.
NC		**No Connect:** No internal electrical connection is present.
V_{DDQ}	Supply	**DQ Power Supply:** 1.5V +/- 0.075V

Input/Output Functional Description

Symbol	Type	Function
V_{DD}	Supply	**Power Supply:** 1.5V +/- 0.075V
V_{SSQ}	Supply	**DQ Ground**
V_{SS}	Supply	**Ground**
V_{REFCA}	Reference	**Reference voltage for CA**
V_{REFDQ}	Reference	**Reference voltage for DQ**
ZQ	Reference	**Reference pin for ZQ calibration**
Note: Input only pins (BA0-BA2, A0-A13, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$, CKE, ODT, and $\overline{RESET}$) do not supply termination.		

DDR3 SDRAM Addressing

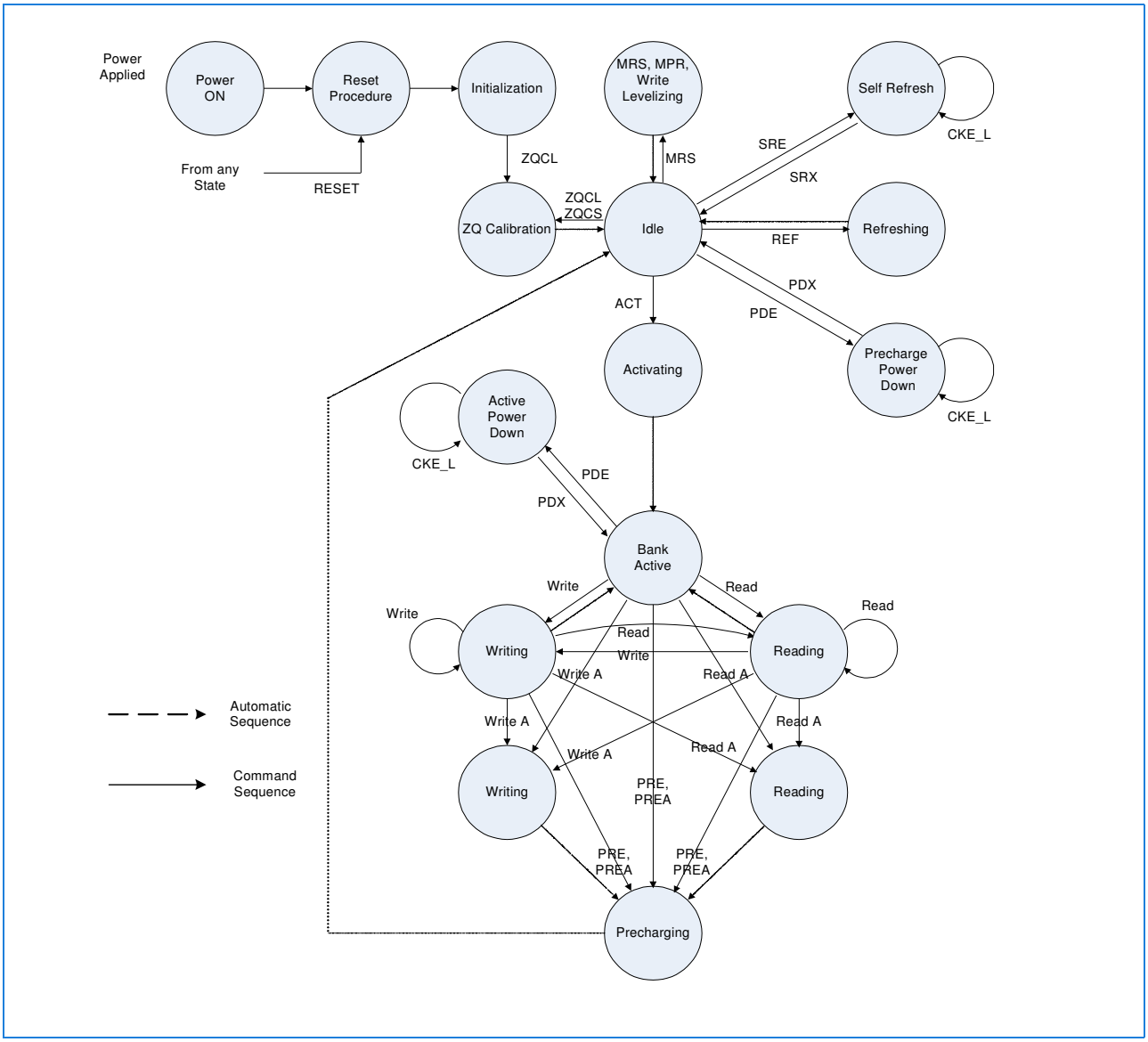
Configuration	NT5CB256M4AN	NT5CB128M8AN	NT5CB64M16AP
# of Banks	8	8	8
Bank Address	BA0 - BA2	BA0 - BA2	BA0 - BA2
Auto precharge	A10 / AP	A10 / AP	A10 / AP
BL switch on the fly	A12 / $\overline{BC}$	A12 / $\overline{BC}$	A12 / $\overline{BC}$
Row Address	A0 - A13	A0 - A13	A0 - A12
Column Address	A0 - A9, A11	A0 - A9	A0 - A9
Page size	1KB	1KB	2KB

Note:
Page size is the number of data delivered from the array to the internal sense amplifiers when an ACTIVE command is registered.
Page size is per bank, calculated as follows:

Page size = $2^{COLBITS} * ORG / 8$

COLBITS = the number of column address bits
ORT = the number of I/O (DQ) bits

Simplified State Diagram



State Diagram Command Definitions

Abbreviation	Function	Abbreviation	Function	Abbreviation	Function
ACT	Active	Read	RD, RDS4, RDS8	PED	Enter Power-down
PRE	Precharge	Read A	RDA, RDAS4, RDAS8	PDX	Exit Power-down
PREA	Precharge All	Write	WR, WRS4, WRS8	SRE	Self-Refresh entry
MRS	Mode Register Set	Write A	WRA, WRAS4, WRAS8	SRX	Self-Refresh exit
REF	Refresh	$\overline{\text{RESET}}$	Start RESET Procedure	MPR	Multi-Purpose Register
ZQCL	ZQ Calibration Long	ZQCS	ZQ Calibration Short	-	-

Basic Functionality

The DDR3 SDRAM is a high-speed dynamic random access memory internally configured as an eight-bank DRAM. The DDR3 SDRAM uses a 8n prefetch architecture to achieve high speed operation. The 8n prefetch architecture is combined with an interface designed to transfer two data words per clock cycle at the I/O pins. A single read or write operation for the DDR3 SDRAM consists of a single 8n-bit wide, four clock data transfer at the internal DRAM core and two corresponding n-bit wide, one-half clock cycle data transfers at the I/O pins.

Read and write operation to the DDR3 SDRAM are burst oriented, start at a selected location, and continue for a burst length of eight or a 'chopped' burst of fourin a programmed sequence. Operation begins with the registration of an Active command, which is then followed by a Read or Write command. The address bits registered coincident with the Active command are used to select the bank and row to be activated (BA0-BA2 select the bank; A0-A13 select the row). The address bit registered coincident with the Read or Write command are used to select the starting column location for the burst operation, determine if the auto precharge command is to be issued (via A10), and select BC4 or BC8 mode 'on the fly' (via A12) if enabled in the mode register.

Prior to normal operation, the DDR3 SDRAM must be powered up and initialized in a predefined manner. The following sections provide detailed information convering device reset and initialization, register definition, command descriptions and device operation.

DRAM Initialization and RESET

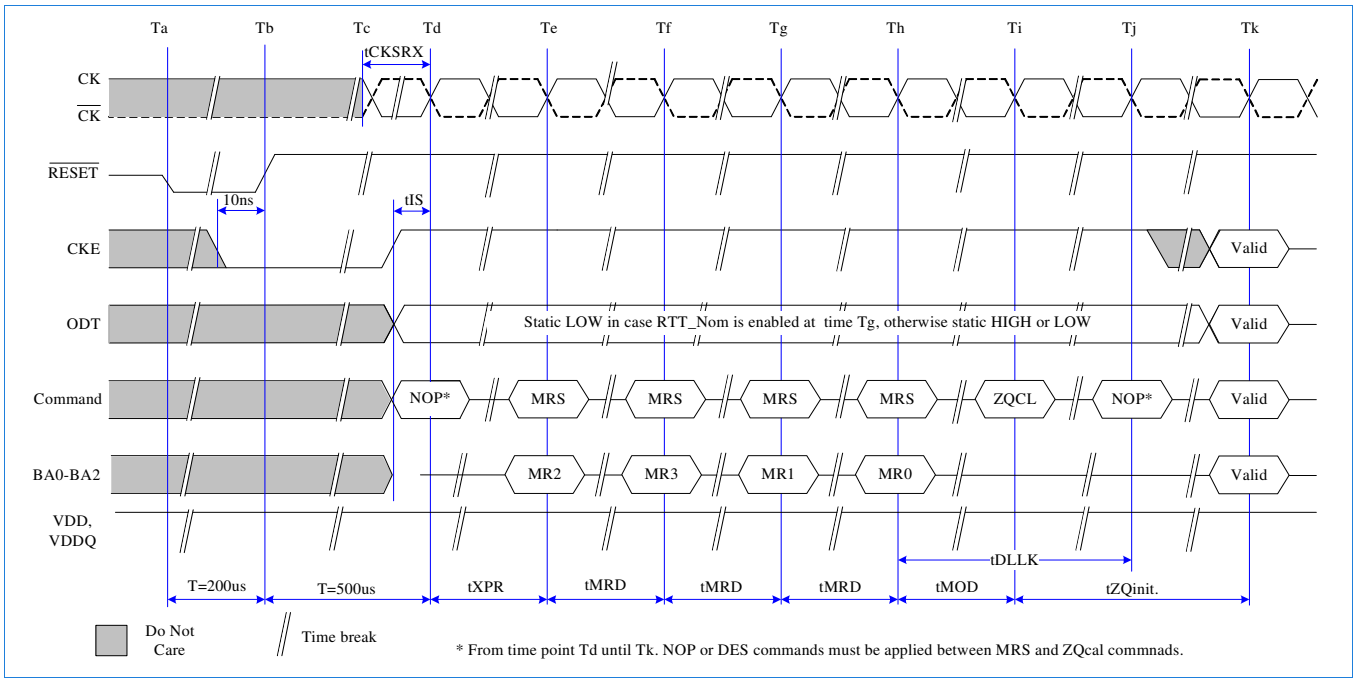
Power-up Initialization sequence

The Following sequence is required for POWER UP and Initialization

1. Apply power ($\overline{\text{RESET}}$ is recommanded to be maintained below 0.2 x VDD, all other inputs may be undefined). $\overline{\text{RESET}}$ needs to be maintained for minimum 200us with stable power. CKE is pulled “Low” anytime before $\overline{\text{RESET}}$ being de-asserted (min. time 10ns). The power voltage ramp time between 300mV to VDDmin must be no greater than 200ms; and during the ramp, VDD>VDDQ and (VDD-VDDQ)<0.3 Volts.
   - VDD and VDDQ are driven from a single power converter output, AND
   - The voltage levels on all pins other than VDD, VDDQ, VSS, VSSQ must be less than or equal to VDDQ and VDD on one side and must be larger than or equal to VSSQ and VSS on the other side. In addition, VTT is limited to 0.95V max once power ramp is finished, AND
   - Vref tracks VDDQ/2.

   OR
   - Apply VDD without any slope reversal before or at the same time as VDDQ.
   - Apply VDDQ without any slope reversal before or at the same time as VTT & Vref.
   - The voltage levels on all pins other than VDD, VDDQ, VSS, VSSQ must be less than or equal to VDDQ and VDD on one side and must be larger than or equal to VSSQ and VSS on the other side.
2. After $\overline{\text{RESET}}$ is de-asserted, wait for another 500us until CKE become active. During this time, the DRAM will start internal state initialization; this will be done independently of external clocks.
3. Clock (CK, $\overline{\text{CK}}$) need to be started and stablized for at least 10ns or 5tCK (which is larger) before CKE goes active. Since CKE is a synchronous signal, the corresponding set up time to clock (tIS) must be meet. Also a NOP or Deselect command must be registered (with tIS set up time to clock) before CKE goes active. Once the CKE registered “High” after Reset, CKE needs to be continuously registered “High” until the initialization sequence is finished, including expiration of tDLLK and tZQinit.
4. The DDR3 DRAM will keep its on-die termination in high impedance state as long as $\overline{\text{RESET}}$ is asserted. Further, the DRAM keeps its on-die termination in high impedance state after RESET deassertion until CKE is registered HIGH. The ODT input signal may be in undefined state until tIS before CKE is registered HIGH. When CKE is registered HIGH, the ODT input signal may be statically held at either LOW or HIGH. If RTT_NOM is to be enabled in MR1, the ODT input signal must be statically held LOW. In all cases, the ODT input signal remains static until the power up initialization sequence is finished, including the expiration of tDLLK and tZQinit.
5. After CKE being registered high, wait minimum of Reset CKE Exit time, tXPR, before issuing the first MRS command to load mode register. [tXPR=max(tXS, 5tCK)]
6. Issue MRS Command to load MR2 with all application settings. (To issue MRS command for MR2, provide “Low” to BA0 and BA2, “High” to BA1)
7. Issue MRS Command to load MR3 with all application settings. (To issue MRS command for MR3, provide “Low” to BA2, “High” to BA0 and BA1)
8. Issue MRS command to load MR1 with all application setings and DLL enabled. (To issue “DLL Enable” command, provide “Low” to A0, “High” to BA0 and “Low” to BA1 and BA2)
9. Issue MRS Command to load MR0 with all application settings and “DLL reset”. (To issue DLL reset command, provide “High” to A8 and “Low” to BA0-BA2)
10. Issue ZQCL command to starting ZQ calibration.
11. Wait for both tDLLK and tZQinit completed.
12. The DDR3 SDRAM is now ready for normal operation.

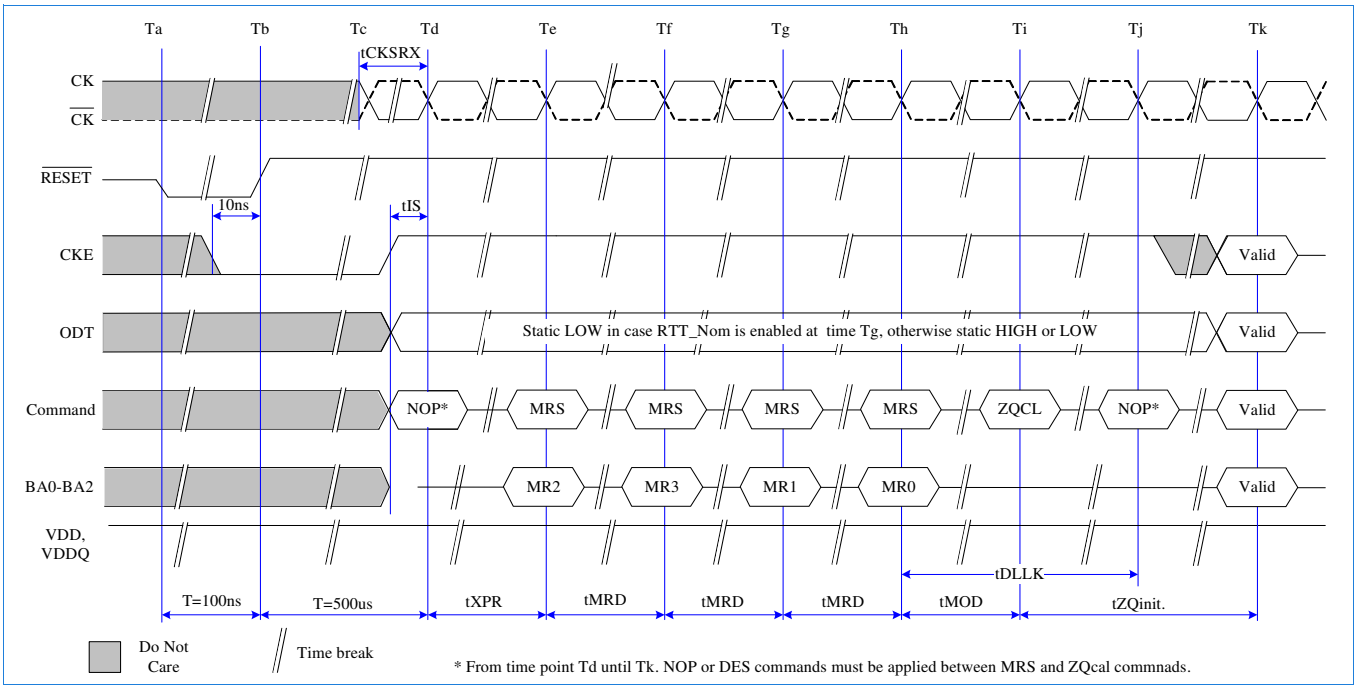
DDR3 Reset and Initialization Sequence at Power-on Ramping



DDR3 Reset Procedure at Power Stable Condition

The following sequence is required for RESET at no power interruption initialization.

1. Asserted RESET below 0.2*VDD anytime when reset is needed (all other inputs may be undefined). RESET needs to be maintained for minimum 100ns. CKE is pulled “Low” before RESET being de-asserted (min. time 10ns).
2. Follow Power-up Initialization Sequence step 2 to 11.
3. The Reset sequence is now completed, DDR3 SDRAM is ready for normal operation.

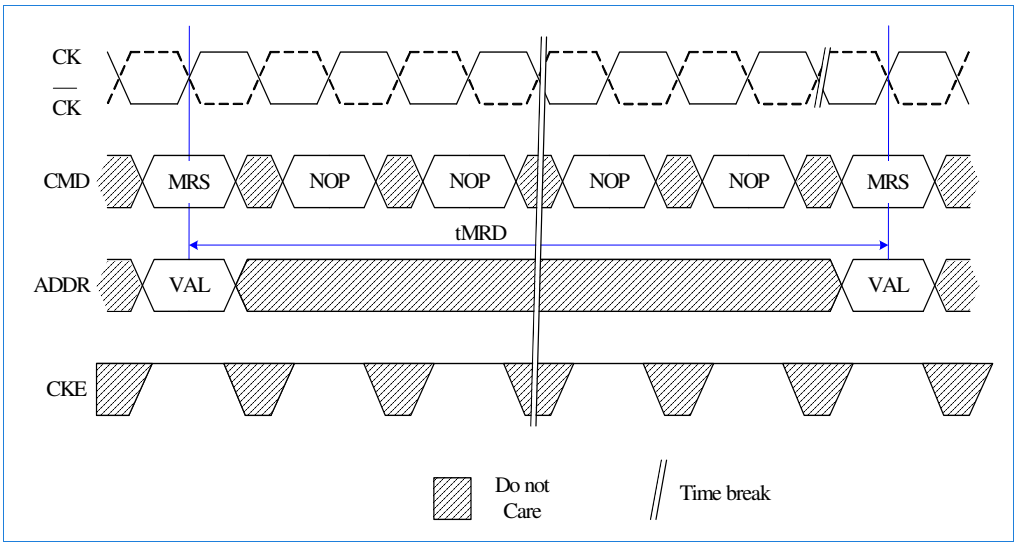


Register Definition

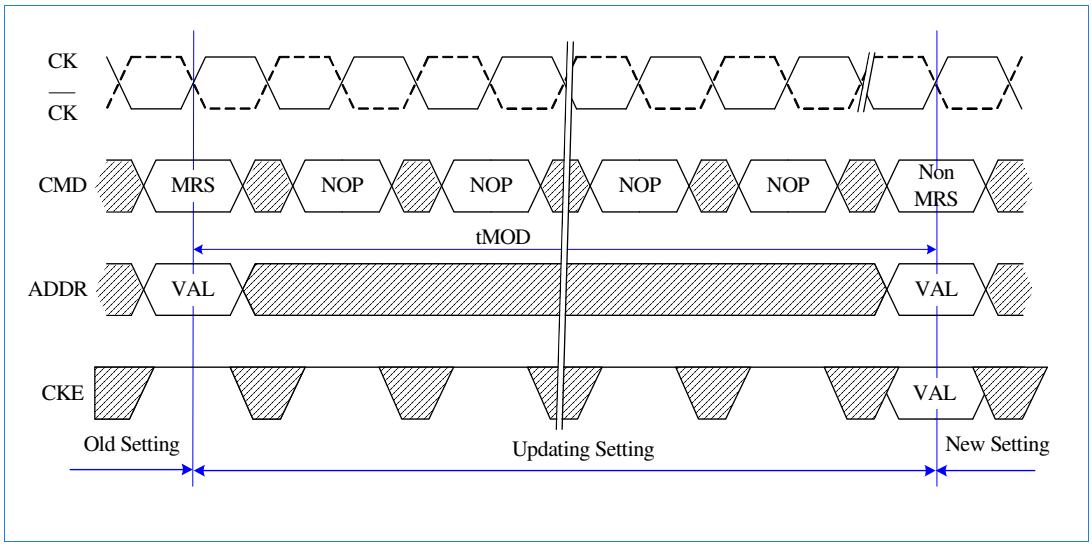
Programming the Mode Registers

For application flexibility, various functions, features, and modes are programmable in four Mode Registers, provided by the DDR3 SDRAM, as user defined variables and they must be programmed via a Mode Register Set (MRS) command. As the default values of the Mode Registers (MR#) are not defined, contents of Mode Registers must be fully initialized and/or re-initialized, i.e. written, after power up and/or reset for proper operation. Also the contents of the Mode Registers can be altered by re-executing the MRS command during normal operation. When programming the mode registers, even if the user chooses to modify only a sub-set of the MRS fields, all address fields within the accessed mode register must be redefined when the MRS command is issued. MRS command and DLL Reset do not affect array contents, which means these commands can be executed any time after power-up without affecting the array contents

The mode register set command cycle time, tMRD is required to complete the write operation to the mode register and is the minimum time required between two MRS commands shown as below.



The MRS command to Non-MRS command delay, tMOD, is require for the DRAM to update the features except DLL reset, and is the minimum time required from an MRS command to a non-MRS command excluding NOP and DES shown as the following figure.



The mode register contents can be changed using the same command and timing requirements during normal operation as long as the DRAM is in idle state, i.e. all banks are in the precharged state with tRP satisfied, all data bursts are completed and CKE is high prior to writing into the mode register. The mode registers are divided into various fields depending on the functionality and/or modes.

The mode register MR0 stores data for controlling various operating modes of DDR3 SDRAM. It controls burst length, read burst type, CAS latency, test mode, DLL reset, WR, and DLL control for precharge Power-Down, which include various vendor specific options to make DDR3 SDRAM useful for various applications. The mode register is written by asserting low on $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$, BA0, BA1, and BA2, while controlling the states of address pins according to the following figure.

MR0 Definition

Address Filed

BA2*	BA1	BA0	A13*	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0

MRS mode

BA1	BA0	MRS mode
0	0	**MR0**
0	1	**MR1**
1	0	**MR2**
1	1	**MR3**

Burst Length

A1	A0	BL
0	0	8 (Fixed)
0	1	BC4 or 8 (on the fly)
1	0	BC4 (Fixed)
1	1	Reserved

Burst Type

A3	Burst Type
0	Nibble Sequential
1	Interleave

Precharge Power Down

A12	DLL Control for Precharge PD
0	Slow Exit (Low Power)
1	Fast Exit (Normal)

CAS Latency

A6	A5	A4	A2	CAS Latency
0	0	0	0	Reserved
0	0	1	0	5
0	1	0	0	6
0	1	1	0	7
1	0	0	0	8
1	0	1	0	9
1	1	0	0	10
1	1	0	0	Reserved

Write recovery for autoprecharge**

A11	A10	A9	WR(cycles)
0	0	0	Reserved
0	0	1	5
0	1	0	6
0	1	1	7
1	0	0	8
1	0	1	10
1	1	0	12
1	1	1	Reserved

Mode

A7	Mode
0	Normal
1	TEST

DLL Reset

A8	DLL Reset
0	NO
1	YES

* BA2 and A13 are reserved for future use and must be set to 0 when programming the MR.
**WR(write recovery for autoprecharge)min in clock cycles is calculated by dividing tWR (ns) by tCK (ns) and rounding up to the next integer: Wrmin[cycles] = Roundup(tWR/tCK). The value in the mode register must be programmed to be equal or larger than WRmin. The programmed WR value is used with tRP to determine tDAL.

Burst Length, Type, and Order

Accesses within a given burst may be programmed to sequential or interleaved order. The burst type is selected via bit A3 as shown in the MR0 Definition as above figure. The ordering of access within a burst is determined by the burst length, burst type, and the starting column address. The burst length is defined by bits A0-A1. Burst length options include fix BC4, fixed BL8, and on the fly which allow BC4 or BL8 to be selected coincident with the registration of a Read or Write command via A12/BC.

Burst Type and Burst Order

Burst Length	Read/ Write	Starting Column Address (A2,A1,A0)	Burst type = Sequential (decimal) A3 = 0	Burst type = Interleaved (decimal) A3 = 1	Note
4 Chop	Read	000	0,1,2,3,T,T,T,T	0,1,2,3,T,T,T,T	1,2,3
		001	1,2,3,0,T,T,T,T	1,0,3,2,T,T,T,T	
		010	2,3,0,1,T,T,T,T	2,3,0,1,T,T,T,T	
		011	3,0,1,2,T,T,T,T	3,2,1,0,T,T,T,T	
		100	4,5,6,7,T,T,T,T	4,5,6,7,T,T,T,T	
		101	5,6,7,4,T,T,T,T	5,4,7,6,T,T,T,T	
		110	6,7,4,5,T,T,T,T	6,7,4,5,T,T,T,T	
		111	7,4,5,6,T,T,T,T	7,6,5,4,T,T,T,T	
	Write	0,V,V	0,1,2,3,x,x,x,x	0,1,2,3,x,x,x,x	1,2,4,5
		1,V,V	4,5,6,7,x,x,x,x	4,5,6,7,x,x,x,x	
8	Read	000	0,1,2,3,4,5,6,7	0,1,2,3,4,5,6,7	2
		001	1,2,3,0,5,6,7,4	1,0,3,2,5,4,7,6	
		010	2,3,0,1,6,7,4,5	2,3,0,1,6,7,4,5	
		011	3,0,1,2,7,4,5,6	3,2,1,0,7,6,5,4	
		100	4,5,6,7,0,1,2,3	4,5,6,7,0,1,2,3	
		101	5,6,7,4,1,2,3,0	5,4,7,6,1,0,3,2	
		110	6,7,4,5,2,3,0,1	6,7,4,5,2,3,0,1	
		111	7,4,5,6,3,0,1,2	7,6,5,4,3,2,1,0	
	Write	V,V,V	0,1,2,3,4,5,6,7	0,1,2,3,4,5,6,7	2,4

Note:
1. In case of burst length being fixed to 4 by MR0 setting, the internal write operation starts two clock cycles earlier than the BL8 mode. This means that the starting point for tWR and tWTR will be pulled in by two clocks. In case of burst length being selected on-th-fly via A12/BC, the internal write operation starts at the same point in time like a burst of 8 write operation. This means that during on-the-fly control, the starting point for tWR and tWTR will not be pulled in by two clocks.
2. 0~7 bit number is value of CA[2:0] that causes this bit to be the first read during a burst.
3. T: Output driver for data and strobes are in high impedance.
4. V: a valid logic level (0 or 1), but respective buffer input ignores level on input pins.
5. X: Do not Care.

CAS Latency

The CAS Latency is defined by MR0 (bit A9~A11) as shown in the MR0 Definition figure. CAS Latency is the delay, in clock cycles, between the internal Read command and the availability of the first bit of output data. DDR3 SDRAM does not support any half clock latencies. The overall Read Latency (RL) is defined as Additive Latency (AL) + CAS Latency (CL); RL = AL + CL.

Test Mode

The normal operatig mode is selected by MR0 (bit7=0) and all other bits set to the desired values shown in the MR0 defination figure. Programming bit A7 to a '1' places the DDR3 SDRAM into a test mode that is only used by the DRAM manufacturer and should not be used. No operations or functionality is guarenteed if A7=1.

DLL Reset

The DLL Reset bit is self-clearing, meaning it returns back to the value of '0' after the DLL reset function has been issued. Once the DLL is enabled, a subsequent DLL Reset should be applied. Anytime the DLL reset function is used, tDLLK must be met before any functions that require the DLL can be used. (i.e. Read commands or ODT synchronous operations)

Precharge PD DLL

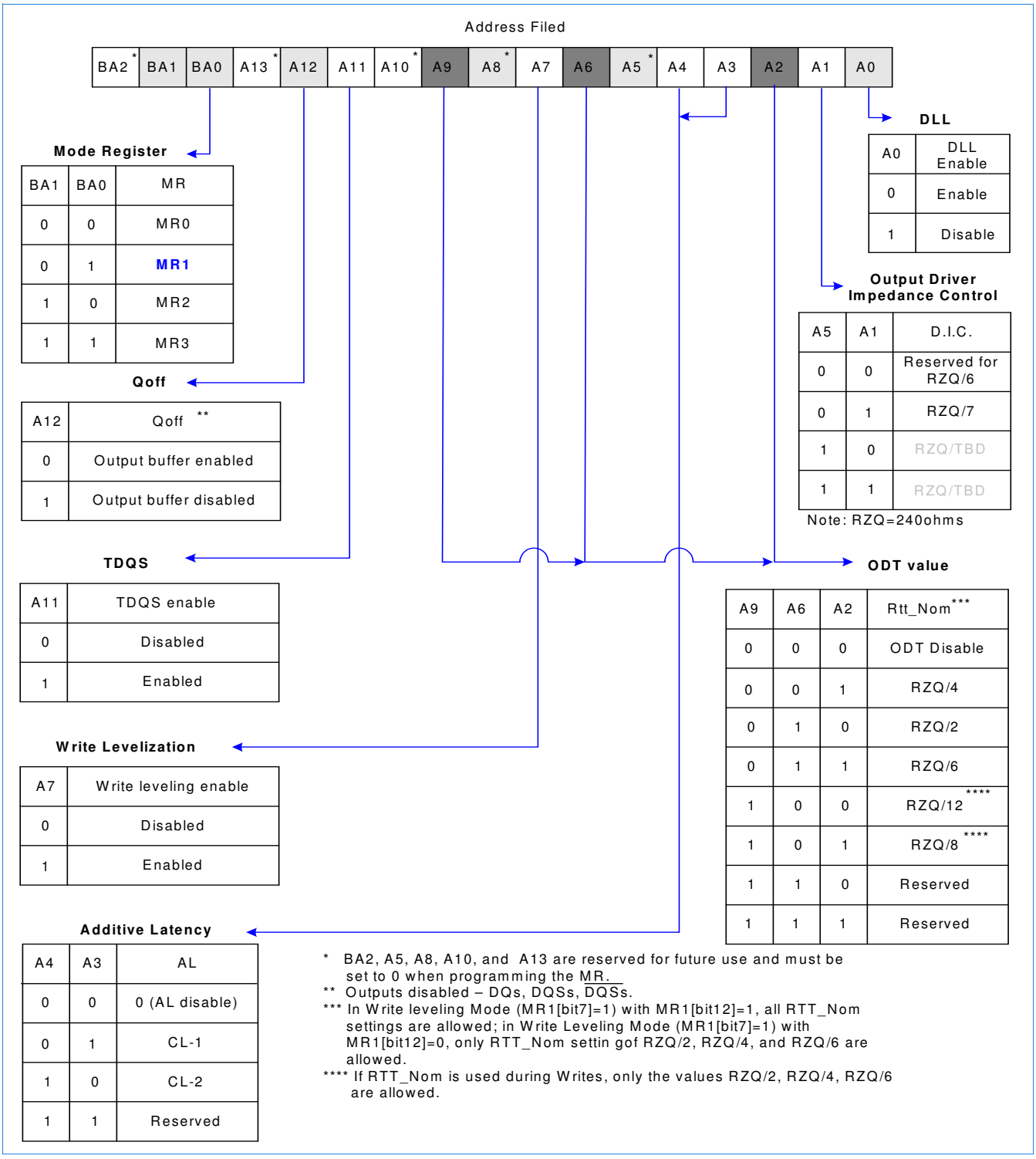
MR0 (bit A12) is used to select the DLL usage during precharge power-down mode. When MR0 (A12=0), or 'slow-exit', the DLL is frozen after entering precharge power-down (for potential power savings) and upon exit requires tXPDLL to be met prior to the next valid command. When MR0 (A12=1), or 'fast-exit', the DLL is maintained after entering precharge power-down and upon exiting power-down requires tXP to be met prior to the next valid command.

Write Recovery

The programmed WR value MR0(bits A9, A10, and A11) is used for the auto precharge feature along with tRP to determine tDAL WR (write recovery for auto-precharge)min in clock cycles is calculated by dividing tWR(ns) by tCK(ns) and rounding up to the next integer: WRmin[cycles] = Roundup(tWR[ns]/tCK[ns]). The WR must be programmed to be equal or larger than tWR(min).

Mode Register MR1

The Mode Register MR1 stores the data for enabling or disabling the DLL, output strength, Rtt_Nom impedance, additive latency, Write leveling enable and Qoff. The Mode Register 1 is written by asserting low on CS, RAS, CAS, WE, high on BA0 and low on BA1 and BA2, while controlling the states of address pins according to the following figure.



DLL Enable/Disable

The DLL must be enabled for normal operation. DLL enable is required during power up initizlization, and upon returning to normal operation after having the DLL disabled. During normal operation (DLL-on) with MR1 (A0=0), the DLL is automatically disabled when entering Self-Refresh operation and is automatically re-enable upon exit of Self-Refresh operation. Any time the DLL is enabled and subsequently reset, tDLLK clock cycles must occur before a Read or synchronous ODT command can be issued to allow time for the internal clock to be synchronized with the external clock. Failing to wait for synchronization to occur may result in a violation of the tDQSCK, tAON, or tAOF parameters. During tDLLK, CKE must continuously be registered high. DDR3 SDRAM does not require DLL for any Write operation, expect when RTT_WR is enabled and the DLL is required for proper ODT operation. For more detailed information on DLL Disable operation in DLL-off Mode.

The direct ODT feature is not supported during DLL-off mode. The on-die termination resistors must be disabled by continuously registering the ODT pin low and/or by programming the RTT_Nom bits MR1{A9,A6,A2} to {0,0,0} via a mode register set command during DLL-off mode.

The dynamic ODT feature is not supported at DLL-off mode. User must use MRS command to set Rtt_WR, MR2{A10,A9}={0,0}, to disable Dynamic ODT externally.

Output Driver Impedance Control

The output driver impedance of the DDR3 SDRAM device is selected by MR1(bit A1 and A5) as shown in MR1 defination figure.

ODT Rtt Values

DDR3 SDRAM is capable of providing two different termination values (Rtt_Nom and Rtt_WR). The nominal termination value Rtt_Nom is programmabled in MR1. A seperate value (Rtt_WR) may be programmabled in MR2 to enable a unique Rtt value when ODT is enabled during writes. The Rtt_WR value can be applied during writes even when Rtt_Nom is disabled.

Additive Latency (AL)

Additive Latency (AL) operation is supported to make command and data bus efficient for sustainable bandwidth in DDR3 SDRAM. In this operation, the DDR3 SDRAM allows a read or write command (either with or without auto-precharge) to be issued immediately after the active command. The command is held for the time of the Additive Latency (AL) before it is issued inside the device. The Read Latency (RL) is controlled by the sum of the AL and CAS Latency (CL) register settings. Write Latency (WL) is controlled by the sum of the AL and CAS Write Latency (CWL) register settings. A summary of the AL register options are shown as the following table.

Additive Latency (AL) Settings

A4	A3	AL
0	0	0 (AL Disable)
0	1	CL-1
1	0	CL-2
1	1	Reserved

Write leveling

For better signal integrity, DDR3 memory module adopted fly by topology for the commands, addresses, control signals, and clocks. The fly by topology has benefits from reducing number of stubs and their length but in other aspect, causes flight time skew between clock and strobe at every DRAM on DIMM. It makes difficult for the Controller to maintain tDQSS, tDSS, and tDSH specification. Therefore, the controller should support ‘write leveling’ in DDR3 SDRAM to compensate for skew.

Output Disable

The DDR3 SDRAM outputs maybe enable/disabled by MR1 (bit12) as shown in MR1 defination. When this feature is enabled (A12=1) all output pins (DQs, DQS, $\overline{\text{DQS}}$, etc.) are disconnected from the device removing any loading of the output drivers. This feature may be useful when measuring modules power for example. For normal operation A12 should be set to ‘0’.

TDQS, $\overline{\text{TDQS}}$

TDQS (Termination Data Strobe) is a feature of x8 DDR3 SDRAM that provides additional termination resistance outputs that may be useful in some system configurations.

TDQS is not supported in x4 and x16 configurations. When enabled via the mode register, the same termination resistance function is applied to be TDQS/$\overline{\text{TDQS}}$ pins that is applied to the DQS/$\overline{\text{DQS}}$ pins.

In contrast to the RDQS function of DDR2 SDRAM, TDQS provides the termination resistance function only. The data strobe function of RDQS is not provided by TDQS.

The TDQS and DM functions share the same pin. When the TDQS function is enabled via the mode register, the DM function is not supported. When the TDQS function is disabled, the DM function is provided and the $\overline{\text{TDQS}}$ pin is not used.

The TDQS function is avilable in x8 DDR3 SDRAM only and must be disabled via the mode register A11=0 in MR1 for x4 and x16 configurations.

TDQS, $\overline{\text{TDQS}}$ Function Matrix

MR1 (A11)	DM / TDQS	NU / TDQS
0 (TDQS Disabled)	DM	Hi-Z
1 (TDQS Enabled)	TDQS	$\overline{\text{TDQS}}$

Note:
1. If TDQS is enabled, the DM function is disabled.
2. When not used, TDQS function can be disabled to save termination power.
3. TDQS function is only available for x8 DRAM and must be disabled for x4 and x16

Mode Register MR2

The Mode Register MR2 stores the data for controlling refresh related features, Rtt_WR impedance, and CAS write latency. The Mode Register 2 is written by asserting low on $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$, high on BA1 and low on BA0 and BA2, while controlling the states of address pins according to the table below.

Address Filed

BA2*	BA1	BA0	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0

MRS mode

BA1	BA0	MRS mode
0	0	**MR0**
0	1	**MR1**
1	0	**MR2**
1	1	**MR3**

Rtt_WR**

A10	A9	Rtt_WR
0	0	**Dynamic ODT off (Write does not affect RTT value)**
0	1	**RZQ/4**
1	0	**RZQ/2**
1	1	**Reserved**

Self-Refresh Temperature Range

A7	SRT
0	Normal Operating temperature range
1	Extended operating temperature range

Auto Self Refresh

A6	ASR
0	Manual Self Refresh Reference
1	ASR Enable

PASR

A2	A1	A0	PASR
0	0	0	Full Array
0	0	1	Half Array (000,001,010,011)
0	1	0	Quarter Array (000,001)
0	1	1	1/8th Array (000)
1	0	0	3/4 array (010, 011, 100, 101, 110, 111)
1	0	1	Half array (100, 101, 110, 111)
1	1	0	Quarter array (110, 111)
1	1	1	1/8th array (111)

CAS Write Latency

A5	A4	A3	CAS Write Latency
0	0	0	5(tCK>=2.5ns)
0	0	1	6 (2.5ns>tCK>=1.875ns)
0	1	0	7 (1.875ns>tCK>=1.5ns)
0	1	1	8 (1.5ns>tCK>=1.25ns)
1	0	0	Reserved
1	0	1	Reserved
1	1	0	Reserved
1	1	1	Reserved

* BA2, A5, A8, A13 are reserved for future use and must be set to 0 when programming the MR.
** The Rtt_WR value can be applied during writes even when Rtt_Nom is disabled. During write leveling, Dynamic ODT is not available.

Partial Array Self-Refresh (PASR)

If PASR (Partial Array Self-Refresh) is enabled, data located in areas of the array beyond the specified address range shown in MR2 will be lost if Self-Refresh is entered. Data integrity will be maintained if tREFI conditions are met and no Self-Refresh command is issued.

CAS Write Latency (CWL)

The CAS Write Latency is defined by MR2 (bits A3-A5) shown in MR2. CAS Write Latency is the delay, in clock cycles, between the internal Write command and the availability of the first bit of input data. DDR3 DRAM does not support any half clock latencies. The overall Write Latency (WL) is defined as Additive Latency (AL) + CAS Write Latency (CWL); WL=AL+CWL.

Auto Self-Refresh (ASR) and Self-Refresh Temperature (SRT)

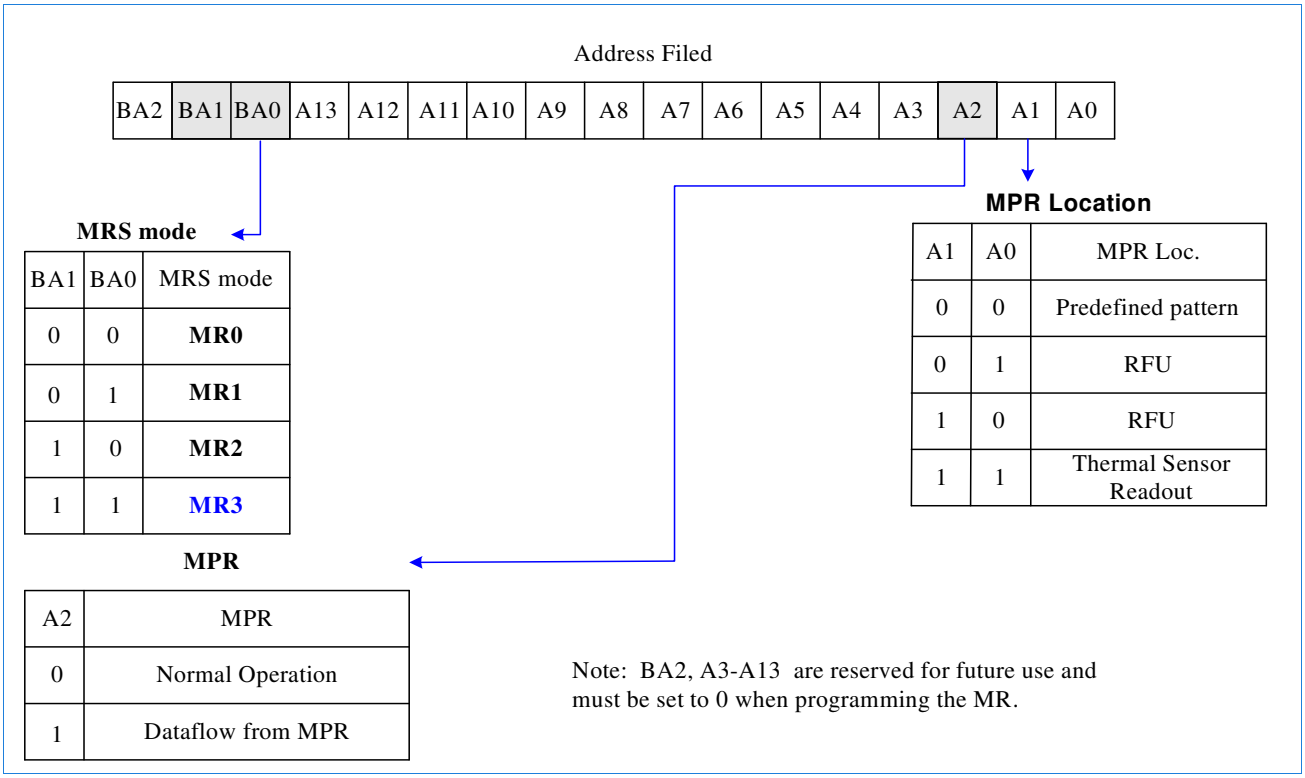
DDR3 SDRAM must support Self-Refresh operation at all supported temperatures. Applications requiring Self-Refresh operation in the Extended Temperature Range must use the ASR function or program the SRT bit appropriately.

Dynamic ODT (Rtt_WR)

DDR3 SDRAM introduces a new feature “Dynamic ODT”. In certain application cases and to further enhance signal integrity on the data bus, it is desireable that the termination strength of the DDR3 SDRAM can be changed without issuing an MRS command. MR2 Register locations A9 and A10 configure the Dynamic ODT settings.

Mode Register MR3

The Mode Register MR3 controls Multi purpose registers. The Mode Register 3 is written by asserting low on $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$, high on BA1 and BA0, and low on BA2 while controlling the states of address pins according to the table below.



BA1	BA0	MRS mode
0	0	**MR0**
0	1	**MR1**
1	0	**MR2**
1	1	**MR3**

A1	A0	MPR Loc.
0	0	Predefined pattern
0	1	RFU
1	0	RFU
1	1	Thermal Sensor Readout

A2	MPR
0	Normal Operation
1	Dataflow from MPR

Note: BA2, A3-A13 are reserved for future use and must be set to 0 when programming the MR.

Multi-Purpose Register (MPR)

The Multi Purpose Register (MPR) function is used to Read out a predefined system timing calibration bit sequence. To enable the MPR, a Mode Register Set (MRS) command must be issued to MR3 register with bit A2=1. Prior to issuing the MRS command, all banks must be in the idle state (all banks precharged and tRP met). Once the MPR is enabled, any subsequent RD or RDA commands will be redirected to the Multi Purpose Register. When the MPR is enabled, only RD or RDA commands are allowed until a subsequent MRS command is issued with the MPR disabled (MR3 bit A2=0). Power down mode, Self-Refresh, and any other non-RD/RDA command is not allowed during MPR enable mode. The RESET function is supported during MPR enable mode.

DDR3 SDRAM Command Description and Operation

Command Truth Table

Function	Abbreviation	CKE		$\overline{CS}$	$\overline{RAS}$	$\overline{CAS}$	$\overline{WE}$	BA0-BA2	A13	A12-$\overline{BC}$	A10-AP	A0-A9, A11	Notes
		Previous Cycle	Current Cycle										
Mode Register Set	MRS	H	H	L	L	L	L	BA	OP Code				
Refresh	REF	H	H	L	L	L	H	V	V	V	V	V	
Self Refresh Entry	SRE	H	L	L	L	L	H	V	V	V	V	V	7,9,12
Self Refresh Exit	SRX	L	H	H	V	V	V	V	V	V	V	V	7,8,9,12
				L	H	H	H						
Single Bank Precharge	PRE	H	H	L	L	H	L	BA	V	V	L	V	
Precharge all Banks	PREA	H	H	L	L	H	L	V	V	V	H	V	
Bank Activate	ACT	H	H	L	L	H	H	BA	Row Address (RA)				
Write (Fixed BL8 or BC4)	WR	H	H	L	H	L	L	BA	RFU	V	L	CA	
Write (BC4, on the fly)	WRS4	H	H	L	H	L	L	BA	RFU	L	L	CA	
Write (BL8, on the fly)	WRS8	H	H	L	H	L	L	BA	RFU	H	L	CA	
Write with Auto Precharge (Fixed BL8 or BC4)	WRA	H	H	L	H	L	L	BA	RFU	V	H	CA	
Write with Auto Precharge (BC4, on the fly)	WRAS4	H	H	L	H	L	L	BA	RFU	L	H	CA	
Write with Auto Precharge (BL8, on the fly)	WRAS8	H	H	L	H	L	L	BA	RFU	H	H	CA	
Read (Fixed BL8 or BC4)	RD	H	H	L	H	L	H	BA	RFU	V	L	CA	
Read (BC4, on the fly)	RDS4	H	H	L	H	L	H	BA	RFU	L	L	CA	
Read (BL8, on the fly)	RDS8	H	H	L	H	L	H	BA	RFU	H	L	CA	
Read with Auto Precharge (Fixed BL8 or BL4)	RDA	H	H	L	H	L	H	BA	RFU	V	H	CA	
Read with Auto Precharge (BC4, on the fly)	RDAS4	H	H	L	H	L	H	BA	RFU	L	H	CA	

Note: (Note1-4 apply to the entire command Truth Table; Note 5 applies to all Read/Write command)
[BA=Bank Address, RA=Rank Address, CA=Column Address, $\overline{BC}$=Burst Chop, X=Do not care, V=Valid]
1. All DDR3 SDRAM commands are defined by states of $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$, and CKE at the rising edge of the clock. The MSB of BA, RA, and CA are device density and configuration dependent.
2. $\overline{RESET}$ is Low enable command which will be used only for asynchronous reset so must be maintained HIGH during any function.
3. Bank Address (BA) determine which bank is to be operated upon. For (E)MRS BA selects an (Extended) Mode Register.
4. “V” means “H or L (but a defined logic level)” and “X” means either “defined or undefined (like floating) logic level”.
5. Burst reads or writes cannot be terminated or interrupted and Fixed/on the fly BL will be defined by MRS.
6. The Power Down Mode does not perform any refresh operation.
7. The state of ODT does not affect the states described in this table. The ODT function is not available during Self Refresh.
8. Self Refresh Exit is asynchronous.
9. Vref (Both VrefDQ and VrefCA) must be maintained during Self Refresh operation.
10. The No Operation command should be used in cases when the DDR3 SDRAM is in an idle or wait state. The purpose of the No Operation command (NOP) is to prevent the DDR3 SDRAM from registering any unwanted commands between operations. A No Operation command will not terminate a pervious operation that is still executing, such as a burst read or write cycle.
11. The Deselect command performs the same function as No Operation command.
12. Refer to the CKE Truth Table for more detail with CKE transition.

Function	Abbreviation	CKE		$\overline{CS}$	$\overline{RAS}$	$\overline{CAS}$	$\overline{WE}$	BA0-BA2	A13	A12-$\overline{BC}$	A10-AP	A0-A9, A11	Notes
		Previous Cycle	Current Cycle										
Read with Auto Precharge (BL8, on the fly)	RDAS8	H	H	L	H	L	H	BA	RFU	H	H	CA	
No Operation	NOP	H	H	L	H	H	H	V	V	V	V	V	10
Device Deselected	DES	H	H	H	X	X	X	X	X	X	X	X	11
Power Down Entry	PDE	H	L	L	H	H	H	V	V	V	V	V	6,12
				H	V	V	V						
Power Down Exit	PDX	L	H	L	H	H	H	V	V	V	V	V	6,12
				H	V	V	V						
ZQ Calibration Long	ZQCL	H	H	L	H	H	L	X	X	X	H	X	
ZQ Calibration Short	ZQCS	H	H	L	H	H	L	X	X	X	L	X	

Note: (Note1-4 apply to the entire command Truth Table; Note 5 applies to all Read/Write command)
[BA=Bank Address, RA=Rank Address, CA=Column Address, $\overline{BC}$=Burst Chop, X=Do not care, V=Valid]
1. All DDR3 SDRAM commands are defined by states of $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$, and CKE at the rising edge of the clock. The MSB of BA, RA, and CA are device density and configuration dependent.
2. $\overline{RESET}$ is Low enable command which will be used only for asynchronous reset so must be maintained HIGH during any function.
3. Bank Address (BA) determine which bank is to be operated upon. For (E)MRS BA selects an (Extended) Mode Register.
4. “V” means “H or L (but a defined logic level)” and “X” means either “defined or undefined (like floating) logic level”.
5. Burst reads or writes cannot be terminated or interrupted and Fixed/on the fly BL will be defined by MRS.
6. The Power Down Mode does not perform any refresh operation.
7. The state of ODT does not affect the states described in this table. The ODT function is not available during Self Refresh.
8. Self Refresh Exit is asynchronous.
9. Vref (Both VrefDQ and VrefCA) must be maintained during Self Refresh operation.
10. The No Operation command should be used in cases when the DDR3 SDRAM is in an idle or wait state. The purpose of the No Operation command (NOP) is to prevent the DDR3 SDRAM from registering any unwanted commands between operations. A No Operation command will not terminate a pervious operation that is still executing, such as a burst read or write cycle.
11. The Deselect command performs the same function as No Operation command.
12. Refer to the CKE Truth Table for more detail with CKE transition.

CKE Truth Table

Current State	CKE		Command (N) $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$, $\overline{CS}$	Action(N)	Notes
	Previous Cycle (N-1)	Current Cycle (N)			
Power-Down	L	L	X	Maintain Power-Down	14,15
	L	H	Deselect or NOP	Power-Down Exit	11,14
Self-Refresh	L	L	X	Maintain Self-Refresh	15,16
	L	H	Deselect or NOP	Self-Refresh Exit	8,12,16
Bank(s) Active	H	L	Deselect or NOP	Active Power-Down Entry	11,13,14
Reading	H	L	Deselect or NOP	Power-Down Entry	11,13,14,17
Writing	H	L	Deselect or NOP	Power-Down Entry	11,13,14,17
Precharging	H	L	Deselect or NOP	Power-Down Entry	11,13,14,17
Refreshing	H	L	Deselect or NOP	Precharge Power-Down Entry	11
All Banks Idle	H	L	Deselect or NOP	Precharge Power-Down Entry	11,13,14,18
	H	L	Refresh	Self-Refresh	9,13,18

Note: (Note1-7 apply to the entire CKE Truth Table; CKE low is allowed only if tMRD and tMOD are satisfied)
1. CKE (N) is the logic state of CKE at clock edge N; CKE (N-1) was the state of CKE at the previous clock edge.
2. Current state is defined as the state of the DDR3 SDRAM immediately prior to clock edge N.
3. Command (N) is the command registered at clock edge N, and Action (N) is a result of Command (N), ODT is not included here.
4. All states and sequences not shown are illegal or reserved unless explicitly described elsewhere in this document.
5. The state of ODT does not affect the states described in this table. The ODT function is nto available during Self-Refresh.
6. CKE must be registered with the same value on tCKEmin consecutive positive clock edges. CKE must remain at the valid input level the entire time it takes to achieve the tCKEmin clocks of registeration. Thus, after any CKE transition, CKE may not transition from its valid level during the time period of tIS + tCKEmin + tIH.
7. Deselect and NOP are defined in the Command Truth Table.
8. On Self-Refresh Exit Deselect or NOP commands must be issued on every clock edge occurring during the tXS period. Read or ODT commands may be issued only after tXSDLL is satisfied.
9. Self-Refresh mode can only be entered from the All Banks Idle state.
10. Must be a legal command as defined in the Command Truth Table.
11. Valid commands for Power-Down Entry and Exit are NOP and Deselect only.
12. Valid commands for Self-Refresh Exit are NOP and Deselect only.
13. Self-Refresh can not be entered during Read or Write operations.
14. The Power-Down does not perform any refresh operations.
15. “X” means “Do not Care” (including floating around Vref) in Self-Refresh and Power-Down. It also applies to Address pins.
16. Vref (Both Vref_DQ and Vref_CA) must be maintained during Self-Refresh operation.
17. If all banks are closed at the conclusion of the read, write, or precharge command, then Precharge Power-Down is entered, otherwise Active Power-Down is entered.
18. “Idle State” is defined as all banks are close (tRP, tDAL, etc. satisified), no data bursts are in progress, CKE is high, and all timings from previous operations are satisfied (tMRD, tMOD, tRFC, tZQinit, tZQoper, tZQCS, etc) as well as all Self-Refresh exit and Power-Down Exit parameters are satisfied (tXS, tXP, tXPDLL, etc).

No Operation (NOP) Command

The No operation (NOP) command is used to instruct the selected DDR3 SDRAM to perform a NOP ($\overline{CS}$ low and $\overline{RAS}$, $\overline{CAS}$, and $\overline{WE}$ high). This prevents unwanted commands from being registered during idle or wait states. Operations already in progress are not affected.

Deselect Command

The Deselect function ($\overline{CS}$ HIGH) prevents new commands from being executed by the DDR3 SDRAM. The DDR3 SDRAM is effectively deselected. Operations already in progress are not affected.

DLL-off Mode

DDR3 DLL-off mode is entered by setting MR1 bit A0 to "1"; this will disable the DLL for subsequent operations until A0 bit set back to "0". The MR1 A0 bit for DLL control can be switched either during initialization or later.

The DLL-off Mode operations listed below are an optional feature for DDR3. The maximum clock frequency for DLL-off Mode is specified by the parameter tCKDLL_OFF. There is no minimum frequency limit besides the need to satisfy the refresh interval, tREFI.

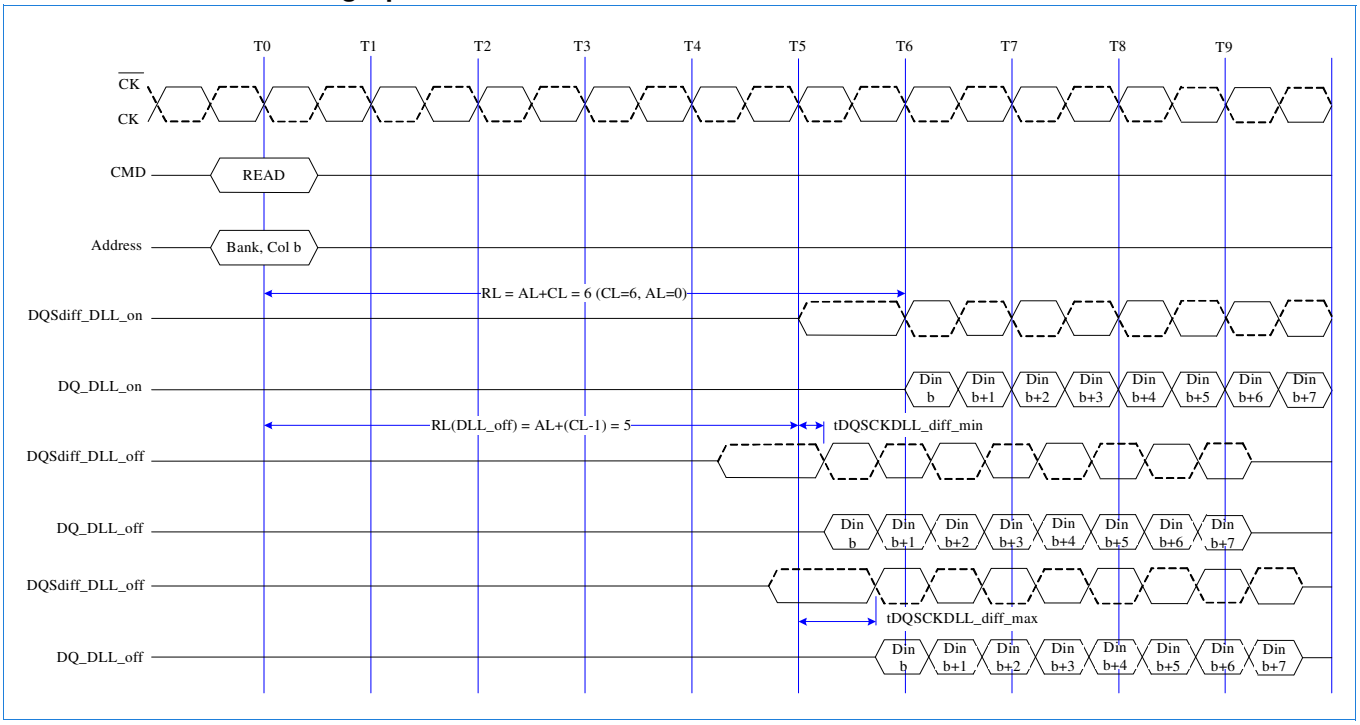
Due to latency counter and timing restrictions, only one value of CAS Latency (CL) in MR0 and CAS Write Latency (CWL) in MR2 are supported. The DLL-off mode is only required to support setting of both CL=6 and CWL=6.

DLL-off mode will affect the Read data Clock to Data Strobe relationship (tDQSCK) but not the data Strobe to Data relationship (tDQSQ, tQH). Special attention is needed to line up Read data to controller time domain.

Comparing with DLL-on mode, where tDQSCK starts from the rising clock edge (AL+CL) cycles after the Read command, the DLL-off mode tDQSCK starts (AL+CL-1) cycles after the read command. Another difference is that tDQSCK may not be small compared to tCK (it might even be larger than tCK) and the difference between tDQSCKmin and tDQSCKmax is significantly larger than in DLL-on mode.

The timing relations on DLL-off mode READ operation have shown at the following Timing Diagram (CL=6, BL=8)

DLL-off mode READ Timing Operation



Note: The tDQSCK is used here for DQS, $\overline{DQS}$, and DQ to have a simplified diagram; the DLL_off shift will affect both timings in the same way and the skew between all DQ, DQS, and $\overline{DQS}$ signals will still be tDQSQ.

DLL on/off switching procedure

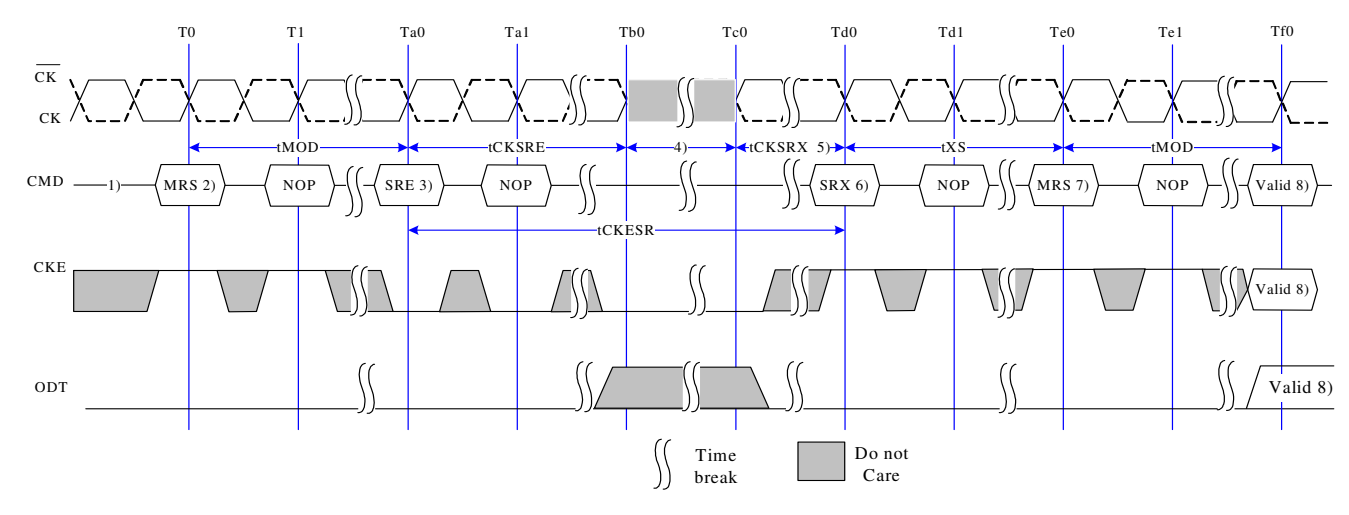
DDR3 DLL-off mode is entered by setting MR1 bit A0 to “1”; this will disable the DLL for subsequent operation until A0 bit set back to “0”.

DLL “on” to DLL “off” Procedure

To switch from DLL “on” to DLL “off” requires te frequency to be changed during Self-Refresh outlined in the following procedure:

1. Starting from Idle state (all banks pre-charged, all timing fulfilled, and DRAMs On-die Termination resistors, RTT, must be in high impedance state before MRS to MR1 to disable the DLL).
2. Set MR1 Bit A0 to “1” to disable the DLL.
3. Wait tMOD.
4. Enter Self Refresh Mode; wait until (tCKSRE) satisfied.
5. Change frequency, in quidance with “Input Clock Frequency Change” section.
6. Wait until a stable clock is available for at least (tCKSRX) at DRAM inputs.
7. Starting with the Self Refresh Exit command, CKE must continuously be registered HIGH until all tMOD timings from any MRS command are satisfied. In addition, if any ODT features were enabled in the mode registers when Self Refresh mode was entered, the ODT signal must continuously be registered LOW until all tMOD timings from any MRS command are satisfied. If both ODT features were disabled in the mode registers when Self Refresh mode was entered, ODT signal can be registered LOW or HIGH.
8. Wait tXS, then set Mode Regsiters with appropriate values (especially an update of CL, CWL, and WR may be necessary. A ZQCL command may also be issued after tXS).
9. Wait for tMOD, then DRAM is ready for next command.

DLL Switch Sequence from DLL-on to DLL-off



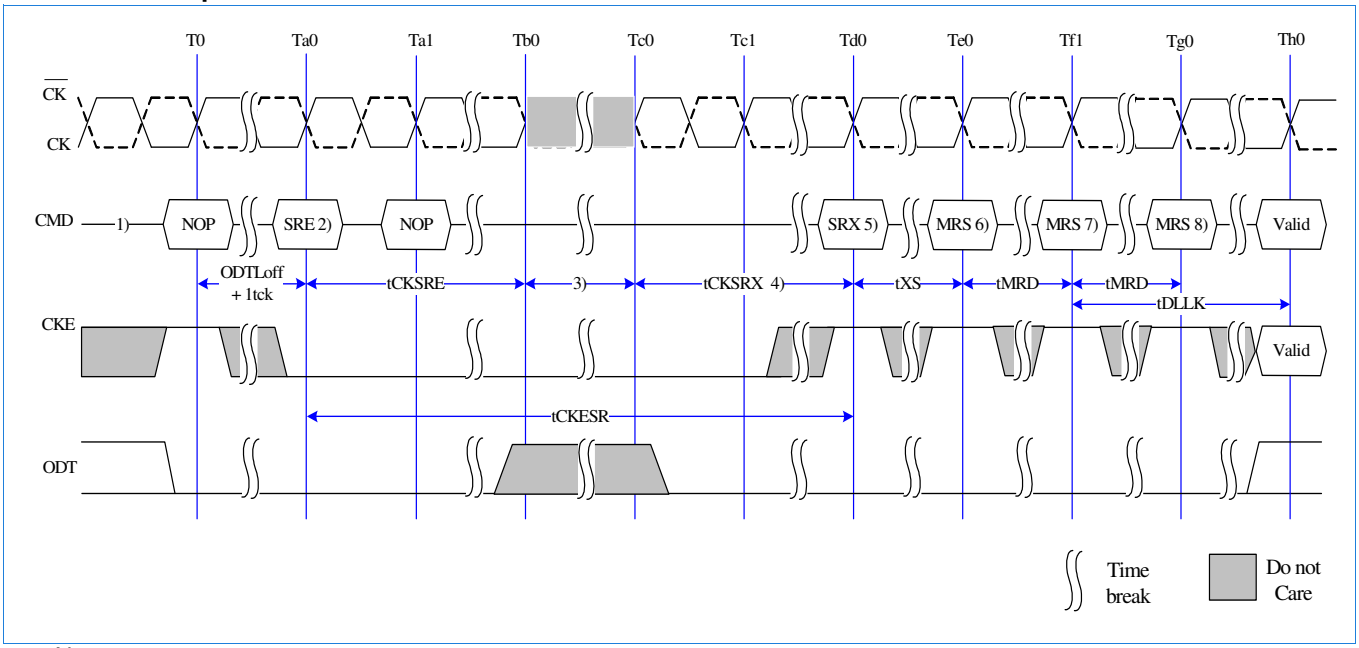
Note:
ODT: Static LOW in case RTT_Nom and RTT_WR is enabled, otherwise static Low or High
1) Starting with Idle State, RTT in Hi-Z State.
2) Disable DLL by setting MR1 Bit A0 to 1.
3) Enter SR.
4) Change Frequency.
5) Clock must be stable at least tCKSRX.
6) Exit SR.
7) Update Mode registers with DLL off parameters setting.
8) Any valid command.

DLL "off" to DLL "on" Procedure

To switch from DLL "off" to DLL "on" (with requires frequency change) during Self-Refresh:

1. Starting from Idle state (all banks pre-charged, all timings fulfilled and DRAMs On-die Termination resistors (RTT) must be in high impedance state before Self-Refresh mode is entered).
2. Enter Self Refresh Mode, wait until tCKSRE satisfied.
3. Change frequency, in guidance with "Input clock frequency change" section.
4. Wait until a stable is available for at least (tCKSRX) at DRAM inputs.
5. Starting with the Self Refresh Exit command, CKE must continuously be registered HIGH untill tDLLK timing from subsequent DLL Reset command is satisfied. In addition, if any ODT features were enabled in the mode registers when Self Refresh mode was entered. the ODT signal must continuously be registered LOW until tDLLK timings from subsequent DLL Reset command is satisfied. If both ODT features are disabled in the mode registers when Self Refresh mode was entered, ODT signal can be registered LOW or HIGH.
6. Wait tXS, then set MR1 Bit A0 to "0" to enable the DLL.
7. Wait tMRD, then set MR0 Bit A8 to "1" to start DLL Reset.
8. Wait tMRD, then set Mode registers with appropriate values (especially an update of CL, CWL, and WR may be necessary. After tMOD satisfied from any proceeding MRS command, a ZQCL command may also be issued during or after tDLLK).
9. Wait for tMOD, then DRAM is ready for next command (remember to wait tDLLK after DLL Reset before applying command requiring a locked DLL!). In addition, wait also for tZQoper in case a ZQCL command was issued.

DLL Switch Sequence from DLL-off to DLL-on



Note:
ODT: Static LOW in case RTT_Nom and RTT_WR is enabled, otherwise static Low or High
1) Starting from Idle State.
2) Enter SR.
3) Change Frequency.
4) Clock must be stable at least tCKSRX.
5) Exit SR.
6) Set DLL-on by MR1 A0="0"
7) Start DLL Reset
8) Any valid command

Input Clock frequency change

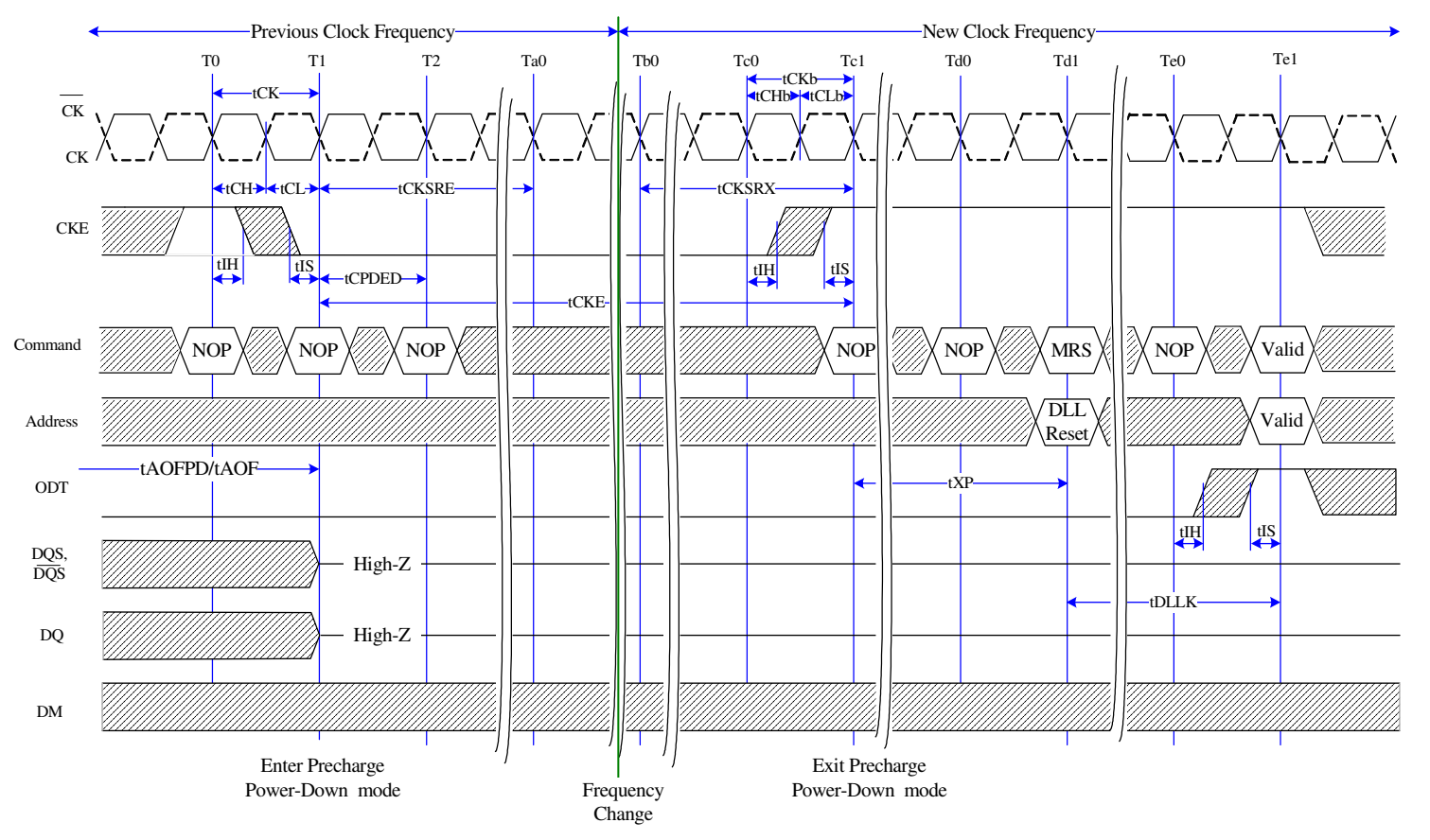
Once the DDR3 SDRAM is initialized, the DDR3 SDRAM requires the clock to be “stable” during almost all states of normal operation. This means once the clock frequency has been set and is to be in the “stable state”, the clock period is not allowed to deviate except for what is allowed for by the clock jitter and SSC (spread spectrum clocking) specification.

The input clock frequency can be changed from one stable clock rate to another stable clock rate under two conditions: (1) Self-Refresh mode and (2) Precharge Power-Down mode. Outside of these two modes, it is illegal to change the clock frequency.

For the first condition, once the DDR3 SDRAM has been successfully placed in to Self-Refresh mode and tCKSRE has been satisfied, the state of the clock becomes a don’t care. Once a don’t care, changing the clock frequency is permissible, provided the new clock frequency is stable prior to tCKSRX. When entering and exiting Self-Refresh mode of the sole purpose of changing the clock frequency. The DDR3 SDRAM input clock frequency is allowed to change only within the minimum and maximum operating frequency specified for the particular speed grade.

The second condition is when the DDR3 SDRAM is in Precharge Power-Down mode (either fast exit mode or slow exit mode). If the RTT_Nom feature was enabled in the mode register prior to entering Precharge power down mode, the ODT signal must continuously be registered LOW ensuring RTT is in an off state. If the RTT_Nom feature was disabled in the mode register prior to engering Precharge power down mode, RTT will remain in the off state. The ODT signal can be registered either LOW or HIGH in this case. A minimum of tCKSRE must occur after CKE goes LOW before the clock frequency may change. The DDR3 SDRAM input clock frequency is allowed to change only within the minimum and maximum operating frequency specified for the particular speed grade. During the input clock frequency change, ODT and CKE must be held at stable LOW levels. Once the input clock frequency is changed, stable new clocks must be provided to the DRAM tCKSRX before precharge Power Down may be exited; after Precharge Power Down is exited and tXP has expired, the DLL must be RESET via MRS. Depending on the new clock frequency additional MRS commands may need to be issued to appropriately set the WR, CL, and CWL with CKE continuously registered high. During DLL re-lock period, ODT must remain LOW and CKE must remain HIGH. After the DLL lock time, the DRAM is ready to operate with new clock frequency.

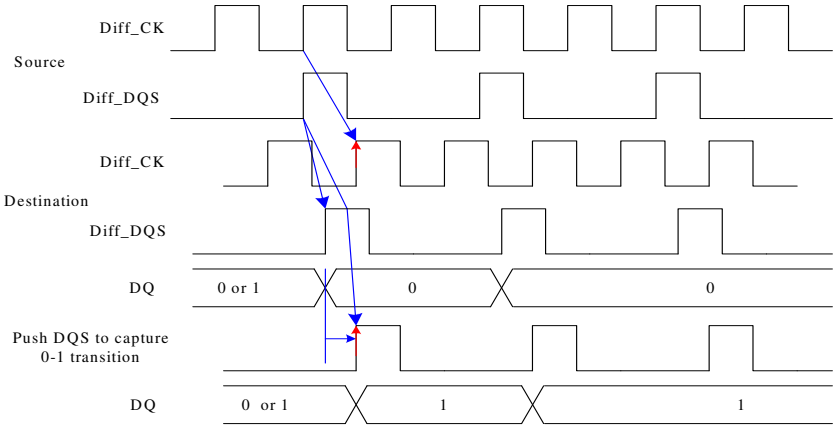
Change Frequency during Precharge Power-down



Write Leveling

For better signal integrity, DDR3 memory adopted fly by topology for the commands, addresses, control signals, and clocks. The fly by topology has benifits from reducing number of stubs and their length but in other aspect, causes flight time skew between clock and strobe at every DRAM on DIMM. It makes it difficult for the Controller to maintain tDQSS, tDSS, and tDSH specification. Therefore, the contorller should support “write leveling” in DDR3 SDRAM to compensate the skew.

The memory controller can use the “write leveling” feature and feedback from the DDR3 SDRAM to adjust the DQS - $\overline{\text{DQS}}$ to CK - $\overline{\text{CK}}$ relationship. The memory controller involved in the leveling must have adjustable delay setting on DQS - $\overline{\text{DQS}}$ to align the rising edge of DQS - $\overline{\text{DQS}}$ with that of the clock at the DRAM pin. DRAM asynchronously feeds back CK - $\overline{\text{CK}}$, sampled with the rising edge of DQS - $\overline{\text{DQS}}$, through the DQ bus. The controller repeatedly delays DQS - $\overline{\text{DQS}}$ until a transition from 0 to 1 is detected. The DQS - $\overline{\text{DQS}}$ delay established though this exercise would ensure tDQSS specification. Besides tDQSS, tDSS, and tDSH specification also needs to be fulfilled. One way to achieve this is to combine the actual tDQSS in the application with an appropriate duty cycle and jitter on the DQS- $\overline{\text{DQS}}$ signals. Depending on the actual tDQSS in the application, the actual values for tDQSL and tDQSH may have to be better than the absolute limites provided in “AC Timing Parameters” section in order to satisfy tDSS and tDSH specification. A conceptual timing of this scheme is show as below figure.



DQS/$\overline{\text{DQS}}$ driven by the controller during leveling mode must be determined by the DRAM based on ranks populated. Similarly, the DQ bus driven by the DRAM must also be terminated at the controller.

One or more data bits should carry the leveling feedback to the controller across the DRAM configurations x4,x8, and x16. On a x16 device, both byte lanes should be leveled independently. Therefore, a separate feedback mechanism should be able for each byte lane. The upper data bits should provide the feedback of the upper diff_DQS (diff_UDQS) to clock relationship whereas the lower data bits would indicate the lower diff_DQS (diff_LDQS) to clock relationship.

DRAM setting for write leveling and DRAM termination function in that mode

DRAM enters into Write leveling mode if A7 in MR1 set “High” and after finishing leveling, DRAM exits from write leveling mode if A7 in MR1 set “Low”. Note that in write leveling mode, only DQS/$\overline{\text{DQS}}$ terminations are activated and deactivated via ODT pin not like normal operation.

MR setting involved in the leveling procedure

Function	MR1	Enable	Disable
Write leveling enable	A7	1	0
Output buffer mode (Qoff)	A12	0	1

DRAM termination function in the leveling mode

ODT pin at DRAM	DQS/$\overline{\text{DQS}}$ termination	DQs termination
De-asserted	off	off
Asserted	on	off

Note: In write leveling mode with its output buffer disabled (MR1[bit7]=1 with MR1[bit12]=1) all RTT_Nom settings are allowed; in Write Leveling Mode with its output buffer enabled (MR1[bit7]=1 with MR1[bit12]=0) only RTT_Nom settings of RZQ/2, RZQ/4, and RZQ/6 are allowed.

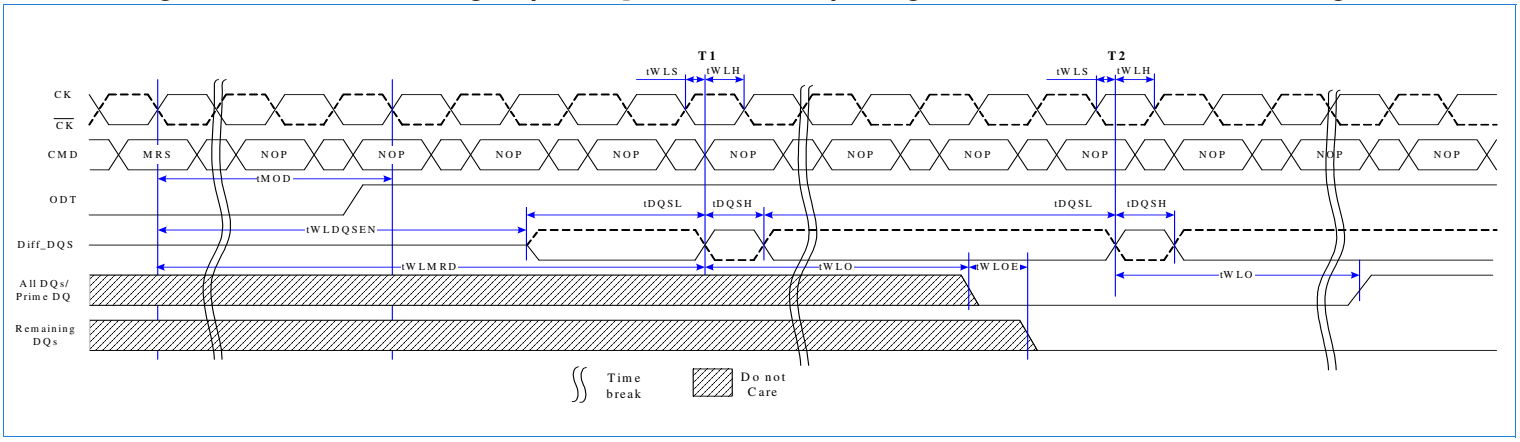
Procedure Description

Memory controller initiates Leveling mode of all DRAMs by setting bit 7 of MR1 to 1. With entering write leveling mode, the DQ pins are in undefined driving mode. During write leveling mode, only NOP or Delesect commands are allowed. as well as an MRS command to exit write leveling mode. Since the controller levels one rank at a time, the output of other rank must be disabled by setting MR1 bit A12 to 1. Controller may assert ODT after tMOD, time at which DRAM is ready to accept the ODT signal.

Controller may drive DQS low and $\overline{DQS}$ high after a delay of tWLDQSEN, at which time DRAM has applied on-die termination on these signals. After tDQSL and tWLMRD controller provides a single DQS, $\overline{DQS}$ edge which is used by the DRAM to sample CK - $\overline{CK}$ driven from controller. tWLMRD(max) timing is controller dependent.

DRAM samples CK - $\overline{CK}$ status with rising edge of DQS and provides feedback on all the DQ bits asynchronously after tWLO timing. There is a DQ output uncertainty of tWLOE defined to allow mismatch on DQ bits; there are no read strobes (DQS/$\overline{DQS}$) needed for these DQs. Controller samples incoming DQ and decides to increment or decrement DQS - $\overline{DQS}$ delay setting and launches the next DQS/$\overline{DQS}$ pulse after some time, which is controller dependent. Once a 0 to 1 transition is detected, the controller locks DQS - $\overline{DQS}$ delay setting and write leveling is achieved for the device. The following figure describes the timing diagram and parameters for the overall Write leveling procedure.

Timing details of Write Leveling sequence [DQS - $\overline{DQS}$ is capturing CK - $\overline{CK}$ low at T1 and CK - $\overline{CK}$ high at T2



Note:

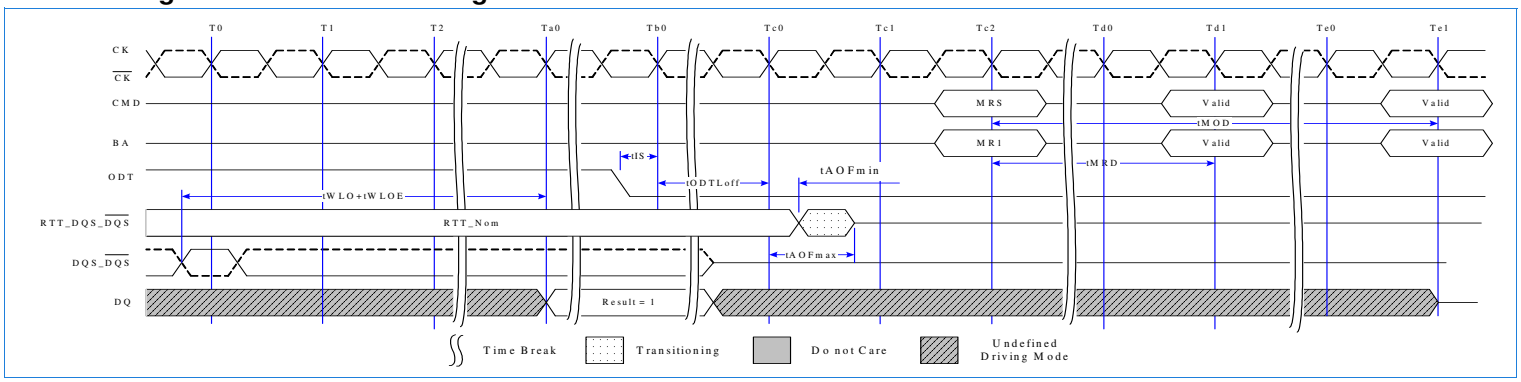
1. DRAM has the option to drive leveling feedback on a prime DQ or all DQs. If feedback is driven only on one DQ, the remaining DQs must be driven low as shown in above Figure, and maintained at this state through out the leveling procedure.
2. MRS: Load MR1 to enter write leveling mode
3. NOP: NOP or deselect
4. diff_DQS is the differential data strobe (DQS, $\overline{DQS}$). Timing reference points are the zero crossings. DQS is shown with solid line, $\overline{DQS}$ is shown with dotted line.
5. CK/$\overline{CK}$: CK is shown with solid line, where as $\overline{CK}$ is shown with dotted line.
6. DQS/$\overline{DQS}$ needs to fulfill minimum pulse width requirements tDQSH(min) and tDQSL(min) as defined for regular Writes; the max pulse width is system dependent.

Write Leveling Mode Exit

The following sequence describes how Write Leveling Mode should be exited:

1. After the last rising strobe edge (see ~T0), stop driving the strobe signals (see ~Tc0). Note: From now on, DQ pins are in undefined driving mode, and will remain undefined, until tMOD after the respective MR command (Te1).
2. Drive ODT pin low (tIS must be satisfied) and keep it low (see Tb0).
3. After the RTT is switched off, disable Write Level Mode via MRS command (see Tc2).
4. After tMOD is satisfied (Te1), an any valid command may be registered. (MR commands may be issued after tMRD (Td1).

Timing details of Write Leveling exit



Extended Temperature Usage

a. Auto Self-refresh supported

b. Extended Temperature Range supported

c. Double refresh required for operation in the Extended Temperature Range.

Mode Register Description

Field	Bits	Description
ASR	MR2(A6)	**Auto Self-Refresh (ASR)** When enabled, DDR3 SDRAM automatically provides Self-Refresh power management functions for all supported operating temperature values. If not enabled, the SRT bit must be programmed to indicate T_{OPER} during subsequent Self-Refresh operation. 0 = Manual SR Reference (SRT) 1 = ASR enable
SRT	MR2(A7)	**Self-Refresh Temperature (SRT) Range** If ASR = 0, the SRT bit must be programmed to indicate T_{OPER} during subsequent Self-Refresh operation. If ASR = 1, SRT bit must be set to 0. 0 = Normal operating temperature range 1 = Extended operating temperature range

Auto Self-Refresh mode - ASR mode

DDR3 SDRAM provides an Auto-Refresh mode (ASR) for application ease. ASR mode is enabled by setting MR2 bit A6=1 and MR2 bit A7=0. The DRAM will manage Self-Refresh entry in either the Normal or Extended Temperature Ranges. In this mode, the DRAM will also manage Self-Refresh power consumption when the DRAM operating temperature changes, lower at low temperatures and higher at high temperatures.

If the ASR option is not supported by DRAM, MR2 bit A6 must set to 0.

If the ASR option is not enabled (MR2 bit A6=0), the SRT bit (MR2 bit A7) must be manually programmed with the operating temperature range required during Self-Refresh operation.

Support of the ASR option does not automatically imply suport of the Extended Temperature Range.

Self-Refresh Temperature Range - SRT

SRT applies to devices supporting Extended Temperature Range only. If ASR=0, the Self-Refresh Temperature (SRT) Range bit must be programmed to guarantee proper self-refresh operation. If SRT=0, then the DRAM will set an appropriate refresh rate for Self-Refresh operation in the Normal Temperature Range. If SRT=1, then the DRAM will set an approriate, potentially different, refresh rate to allow Self-Refresh operation in either the Normal or Extended Temperature Ranges. The value of the SRT bit can effect self-refresh power consumption, please refer to IDD table for details.

Self-Refresh mode summary

MR2 A[6]	MR2 A[7]	Self-Refresh operation	Allowed Operating Temperature Range for Self-Refresh mode
0	0	Self-Refresh rate appropriate for the Normal Temperature Range	Normal (0 ~ 85C)
0	1	Self-Refresh appropriate for either the Normal or Extended Temperature Ranges. The DRAM must support Extended Temperature Range. The value of the SRT bit can effect self-refresh power consumption, please refer to the IDD table for details.	Normal and Extended (0 ~ 95C)
1	0	ASR enabled (for devices supporting ASR and **Normal** Temperature Range). Self-Refresh power consumption is temperature dependent.	Normal (0 ~ 85C)
1	0	ASR enabled (for devices supporting ASR and **Extended** Temperature Range). Self-Refresh power consumption is temperature dependent.	Normal and Extended (0 ~ 95C)
1	1	Illegal	

MPR MR3 Register Definition

MR3 A[2]	MR3 A[1:0]	Function
0	don't care (0 or 1)	Normal operation, no MPR transaction. All subsequent Reads will come from DRAM array. All subsequent Writes will go to DRAM array.
1	See the following table	Enable MPR mode, subsequent RD/RDA commands defined by MR3 A[1:0].

MPR Functional Description

- One bit wide logical interface via all DQ pins during READ operation.
- Register Read on x4:
  - DQ[0] drives information from MPR.
  - DQ[3:1] either drive the same information as DQ[0], or they drive 0.
- Register Read on x8:
  - DQ[0] drives information from MPR.
  - DQ[7:1] either drive the same information as DQ[0], or they drive 0.
- Register Read on x16:
  - DQL[0] and DQU[0] drive information from MPR.
  - DQL[7:1] and DQU[7:1] either drive the same information as DQL[0], or they drive 0.
- Addressing during for Multi Purpose Register reads for all MPR agents:
  - BA[2:0]: don't care.
  - A[1:0]: A[1:0] must be equal to "00". Data read burst order in nibble is fixed.
  - A[2]: For BL=8, A[2] must be equal to 0, burst order is fixed to [0,1,2,3,4,5,6,7]; For Burst chop 4 cases, the burst order is switched on nibble base, A[2]=0, burst order: 0,1,2,3, A[2]=1, burst order: 4,5,6,7. *)
  - A[9:3]: don't care.
  - A10/AP: don't care.
  - A12/BC: Selects burst chop mode on-the-fly, if enabled within MR0
  - A11, A13: don't care.
- Regular interface functionality during register reads:
  - Support two Burst Ordering which are switched with A2 and A[1:0]=00.
  - Support of read burst chop (MRS and on-the-fly via A12/BC).
  - All other address bits (remaining column addresses bits including A10, all bank address bits) will be ignored by the DDR3 SDRAM.
  - Regular read latencies and AC timings apply.
  - DLL must be locked prior to MPR READs.

Note *): Burst order bit 0 is assigned to LSB and burst order bit 7 is assigned to MSB of the selected MPR agent.

MPR Register Address Definition

The following table provide an overview of the available data locatoin, how they are addressed by MR3 A[1:0] during a MRS to MR3, and how their individual bits are mapped into the burst order bits during a Multi Purpose Register Read.

MPR MR3 Register Definition

MR3 A[2]	MR3 A[1:0]	Function	Burst Length	Read Address A[2:0]	Burst Order and Data Pattern
1	00	Read Predefined Pattern for System Calibration	BL8	000	Burst order 0,1,2,3,4,5,6,7 Pre-defined Data Pattern [0,1,0,1,0,1,0,1]
			BC4	000	Burst order 0,1,2,3 Pre-defined Data Pattern [0,1,0,1]
			BC4	100	Burst order 4,5,6,7 Pre-defined Data Pattern [0,1,0,1]
1	01	RFU	BL8	000	Burst order 0,1,2,3,4,5,6,7
			BC4	000	Burst order 0,1,2,3
			BC4	100	Burst order 4,5,6,7
1	10	RFU	BL8	000	Burst order 0,1,2,3,4,5,6,7
			BC4	000	Burst order 0,1,2,3
			BC4	100	Burst order 4,5,6,7
1	11	RFU	BL8	000	Burst order 0,1,2,3,4,5,6,7
			BC4	000	Burst order 0,1,2,3
			BC4	100	Burst order 4,5,6,7
Note: Burst order bit 0 is assigned to LSB and the burst order bit 7 is assigned to MSB of the selected MPR agent.					

ACTIVE Command

The ACTIVE command is used to open (or activate) a row in a particular bank for subsequent access. The value on the BA0-BA2 inputs selects the bank, and the address provided on inputs A0-A13 selects the row. This row remains active (or open) for accesses until a precharge command is issued to that bank. A PRECHARGE command must be issued before opening a different row in the same bank.

PRECHARGE Command

The PRECHARGE command is used to deactivate the open row in a particular bank or the open row in all banks. The bank(s) will be available for a subsequent row activation a specified time (tRP) after the PRECHARGE command is issued, except in the case of concurrent auto precharge, where a READ or WRITE command to a different bank is allowed as long as it does not interrupt the data transfer in the current bank and does not violate any other timing parameters. Once a bank has been precharged, it is in the idle state and must be activated prior to any READ or WRITE commands being issued to that bank. A PRECHARGE command is allowed if there is no open row in that bank (idle bank) or if the previously open row is alrady in the process of precharging. However, the precharge period will be determined by the last PRECHARGE command issued to the bank.

READ Operation

Read Burst Operation

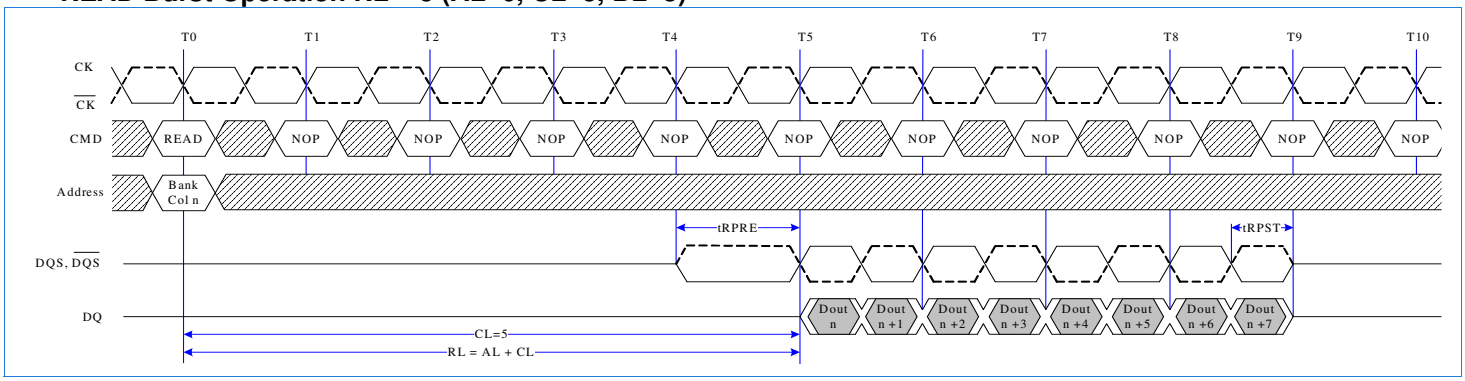
During a READ or WRITE command DDR3 will support BC4 and BL8 on the fly using address A12 during the READ or WRITE (AUTO PRECHARGE can be enabled or disabled).

A12=0, BC4 (BC4 = burst chop, tCCD=4)

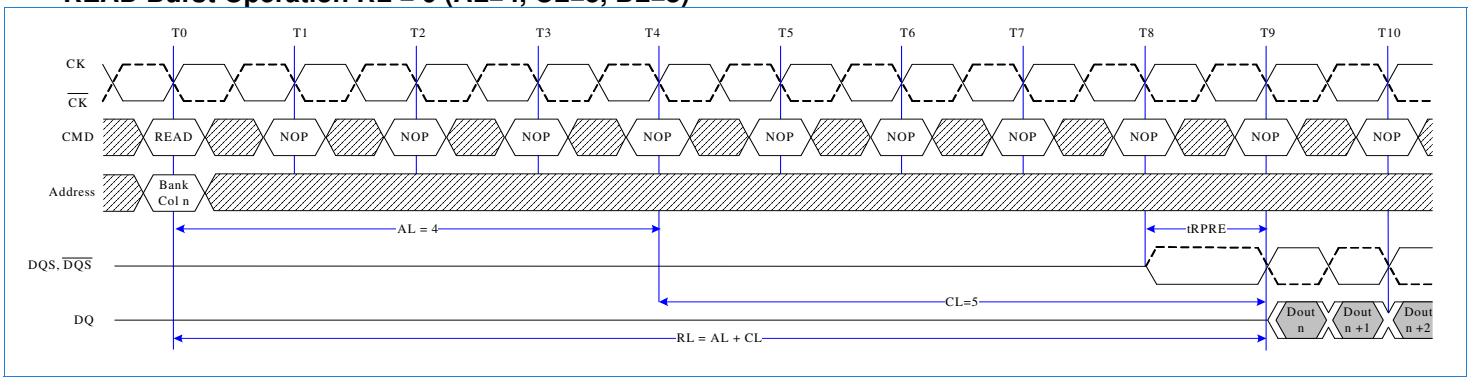
A12=1, BL8

A12 will be used only for burst length control, not a column address.

READ Burst Operation RL = 5 (AL=0, CL=5, BL=8)



READ Burst Operation RL = 9 (AL=4, CL=5, BL=8)



READ Timing Definitions

Read timing is shown in the following figure and is applied when the DLL is enabled and locked.

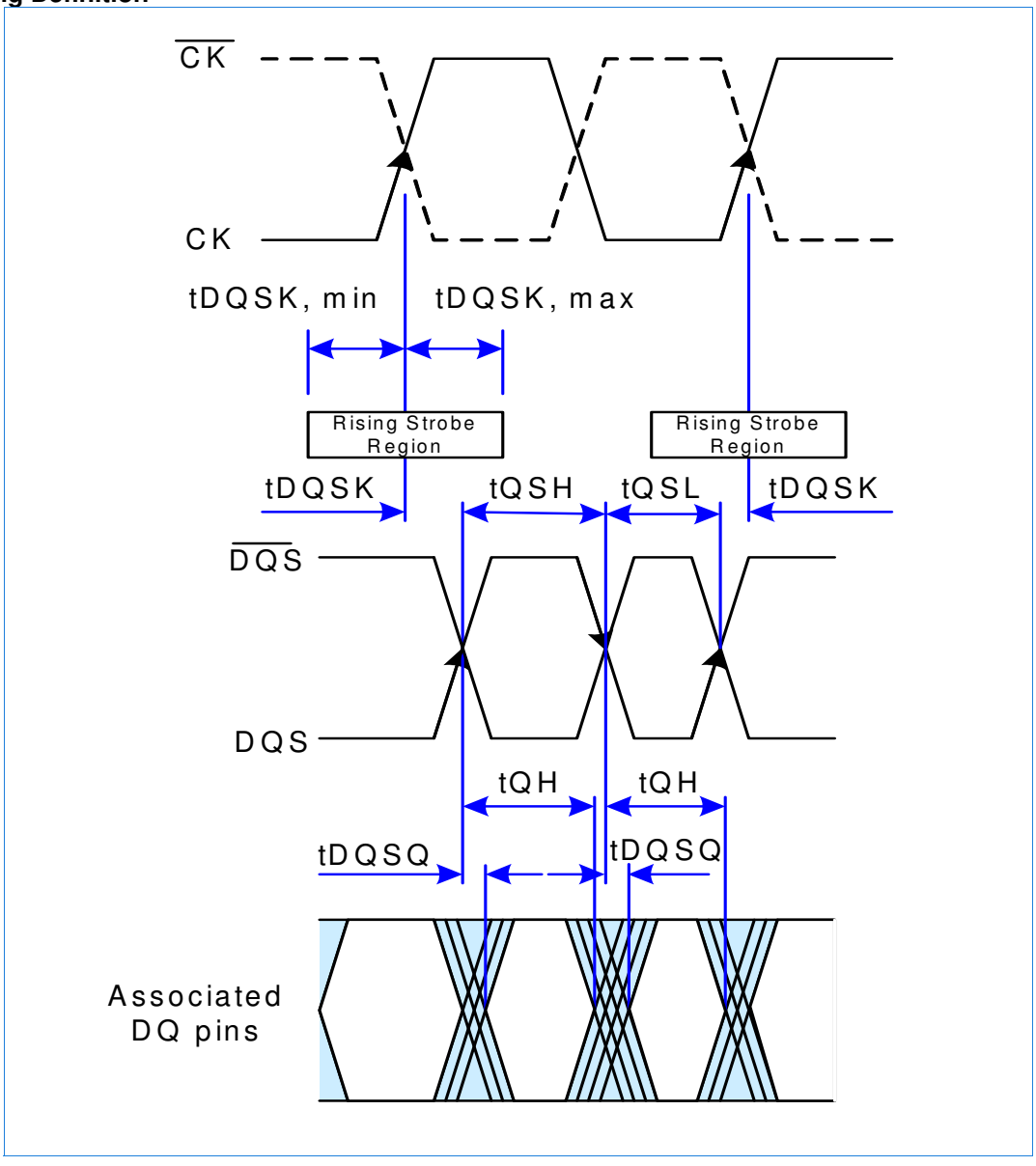
Rising data strobe edge parameters:

- tDQSCK min/max describes the allowed range for a rising data strobe edge relative to CK, $\overline{CK}$.
- tDQSCK is the actual position of a rising strobe edge relative to CK, $\overline{CK}$.
- tQSH describes the DQS, $\overline{DQS}$ differential output high time.
- tDQSQ describes the latest valid transition of the associated DQ pins.
- tQH describes the earliest invalide transition of the associated DQ pins.

Falling data strobe edge parameters:

- tQSL describes the DQS, $\overline{DQS}$ differential output low time.
- tDQSQ describes the latest valid transition of the associated DQ pins.
- tQH describes the earliest invalide transition of the associated DQ pins.

Read Timing Definition



Read Timing; Clock to Data Strobe relationship

Clock to Data Strobe relationship is shown in the following figure and is applied when the DLL is enabled and locked.

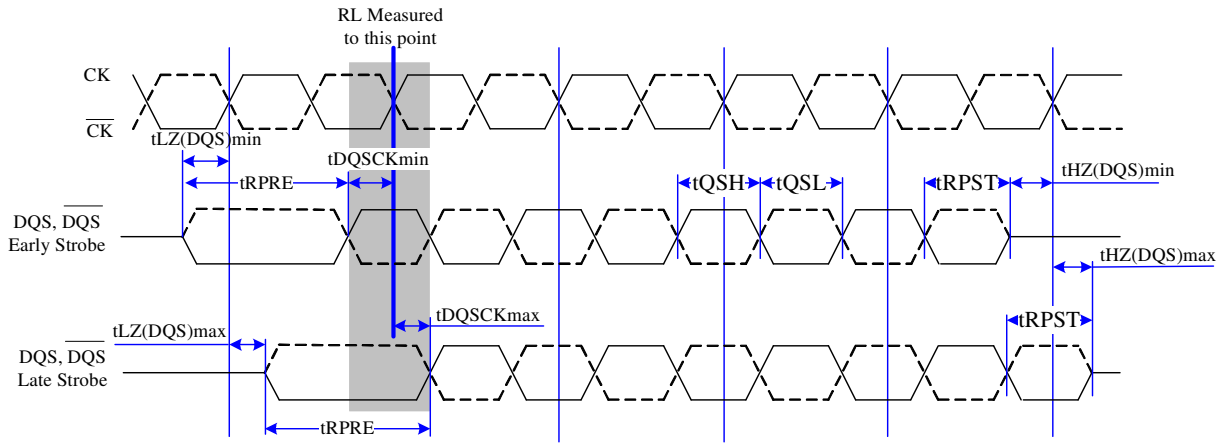
Rising data strobe edge parameters:

- tDQSCK min/max describes the allowed range for a rising data strobe edge relative to CK and $\overline{CK}$.
- tDQSCK is the actual position of a rising strobe edge relative to CK and $\overline{CK}$.
- tQSH describes the data strobe high pulse width.

Falling data strobe edge parameters:

- tDSL describes the data strboe low pulse width.

Clock to Data Strobe Relationship



Read Timing; Data Strobe to Data Relationship

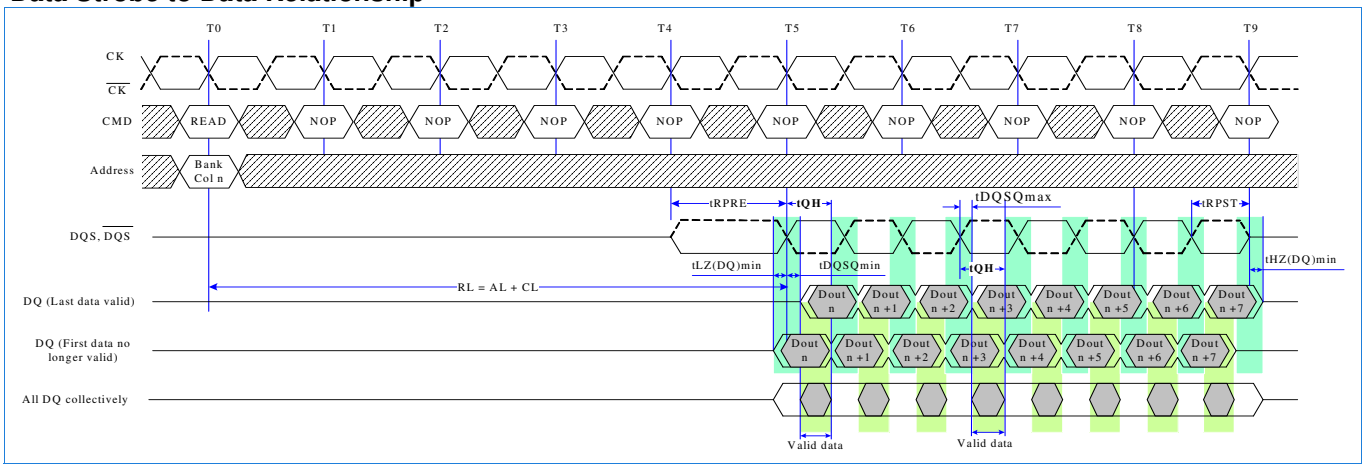
The Data Strobe to Data relationship is shown in the following figure and is applied when the DLL and enabled and locked.
Rising data strobe edge parameters:

- tDQSQ describes the latest valid transition of the associated DQ pins.
- tQH describes the earliest invalid tansition of the associated DQ pins.

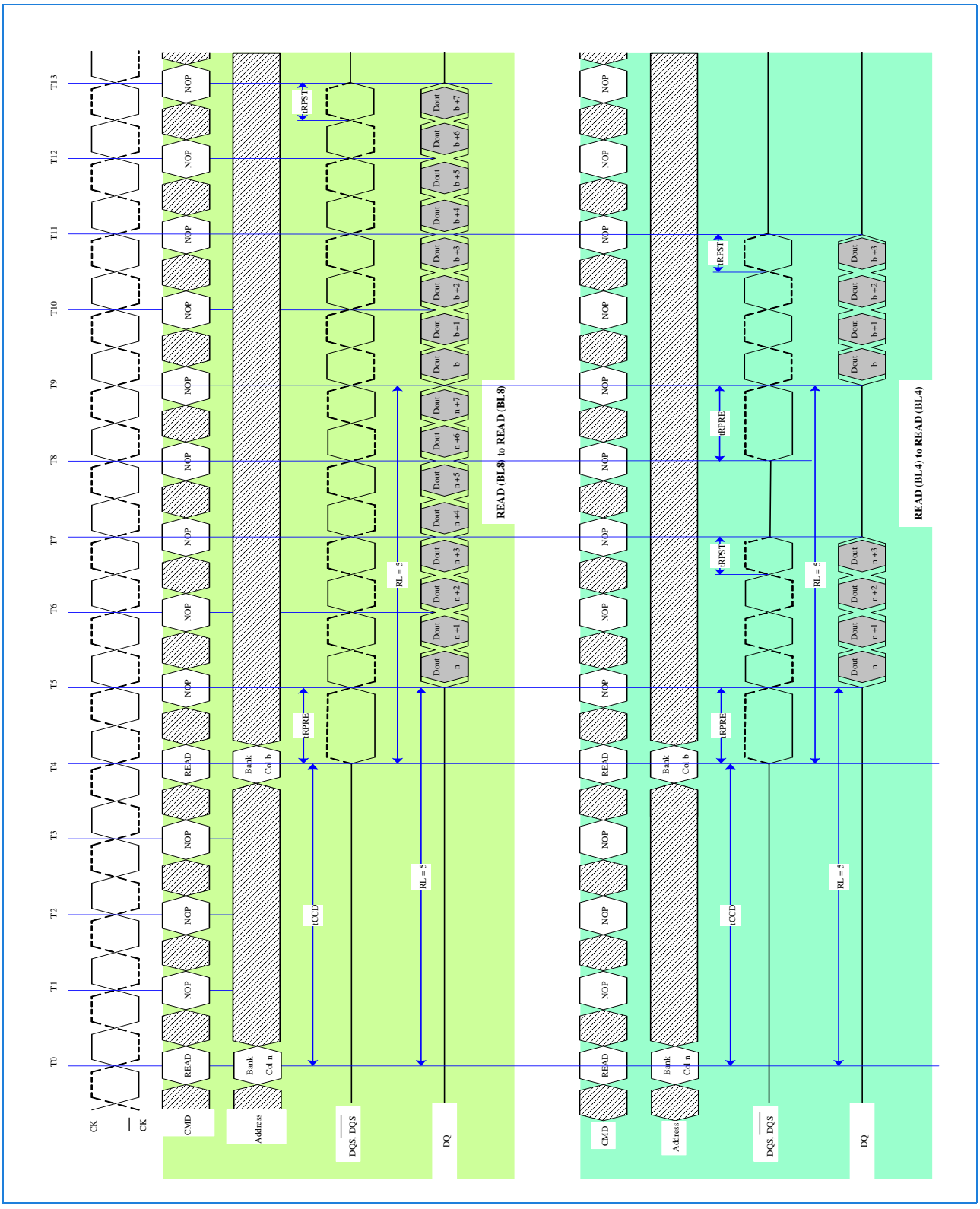
Falling data strobe edge parameters:

- tDQSQ describes the latest valid transition of the associated DQ pins.
- tQH describes the earliest invalid tansition of the associated DQ pins.

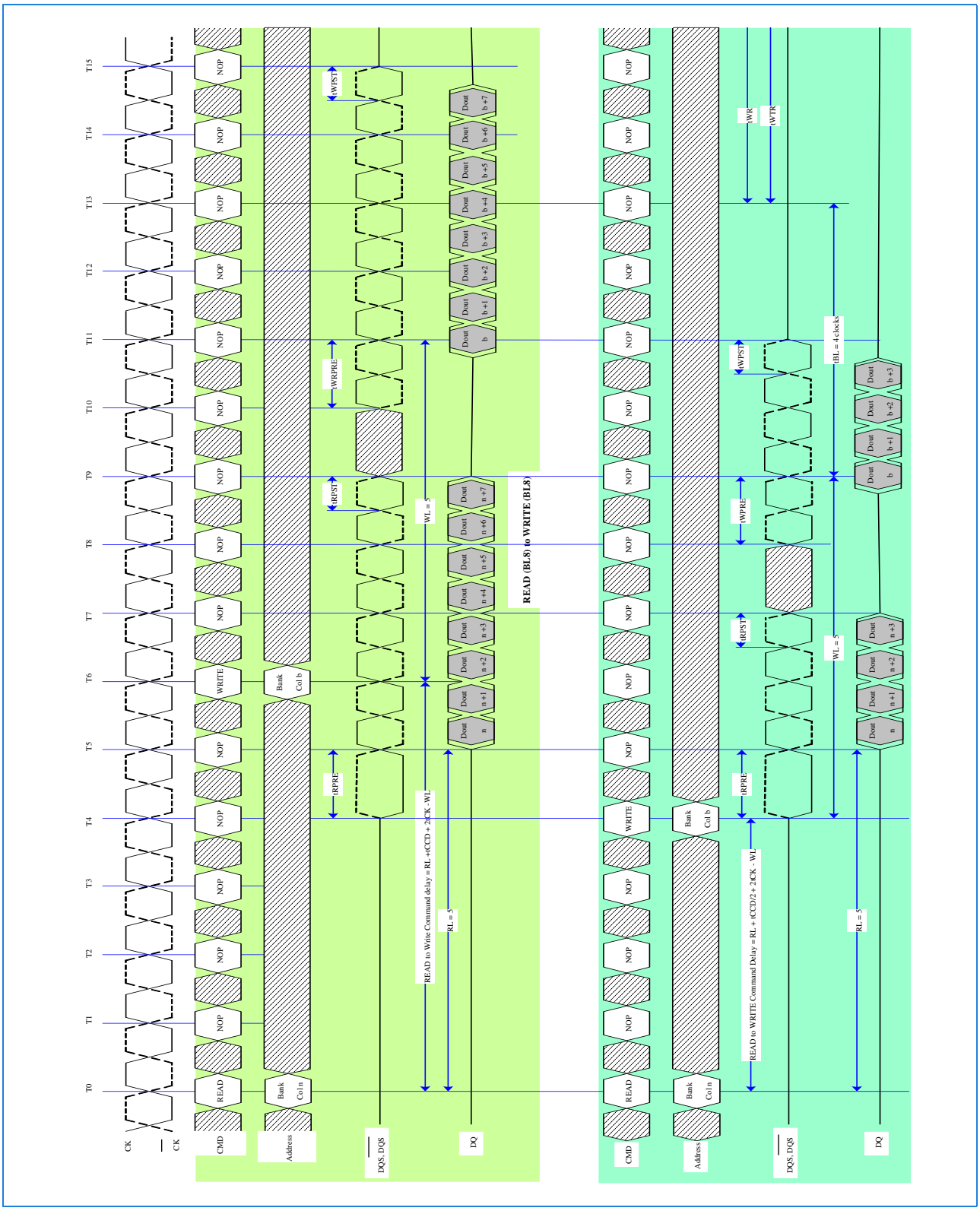
Data Strobe to Data Relationship



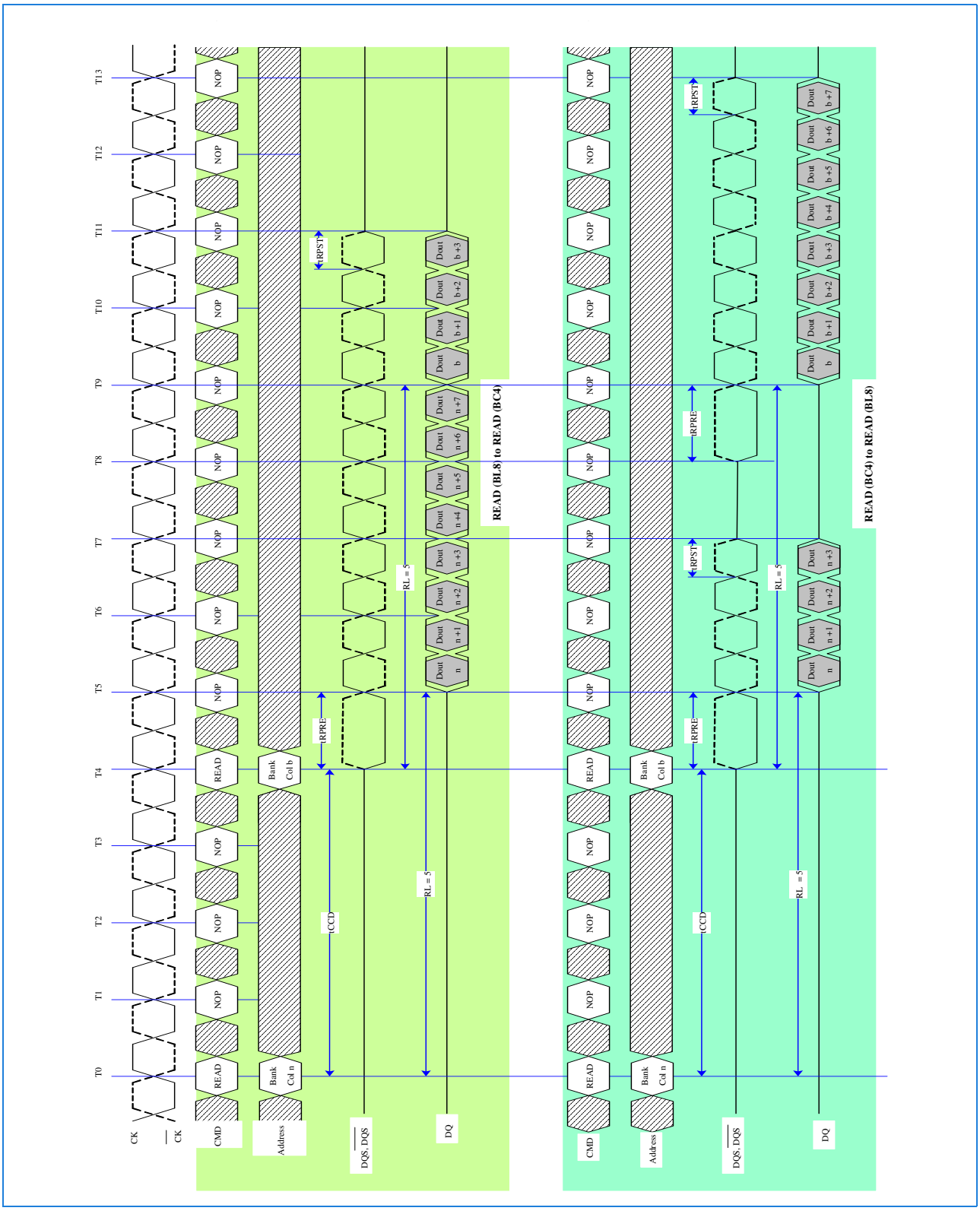
Read to Read (CL=5, AL=0)



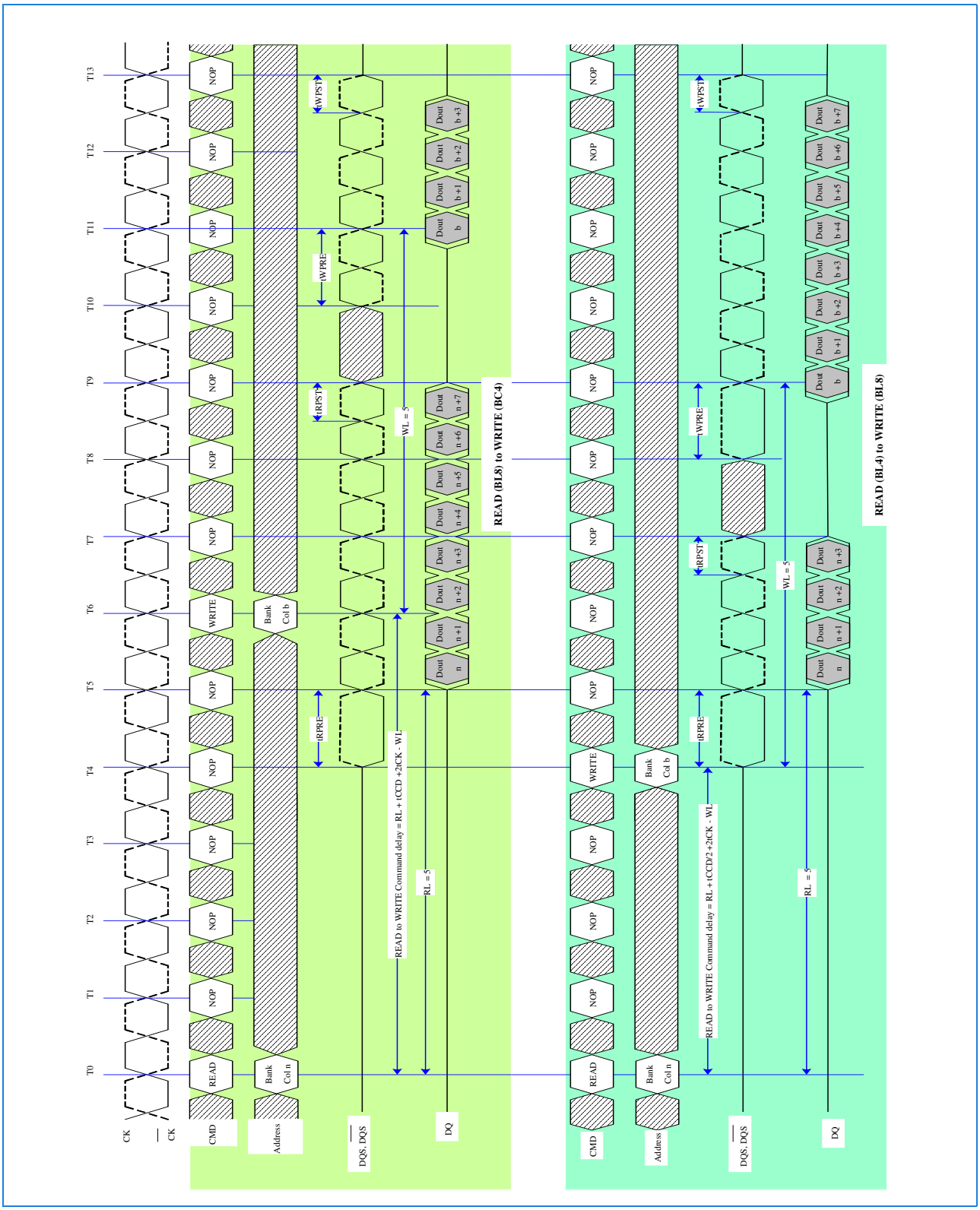
READ to WRITE (CL=5, AL=0; CWL=5, AL=0)



READ to READ (CL=5, AL=0)



READ to WRITE (CL=5, AL=0; CWL=5, AL=0)



Write Operation

During a READ or WRITE command, DDR3 will support BC4 and BL8 on the fly using address A12 during the READ or WRITE (Auto Precharge can be enabled or disabled).
A12=0, BC4 (BC4 = Burst Chop, tCCD=4)
A12=1, BL8
A12 is used only for burst length control, not as a column address.

WRITE Timing Violations
Motivation

Generally, if timing parameters are violated, a complete reset/initialization procedure has to be initiated to make sure the DRAM works properly. However, it is desireable for certain minor violations that the DRAM is guaranteed not to “hang up” and errors be limited to that particular operation.
For the following, it will be assumed that there are no timing violations w.r.t. to the Write command itself (including ODT, etc.) and that it does satisfy all timing requirements not mentioned below.

Data Setup and Hold Violations

Should the strobe timing requirements (tDS, tDH) be violated, for any of the strobe edges assocated with a write burst, then wrong data might be written to the memory location addressed with the offending WRITE command.
Subsequent reads from that location might result in unpredictable read data, however, the DRAM will work properly otherwise.

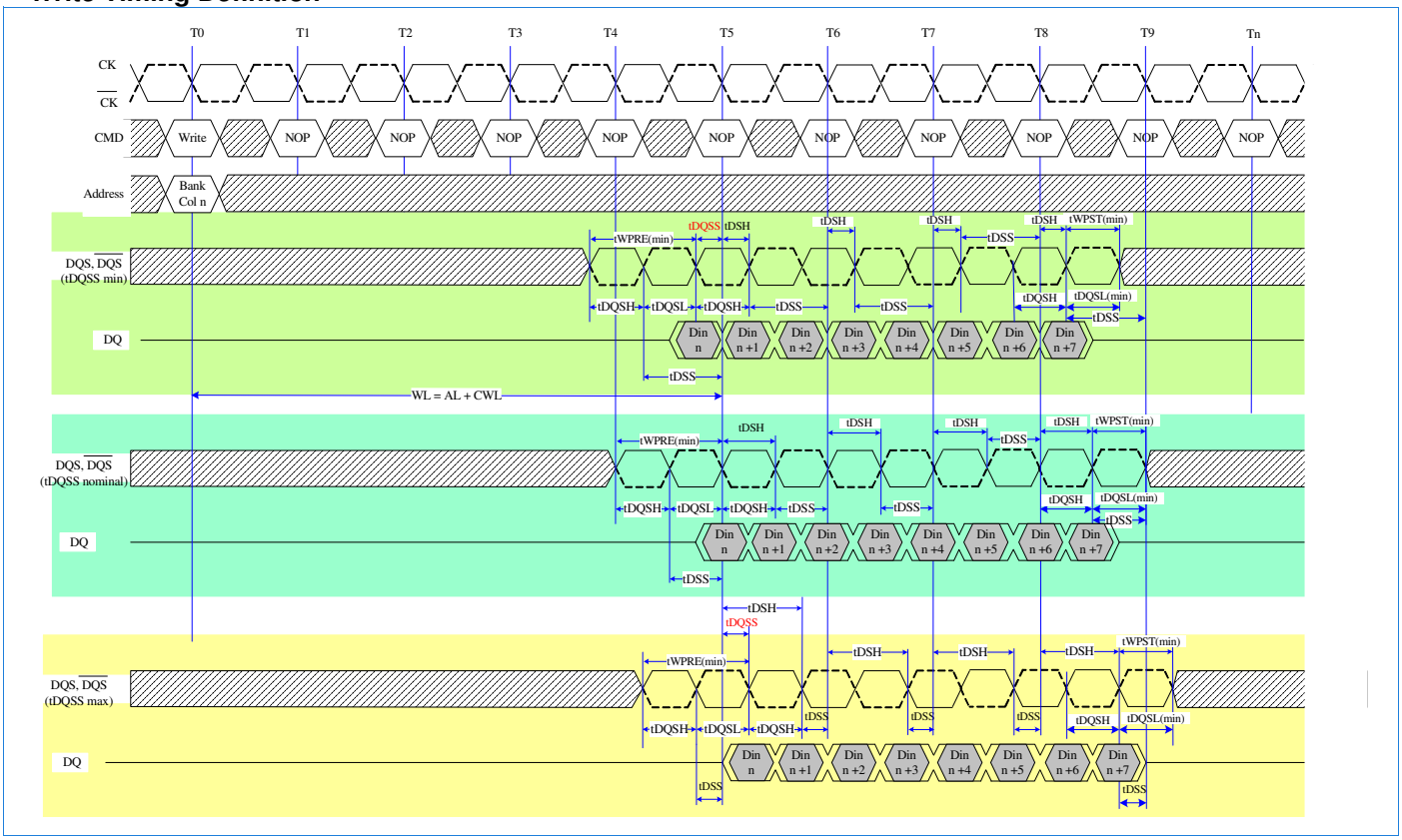
Strobe to Strobe and Strobe to Clock Violations

Should the strobe timing requirements (tDQSH, tDQSL, tWPRE, tWPST) or the strobe to clock timing requirements (tDSS, tDSH, tDQSS) be violated, for any of the strobe edges associated with a Write burst, then wrong data might be written to the memory location addressed with the offending WRITE command. Subsequent reads from that location might result in unpredictable read data, however the DRAM will work properly otherwise.

Write Timing Parameters

This drawing is for example only to enumerate the strobe edges that “belong” to a write burst. No actual timing violations are shown here. For a valid burst all timing parameters for each edge of a burst need to be satisfied (not only for one edge - as shown).

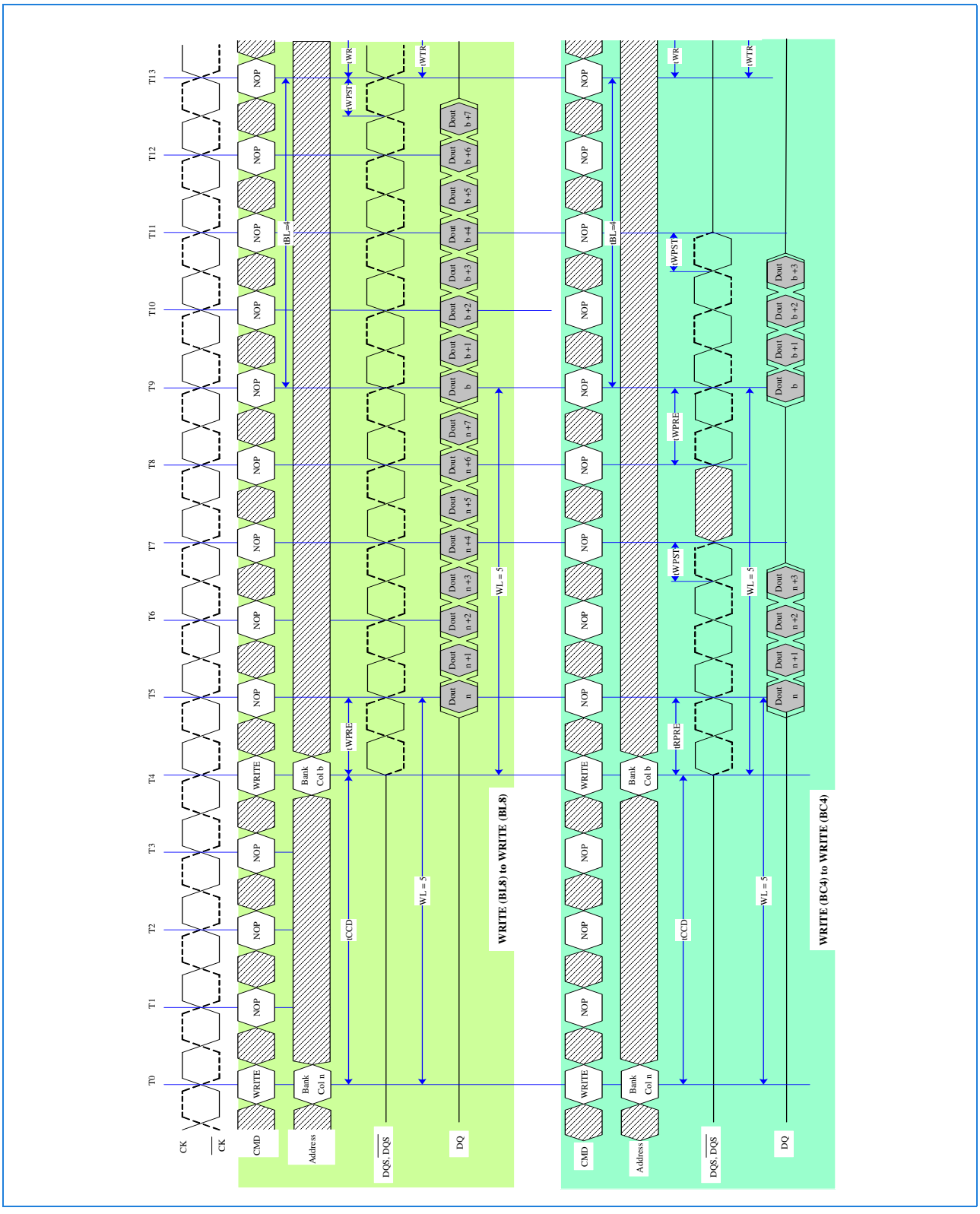
Write Timing Definition



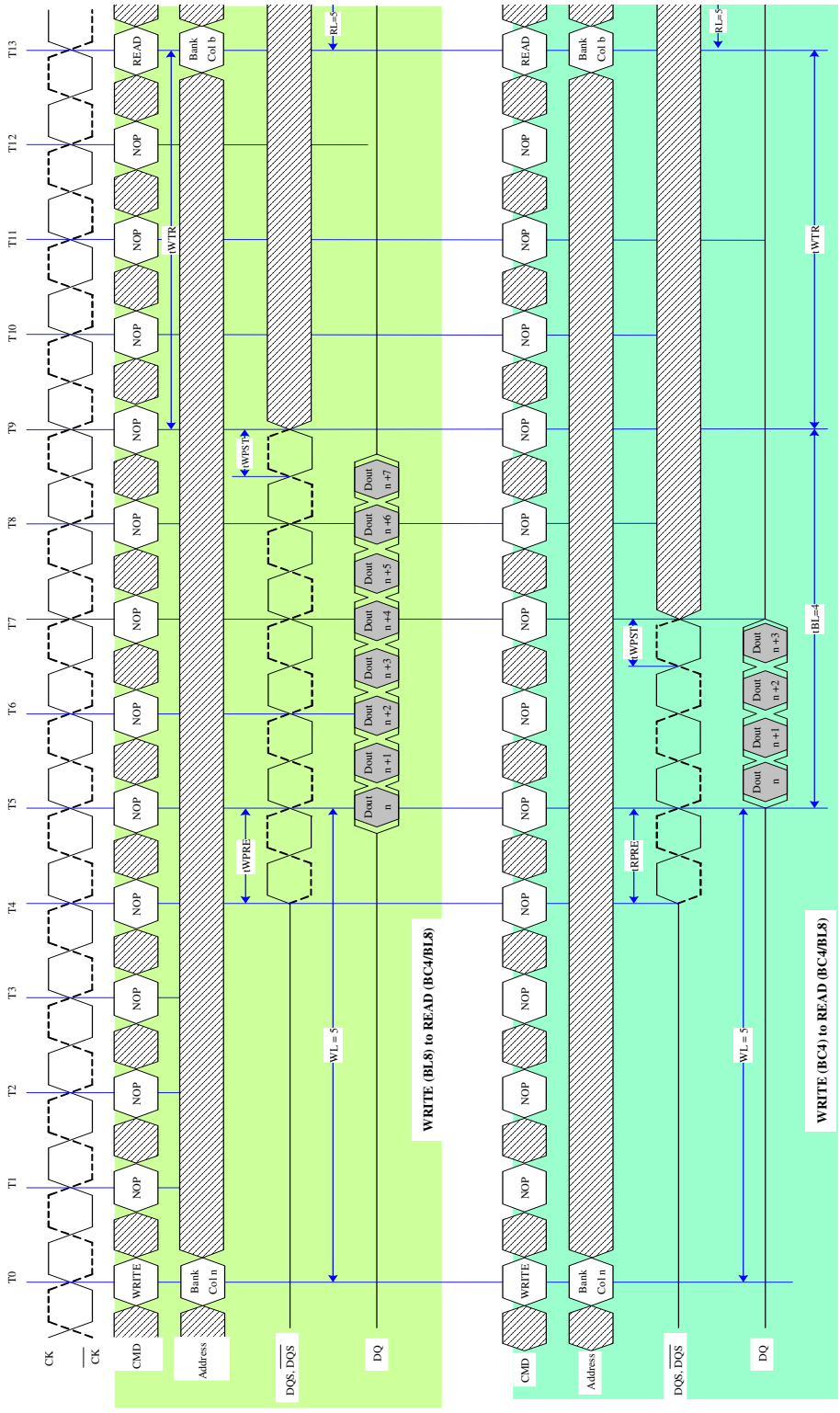
Note:

1. BL=8, WL=5 (AL=0, CWL=5).
2. Din n = data in from column n.
3. NOP commands are shown for ease of illustration; other command may be valid at these times.
4. BL8 setting activated by either MR0[A1:0=00] or MR0[A1:0=01] and A12 = 1 during WRITE command at T0.
4. tDQSS must be met at each rising clock edge.

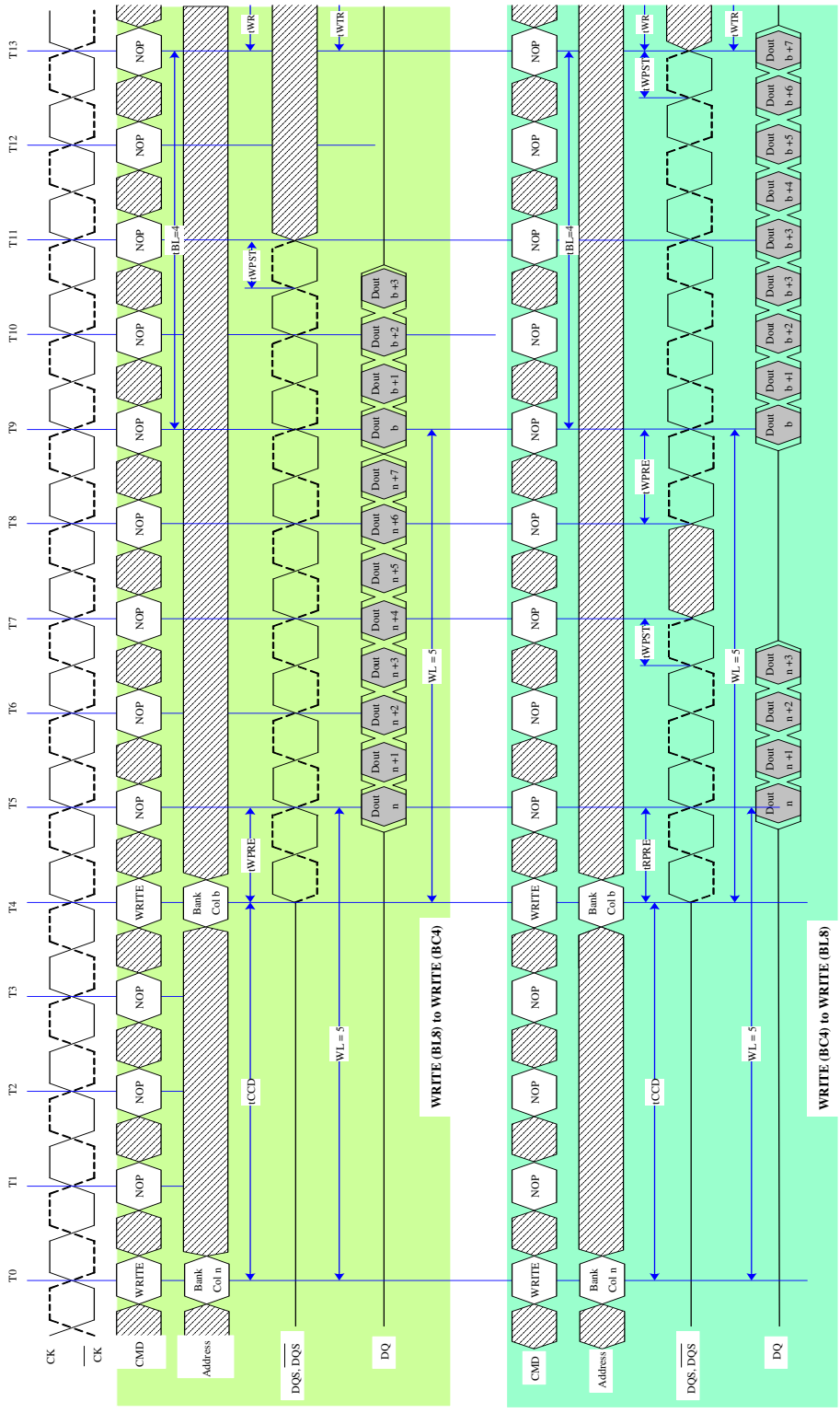
WRITE to WRITE (WL=5; CWL=5, AL=0)



WRITE to READ (RL=5, CL=5, AL=0; WL=5, CWL=5, AL=0; BL=4)



WRITE to WRITE (WL=5, CWL=5, AL=0)



Self-Refresh Operation

The Self-Refresh command can be used to retain data in the DDR3 SDRAM, even if the reset of the system is powered down. When in the Self-Refresh mode, the DDR3 SDRAM retains data without external clocking. The DDR3 SDRAM device has a built-in timer to accommodate Self-Refresh operation. The Self-Refresh Entry (SRE) Command is defined by having $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, and CKE held low with $\overline{WE}$ high at the rising edge of the clock.

Before issuing the Self-Refreshing-Entry command, the DDR3 SDRAM must be idle with all bank precharge state with tRP satisfied. Also, on-die termination must be turned off before issuing Self-Refresh-Entry command, by either registering ODT pin low "ODTL + 0.5tCK" prior to the Self-Refresh Entry command or using MRS to MR1 command. Once the Self-Refresh Entry command is registered, CKE must be held low to keep the device in Self-Refresh mode. During normal operation (DLL on), MR1 (A0=0), the DLL is automatically disabled upon entering Self-Refresh and is automatically enabled (including a DLL-RESET) upon exiting Self-Refresh.

When the DDR3 SDRAM has entered Self-Refresh mode, all of the external control signals, execpt CKE and $\overline{RESET}$, are "don't care". For proper Self-Refresh operation, all power supply and reference pins (VDD, VDDQ, VSS, VSSQ, VRefCA, and VRefDQ) must be at valid levels. The DRAM initiates a minimum of one Refresh command internally within tCKE period once it enters Self-Refresh mode.

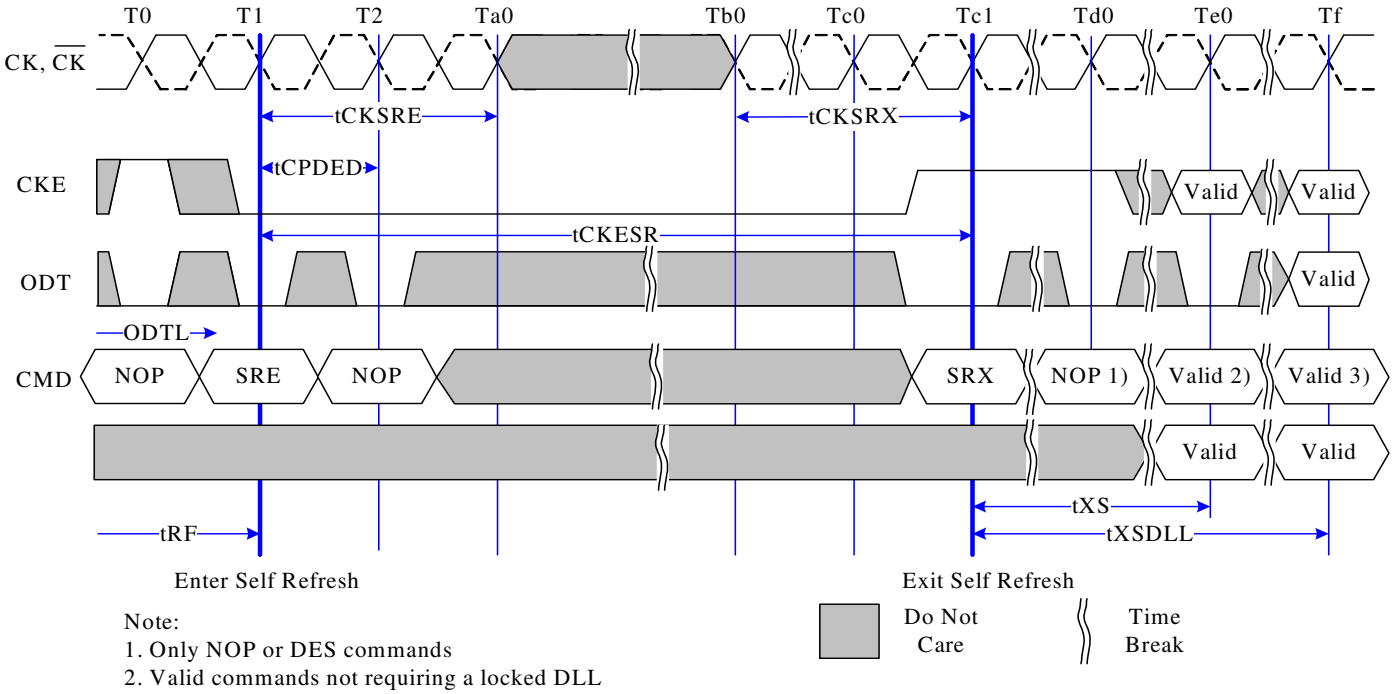
The clock is internally disabled during Self-Refresh operation to save power. The minimum time that the DDR3 SDRAM must remain in Self-Refresh mode is tCKE. The user may change the external clock frequency or halt the external clock tCKSRE after Self-Refresh entry is registered; however, the clock must be restarted and stable tCKSRX before the device can exit Self-Refresh mode.

The procedure for exiting Self-Refresh requires a sequence of events. First, the clock must be stable prior to CKE going back HIGH. Once a Self-Refresh Exit Command (SRX, combination of CKE going high and either NOP or Deselect on command bus) is registered, a delay of at least tXS must be satisfied before a valid command not requiring a locked DLL can be issued to the device to allow for any internal refresh in progress. Before a command which requires a locked DLL can be applied, a delay of at least tXSDLL and applicable ZQCAL function requirements [TBD] must be satisfied.

CKE must remain HIGH for the entire Self-Refresh exit period tXSDLL for proper operation except for Self-Refresh re-entry. Upon exit from Self-Refresh, the DDR3 SDRAM can be put back into Self-Refresh mode after waiting at least tXS period and issuing one refresh command (refresh period of tRFC). NOP or deselect commands must be registered on each positive clock edge during the Self-Refresh exit interval tXS. ODT must be turned off during tXSDLL.

The use of Self-Refresh mode instruces the possibility that an internally times refresh event can be missed when CKE is raised for exit from Self-Refresh mode. Upon exit from Self-Refresh, the DDR3 SDRAM requires a minimum of one extra refresh command before it is put back into Self-Refresh mode.

Self-Refresh Entry/Exit Timing



Note:
1. Only NOP or DES commands
2. Valid commands not requiring a locked DLL
3. Valid commands requiring a locked DLL

Power-Down Modes

Power-Down Entry and Exit

Power-Down is synchronously entered when CKE is registered low (along with NOP or Deselect command). CKE is not allowed to go low while mode register set command, MPR operations, ZQCAL operations, DLL locking or read/write operation are in progress. CKE is allowed to go low while any of other operation such as row activation, precharge or auto precharge and refresh are in progress, but power-down IDD spec will not be applied until finishing those operation.

The DLL should be in a locked state when power-down is entered for fastest power-down exit timing. If the DLL is not locked during power-down entry, the DLL must be reset after exiting power-down mode for proper read operation and synchronous ODT operation. DRAM design provides all AC and DC timing and voltage specification as well proper DLL operation with any CKE intensive operations as long as DRAM controller complies with DRAM specifications.

During Power-Down, if all banks are closed after any in progress commands are completed, the device will be in precharge Power-Down mode; if any bank is open after in progress commands are completed, the device will be in active Power-Down mode.

Entering Power-down deactivates the input and output buffers, excluding CK, $\overline{CK}$, ODT, CKE, and $\overline{RESET}$. To protect DRAM internal delay on CKE line to block the input signals, multiple NOP or Deselect commands are needed during the CKE switch off and cycle(s) after, this timing period are defined as tCPDED. CKE_low will result in deactivation of command and address receivers after tCPDED has expired.

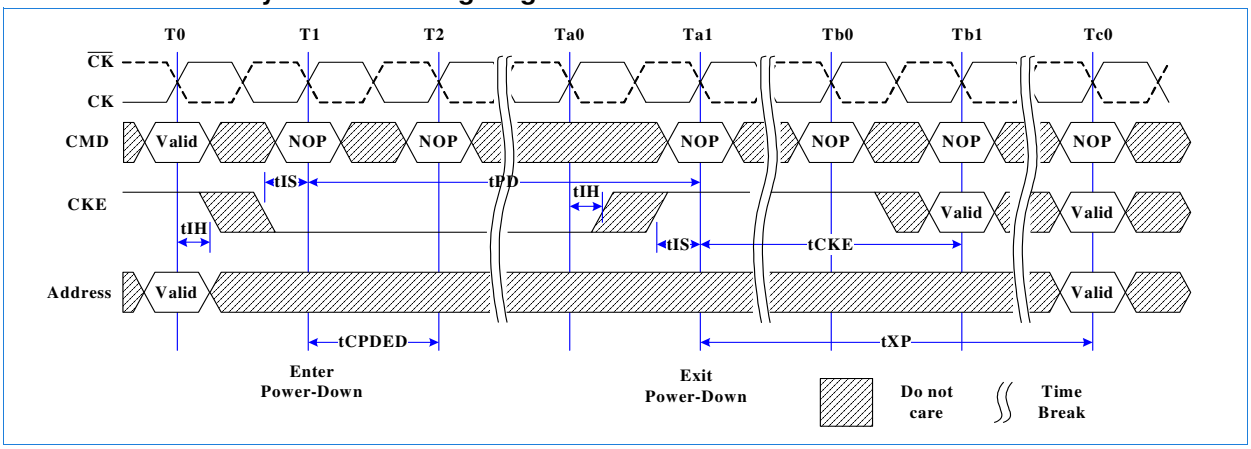
Power-Down Entry Definitions

Status of DRAM	MRS bit A12	DLL	PD Exit	Relevant Parameters
Active (A Bank or more open)	Don't Care	On	Fast	tXP to any valid command.
Precharged (All Banks Pre-charged)	0	Off	Slow	tXP to any valid command. Since it is in precharge state, commands here will be ACT, AR, MRS/EMRS, PR, or PRA. tXPDLL to commands who need DLL to operate, such as RD, RDA, or ODT control line.
Precharged (All Banks Pre-charged)	1	On	Fast	tXP to any valid command.

Also the DLL is disabled upon entering precharge power-down (Slow Exit Mode), but the DLL is kept enabled during precharge power-down (Fast Exit Mode) or active power-down. In power-down mode, CKE low, $\overline{RESET}$ high, and a stable clock signal must be maintained at the inputs of the DDR3 SDRAM, and ODT should be in a valid state but all other input signals are "Don't care" (If $\overline{RESET}$ goes low during Power-Down, the DRAM will be out of PD mode and into reset state). CKE low must be maintaine until tCKE has been satisfied. Power-down duration is limited by 9 times tREFI of the device.

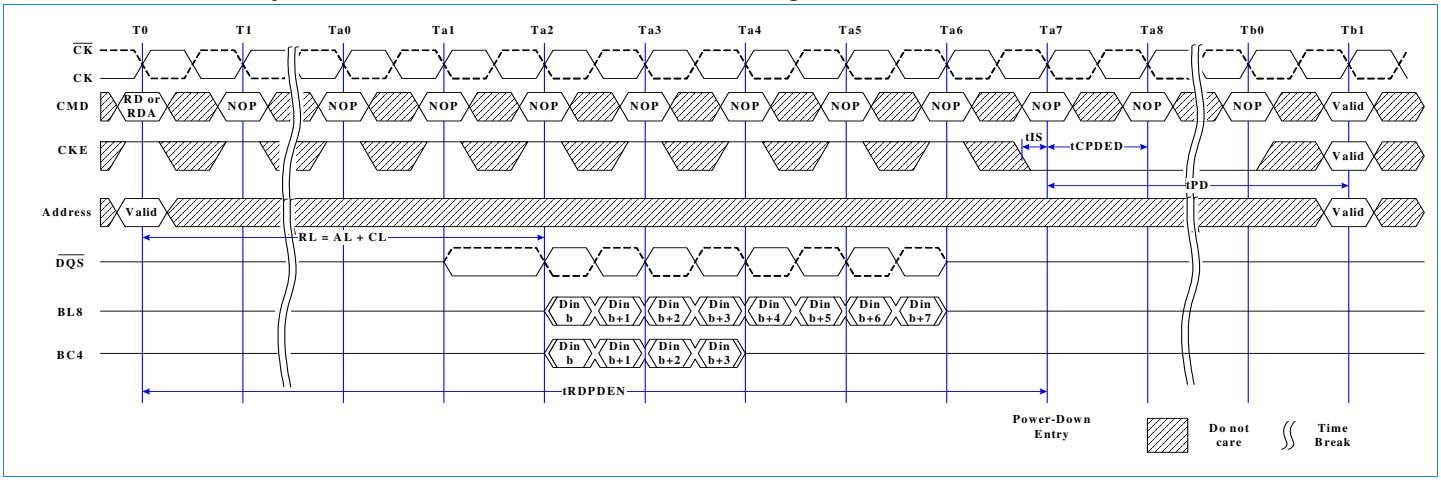
The power-down state is synchronously exited when CKE is registered high (along with a NOP or Deselect command). CKE high must be maintained until tCKE has been satisfied. A valid, executable command can be applied with power-down exit latency, tXP and/or tXPDLL after CKE goes high. Power-down exit latency is defined at AC spec table of this datasheet.

Active Power Down Entry and Exit timing diagram

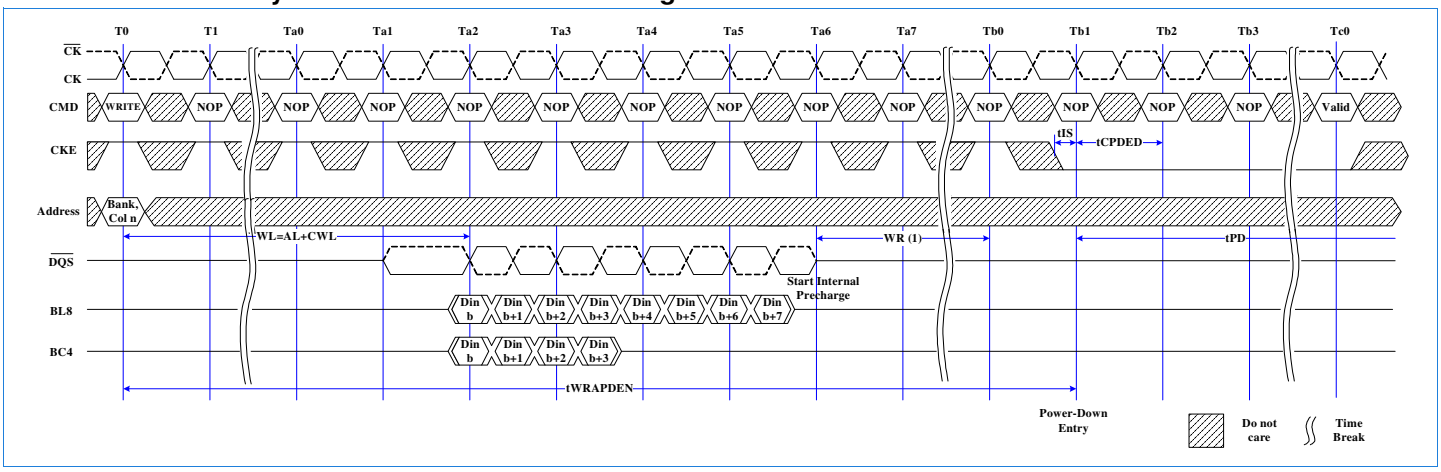


Timing Diagrams for CKE with PD Entry, PD Exit with Read, READ with Auto Precharge, Write and Write with Auto Precharge, Activate, Precharge, Refresh, MRS:

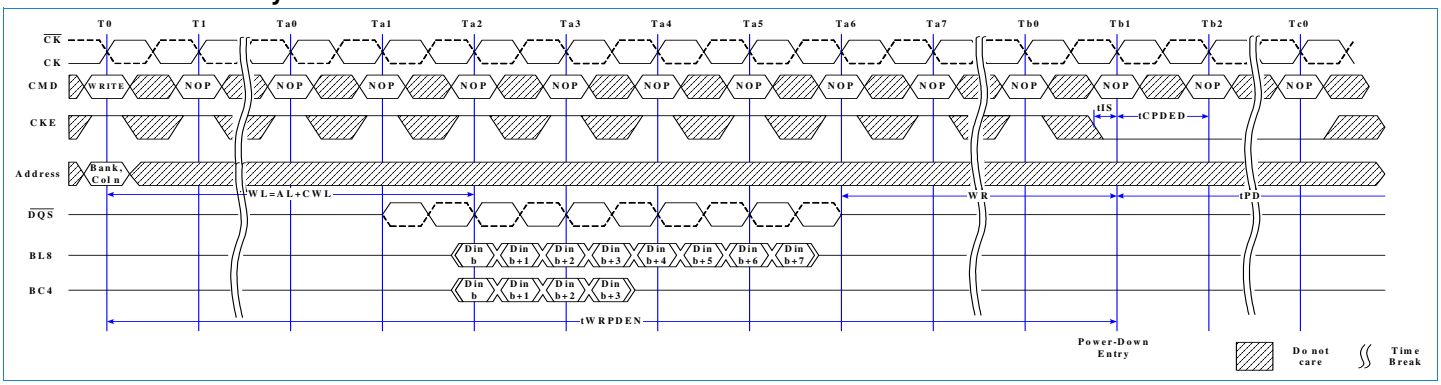
Power-Down Entry after Read and Read with Auto Precharge



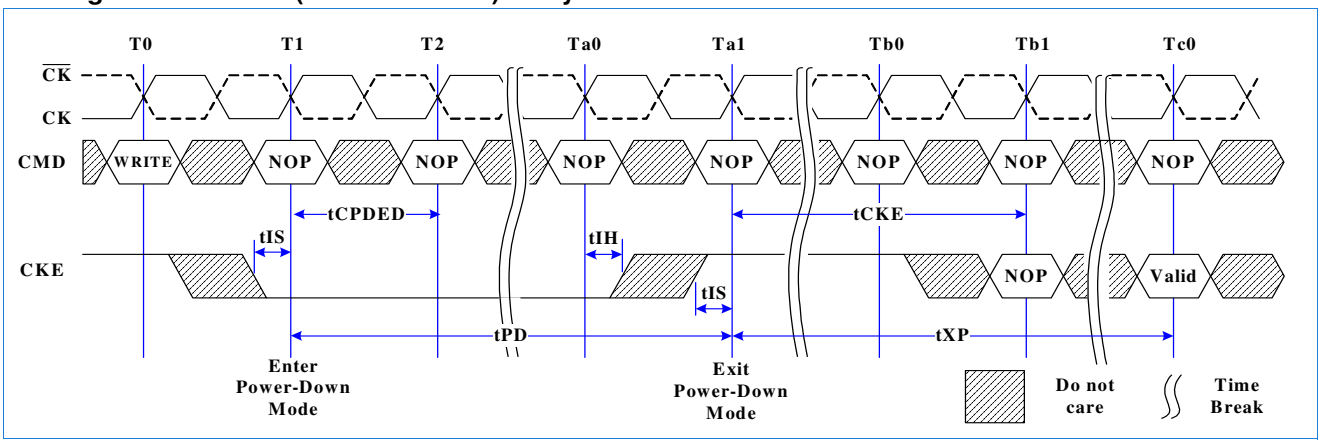
Power-Down Entry after Write with Auto Precharge



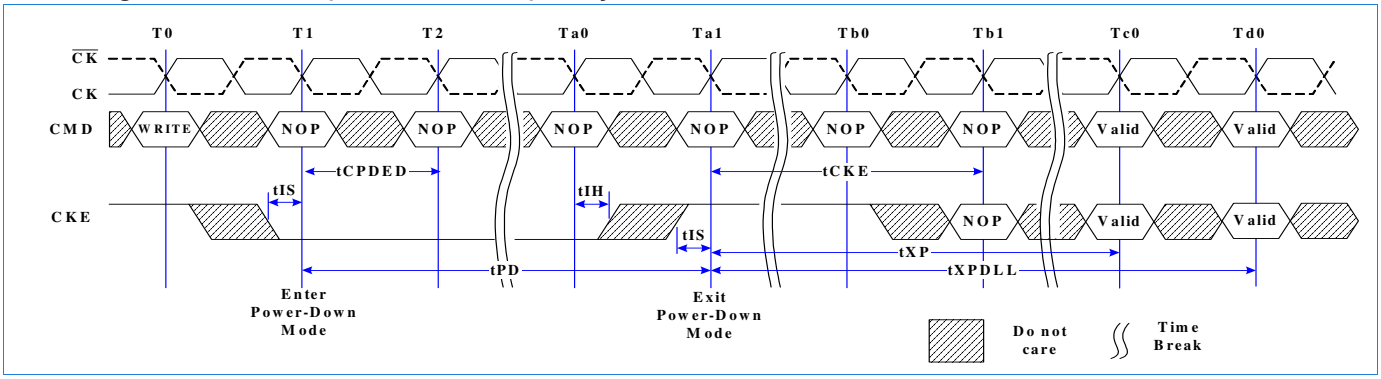
Power-Down Entry after Write



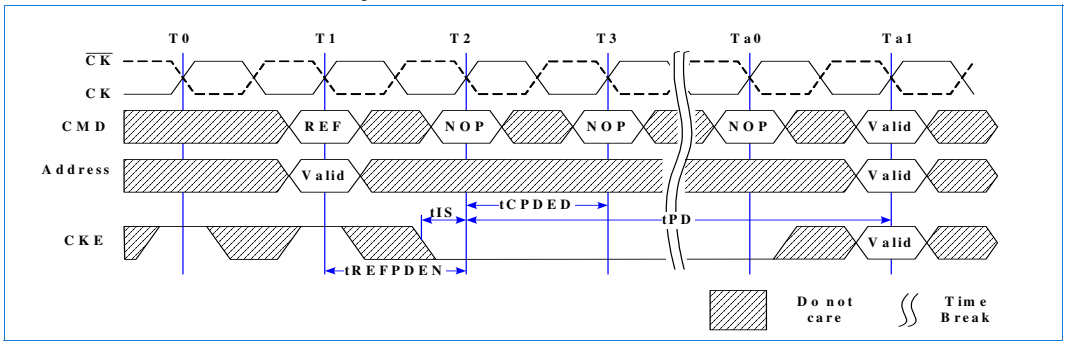
Precharge Power-Down (Fast Exit Mode) Entry and Exit



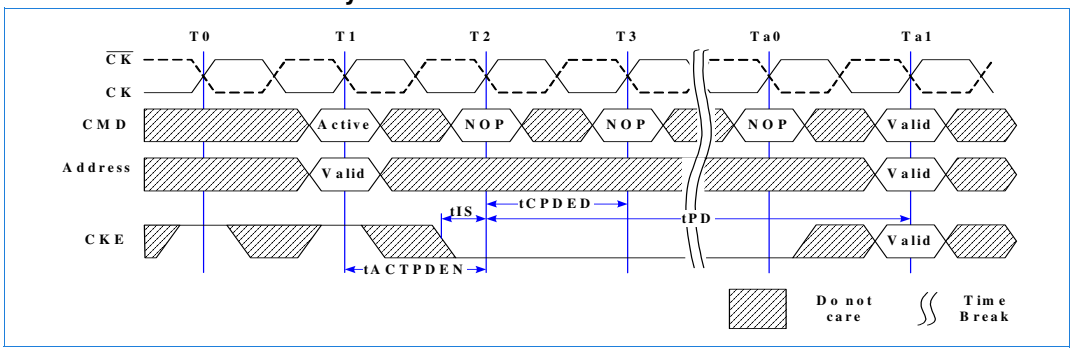
Precharge Power-Down (Slow Exit Mode) Entry and Exit



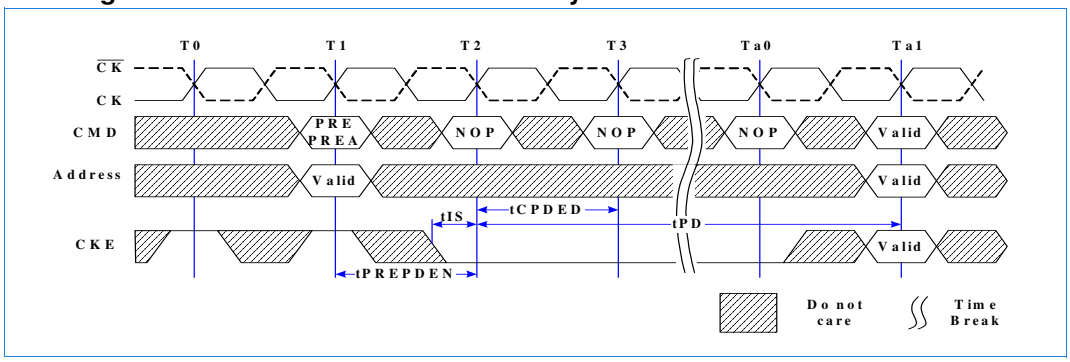
Refresh Command to Power-Down Entry



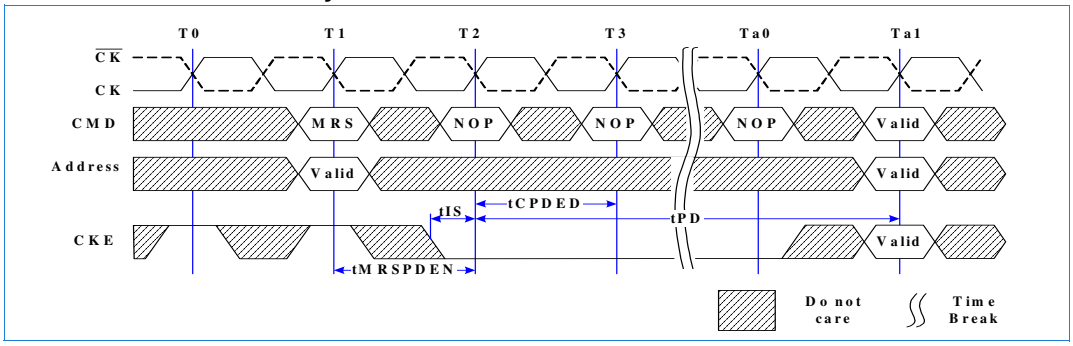
Active Command to Power-Down Entry



Precharge/Precharge all Command to Power-Down Entry



MRS Command to Power-Down Entry

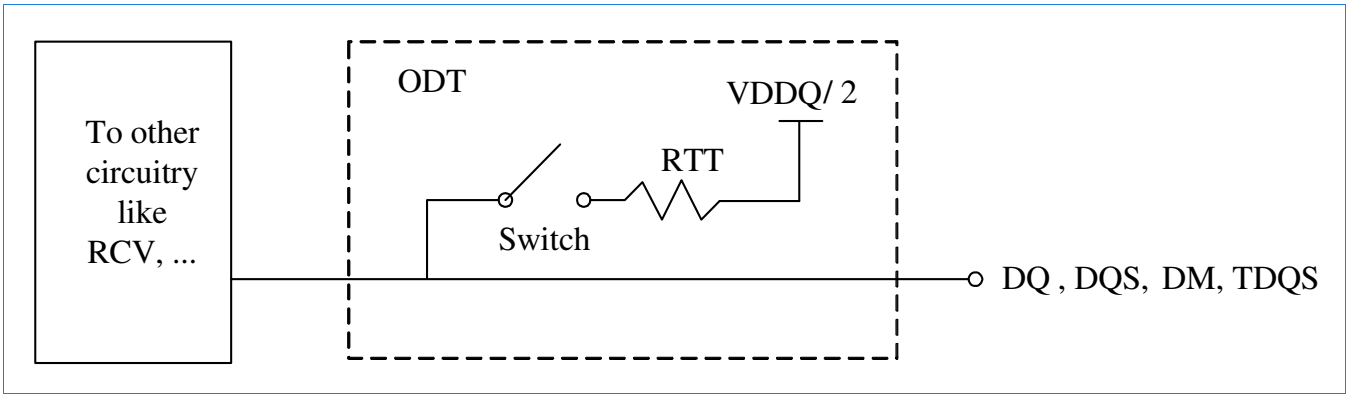


On-Die Termination (ODT)

ODT (On-Die Termination) is a feature of the DDR3 SDRAM that allows the DRAM to turn on/off termination resistance for each DQ, DQS, $\overline{DQS}$, and DM for x4 and x8 configuration (and TDQS, $\overline{TDQS}$ for x8 configurattion, when enabled via A11=1 in MR1) via the ODT control pin. For x16 configuration, ODT is applied to each DQU, DQL, DQSU, $\overline{DQSU}$, DQSL, $\overline{DQSL}$, DMU, and DML signal via the ODT control pin. The ODT feature is designed to improve signal integrity of the memory channel by allowing the DRAM controller to independently turn on/off termination resistance for any or all DRAM devices.

The ODT feature is turned off and not supported in Self-Refresh mode.

A simple functional representation of the DRAM ODT feature is shown as below.



The switch is enabled by the internal ODT control logic, which uses the external ODT pin and other control information. The value of RTT is determined by the settings of Mode Register bits. The ODT pin will be ignored if the Mode Register MR1 and MR2 are programmed to disable ODT and in self-refresh mode.

ODT Mode Register and ODT Truth Table

The ODT Mode is enabled if either of MR1 {A2, A6, A9} or MR2 {A9, A10} are non-zero. In this case, the value of RTT is determined by the settings of those bits.

Application: Controller sends WR command together with ODT asserted.

- One possible application: The rank that is being written to provides termination.
- DRAM turns ON termination if it sees ODT asserted (except ODT is disabled by MR)
- DRAM does not use any write or read command decode information.

Termination Truth Table

ODT pin	DRAM Termination State
0	OFF
1	ON, (OFF, if disabled by MR1 {A2, A6, A9} and MR2{A9, A10} in general)

Synchronous ODT Mode

Synchronous ODT mode is selected whenever the DLL is turned on and locked. Based on the power-down definition, these modes are:

- Any bank active with CKE high
- Refresh with CKE high
- Idle mode with CKE high
- Active power down mode (regardless of MR0 bit A12)
- Percharge power down mode if DLL is enabled during precharge power down by MR0 bit A12

The direct ODT feature is not supported during DLL-off mode. The on-die termination resistors must be disabled by continuously registering the ODT pin low and/or by programming the RTT_Nom bits MR1{A9,A6,A2} to {0,0,0} via a mode register set command during DLL-off mode.

In synchronous ODT mode, RTT will be turned on ODTLon clock cycles after ODT is sampled high by a rising clock edge and turned off ODTLoff clock cycles after ODT is registered low by a rising clock edge. The ODT latency is tied to the write latency (WL) by: ODTLonn = WL - 2; ODTLoff = WL-2.

ODT Latency and Posted ODT

In synchrouous ODT Mode, the Additive Latency (AL) programmed into the Mode Register (MR1) also applies to the ODT signal. The DRAM internal ODT signal is delayed for a number of clock cycles defined by the Additive Latency (AL) relative to the external ODT signal. ODTLon = CWL + AL - 2; ODTLoff = CWL + AL - 2. For details, refer to DDR3 SDRAM latency definitions.

ODT Latency

Symbol	Parameter	DDR3 SDRAM	Unit
ODTLon	ODT turn on Latency	WL - 2 = CWL + AL - 2	tCK
ODTLoff	ODT turn off Latency	WL - 2 = CWL + AL - 2	tCK

Timing Parameters

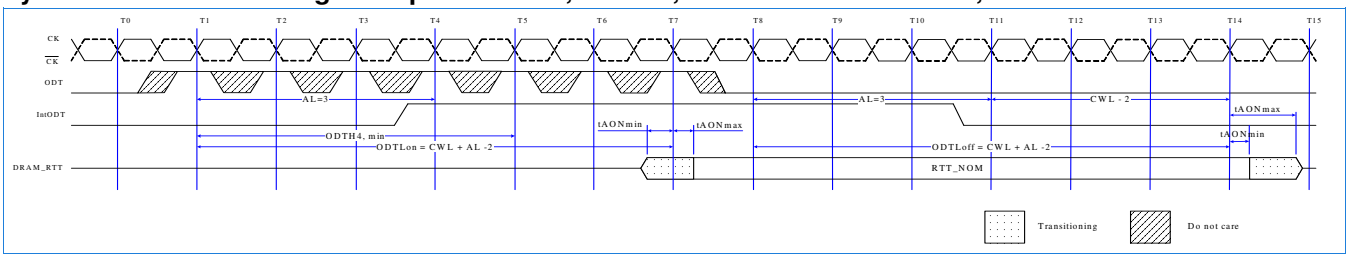
In synchronous ODT mode, the following timing parameters apply: ODTLon, ODTLoff, tAON min/max, AOF min/max.

Minimum RTT turn-on time (tAON min) is the point in time when the device leaves high impedance and ODT resistance begins to turn on. Maximum RTT turn-on time (tAON max) is the point in time when the ODT resistance is fully on. Both are measured from ODTLon.

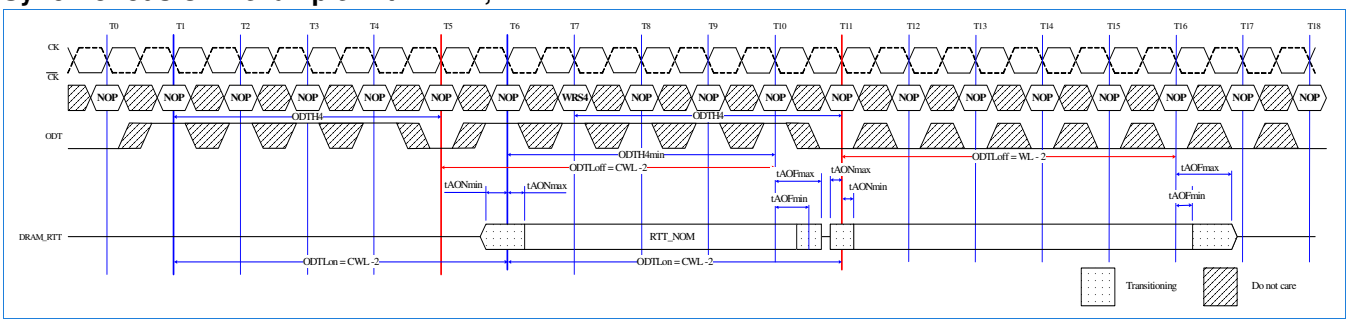
Minimum RTT turn-off time (tAOF min) is the point in time when the device starts to turn off the ODT resistance. Maximum RTT turn off time (tAOF max) is the point in time when the on-die termination has reached high impedance. Both are measured from ODTLoff.

When ODT is asserted, it must remain high until ODTH4 is satisfied. If a Write command is registered by the SDRAM with ODT high, then ODT must remain high until ODTH4 (BL=4) or ODTH8 (BL=8) after the write command. ODTH4 and ODTH8 are measured from ODT registered high to ODT registered low or from the registration of a write command until ODT is registered low.

Synchronous ODT Timing Example for AL=3; CWL=5; ODTLon=AL+CWL-2=6; ODTLoff=AL+CWL-2=6



Synchronous ODT example with BL=4, WL=7

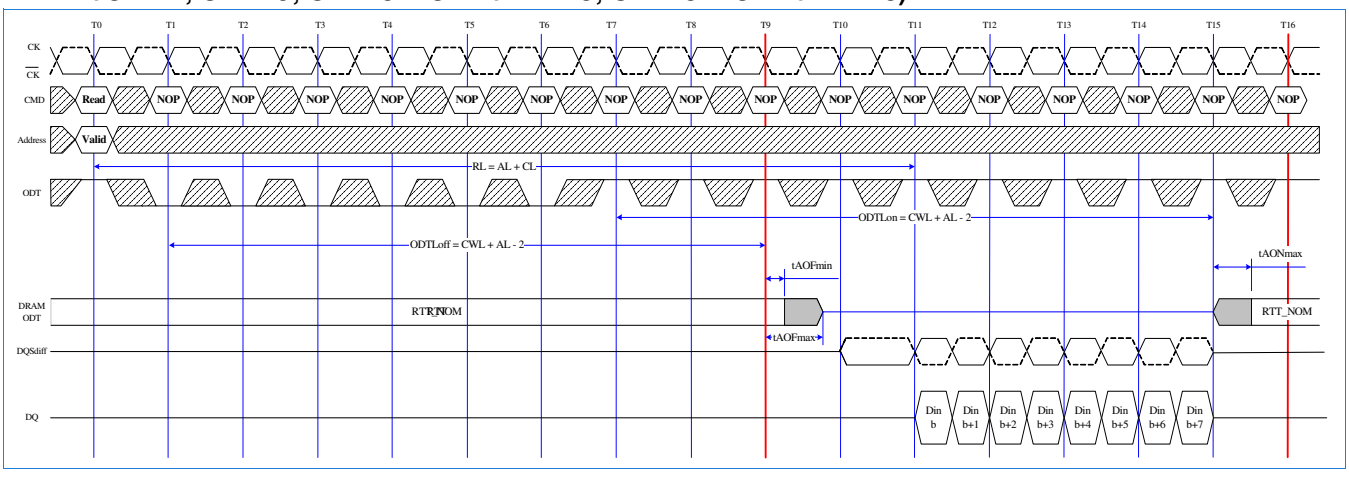


ODT must be held for at least ODTH4 after assertion (T1); ODT must be kept high ODTH4 (BL=4) or ODTH8 (BL=8) after Write commmand (T7). ODTH is measured from ODT first registered high to ODT first registered low, or from registration of Write command with ODT high to ODT registered low. Note that although ODTH4 is satisfied from ODT registered at T6 ODT must not go low before T11 as ODTH4 must alos be satisfied from the registration of the Write command at T7.

ODT during Reads:

As the DDR3 SDRAM can not terminate and drive at the same time, RTT must be disabled at least half a clock cycle before the read preamble by driving the ODT pin low appropriately. RTT may not be enabled until the end of the post-amble as shown in the following figure. DRAM turns on the termination when it stops driving which is determined by tHZ. If DRAM stops driving early (i.e. tHZ is early), then tAONmin time may apply. If DRAM stops driving late (i.e tHZ is late), then DRAM complies with tAONmax timing. Note that ODT may be disabled earlier before the Read and enabled later after the Read than shown in this example.

ODT must be disabled externally during Reads by driving ODT low. (Example: CL=6; AL=CL-1=5; RL=AL+CL=11; CWL=5; ODTLon=CWL+AL-2=8; ODTLoff=CWL+AL-2=8)



Dynamic ODT

In certain application cases and to further enhance signal integrity on the data bus, it is desireable that the termination strength of the DDR3 SDRAM can be changed without issuing an MRS command. This requirement is supported by the “Dynamic ODT” feature as described as follows:

Functional Description

The Dynamic ODT Mode is enabled if bit (A9) or (A10) of MR2 is set to ‘1’. The function is described as follows:

Two RTT values are available: RTT_Nom and RTT_WR.

- The value for RTT_Nom is preselected via bits A[9,6,2] in MR1.
- The value for RTT_WR is preselected via bits A[10,9] in MR2.

During operation without write commands, the termination is controlled as follows:

- Nominal termination strength RTT_Nom is selected.
- Termination on/off timing is controlled via ODT pin and latencies ODTLon and ODTLoff.

When a Write command (WR, WRA, WRS4, WRS8, WRAS4, WRAS8) is registered, and if Dynamic ODT is enabled, the termination is controlled as follows:

- A latency ODTLcnw after the write command, termination strength RTT_WR is selected.
- A latency ODTLcwn8 (for BL8, fixed by MRS or selected OTF) or ODTLcwn4 (for BC4, fixed by MRS or selected OTF) after the write command, termination strength RTT_Nom is selected.
- Termination on/off timing is controlled via ODT pin and ODTLon, ODTLoff.

The following table shows latencies and timing parameters which are relevant for the on-die termination control in Dynamic ODT mode.

The dynamic ODT feature is not supported at DLL-off mode. User must use MRS command to set RTT_WR, MR2[A10,A9 = [0,0], to disable Dynamic ODT externally.

When ODT is asserted, it must remain high until ODTH4 is satisfied. If a Write command is registered by the SDRAM with ODT high, then ODT must remain high until ODTH4 (BL=4) or ODTH8 (BL=8) after the Write command. ODTH4 and ODTH8 are measured from ODT registered high to ODT registered low or from the registration of Write command until ODT is register low.

Latencies and timing parameters relevant for Dynamic ODT

Name and Description	Abbr.	Defined from	Defined to	Definition for all DDR3 speed pin	Unit
ODT turn-on Latency	ODTLon	registering external ODT signal high	turning termination on	ODTLon=WL-2	tCK
ODT turn-off Latency	ODTLoff	registering external ODT signal low	turning termination off	ODTLoff=WL-2	tCK
ODT Latency for changing from RTT_Nom to RTT_WR	ODTLcnw	registering external write command	change RTT strength from RTT_Nom to RTT_WR	ODTLcnw=WL-2	tCK
ODT Latency for change from RTT_WR to RTT_Nom (BL=4)	ODTLcwn4	registering external write command	change RTT strength from RTT_WR to RTT_Nom	ODTLcwn4=4+ODTLoff	tCK
ODT Latency for change from RTT_WR to RTT_Nom (BL=8)	ODTLcwn8	registering external write command	change RTT strength from RTT_WR to RTT_Nom	ODTLcwn8=6+ODTLoff	tCK(avg)

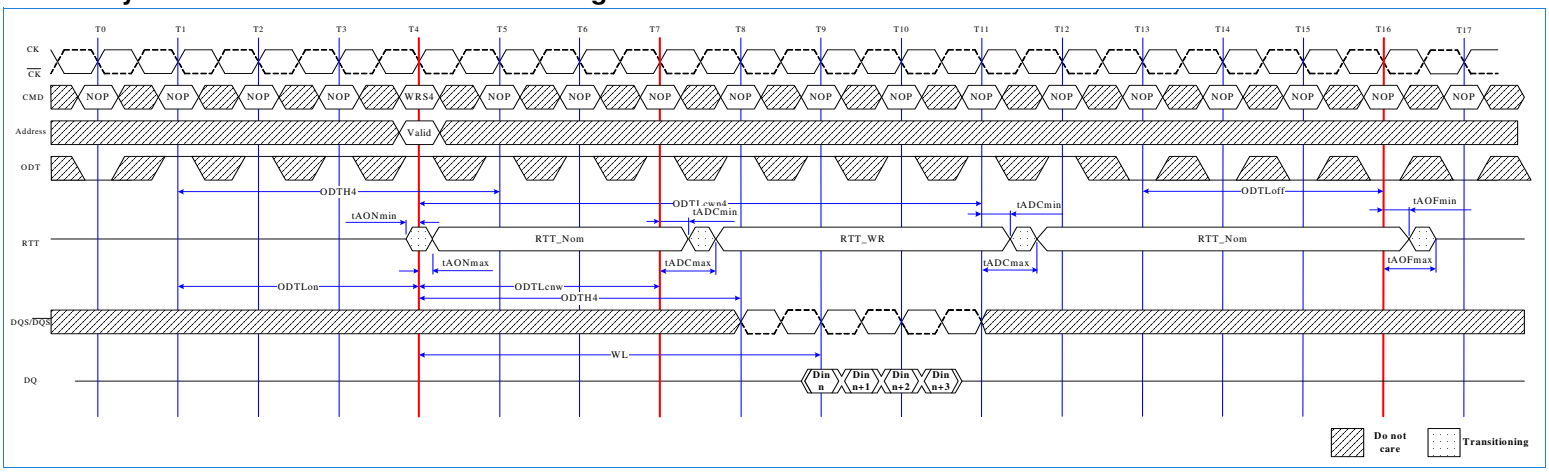
Latencies and timing parameters relevant for Dynamic ODT

Name and Description	Abbr.	Defined from	Defined to	Definition for all DDR3 speed pin	Unit
Minimum ODT high time after ODT assertion	ODTH4	registering ODT high	ODT registered low	ODTH4=4	tCK(avg)
Minimum ODT high time after Write (BL=4)	ODTH4	registering write with ODT high	ODT registered low	ODTH4=4	tCK(avg)
Minimum ODT high time after Write (BL=8)	ODTH8	registering write with ODT high	ODT register low	ODTH8=6	tCK(avg)
RTT change skew	tADC	ODTLcnw ODTLcwn	RTT valid	tADC(min)=0.3tCK(avg) tADC(max)=0.7tCK(avg)	tCK(avg)

Note: tAOF,nom and tADC,nom are 0.5tCK (effectively adding half a clock cycle to ODTLoff, ODTcnw, and ODTLcwn)

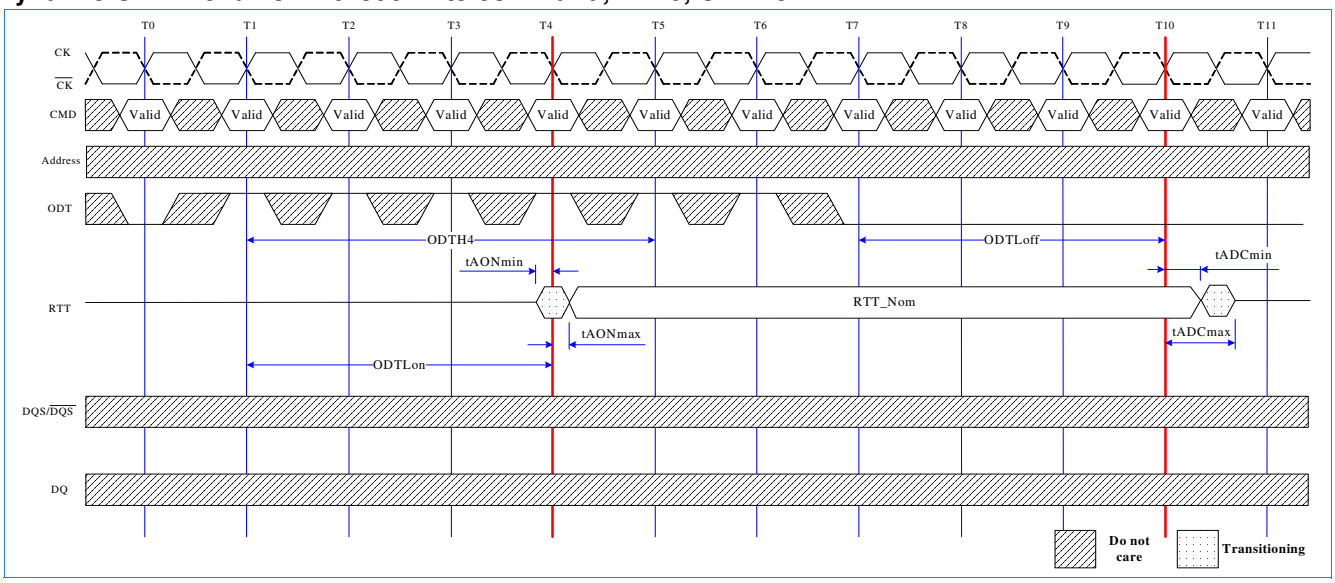
ODT Timing Diagrams

Dynamic ODT: Behavior with ODT being asserted before and after the write



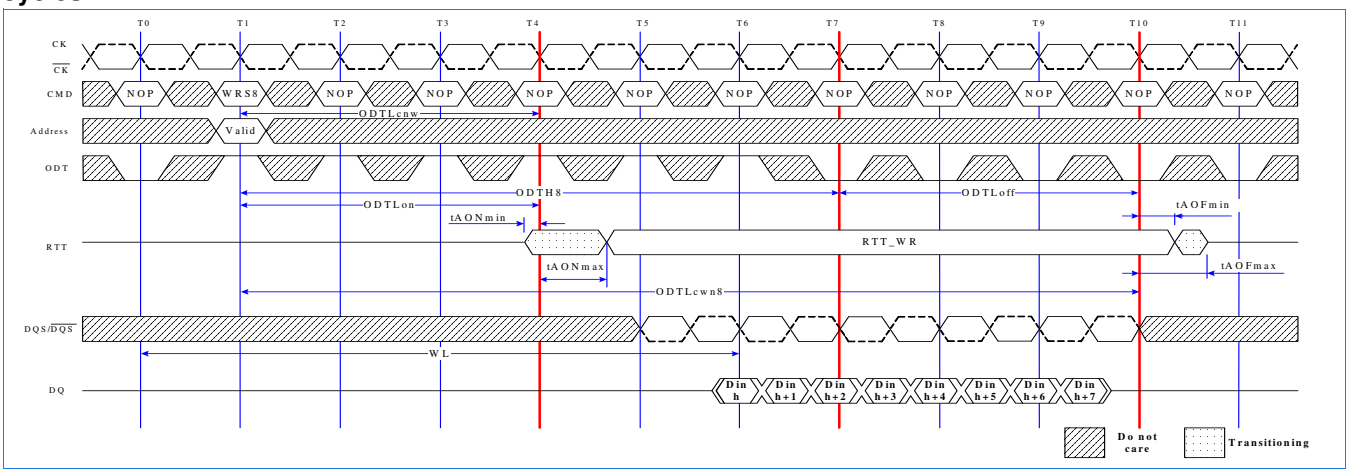
Note: Example for BC4 (via MRS or OTF), AL=0, CWL=5. ODTH4 applies to first registering ODT high and to the registration of the Write command. In tihs example ODTH4 would be satisfied if ODT went low at T8. (4 clocks after the Write command).

Dynamic ODT: Behavior without write command, AL=0, CWL=5



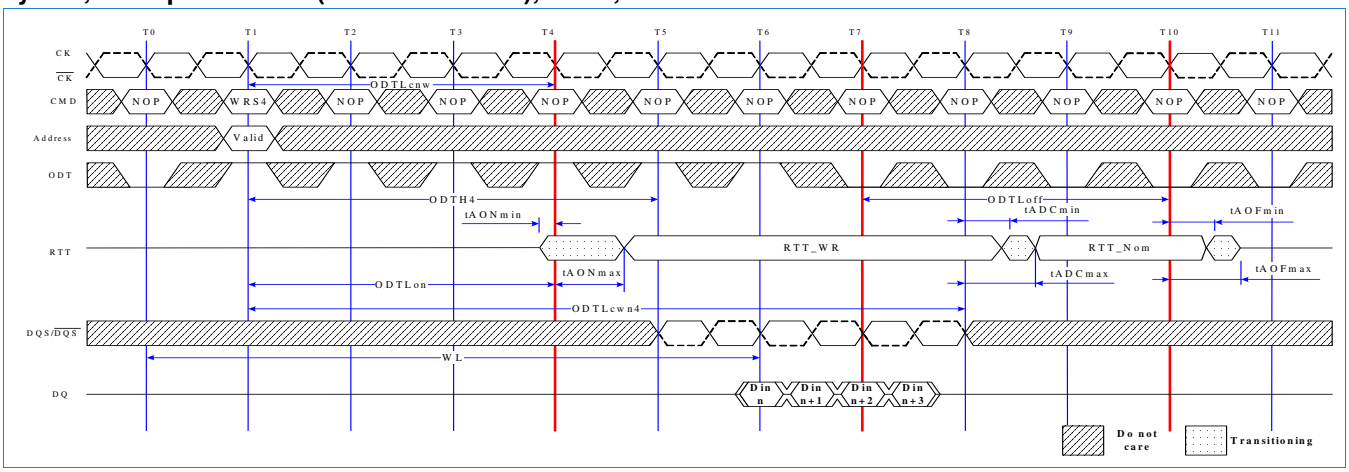
Note: ODTH4 is defined from ODT registered high to ODT registered low, so in this example ODTH4 is satisfied; ODT registered low at T5 would also be legal.

Dynamic ODT: Behavior with ODT pin being asserted together with write command for a duration of 6 clock cycles.

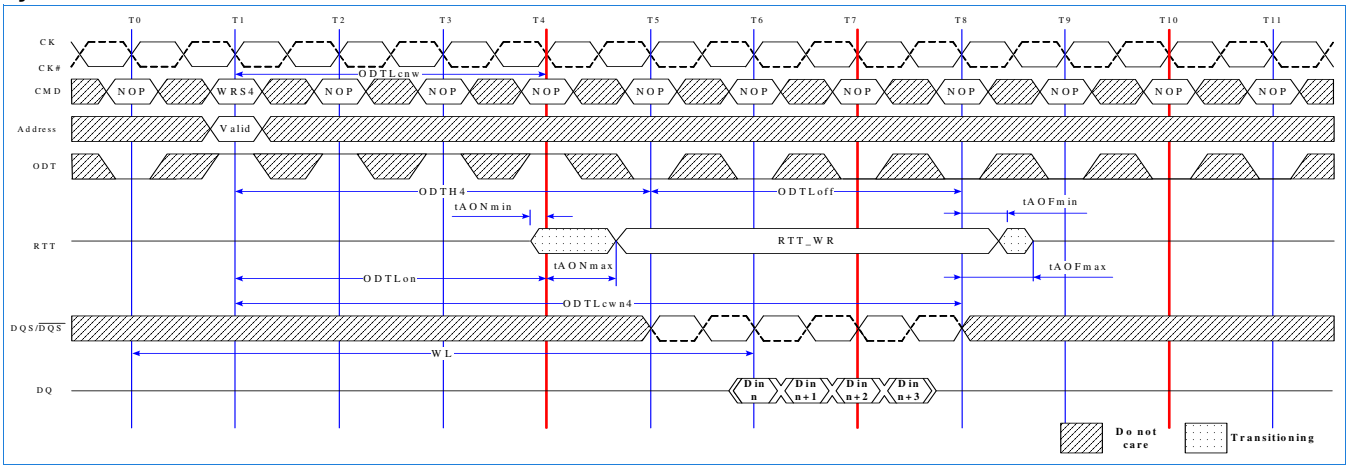


Note: Example for BL8 (via MRS or OTF), AL=0, CWL=5. In this example ODTH8=6 is exactly satisfied.

Dynamic ODT: Behavior with ODT pin being asserted together with write command for a duration of 6 clock cycles, example for BC4 (via MRS or OTF), AL=0, CWL=5.



Dynamic ODT: Behavior with ODT pin being asserted together with write command for a duration of 4 clock cycles.



Asynchronous ODT Mode

Asynchronous ODT mode is selected when DRAM runs in DLLon mode, but DLL is temporarily disabled (i.e. frozen) in precharge power-down (by MR0 bit A12). Based on the power down mode definitions, this is currently Precharge power down mode if DLL is disabled during precharge power down by MR0 bit A12.

In asynchronous ODT timing mode, internal ODT command is NOT delayed by Additive Latency (AL) relative to the external ODT command.

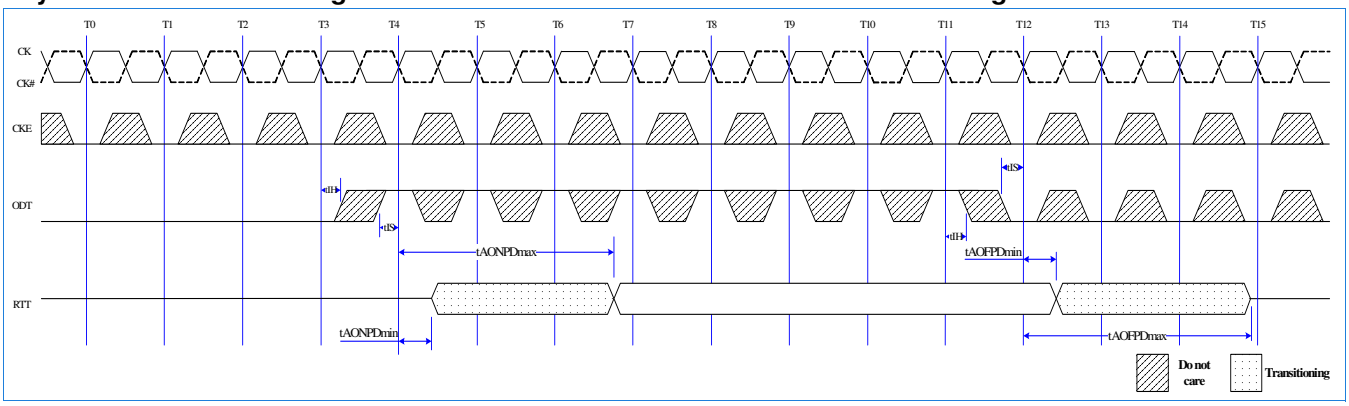
In asynchronous ODT mode, the following timing parameters apply: tAONPD min/max, tAOFPD min/max.

Minimum RTT turn-on time (tAONPD min) is the point in time when the device termination circuit leaves high impedance state and ODT resistance begins to turn on. Maximum RTT turn on time (tAONPD max) is the point in time when the ODT resistance is fully on.

tAONPDmin and tAONPDmax are measured from ODT being sampled high.

Minimum RTT turn-off time (tAOFPDmin) is the point in time when the devices termination circuit starts to turn off the ODT resistance. Maximum ODT turn off time (tAOFPDmax) is the point in time when the on-die termination has reached high impedance. tAOFPDmin and tAOFPDmax are measured from ODT being sample low.

Asynchronous ODT Timings on DDR3 SDRAM with fast ODT transition: AL is ignored.



In Precharge Power Down, ODT receiver remains active, however no Read or Write command can be issued, as the respective ADD/CMD receivers may be disabled.

Asynchronous ODT Timing Parameters for all Speed Bins

Symbol	Description	min	max	Unit
tAONPD	Asynchronous RTT turn-on delay (Power-Down with DLL frozen)	1	9	ns
tAOFPD	Asynchronous RTT turn-off delay (Power-Down with DLL frozen)	1	9	ns

ODT timing parameters for Power Down (with DLL frozen) entry and exit transition period

Description	min	max
ODT to RTT turn-on delay	min{ ODTLon * tCK + tAONmin; tAONPDmin } min{ (WL - 2) * tCK + tAONmin; tAONPDmin }	max{ ODTLon * tCK + tAONmax; tAONPDmax } max{ (WL - 2) * tCK + tAONmax; tAONPFmax }
ODT to RTT turn-off delay	min{ ODTLoff * tCK + tAOFmin; tAOFPDmin } min{ (WL - 2) * tCK + tAOFmin; tAOFPDmin }	max{ ODTLoff * tCK + tAOFmax; tAOFPDmax } max{ (WL - 2) * tCK + tAOFmax; tAOFPDmax }
tANPD	WL-1	

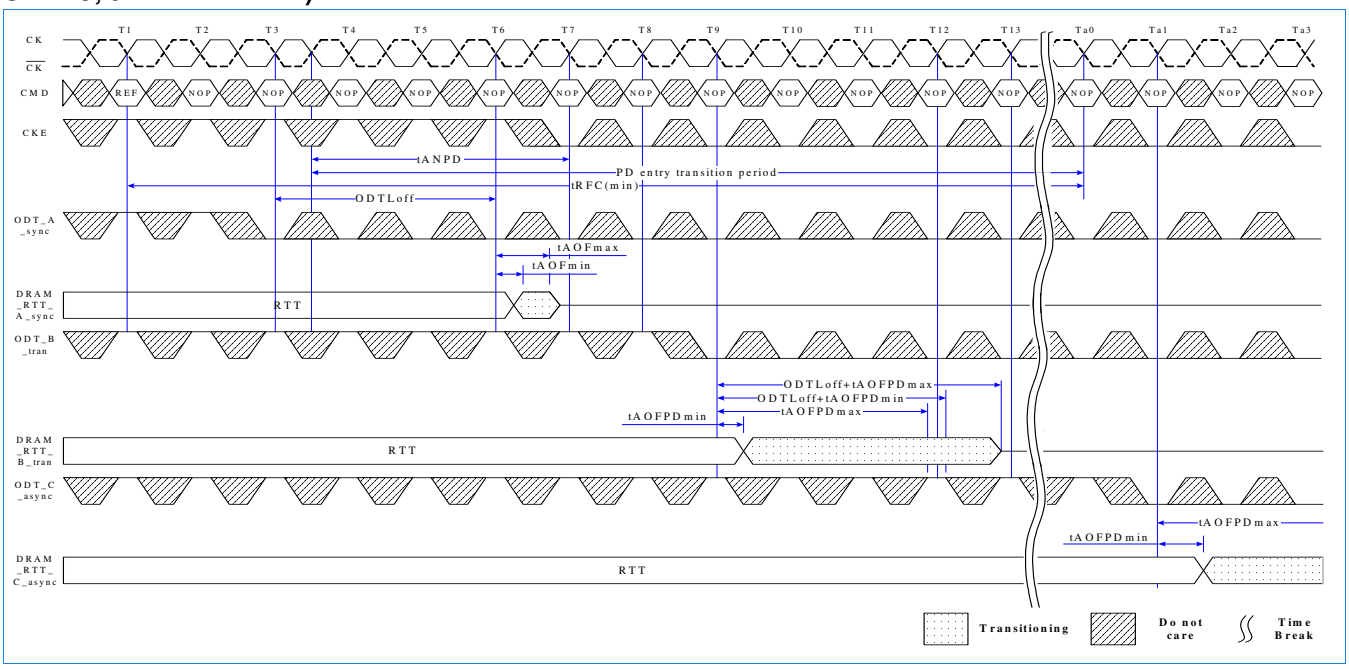
Synchronous to Asynchronous ODT Mode Transition during Power-Down Entry

If DLL is selected to be frozen in Precharge Power Down Mode by the setting of bit A12 in MR0 to “0”, there is a transition period around power down entry, where the DDR3 SDRAM may show either synchronous or asynchronous ODT behavior.

This transition period ends when CKE is first registered low and starts tANPD before that. If there is a Refresh command in progress while CKE goes low, then the transition period ends tRFC after the Refresh command. tANPD is equal to (WL-1) and is counted (backwards) from the clock cycle where CKE is first registered low.

ODT assertion during the transition period may result in an RTT changes as early as the smaller of tAONPDmin and (ODTLon*tck+tAONmin) and as late as the larger of tAONPDmax and (ODTLon*tCK+tAONmax). ODT de-assertion during the transition period may result in an RTT change as early as the smaller of tAOFPDmin and (ODTLoff*tCK+tAOFmin) and as late as the larger of tAOFPDmax and (ODTLoff*tCK+tAOFmax). Note that, if AL has a large value, the range where RTT is uncertain becomes quite large. The following figure shows the three different cases: ODT_A, synchonous behavior before tANPD; ODT_B has a state change during the transition period; ODT_C shows a state change after the transition period.

Synchronous to asynchronous transition during Precharge Power Down (with DLL frozen) entry (AL=0; CWL=5; tANPD=WL-1=4)



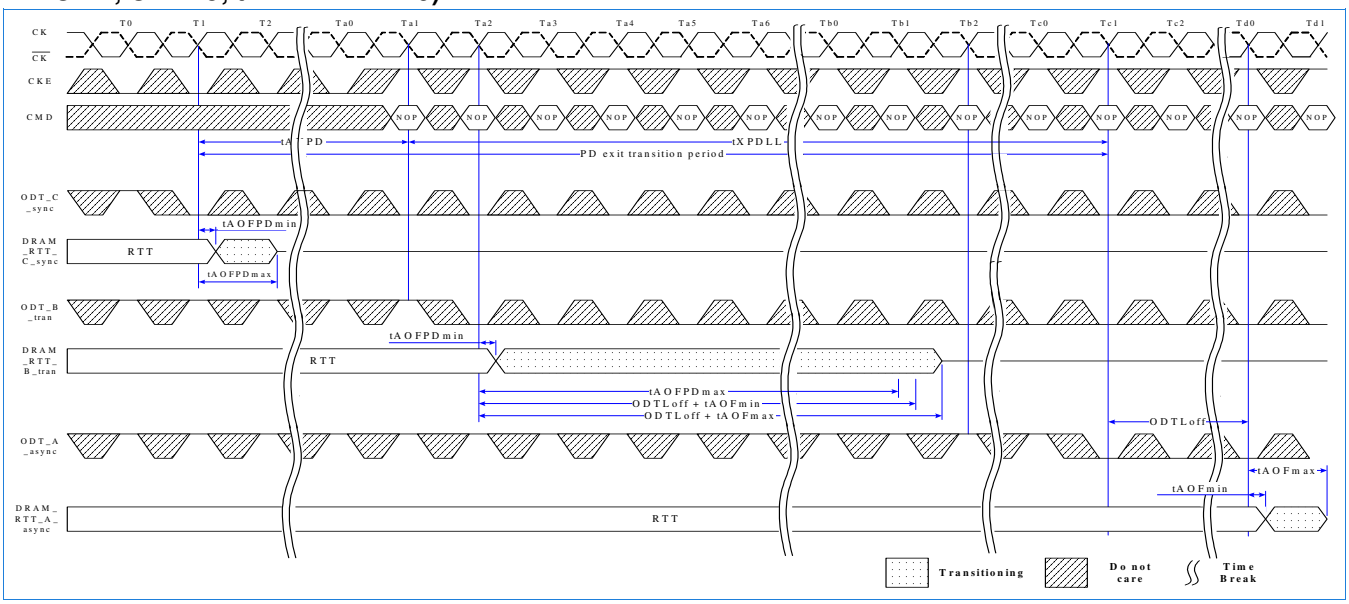
Asynchronous to Synchronous ODT Mode transition during Power-Down Exit

If DLL is selected to be frozen in Precharge Power Down Mode by the setting of bit A12 in MR0 to “0”, there is also a transition period around power down exit, where either synchronous or asynchronous response to a change in ODT must be expected from the DDR3 SDRAM.

This transition period starts tANPD before CKE is first registered high, and ends tXPDLL after CKE is first registered high. tANPD is equal to (WL -1) and is counted (backwards) from the clock cycle where CKE is first registered high.

ODT assertion during the transition period may result in an RTT change as early as the smaller of tAONPDmin and (ODTLon*tCK+tAONmin) and as late as the larger of tAONPDmax and (ODTLon*tCK+tAONmax). ODT de-assertion during the transition period may result in an RTT change as early as the smaller of tAOFPDmin and (ODTLoff*tCK+tAOFmin) and as late as the larger of tAOFPDmax and (ODToff*tCK+tAOFmax). Note that if AL has a large value, the range where RTT is uncertain becomes quite large. The following figure shows the three different cases: ODT_C, asynchonous response before tANPD; ODT_B has a state change of ODT during the transition period; ODT_A shows a state change of ODT after the transition period with synchonous response.

Asynchronous to synchronous transition during Precharge Power Down (with DLL frozen) exit (CL=6; AL=CL-1; CWL=5; tANPD=WL-1=9)



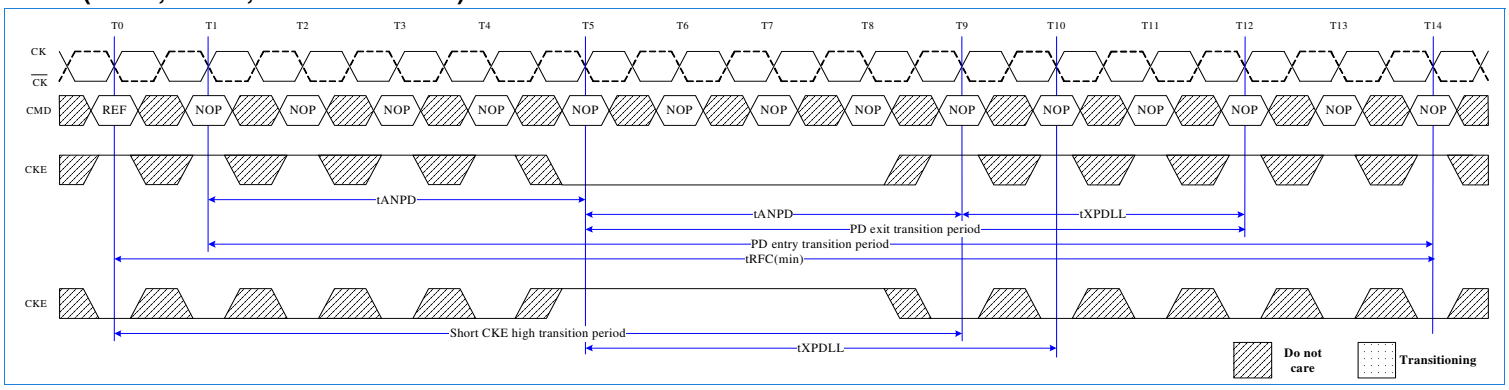
Asynchronous to Synchronous ODT Mode during short CKE high and short CKE low periods

If the total time in Precharge Power Down state or Idle state is very short, the transition periods for PD entry and PD exit may overlap. In this case, the response of the DDR3 SDRAMs RTT to a change in ODT state at the input may be synchronous or asynchronous from the state of the PD entry transition period to the end of the PD exit transition period (even if the entry ends later than the exit period).

If the total time in Idle state is very short, the transition periods for PD exit and PD entry may overlap. In this case, the response of the DDR3 SDRAMs RTT to a change in ODT state at the input may be synchronous or asynchronous from the state of the PD exit transition period to the end of the PD entry transition period. Note that in the following figure, it is assumed that there was no Refresh command in progress when Idle state was entered.

Transition period for short CKE cycles with entry and exit period overlapping

(AL=0; WL=5; tANPD=WL-1=4)



ZQ Calibration Commands

ZQ Calibration Description

ZQ Calibration command is used to calibrate DRAM Ron and ODT values. DDR3 SDRAM needs longer time to calibrate output driver and on-die termination circuits at initialization and relatively smaller time to perform periodic calibrations.

ZQCL command is used to perform the initial calibration during power-up initialization sequence. This command may be issued at any time by the controller depending on the system environment. ZQCL command triggers the calibration engine inside the DRAM and once calibration is achieved the calibrated values are transferred from calibration engine to DRAM IO which gets reflected as updated output driver and on-die termination values.

The first ZQCL command issued after reset is allowed a timing period of tZQinit to perform the full calibration and the transfer of values. All other ZQCL commands except the first ZQCL command issued after RESET is allowed a timing period of tZQoper.

ZQCS command is used to perform periodic calibrations to account for voltage and tempeartue variations. A shorter timing window is provided to perform the calibration and transfer of values as defined by timing parameter tZQCS.

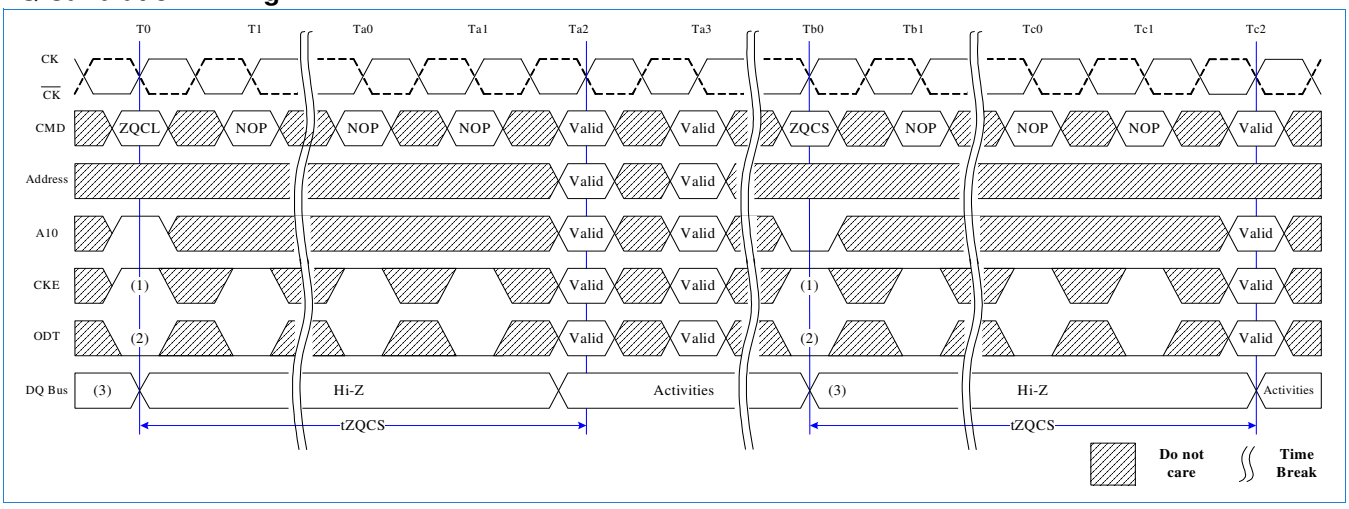
No other activities should be performed on the DRAM channel by the controller for the duration of tZQinit, tZQoper, or tZQCS. The quiet time on the DRAM channel allows calibration of output driver and on-die termination values. Once DRAM calibration is achieved, the DRAM should disable ZQ current consumption path to reduce power.

All banks must be precharged and tRP met before ZQCL or ZQCS commands are issued by the controller.

ZQ calibration commands can also be issued in parallel to DLL lock time when coming out of self refresh. Upon self-refresh exit, DDR3 SDRAM will not perform an IO calibration without an explicit ZQ calibration command. The earliest possible time for ZQ Calibration command (short or long) after self refresh exit is tXS.

In systems that share the ZQ resistor between devices, the controller must not allow any overlap of tZQoper, tZQinit, or tZQCS between ranks.

ZQ Calibration Timing



Note:

1. CKE must be continuously registered high during the calibration procedure.
2. On-die termination must be disabled via the ODT signal or MRS during the calibration procedure.
3. All devices connected to the DQ bus should be high impedance during the calibration procedure.

ZQ External Resistor Value, Tolerance, and Capacitive loading

In order to use the ZQ calibration funcation, a 240 ohm +/- 0.1% tolerance external resistor connected between the ZQ pin and ground. The single resistor can be used for each SDRAM or one resistor can be shared between two SDRAMs if the ZQ calibration timings for each SDRAM do not overlap. The total capacitive loading on the ZQ pin must be limited.

Absolute Maximum Ratings

Absolute Maximum DC Ratings

Symbol	Parameter	Rating	Units	Note
VDD	Voltage on VDD pin relative to Vss	-0.4 ~ 1.975	V	1,3
VDDQ	Voltage on VDDQ pin relative to Vss	-0.4 ~ 1.975	V	1,3
Vin, Vout	Voltage on any pin relative to Vss	-0.4 ~ 1.975	V	1
Tstg	Storage Temperature	-55 ~ 100	°C	1,2

Note:
1. Stresses greater than those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the opearational sections of this specification is nto implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.
2. Storage Temperature is the case surface temperature on the center/top side of the DRAM.
3. VDD and VDDQ must be within 300mV of each other at all times; and Vref must be not greater than 0.6VDDQ, when VDD and VDDQ are less than 500mV; Vref may be equal to or less than 300mV.

Temperature Range

Symbol	Parameter	Rating	Units	Notes
Toper	Normal Operating Temperature Range	0 to 85	°C	1,2
	Extended Temperature Range	85 to 95	°C	1,3

Note:
1. Operating Temperature Toper is the case surface temperature on the center/top side of the DRAM.
2. The Normal Temperature Range specifies the temperatures where all DRAM specification will be supported. During operation, the DRAM case temperature must be maintained between 0-85°C under all operating conditions.
3. Some applications require operation of the DRAM in the Extended Temperature Range between 85°C and 95°C case temperature. Full specifications are guaranteed in this range, but the following additional apply:
a) Refresh commands must be doubled in frequency, therefore, reducing the Refresh interval tREFI to 3.9us. It is also possible to specify a component with 1x refresh (tREFI to 7.8us) in the Extended Temperature Range.
b) If Self-Refresh operation is required in the Extended Temperature Range, then it is mandatory to either use the Manual Self-Refresh mode with Extended Temperature Range capability (MR2 A6=0 and MR2 A7=1) or enable the optional Auto Self-Refresh mode (MR2 A6=1 and MR2 A7=0).

AC & DC Operating Conditions

Recommanded DC Operating Conditions

Symbol	Parameter	Rating			Unit	Note
		Min.	Typ.	Max.		
VDD	Supply Voltage	1.425	1.5	1.575	V	1,2
VDDQ	Supply Voltage for Output	1.425	1.5	1.575	V	1,2

Note:
1. Under all conditions VDDQ must be less than or equal to VDD.
2. VDDQ tracks with VDD. AC parameters are measured with VDD and VDDQ tied together.

AC & DC Input Measurement Levels

AC and DC Logic Input Levels for Single-Ended Signals

Symbol	Parameter	Min.	Max.	Unit	Note
VIH(DC)	DC input logic high	Vref + 0.100	VDD	V	1
VIL(DC)	DC input logic low	VSS	Vref - 0.100	V	1
VIH(AC)	AC input logic high	Vref + 0.175	-	V	1
VIL(AC)	AC input logic low	-	Vref - 0.175	V	1
VrefDQ(DC)	Reference Voltage for DQ, DM inputs	0.49 * VDD	0.51 * VDD	V	2,3
VrefCA(DC)	Reference Voltage for ADD, CMD inputs	0.49 * VDD	0.51 * VDD	V	2,3

Note:
1. For DQ and DM: Vref=VrefDQ. For input only pins except $\overline{\text{RESET}}$: Vref=VrefCA.
2. The ac peak noise on Vref may not allow Vref to deviate from Vref(DC) by more than +/- 0.1% VDD.
3. For reference: approx. VDD/2 +/- 15mV.

AC and DC Logic Input Levels for Differential Signals

Symbol	Parameter	Min.	Max.	Unit	Notes
VIHdiff	Differential input logic high	0.200	note3	V	1
VILdiff	Differential input logic low	note3	-0.200	V	1
VIHdiff(ac)	Differential input high ac	2 x (VIH(ac) - Vref)	note3	V	2
VILdiff(ac)	Differential input low ac	note3	2 x (Vref - VIL(ac))	V	2

Note:
1. Used to define a differential signal slew-rate.
2. For CK - $\overline{\text{CK}}$ use VIH/VIL(ac) of ADD/CMD and VREFCA; for DQS - $\overline{\text{DQS}}$, DQSL, $\overline{\text{DQSL}}$, DQSU, $\overline{\text{DQSU}}$ use VIH/VIL(ac) of DQs and VREFDQ; if a reduced ac-high or ac-low level is used for a signal group, then the reduced level applies also there.
3. These values are not defined, however the single-ended signals CK, $\overline{\text{CK}}$, DQS, $\overline{\text{DQS}}$, DQSL, $\overline{\text{DQSL}}$, DQSU, $\overline{\text{DQSU}}$ need to be within the respective limits (VIH(dc)max, VIL(dc)min) for single-ended signals as wel as limitations for overshoot and undershoot.

Allowed time before ringback (tDVAC) for CK - $\overline{\text{CK}}$ and DQS - $\overline{\text{DQS}}$

Slew Rate [V/ns]	tDVAC [ps] @IVIH/Ldiff(ac)I = 350mV		tDVAC [ps] @IVIH/Ldiff(ac)I = 300mV	
> 4.0	75	-	175	-
4.0	57	-	170	-
3.0	50	-	167	-
2.0	38	-	163	-
1.8	34	-	162	-
1.6	29	-	161	-
1.4	22	-	159	-
1.2	13	-	155	-
1.0	0	-	150	-
< 1.0	0	-	150	-

Single-ended requirements for differential signals

Each individual component of a differential signal (CK, DQS, DQSL, DQSU, $\overline{CK}$, $\overline{DQS}$, $\overline{DQSL}$, or $\overline{DQSU}$) has also to comply with certain requirements for single-ended signals.

CK and $\overline{CK}$ have to approximately reach VSEHmin / VSELmax (approximately equal to the ac-levels (VIH(ac) / VIL(ac)) for ADD/CMD signals) in every half-cycle. DQS, DQSL, DQSU, DQS, DQSL, DQSL have to reach VSEHmin / VSELmax (approximately the ac-levels (VIH(ac) / VIL(ac)) for DQ signals) in every half-cycle preceeding and following a valid transition.

Single-ended levels for CK, DQS, DQSL, DQSU, $\overline{CK}$, $\overline{DQS}$, $\overline{DQSL}$, or $\overline{DQSU}$

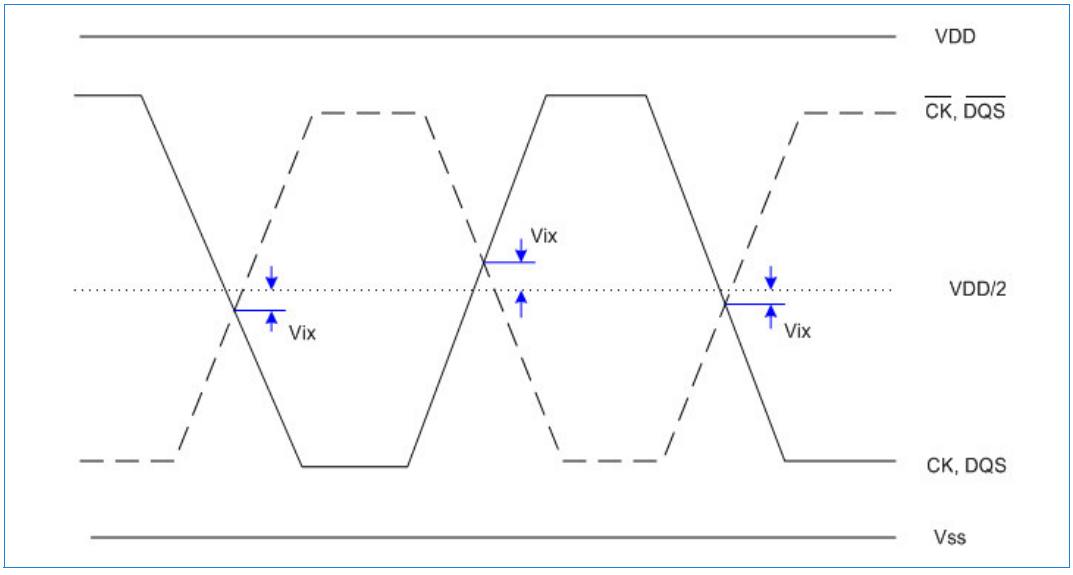
Symbol	Parameter	Min	Max	Unit	Notes
VSEH	Single-ended high-level for strobes	VIH(ac) - VREFDQ + VDDQ/2	note3	V	1, 2
	Single-ended high-level for CK, $\overline{CK}$	VIH(ac) - VREFCA + VDD/2	note3	V	1, 2
VSEL	Single-ended low-level for strobes	note3	VIL(ac) + VREFDQ - VDDQ/2	V	1, 2
	Single-ended Low-level for CK, $\overline{CK}$	note3	VIH(ac) + VREFCA - VDD/2	V	1, 2

Note:
1. For CK, $\overline{CK}$ use VIH/VIL(ac) of ADD/CMD; for strobes (DQS, DQSL, DQSU, $\overline{CK}$, $\overline{DQS}$, $\overline{DQSL}$, or $\overline{DQSU}$) use VIH/VIL(ac) of DQs.
2. VIH(ac)/VIL(ac) for DQs is based on VREFDQ; VIH(ac)/VIL(ac) for ADD/CMD is based on VREFCA; if a reduced ac-high or ac-low level is used for a singal group, then the reduced level applies also there.
3. These values are not defined, however the single-ended signals CK, $\overline{CK}$, DQS, $\overline{DQS}$, DQSL, $\overline{DQSL}$, DQSU, $\overline{DQSU}$ need to be within the respective limits (VIH(dc)max, VIL(dc)min) for single-ended signals as wel as limitations for overshoot and undershoot.

Differential Input Cross Point Voltage

To guarantee tight setup and hold times as well as output skew parameters with respect to clock and strobe, each cross point voltage of differential input signals (CK, $\overline{CK}$ and DQS, $\overline{DQS}$) must meet the requirements in the following table. The differential input cross point voltage Vix is measured from the actual cross point of true and completement signal to the midlevel between of VDD and VSS.

Vix Definition



Cross point voltage for differential input signals (CK, DQS)

Symbol	Parameter	Min.	Max.	Unit
Vix	Differential Input Cross Point Voltage relative to VDD/2	-150	150	mV

Slew Rate Definitions for Single Ended Input Signals

Input Slew Rate for Input Setup Time (tIS) and Data Setup Time (tDS)

Setup (tIS and tDS) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of Vref and the first crossing of VIH(AC)min. Setup (tIS and tDS) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of Vref and the first crossing of VIL(AC)max.

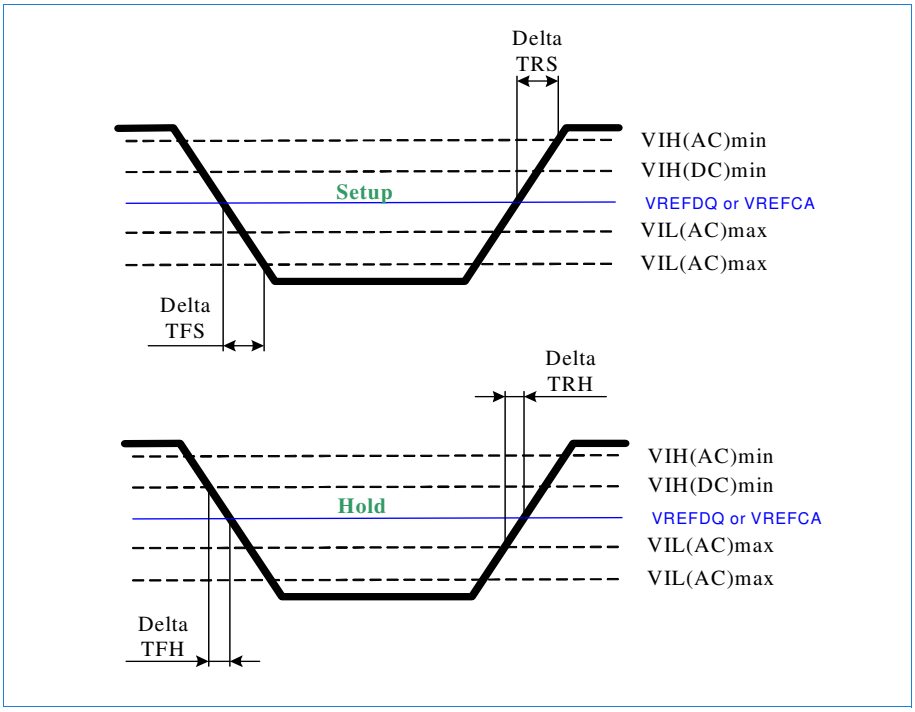
Input Slew Rate for Input Hold Time (tIH) and Data Hold Time (tDH)

Hold nominal slew rate for a rising signal is defined as the slew rate between the last crossing of VIL(DC)max and the first crossing of Vref. Hold (tIH and tDH) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of VIH(DC)min and the first crossing of Vref.

Single-ended Input Slew Rate Definition

Description	Measured		Defined by	Applicable for
	from	to		
Input slew rate for rising edge	Vref	VIH(AC)min	[VIH(AC)min-Vref] / DeltaTRS	Setup (tIS, tDS)
Input slew rate for falling edge	Vref	VIL(AC)max	[Vref-VIL(AC)max] / DeltaTFS	
Input slew rate for rising edge	VIL(DC)max	Vref	[Vref-VIL(DC)max] / DeltaTFH	Hold (tIH, tDH)
Input slew rate for falling edge	VIH(DC)max	Vref	[VIH(DC)min-Vref] / DeltaTRH	

Input Nominal Slew Rate Defination for single ended signals

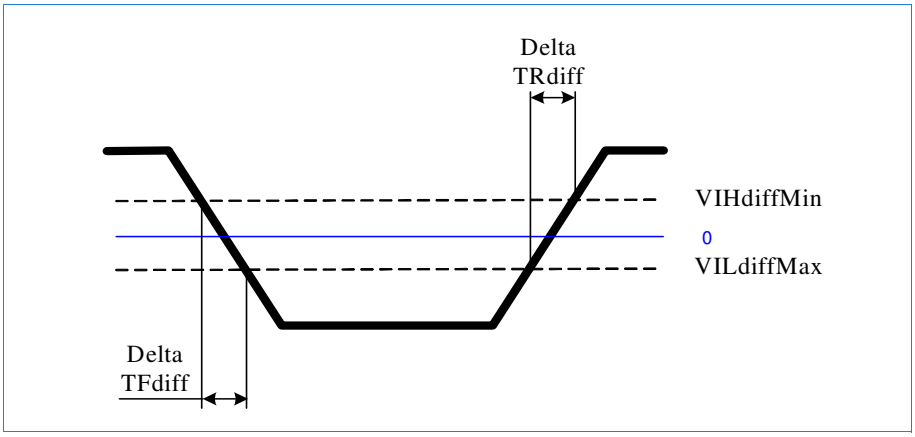


Slew Rate Definiation for Differential Input Signals

Differential Input Slew Rate Definition

Description	Measured		Defined by
	From	To	
Differential input slew rate for rising edge (CK-$\overline{CK}$ & DQS-DQS)	VILdiffmax	VIHdiffmin	[VIHdiffmin-VILdiffmax] / DeltaTRdiff
Differential input slew rate for falling edge (CK-$\overline{CK}$ & DQS-DQS)	VIHdiffmin	VILdiffmax	[VIHdiffmin-VILdiffmax] / DeltaTFdiff
The differential signal (CK-$\overline{CK}$ & DQS-$\overline{DQS}$) must be linear between these thresholds.			

Input Nominal Slew Rate Defination for single ended signals



AC and DC Output Measurement Levels

Single Ended AC and DC Output Levels

Symbol	Parameter	Value	Unit	Notes
VOH(DC)	DC output high measurement level (for IV curve linearity)	0.8xVDDQ	V	
VOM(DC)	DC output mid measurement level (for IV curve linearity)	0.5xVDDQ	V	
VOL(DC)	DC output low measurement level (fro IV curve linearity)	0.2xVDDQ	V	
VOH(AC)	AC output hight measurement level (for output SR)	VTT+0.1xVDDQ	V	1
VOL(AC)	AC output low measurement level (for output SR)	VTT-0.1xVDDQ	V	1

Note:
1. The swing of +/- 0.1 x VDDQ is based on approximately 50% of the static single ended output high or low swing with a driver impedance of 40 ohms and an effective test load of 25 ohms to VTT = VDDQ/2.

Differential AC and DC Output Levels

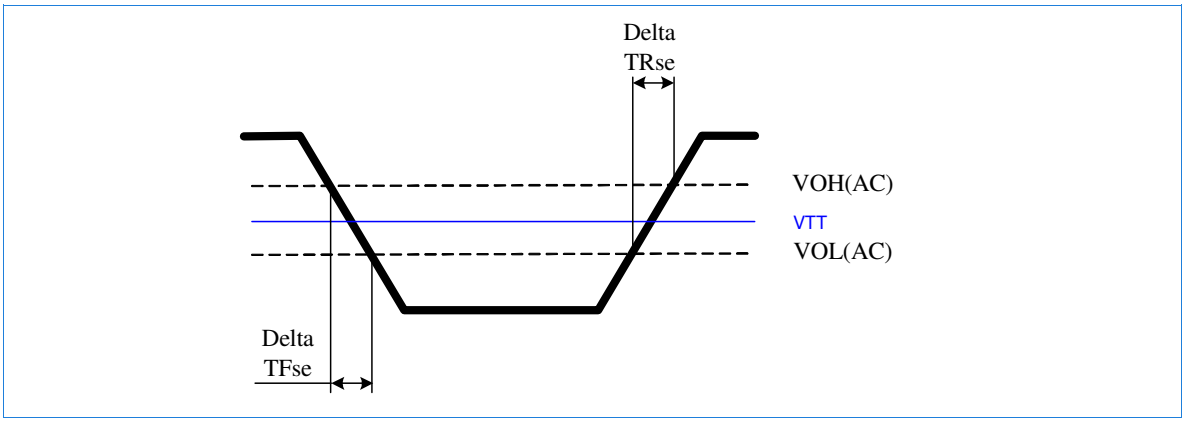
Symbol	Parameter	DDR3	Unit	Notes
VOHdiff(AC)	AC differential output high measurement level (for output SR)	+0.2 x VDDQ	V	1
VOLdiff(AC)	AC differential output low measurement level (for output SR)	-0.2 x VDDQ	V	1

Note:
1. The swing of +/- 0.2 x VDDQ is based on approximately 50% of the static differential output high or low swing with a driver impedance of 40 ohms and an effective test load of 25 ohms to VTT=VDDQ/2 at each of the differential outputs.

Single Ended Output Slew Rate

Description	Measured		Defined by
	From	To	
Single ended output slew rate for rising edge	VOL(AC)	VOH(AC)	[VOH(AC)-VOL(AC)] / DeltaTRse
Single ended output slew rate for falling edge	VOH(AC)	VOL(AC)	[VOH(AC)-VOL(AC)] / DeltaTFse
Note: Output slew rate is verified by design and characterisation, and may not be subject to production test.			

Single Ended Output Slew Rate Definition



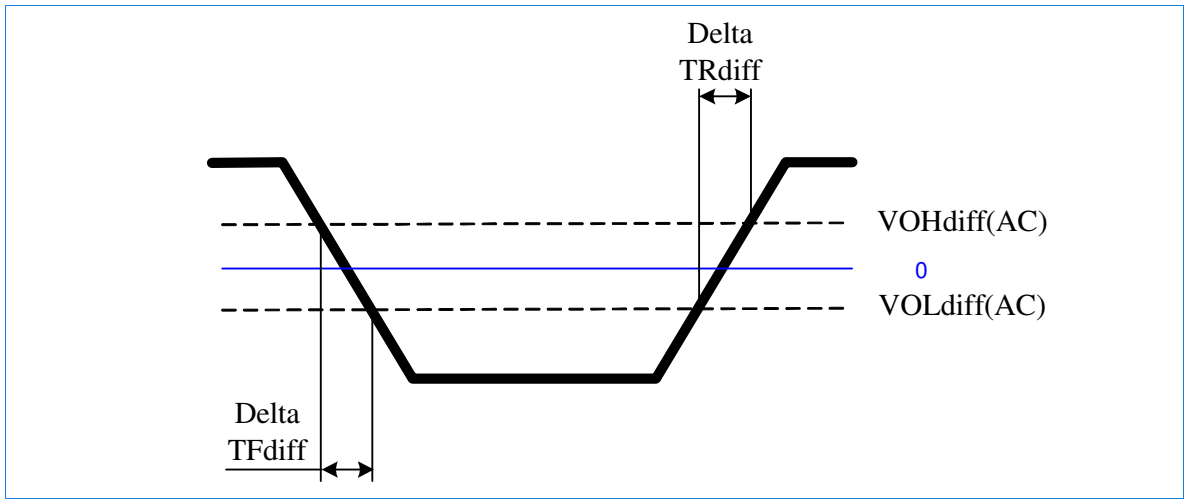
Output Slew Rate (single-ended)

Parameter	Symbol	DDR3-800 (-AC/-AD)		DDR3-1066 (-BE/-BF)		DDR3-1333 (-CF/-CG)		Unit
		Min.	Max.	Min.	Max.	Min.	Max.	
Single-ended Output Slew Rate	SRQse	2.5	5	2.5	5	2.5	5	V/ns
Note: SR: Slew Rate. Q: Query Output (like in DQ, which stands for Data-in, Query -Output). se: Single-ended signals. For Ron = RZQ/7 setting.								

Differential Output Slew Rate

Description	Measured		Defined by
	From	To	
Differential output slew rate for rising edge	VOLdiff(AC)	VOHdiff(AC)	[VOHdiff(AC)-VOLdiff(AC)] / DeltaTRdiff
Differential output slew rate for falling edge	VOHdiff(AC)	VOLdiff(AC)	[VOHdiff(AC)-VOLdiff(AC)] / DeltaTFdiff
Note: Output slew rate is verified by design and characterisation, and may not be subject to production test.			

Differential Output Slew Rate Definition



Differential Output Slew Rate

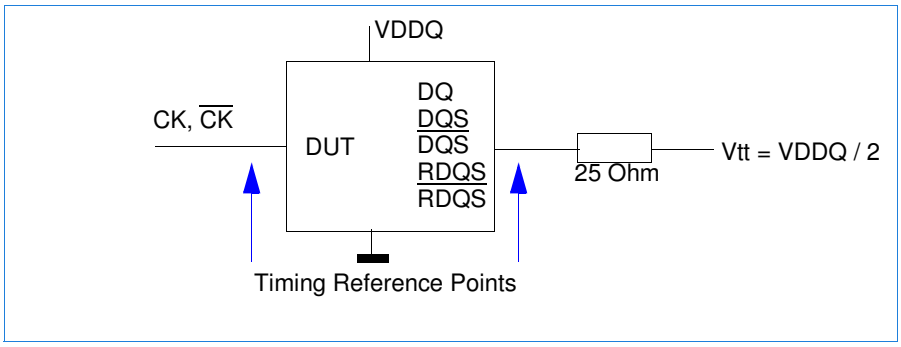
Symbol	Parameter	DDR3-800 (-AC/-AD)		DDR3-1066 (-BE/-BF)		DDR3-1066 (-CF/-CG)		Unit
		Min.	Max.	Min.	Max.	Min.	Max.	
SRQdiff	Differential Output Slew Rate	5	10	5	10	5	10	V/ns

Note:
SR: Slew Rate.
Q: Query Output (like in DQ, which stands for Data-in, Query -Output).
diff: DifferentialSignals.
For Ron = RZQ/7 setting.

Reference Load for AC Timing and Output Slew Rate

The following figure represents the effective reference load of 25 ohms used in defining the relevant AC timing parameters of the device as well as output slew rate measurements.

It is not intended as a precise representation of any particular system environment or a depiction of the actual load presented by a production tester. System designers should use IBIS or other simulation tools to correlate the timing reference load to a system environment. Manufacturers correlate to their production test conditions, generally one or more coaxial transimission lines terminated at the tester electronics.

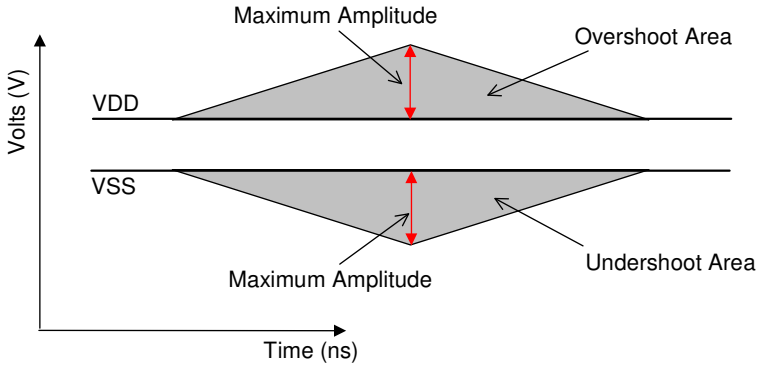


Overshoot and Undershoot Specifications

AC Overshoot/Undershoot Specification for Address and Control Pins

(A0-A13, BA0-BA2, $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$, CKE, ODT)

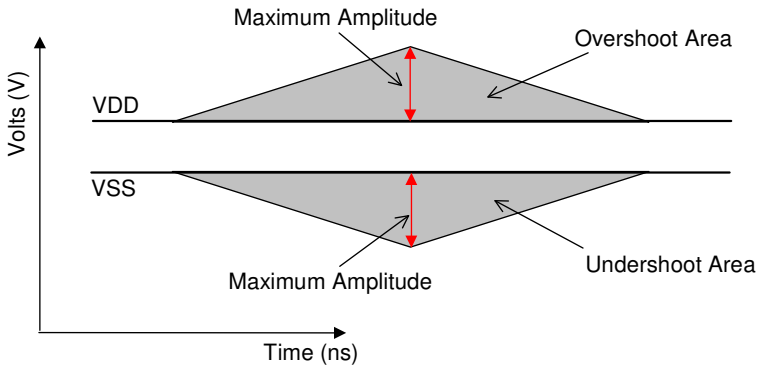
	DDR3-800 (-AC/-AD)	DDR3-1066 (-BE/-BF)	DDR3-1333 (-CF/-CG)	Unit
Maximum peak amplitude allowed for overshoot area	0.4	0.4	0.4	V
Maximum peak amplitude allowed for undershoot area	0.4	0.4	0.4	V
Maximum overshoot area above VDD	0.67	0.5	0.4	V-ns
Maximum undershoot area below VSS	0.67	0.5	0.4	V-ns



AC Overshoot/Undershoot Specification for Clock, Data, Strobe, and Mask

(CK, $\overline{CK}$, DQ, DQS, $\overline{DQS}$, DM)

	DDR3-800 (-AC/-AD)	DDR3-1066 (-BE/-BF)	DDR3-1333 (-CF/-CG)	Unit
Maximum peak amplitude allowed for overshoot area	0.4	0.4	0.4	V
Maximum peak amplitude allowed for undershoot area	0.4	0.4	0.4	V
Maximum overshoot area above VDDQ	0.25	0.19	0.15	V-ns
Maximum undershoot area above VSSQ	0.25	0.19	0.15	V-ns



34 Ohm Output Driver DC Electrical Characteristics

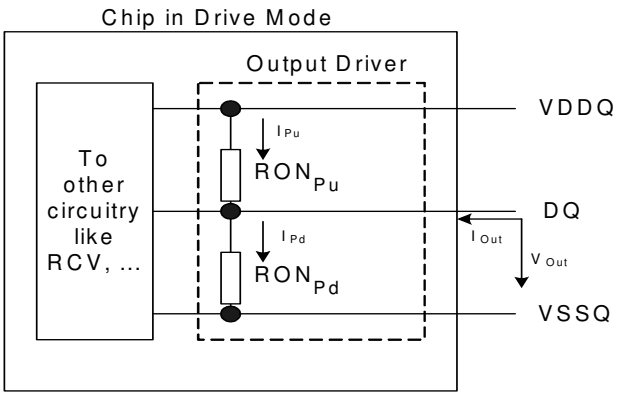
A Functional representation of the output buffer is shown as below. Output driver impedance RON is defined by the value of the external reference resistor RZQ as follows:

RON_{34} = R_{ZQ} / 7 (nominal 34.4ohms +/-10% with nominal R_{ZQ}=240ohms)

The individual pull-up and pull-down resistors (RON_{Pu} and RON_{Pd}) are defined as follows:

RON_{Pu} = [VDDQ-Vout] / I Iout I ---------- under the condition that RON_{Pd} is turned off (1)

RON_{Pd} = Vout / I Iout I ----------under the condition that RON_{Pu} is turned off (2)



Output Driver DC Electrical Characteristics, assuming R_{ZQ} = 240ohms; entire operating temperature range; after proper ZQ calibration

RON_{Nom}	Resistor	Vout	min	nom	max	Unit	Notes
34 ohms	RON_{34Pd}	VOLdc = 0.2 x VDDQ	0.6	1.0	1.1	R_{ZQ} / 7	1,2,3
		VOMdc = 0.5 x VDDQ	0.9	1.0	1.1	R_{ZQ} / 7	1,2,3
		VOHdc = 0.8 x VDDQ	0.9	1.0	1.4	R_{ZQ} / 7	1,2,3
	RON_{34Pu}	VOLdc = 0.2 x VDDQ	0.9	1.0	1.4	R_{ZQ} / 7	1,2,3
		VOMdc = 0.5 x VDDQ	0.9	1.0	1.1	R_{ZQ} / 7	1,2,3
		VOHdc = 0.8 x VDDQ	0.6	1.0	1.1	R_{ZQ} / 7	1,2,3
Mismatch between pull-up and pull-down, MM_{PuPd}		VOMdc = 0.5 x VDDQ	-10		10	%	1,2,4

Note:
1. The tolerance limits are specified after calibration with stable voltage and temperature. For the behavior of the tolerance limits if temperature or voltage changes after calibration, see following section on voltage and temperature sensitivity.
2. The tolerance limits are specified under the condition that VDDQ = VDD and that VSSQ = VSS.
3. Pull-down and pull-up output driver impedances are recommanded to be calibrated at 0.5 x VDDQ. Other calibration schemes may be used to achieve the linearity spec shown above. e.g. calibration at 0.2 x VDDQ and 0.8 x VDDQ.
4. Measurement definition for mismatch between pull-up and pull-down, MM_{PuPd}:
Measure RONPu and RONPd, but at 0.5 x VDDQ:
MM_{PuPd} = [RON_{Pu} - RON_{Pd}] / RON_{Nom} x 100

Output Driver Temperature and Voltage sensitivity

If temperature and/or voltage after calibration, the tolerance limits widen according to the following table.
Delta T = T - T(@calibration); Delta V = VDDQ - VDDQ(@calibration); VDD = VDDQ

Note: $dR_{ON}dT$ and $dR_{ON}dV$ are not subject to production test but are verified by design and characterization.

Output Driver Sensitivity Definition

	min	max	Unit
RONPU@VOHdc	0.6 - $dR_{ON}dTH$*|Delta TI| - $dR_{ON}dVH$*|Delta VI|	1.1 + $dR_{ON}dTH$*|Delta TI| - $dR_{ON}dVH$*|Delta VI|	RZQ/7
RON@VOMdc	0.9 - $dR_{ON}dTM$*|Delta TI| - $dR_{ON}dVM$*|Delta VI|	1.1 + $dR_{ON}dTM$*|Delta TI| - $dR_{ON}dVM$*|Delta VI|	RZQ/7
RONPD@VOLdc	0.6 - $dR_{ON}dTL$*|Delta TI| - $dR_{ON}dVL$*|Delta VI|	1.1 + $dR_{ON}dTL$*|Delta TI| - $dR_{ON}dVL$*|Delta VI|	RZQ/7

Output Driver Voltage and Temperature Sensitivity

	min	max	Unit
$dR_{ON}dTM$	0	1.5	%/°C
$dR_{ON}dVM$	0	0.15	%/mV
$dR_{ON}dTL$	0	1.5	%/°C
$dR_{ON}dVL$	0	TBD	%/mV
$dR_{ON}dTH$	0	1.5	%/°C
$dR_{ON}dVH$	0	TBD	%/mV
Note: These parameters may not be subject to production test. They are verified by design and characterization.			

On-Die Termination (ODT) Levels and I-V Characteristics

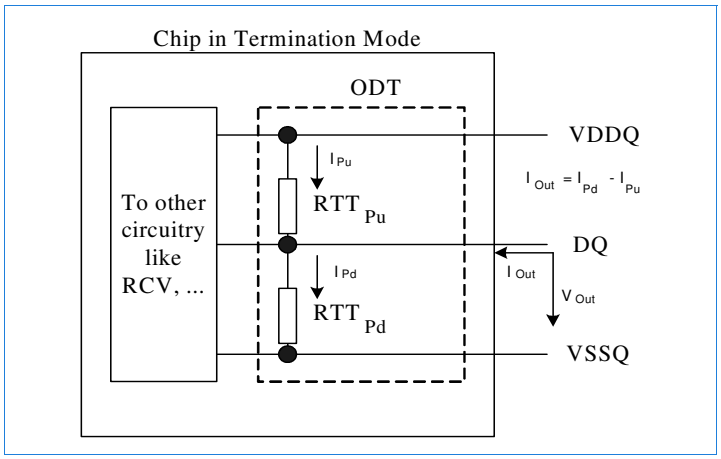
On-Die Termination effective resistance RTT is defined by bits A9, A6, and A2 of the MR1 Register.

ODT is applied to the DQ, DM, DQS/$\overline{DQS}$, and TDQS/$\overline{TDQS}$ (x8 devices only) pins.

A functional representation of the on-die termination is shown in the following figure. The individual pull-up and pull-down resistors (RTT_{Pu} and RTT_{Pd}) are defined as folllows:

RTT_{Pu} = [VDDQ - Vout] / I Iout I ---------- under the condition that RTT_{Pd} is turned off (3)

RTT_{Pd} = Vout / I Iout I ---------- under the condition that RTT_{Pu} is turned off (4)



ODT DC Electrical Characteristics

The following table provides an overview of the ODT DC electrical characteristics. The values for $RTT_{60Pd120}$, $RTT_{60Pu120}$, $RTT_{120Pd240}$, $RTT_{120Pu240}$, RTT_{40Pd80}, RTT_{40Pu80}, RTT_{30Pd60}, RTT_{30Pu60}, RTT_{20Pd40}, RTT_{20Pu40} are not specification requirements, but can be used as design guide lines:

ODT DC Electrical Charateristics, assuming R_{ZQ} = 240ohms +/- 1% entire operating temperature range; after proper ZQ calibration

MR1 A9, A6, A2	RTT	Resistor	Vout	min	nom	max	Unit	Notes
0,1,0	120ohm	$RTT_{120Pd240}$	VOLdc = 0.2 x VDDQ	0.6	1.0	1.1	R_{ZQ}	1,2,3,4
			0.5 x VDDQ	0.9	1.0	1,1	R_{ZQ}	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.9	1.0	1.4	R_{ZQ}	1,2,3,4
		$RTT_{120Pu240}$	VOLdc = 0.2 x VDDQ	0.9	1.0	1.4	R_{ZQ}	1,2,3,4
			0.5 x VDDQ	0.9	1.0	1,1	R_{ZQ}	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.6	1.0	1.1	R_{ZQ}	1,2,3,4
		RTT_{120}	VIL(ac) to VIH(ac)	0.9	1.9	1.6	$R_{ZQ}/2$	1,2,5

0, 0, 1	60ohm	$RTT_{60Pd120}$	VOLdc = 0.2 x VDDQ	0.6	1.0	1.1	$R_{ZQ}/2$	1,2,3,4
			0.5 x VDDQ	0.9	1.0	1.1	$R_{ZQ}/2$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.9	1.0	1.4	$R_{ZQ}/2$	1,2,3,4
		$RTT_{60Pu120}$	VOLdc = 0.2 x VDDQ	0.9	1.0	1.4	$R_{ZQ}/2$	1,2,3,4
			0.5 x VDDQ	0.9	1.0	1.1	$R_{ZQ}/2$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.6	1.0	1.1	$R_{ZQ}/2$	1,2,3,4
		RTT_{60}	VIL(ac) to VIH(ac)	0.9	1.0	1.6	$R_{ZQ}/4$	1,2,5
0, 1, 1	40ohm	RTT_{40Pd80}	VOLdc = 0.2 x VDDQ	0.6	1.0	1.1	$R_{ZQ}/3$	1,2,3,4
			0.5 x VDDQ	0.9	1.0	1.1	$R_{ZQ}/3$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.9	1.0	1.4	$R_{ZQ}/3$	1,2,3,4
		RTT_{40Pu80}	VOLdc = 0.2 x VDDQ	0.9	1.0	1.4	$R_{ZQ}/3$	1,2,3,4
			0.5 x VDDQ	0.9	1.0	1.1	$R_{ZQ}/3$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.6	1.0	1.1	$R_{ZQ}/3$	1,2,3,4
		RTT_{40}	VIL(ac) to VIH(ac)	0.9	1.0	1.6	$R_{ZQ}/6$	1,2,5
1, 0, 1	30ohm	RTT_{30Pd60}	VOLdc = 0.2 x VDDQ	0.6	1.0	1.1	$R_{ZQ}/4$	1,2,3,4
			0.5 x VDDQ	0.9	1.0	1.1	$R_{ZQ}/4$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.9	1.0	1.4	$R_{ZQ}/4$	1,2,3,4
		RTT_{30Pu60}	VOLdc = 0.2 x VDDQ	0.9	1.0	1.4	$R_{ZQ}/4$	1,2,3,4
			0.5 x VDDQ	0.9	1.0	1.1	$R_{ZQ}/4$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.6	1.0	1.1	$R_{ZQ}/4$	1,2,3,4
		RTT_{30}	VIL(ac) to VIH(ac)	0.9	1.0	1.6	$R_{ZQ}/8$	1,2,5
1, 0, 0	20ohm	RTT_{20Pd40}	VOLdc = 0.2 x VDDQ	0.6	1.0	1.1	$R_{ZQ}/6$	1,2,3,4
			0.5 x VDDQ	0.9	1.0	1.1	$R_{ZQ}/6$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.9	1.0	1.4	$R_{ZQ}/6$	1,2,3,4
		RTT_{20Pu40}	VOLdc = 0.2 x VDDQ	0.9	1.0	1.4	$R_{ZQ}/6$	1,2,3,4
			0.5 x VDDQ	0.9	1.0	1.1	$R_{ZQ}/6$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.6	1.0	1.1	$R_{ZQ}/6$	1,2,3,4
		RTT_{20}	VIL(ac) to VIH(ac)	0.9	1.0	1.6	$R_{ZQ}/12$	1,2,5
Deviation of VM w.r.t. VDDQ/2, DVm				-5		5	%	1,2,5,6

Note:
1. The tolerance limits are specified after calibration with stable voltage and temperature. For the behavior of the tolerance limits if temperature or voltage changes after calibration, see following section on voltage and temperature sensitivity.
2. The tolerance limits are specified under the condition that VDDQ = VDD and that VSSQ = VSS.
3. Pull-down and pull-up ODT resistors are recommanded to be calibrated at 0.5 x VDDQ. Other calibration may be used to achieve the linearity spec shown above.
4. Not a specification requirement, but a design guide line.
5. Measurement definition for RTT:
Apply VIH(ac) to pin under test and measure current / (VIH(ac)), then apply VIL(ac) to pin under test and measure current / (VIL(ac)) respectively.
RTT = [VIH(ac) - VIL(ac)] / [I(VIH(ac)) - I(VIL(ac))]
6. Measurement definition for V_M and DV_M:
Measure voltage (V_M) at test pin (midpoint) with no lead:
Delta V_M = [2V_M / VDDQ -1] x 100

ODT Temperature and Voltage sensitivity

If temperature and/or voltage after calibration, the tolerance limits widen according to the following table.
Delta T = T - T(@calibration); Delta V = VDDQ - VDDQ(@calibration); VDD = VDDQ

ODT Sensitivity Definition

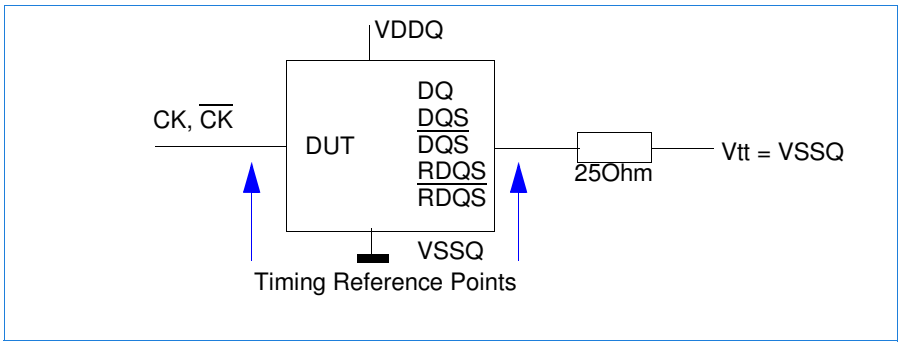
	min	max	Unit
RTT	0.9 - $dR_{TT}dT$*lDelta Tl - $dR_{TT}dV$*lDelta Vl	1.6 + $dR_{TT}dT$*lDelta Tl - $dR_{TT}dV$*lDelta Vl	RZQ/2,4,6,8,12

ODT Voltage and Temperature Sensitivity

	min	max	Unit
$dR_{TT}dT$	0	1.5	%/°C
$dR_{TT}dV$	0	0.15	%/mV
Note: These parameters may not be subject to production test. They are verified by design and characterization.			

Test Load for ODT Timings

Different than for timing measurements, the reference load for ODT timings is defined in the following figure.



ODT Timing Definitions

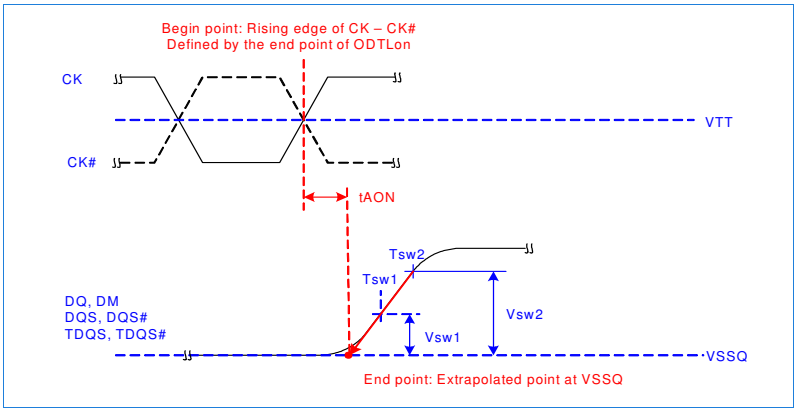
Definitions for t_{AON}, t_{AONPD}, t_{AOF}, t_{AOFPD}, and t_{ADC} are provided in the following table and subsequent figures.

Symbol	Begin Point Definition	End Point Definition
t_{AON}	Rising edge of CK - $\overline{CK}$ defined by the end point of ODTLon	Extrapolated point at VSSQ
t_{AONPD}	Rising edge of CK - $\overline{CK}$ with ODT being first registered high	Extrapolated point at VSSQ
t_{AOF}	Rising edge of CK - $\overline{CK}$ defined by the end point of ODTLoff	End point: Extrapolated point at VRTT_Nom
t_{AOFPD}	Rising edge of CK - $\overline{CK}$ with ODT being first registered low	End point: Extrapolated point at VRTT_Nom
t_{ADC}	Rising edge of CK - $\overline{CK}$ defined by the end point of ODTLcnw, ODTLcwn4, or ODTLcwn8	End point: Extrapolated point at VRTT_Wr and VRTT_Nom respectively

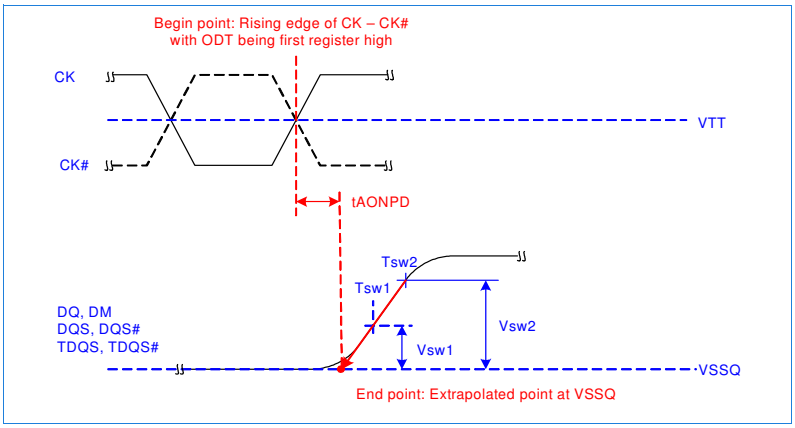
Reference Settings for ODT Timing Measurements

Measured Parameter	RTT_Nom Setting	RTT_Wr Setting	V_{SW1}[V]	V_{SW2}[V]
t_{AON}	$R_{ZQ}/4$	NA	0.05	0.10
	$R_{ZQ}/12$	NA	0.10	0.20
t_{AONPD}	$R_{ZQ}/4$	NA	0.05	0.10
	$R_{ZQ}/12$	NA	0.10	0.20
t_{AOF}	$R_{ZQ}/4$	NA	0.05	0.10
	$R_{ZQ}/12$	NA	0.10	0.20
t_{AOFPD}	$R_{ZQ}/4$	NA	0.05	0.10
	$R_{ZQ}/12$	NA	0.10	0.20
t_{ADC}	$R_{ZQ}/12$	$R_{ZQ}/2$	0.20	0.30

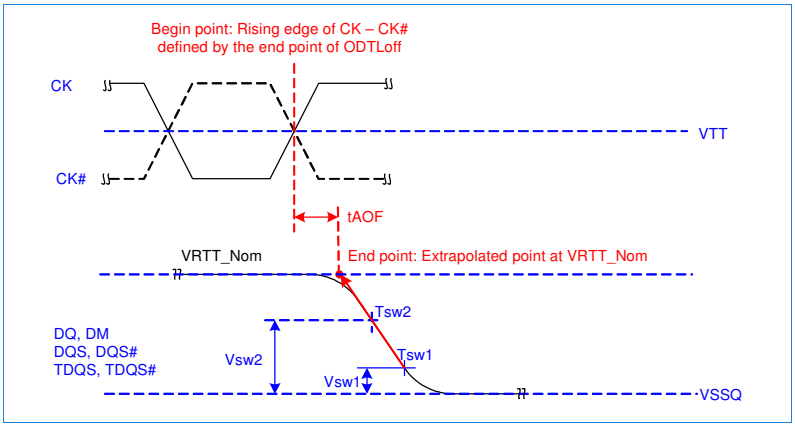
Definition of t_{AON}



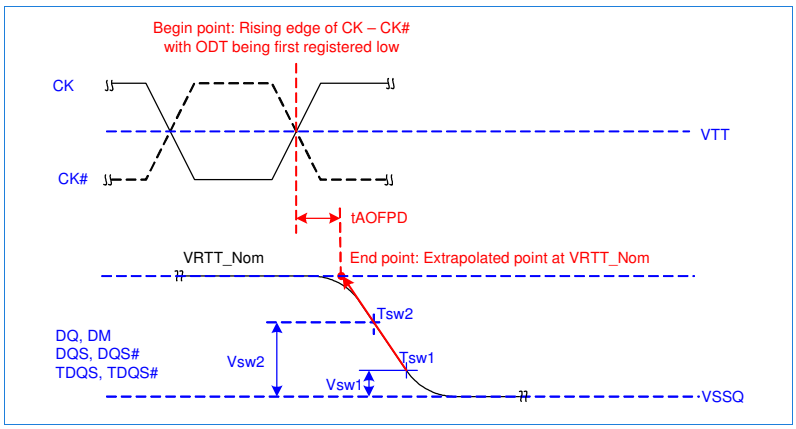
Definition of t_{AONPD}



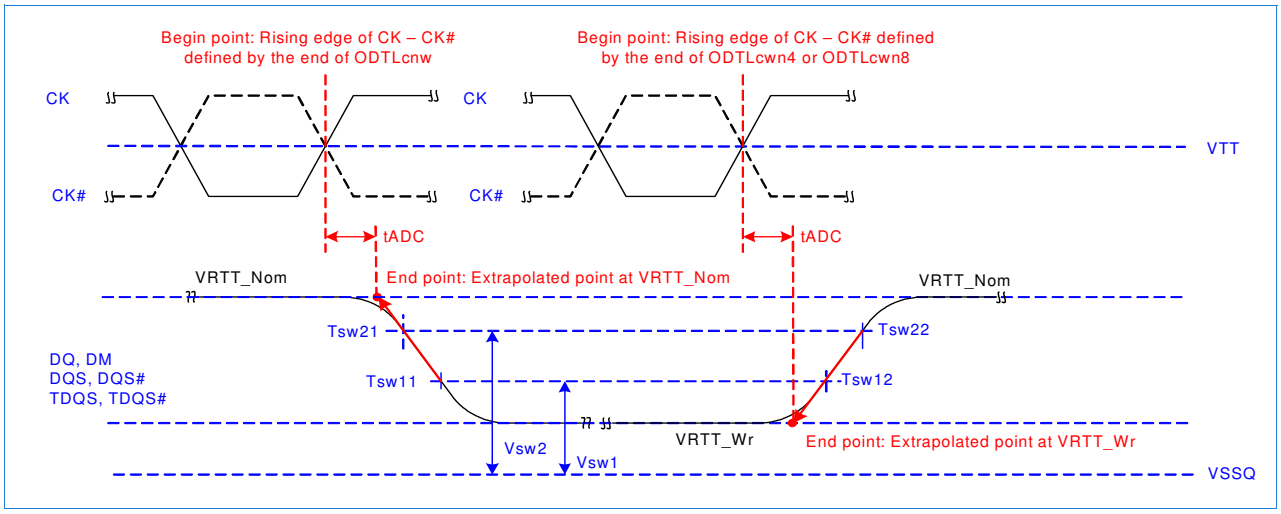
Definition of t_{AOF}



Definition of t_{AOFPD}



Definition of t_{ADC}



Input / Output Capacitance

Symbol	Parameter	DDR3-800 (-AC/-AD)		DDR3-1066 (-BE/-BF)		DDR3-1333 (-CF/-CG)		Units	Notes
		min.	max.	min.	max.	min.	max.		
C_{IO}	Input/output capacitance (DQ, DM, DQS, $\overline{DQS}$, TDQS, $\overline{TDQS}$)	1.5	3.0	1.5	3.0	1.5	2.5	pF	1,2,3
C_{CK}	Input capacitance, CK and $\overline{CK}$	0.8	1.6	0.8	1.6	0.8	1.4	pF	2,3
C_{DCK}	Input capacitance delta, CK and $\overline{CK}$	0	0.15	0	0.15	0	0.15	pF	2,3,4
C_{DDQS}	Input/output capacitance delta, DQS and $\overline{DQS}$	0	0.2	0	0.2	0	0.15	pF	2,3,5
C_I	Input capacitance, CTRL, ADD, CMD input-only pins	0.75	1.5	0.75	1.5	0.75	1.3	pF	2,3,7,8
C_{DI_CTRL}	Input capacitance delta, all CTRL input-only pins	-0.5	0.3	-0.5	0.3	-0.4	0.2	pF	2,3,7,8
$C_{DI\_ADD\_CMD}$	Input capacitance delta, all ADD/CMD input-only pins	-0.5	0.5	-0.5	0.5	-0.4	0.4	pF	2,3,9,10
C_{DIO}	Input/output capacitance delta, DQ, DM, DQS, $\overline{DQS}$, TDQS, $\overline{TDQS}$	-0.5	0.3	-0.5	0.3	-0.5	0.3	pF	2,3,11
C_{ZQ}	Input/output capacitance of ZQ pin	-	3	-	3	-	3	pF	2,3,12

Notes:
1. Although the DM, TDQS, and $\overline{TDQS}$ pins have different functions, the loading matches DQ and DQS.
2. This parameter is not subject to production test. It is verified by design and characterization.
3. This parameter applies to monolithic devices only.
4. Absolute value of C_{CK} - $C_{\overline{CK}}$.
5. Absolute value of $C_{IO}(DQS)$ - $C_{IO}(\overline{DQS})$
6. C_I applies to ODT, CS, CKE, A0-A13, BA0-BA2, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$.
7. CTRL applies to ODT, $\overline{CS}$, and CKE.
8. $C_{DI\_CTRL}=C_I(CNTL)-0.5*(C_I(CLK)+C_I(\overline{CLK}))$.
9. $C_{DI\_ADD\_CMD}$ applies A0-A13, BA0-BA2, $\overline{RAS}$, $\overline{CAS}$, and $\overline{WE}$.
10. $C_{DI\_ADD\_CMD}=C_I(ADD\_CMD)-0.5*(C_I(CLK)+C_I(CLK))$.
11. $C_{DIO}=C_{IO}(DQ, DM)-0.5*(C_{IO}(DQS)+C_{IO}(\overline{DQS}))$.
12. Maximum external load capacitance on ZQ pin: 5pF.

IDD Specifications and Measurement Conditions

IDD Specifications

Symbol	Parameter/Condition	I/O	DDR3-800		DDR3-1066		DDR3-1333		Unit
			5-5-5 (-AC)	6-6-6 (-AD)	7-7-7 (-BE)	8-8-8 (-BF)	8-8-8 (-CF)	9-9-9 (-CG)	
			Maximum						
I_{DD0}	Operating Current 0 -> One Bank Activate -> Precharge	x4/ x8 x16							mA
I_{DD1}	Operating Current 1 -> One Bank Activate -> Read -> Precharge	x4/ x8 x16							mA
$I_{DD2P(0)}$	Precharge Power-Down Current Slow Exit - MR0 bit A12 = 0	all							mA
$I_{DD2P(1)}$	Precharge Power-Down Current Fast Exit - MR0 bit A12 = 1	all							mA
I_{DD2N}	Precharge Standby Current	all							mA
I_{DD2Q}	Precharge Quiet Standby Current	all							mA
I_{DD3P}	Active Power-Down Current Always Fast Exit	all							mA
I_{DD3N}	Active Standby Current	all							mA
I_{DD4R}	Operating Current Burst Write	x4/ x8 x16							mA
I_{DD4W}	Operating Current Burst Read	x4/ x8 x16							mA
I_{DD5B}	Burst Refresh Current	all							mA
I_{DD6}	Self-Refresh Current Normal Temperature Range (0-85C)	all							mA
I_{DD6ET}	Self-Refresh Current Extend Temperature Range (0-95C)	all							mA
I_{DD7}	All Bank Interleave Read Current	x4/ x8 x16							mA

IDD Measurement Conditions

Symbol	Parameter/Condition
I_{DD0}	**Operating Current - One bank Active - Precharge** tCK =tCKmin(IDD); tRC = tRCmin(IDD); tRAS = tRASmin(IDD); CKE is HIGH, External Clock is ON; $\overline{CS}$ is HIGH between active and precharge commands. Address and control inputs are SWITCHING; Data I/O are SWITCHING; Bank address is fixed (bank 0); Output Buffer DQ, DQS are off; MR1 bit A12=1; ODT disabled; MR1 bits[A6,A2]=[0,0]; Burst Length=N/A; Active banks=one/ACT-PRE loop; Idle banks=all other; Precharge Power Down Mode/Mode Register Bit 12=N/A.
I_{DD1}	**Operating Current - One bank Active - Read - Precharge** tCK =tCKmin(IDD); tRC = tRCmin(IDD); tRAS = tRASmin(IDD); CL=CL(IDD); CKE is HIGH, External Clock is ON; $\overline{CS}$ is HIGH between active and precharge commands. Address and control inputs are SWITCHING; Data I/O are Read data switches every clock; Bank address is fixed (bank 0); Output Buffer DQ, DQS are off; MR1 bit A12=1; ODT disabled; MR1 bits[A6,A2]=[0,0]; Burst Length=8 fixed/MR0 bits[A1, A0]=[0,0]; Active banks=one/ACT-RED-PRE loop; Idle banks=all other; Precharge Power Down Mode/Mode Register Bit 12=N/A.
I_{DD2N}	**Precharge Standby Current** CKE=High; External Clock=On; tCK=tCKmin(IDD); tRC=tRAS=tRCD=tRRD=CL=AL=N/A; $\overline{CS}$=High; Address, command, and data inputs are switching; Output Buffer DQ, DQS=off; MR1 bit A12=1; ODT=disabled; MR1 bit[A6,A2]=[0,0]; Burst length=N/A; Active banks=none; Idle banks=All; Precharge Power Down Mode = N/A.
$I_{DD2P(1)}$	**Precharge Power-Down Current - Fast Exit (MRS A12 bit = 1)** CKE=Low; External Clock=On; tCK=tCKmin(IDD); tRC=tRAS=tRCD=tRRD=CL=AL=N/A; $\overline{CS}$=Stable; Address and command are Stable; Data inputs are Floating; Output Buffer DQ, DQS=off; MR1 bit A12=1; ODT=disabled; MR1 bit[A6,A2]=[0,0]; Burst length=N/A; Active banks=none; Idle banks=All; Precharge Power Down Mode = Fast Exit.
$I_{DD2P(0)}$	**Precharge Power-Down Current - Fast Exit (MRS A12 bit = 0)** CKE=Low; External Clock=On; tCK=tCKmin(IDD); tRC=tRAS=tRCD=tRRD=CL=AL=N/A; $\overline{CS}$=Stable; Address and command are Stable; Data inputs are Floating; Output Buffer DQ, DQS=off; MR1 bit A12=1; ODT=disabled; MR1 bit[A6,A2]=[0,0]; Burst length=N/A; Active banks=none; Idle banks=All; Precharge Power Down Mode = Slow Exit.
I_{DD2Q}	**Precharge Quiet Standby Current** CKE=High; External Clock=On; tCK=tCKmin(IDD); tRC=tRAS=tRCD=tRRD=CL=AL=N/A; $\overline{CS}$=High; Address and command are Stable; Data inputs are Floating; Output Buffer DQ, DQS=off; MR1 bit A12=1; ODT=disabled; MR1 bit[A6,A2]=[0,0]; Burst length=N/A; Active banks=none; Idle banks=All; Precharge Power Down Mode = N/A.
I_{DD3N}	**Active Standby Current** CKE=High; External Clock=On; tCK=tCKmin(IDD); tRC=tRAS=tRCD=tRRD=CL=AL=N/A; $\overline{CS}$=High; Address and command are Switching; Data inputs are Switching; Output Buffer DQ, DQS=off; MR1 bit A12=1; ODT=disabled; MR1 bit[A6,A2]=[0,0]; Burst length=N/A; Active banks=All; Idle banks=none; Precharge Power Down Mode = N/A.
I_{DD3P}	**Active Power-Down Current** CKE=Low; External Clock=On; tCK=tCKmin(IDD); tRC=tRAS=tRCD=tRRD=CL=AL=N/A; $\overline{CS}$=Stable; Address and command are Stable; Data inputs are Floating; Output Buffer DQ, DQS=off; MR1 bit A12=1; ODT=disabled; MR1 bit[A6,A2]=[0,0]; Burst length=N/A; Active banks=All; Idle banks=none; Precharge Power Down Mode = N/A. (Active power down mode is always “Fast Exit” with DLL on.)
I_{DD4R}	**Operating Current - Burst Read** CKE=High; External Clock=On; tCK=tCKmin(IDD); tRC=tRAS=tRCD=tRRD=N/A; CL=CL(IDD); AL=0; $\overline{CS}$=High between valid commands; Address and Command are Switching; DQ I/O=Seamless Read Data Burst (BL8); Output Buffer DQ, DQS=off; MR1 bit A12=1; ODT=disabled; MR1 bit[A6,A2]=[0,0]; Burst length=8 fixed/MR0 Bits[A1,A0]=[0,0]; Active banks=All; Idle banks=none; Precharge Power Down Mode = N/A.
I_{DD4W}	**Operating Current - Burst Write** CKE=High; External Clock=On; tCK=tCKmin(IDD); tRC=tRAS=tRCD=tRRD=N/A; CL=CL(IDD); AL=0; $\overline{CS}$=High between valid commands; Address and Command are Switching; DQ I/O=Seamless Write Data Burst (BL8); Output Buffer DQ, DQS=off; MR1 bit A12=1; ODT=disabled; MR1 bit[A6,A2]=[0,0]; Burst length=8 fixed/MR0 Bits[A1,A0]=[0,0]; Active banks=All; Idle banks=none; Precharge Power Down Mode = N/A.
I_{DD5B}	**Burst Refresh Current** CKE=High; External Clock=On; tCK=tCKmin(IDD); tRC=tRAS=tRCD=tRRD=CL=AL=N/A; tRFC=tRFCmin(IDD); $\overline{CS}$=High between valid commands; Address and Command are Switching; Output Buffer DQ, DQS=off; MR1 bit A12=1; ODT=disabled; MR1 bit[A6,A2]=[0,0]; Burst length=N/A; Active banks=Refresh command every tRFC=tRFCmin; Idle banks=none; Precharge Power Down Mode = N/A.
I_{DD6}	**Self-Refresh Current** Tcase=85C; Auto Self Refresh =Disable; Self Refresh Temperature Range=Disable; CKE=Low; External Clock=OFF; tCK=tRC=tRAS=tRCD=tRRD=CL=AL=N/A; CS=Command input=Address=Data I/O=Floating; Output Buffer DQ, DQS=off; ODT=Disable; Burst Length=N/A; Active banks=All during self-refresh actions; Idle banks=all between Self-refresh actions; Precharge Power Down Mode=N/A.

Symbol	Parameter/Condition
I_{DD6ET}	**Self-Refresh Current** Tcase=95C; Auto Self Refresh =Disable; Self Refresh Temperature Range=Enable; CKE=Low; External Clock=OFF; tCK=tRC=tRAS=tRCD=tRRD=CL=AL=N/A; CS=Command input=Address=Data I/O=Floating; Output Buffer DQ, DQS=off; ODT=Disable; Burst Length=N/A; Active banks=All during self=refresh actions; Idle banks=all between Self-refresh actions; Precharge Power Down Mode=N/A.
I_{DD7}	**Operating Bank Interleave Read Current** CKE=High; External Clock=On; tCK=tCKmin(IDD); tRC=tRCmin(IDD); tRAS=tRASmin(IDD); tRCD=tRCDmin(IDD); tRRD=tRRDmin(IDD); CL=CL(IDD); AL=tRCDmin-tCK; CS=High between valid commands; Command is Switching by patterns; Address is Stable during deselects; DQ I/O=Read Data (BL8); Output Buffer DQ, DQS=off; MR1 bit A12=1; ODT=disabled; MR1 bit[A6,A2]=[0,0]; Burst length=8 fixed/MR0 Bits[A1,A0]=[0,0]; Active banks=All, rotational; Idle banks=none; Precharge Power Down Mode = N/A.

IDD Measurement Conditions

For testing the IDD parameters, the following timing parameters are used:

Parameter		Symbol	DDR3-800 (-AC)	DDR3-800 (-AD)	DDR3-1066 (-BE)	DDR3-1066 (-BF)	DDR3-1333 (-CF)	DDR3-1333 (-CG)	Unit
			5-5-5	6-6-6	7-7-7	8-8-8	8-8-8	9-9-9	
Clock Cycle Time		tCKmin(IDD)	2.5	2.5	1.875	1.875	1.5	1.5	ns
CAS Latency		CL(IDD)	5	6	7	8	8	9	
Active to Read or Write delay		tRCDmin(IDD)	12.5	15	13.13	15	12	13.5	ns
Active to Active / Auto-Refresh command period		tRCmin(IDD)	50	52.5	50.63	52.50	48	49.5	ns
Active to Precharge Command		tRASmin(IDD)	37.5	37.5	37.5	37.5	36	36	ns
Precharge Command Period		tRPmin(IDD)	12.5	15	13.13	15	12	13.5	ns
Four activate window	x4/x8	tFAW(IDD)	40	40	37.5	37.5	30	30	ns
	x16		50	50	50	50	40	40	ns
Active to Active command period	x4/x8	tRRD(IDD)	10	10	7.5	7.5	6.0	6.0	ns
	x16		10	10	10	10	7.5	7.5	ns
Auto-Refresh to Active / Auto-Refresh command period		tRFC(IDD)	110	110	110	110	110	110	ns

Standard Speed Bins

Speed Bin		DDR3-800				DDR3-1066				DDR3-1333				Unit
CL-nRCD-nRP		5-5-5 (-AC)		6-6-6 (-AD)		7-7-7 (-BE)		8-8-8 (-BF)		8-8-8 (-CF)		9-9-9 (-CG)		
Parameter	Symbol	min	max	min	max	min	max	min	max	min	max	min	max	
Internal read command to first data	tAA	12.5	20	15	20	13.125	20	15	20	12	20	13.5	20	ns
ACT to internal read or write delay time	tRCD	12.5	-	15	-	13.125	-	15	-	12	-	13.5	-	ns
PRE command period	tRP	12.5	-	15	-	13.125	-	15	-	12	-	13.5	-	ns
ACT to ACT or REF command period	tRC	50	-	52.5	-	50.625	-	52.5	-	48	-	49.5	-	ns
ACT to PRE command period	tRAS	37.5	9tREFI	37.5	9tREFI	37.5	9tREFI	37.5	9tREFI	36	9tREFI	36	9tREFI	ns
CL=5; CWL =5	tCK(AVG)	2.5	3.3	Reserved						2.5	3.3	Reserved		ns
CL=5; CWL =6, 7	tCK(AVG)	Reserved												ns
CL=6; CWL =5	tCK(AVG)	2.5	3.3	2.5	3.3	2.5	3.3	2.5	3.3	2.5	3.3	2.5	3.3	ns
CL=6; CWL =6, 7	tCK(AVG)	Reserved												ns
CL=7; CWL =5	tCK(AVG)	Reserved												ns
CL=7; CWL =6	tCK(AVG)	Reserved				1.875	<2.5	Reserved		1.875	<2.5	Reserved		ns
CL=7; CWL =7	tCK(AVG)	Reserved												ns
CL=8; CWL =5	tCK(AVG)	Reserved												ns
CL=8; CWL =6	tCK(AVG)	Reserved				1.875	<2.5	1.875	<2.5	1.875	<2.5	1.875	<2.5	ns
CL=8; CWL =7	tCK(AVG)	Reserved								1.5	<1.875	1.5	<1.875	ns
CL=9; CWL =5, 6	tCK(AVG)	Reserved												ns
CL=9; CWL =7	tCK(AVG	Reserved								1.5	<1.875	1.5	<1.875	ns
Supported CL Settings		5,6		6		6,7,8		6,8		5,6,7,8,9		6,8,9		nCK
Supported CWL Settings		5		5		5,6		5,6		5,6,7		5,6,7		nCK

Electrical Characteristics & AC Timing

Timing Parameter by Speed Bin

Symbol	Parameter	DDR3-800 (-AC/-AD)		DDR3-1066 (-BE/-BF)		Unit	Notes
		min	max	min	max		
Clock Timing							
$t_{CK(DLL\_OFF)}$	Minimum Clock Cycle Time (DLL off mode)	8	-	8	-	ns	6
$t_{CK(avg)}$	Average Clock Period	Refer to “Standard Speed Bins”					
$t_{CH(avg)}$	Average high pulse width	0.47	0.53	0.47	0.53	$t_{CK(avg)}$	
$t_{CL(avg)}$	Average low pulse width	0.47	0.53	0.47	0.53	$t_{CK(avg)}$	
$t_{CK(abs)}$	Absolute Clock Period	tCK(avg)min +tJIT(per)min	tCK(avg)max +tJIT(per)max	tCK(avg)min +tJIT(per)min	tCK(avg)max +tJIT(per)max	ps	
$t_{CH(abs)}$	Absolute high pulse width	0.43	-	0.43	-	tCK(avg)	25
$t_{CL(abs)}$	Absolute low pulse width	0.43	-	0.43	-	tCK(avg)	26
JIT(per)	Clock Period Jitter	-100	100	-90	90	ps	

Symbol	Parameter	DDR3-800 (-AC/-AD)		DDR3-1066 (-BE/-BF)		Unit	Notes
		min	max	min	max		
$t_{JIT(per,lck)}$	Clock Period Jitter during DLL locking period	-90	90	-80	80	ps	
$t_{JIT(cc)}$	Cycle to Clcyle Period Jitter	200		180		ps	
$t_{JIT(cc,lck)}$	Cycle to Cycle Period Jitter	180		160		ps	
$t_{ERR(2per)}$	Cumulative error accross 2 cycles	-147	147	-132	132	ps	
$t_{ERR(3per)}$	Cumulative error accross 3 cycles	-175	175	-157	157	ps	
$t_{ERR(4per)}$	Cumulative error accross 4cycles	-194	194	-175	175	ps	
$t_{ERR(5per)}$	Cumulative error accross 5cycles	-209	209	-188	188	ps	
$t_{ERR(6per)}$	Cumulative error accross 6 cycles	-222	222	-200	200	ps	
$t_{ERR(7per)}$	Cumulative error accross 7 cycles	-232	232	-209	209	ps	
$t_{ERR(8per)}$	Cumulative error accross 8 cycles	-241	241	-217	217	ps	
$t_{ERR(9per)}$	Cumulative error accross 9 cycles	-249	249	-224	224	ps	
$t_{ERR(10per)}$	Cumulative error accross 10 cycles	-257	257	-231	231	ps	
$t_{ERR(11per)}$	Cumulative error accross 11 cycles	-263	263	-237	237	ps	
$t_{ERR(12per)}$	Cumulative error accross 12 cycles	-269	269	-242	242	ps	
$t_{ERR(nper)}$	Cumulative error accross n=13,14,..,49,50 cycles	tERR(npr)min = (1+ 0.68ln(n)) * tJIT(per)min tERR(npr)max = (1+ 0.68ln(n)) * tJIT(per)max				ps	24
$t_{JIT(duty)}$	Duty Cycle Jitter	-	-	-	-	ps	
Data Timing							
t_{DQSQ}	DQS, $\overline{DQS}$ to DQ skew per group, per access	-	200	-	150	ps	13
t_{QH}	DQ output hold time from DQS, $\overline{DQS}$	0.38	-	0.38	-	$t_{CK(avg)}$	13,b
$t_{LZ(DQ)}$	DQ low-impedence time from CK / $\overline{CK}$	-800	400	-600	300	ps	13,14,a
$t_{HZ(DQ)}$	DQ high-impedence time from CK / $\overline{CK}$	-	400	-	300	ps	13,14,a
$t_{DS(base)}$	Data Setup time to DQS, $\overline{DQS}$ referenced to Vih(ac)/ Vil(ac) levels	75		25		ps	d,17
$t_{DH(base)}$	Data Hold time to DQS, $\overline{DQS}$ referenced to Vih(dc)/ Vil(dc) levels	150		100		ps	d,17
Data Strobe Timing							
t_{RPRE}	DQS, $\overline{DQS}$ differential READ Preamble	0.9	Note 19	0.9	Note 19	$t_{CK(avg)}$	13,19,b
t_{RPST}	DQS, $\overline{DQS}$ differential READ Postamble	0.3	Note 11	0.3	Note 11	$t_{CK(avg)}$	11,13,b
t_{QSH}	DQS, $\overline{DQS}$ differential output high time	0.38	-	0.38	-	$t_{CK(avg)}$	13,b
t_{QSL}	DQS, $\overline{DQS}$ differential output low time	0.38	-	0.38	-	$t_{CK(avg)}$	13,b
t_{WPRE}	DQS, $\overline{DQS}$ differential WRITE Preamble	0.9	-	0.9	-	$t_{CK(avg)}$	
t_{WPST}	DQS, $\overline{DQS}$ differential WRITE Postamble	0.3	-	0.3	-	$t_{CK(avg)}$	
t_{DQSCK}	DQS, $\overline{DQS}$ rising edge output access time from rising CK, $\overline{CK}$	-400	400	-300	300	ps	13,a
$t_{LZ(DQS)}$	DQS, $\overline{DQS}$ low-impedance time (Referenced from RL-1)	-800	400	-600	300	ps	13,14,a
$t_{HZ(DQS)}$	DQS, $\overline{DQS}$ high-impedance time (Referenced from RL+BL/2)	-	400	-	300	ps	13,14,a

Symbol	Parameter		DDR3-800 (-AC/-AD)		DDR3-1066 (-BE/-BF)		Unit	Notes
			min	max	min	max		
t_{DQSL}	DQS, $\overline{DQS}$ differential input low pulse width		0.4	0.6	0.4	0.6	$t_{CK(avg)}$	
t_{DQSH}	DQS, $\overline{DQS}$ differential input high pulse width		0.4	0.6	0.4	0.6	$t_{CK(avg)}$	
t_{DQSS}	DQS, $\overline{DQS}$ rising edge to CK, $\overline{CK}$ rising edge		-0.25	0.25	-0.25	0.25	$t_{CK(avg)}$	c
t_{DSS}	DQS, $\overline{DQS}$ falling edge setup time to CK, $\overline{CK}$ rising edge		0.2	-	0.2	-	$t_{CK(avg)}$	c
t_{DSH}	DQS, $\overline{DQS}$ falling edge hold time to CK, $\overline{CK}$ rising edge		0.2	-	0.2	-	$t_{CK(avg)}$	c
Command and Address Timing								
t_{DLLK}	DLL Locking time		512	-	512	-	nCK	
t_{RTP}	Internal READ command to PRECHARGE Command delay		max(4nCK, 7.5ns)	-	max(4nCK, 7.5ns)	-		e
t_{WTR}	Delay from start of internal write transaction to internal read command		max(4nCK, 7.5ns)	-	max(4nCK, 7.5ns)	-		e,18
t_{WR}	WRITE recovery time		15	-	15	-	ns	e
t_{MRD}	Mode Register Set command cycle time		4	-	4	-	nCK	
t_{MOD}	Mode Register Set command update delay		max(12nCK, 15ns)	-	max(12nCK, 15ns)	-		
t_{CCD}	$\overline{CAS}$ to $\overline{CAS}$ command delay		4	-	4	-	nCK	
t_{DAL}	Auto Precharge write recovery + precharge time		WR + roundup (tRP/tCK(avg))				nCK	
t_{MPRR}	End of MPR Read burst to MSR for MPR (exit)		1	-	1	-	nCK	22
t_{RAS}	ACTIVE to PRECHARGE command period		Refer to “Standard Speed Bins”					e
t_{RRD}	ACTIVE to ACTIVE command period	x4 & x8 (1k page size)	max(4nCK, 10ns)	-	max(4nCK, 7.5ns)	-		e
		x16 (2k page size)	max(4nCK, 10ns)	-	max(4nCK, 10ns)	-		e
t_{FAW}	Four activate window	x4 & x8 (1k page size)	40	-	37.5	-	ns	e
		x16 (2k page size)	50	-	50	-	ns	e
t_{IS}(base)	Command and Address setup time to CK, $\overline{CK}$ referenced Vih(ac) / Vil(ac) levels		200		125		ps	b,16
t_{IH}(base)	Command and Address hold time from CK, $\overline{CK}$ referenced Vih(ac) / Vil(ac) levels		275		200		ps	b,16
Calibration Timing								
t_{ZQinit}	Power-up and RESET calibration time		512	-	512	-	nCK	
t_{ZQoper}	Normal operation Full calibration time		256		256		nCK	
t_{ZQCS}	normal operation Short calibration time		64	-	64	-	nCK	23
Reset Timing								
t_{XPR}	Exit Reset from CKE HIGH to a valid command		max(5nCK, tRFC(min) +10ns)	-	max(5nCK, tRFC(min) +10ns)	-		
Self RefreshTimings								

Symbol	Parameter	DDR3-800 (-AC/-AD)		DDR3-1066 (-BE/-BF)		Unit	Notes
		min	max	min	max		
t_{XS}	Exit Self Refresh to Commands not requiring a locked DLL	max(5nCK, tRFC(min) +10ns)	-	max(5nCK, tRFC(min) +10ns)	-		
t_{XSDLL}	Exit Self Refresh to Commands requiring a locked DLL	tDLLK(min)	-	tDLLK(min)	-	nCK	
t_{CKESR}	Minimum CKE low width for Self Refresh entry to exit timing	tCKE(min)+ 1nCK	-	tCKE(min)+ 1nCK	-		
t_{CKSRE}	Valid Clock Requirement after Self Refresh Entry (SRE) or Power Down Entry (PDE)	max(5nCK, 10ns)	-	max(5nCK, 10ns)	-		
t_{CKSRX}	Valid Clock Requirement before Self Refresh Exit(SRX) or Power-Down Exit (PDX) or Reset Exit	max(5nCK, 10ns)	-	max(5nCK, 10ns)	-		
Power Down Timings							
t_{XP}	Exit Power Down with DLL on to any valid command; Exit Precharge Power Down with DLL frozen to commands not requiring a locked DLL	max(3nCK, 7.5ns)	-	max(3nCK, 7.5ns)	-		
t_{XPDLL}	Exit Precharge Power Down with DLL frozen to commands requiring a locked DLL	max(10nCK, 24ns)	-	max(10nCK, 24ns)	-		2
t_{CKE}	CKE minimm pulse width	max(3nCK, 7.5ns)	-	max(3nCK, 5.625ns)	-		
t_{CPDED}	Command Pass disable delay	1	-	1	-	nCK	
t_{PD}	Power Down Entry to Exit Timing	tCKE(min)	9tREFI	tCKE(min)	9tREFI		15
$t_{ACTPDEN}$	Timing of ACT command to Power Down entry	1	-	1	-	nCK	20
t_{PRPDEN}	Timing of PRE or PREA command to Power Down entry	1	-	1	-	nCK	20
t_{RDPDEN}	Timing of RD/RDA command to Power Down entry	RL + 4 + 1	-	RL + 4 + 1	-	nCK	
t_{WRPDEN}	Timing of WR command to Power Down entry (BL8OTF, BL8MRS, BC4OTF)	WL + 4 + (tWR/tCK(avg))	-	WL + 4 + (tWR/tCK(avg))	-	nCK	9
$t_{WRAPDEN}$	Timing of WRA command to Power Down entry (BL8OTF, BL8MRS, BC4OTF)	WL + 4 + WR + 1	-	WL + 4 + WR + 1	-	nCK	10
t_{WRPDEN}	Timing of WR command to Power Down entry (BC4MRS)	WL + 2 + (tWR/tCK(avg))	-	WL + 2 + (tWR/tCK(avg))	-	nCK	9
$t_{WRAPDEN}$	Timing of WRA command to Power Down entry (BC4MRS)	WL + 2 + WR + 1	-	WL + 2 + WR + 1	-	nCK	10
$t_{REFPDEN}$	Timing of REF command to Power Down entry	1	-	1	-	nCK	20,21
$t_{MRSPDEN}$	Timing of MRS command to Power Down entry	tMOD(min)	-	tMOD(min)	-		
ODT Timings							
t_{ODTH4}	ODT high time without write command or with write command and BC4	4	-	4	-	nCK	
t_{ODTH8}	ODT high time without write command oand BL8	6	-	6	-	nCK	
t_{AONPD}	Asynchronous RTT turn-on delay (Power-Down with DLL frozen)	1	9	1	9	ns	

Symbol	Parameter		DDR3-800 (-AC/-AD)		DDR3-1066 (-BE/-BF)		Unit	Notes
			min	max	min	max		
t_{AOFPD}	Asynchronous RTT turn-off delay (Power Down with DLL frozen)		1	9	1	9	ns	
t_{AON}	RTT turn-on		-400	400	-300	300	ps	7,a
t_{AOF}	RTT_NOM and RTT_WR turn-off time from ODTLoff reference		0.3	0.7	0.3	0.7	$t_{CK(avg)}$	8,a
t_{ADC}	RTT dynamic change skew		0.3	0.7	0.3	0.7	$t_{CK(avg)}$	a
Write Leveling Timings								
t_{WLMRD}	First DQS/$\overline{DQS}$ rising edge after write leveling mode is programmed		40	-	40	-	nCK	3
$t_{WLDQSEN}$	DQS/$\overline{DQS}$ delay after write leveling mode is porgramed		25	-	25	-	nCK	3
t_{WLS}	Write leveling setup time from rising CK, $\overline{CK}$ crossing to rising DQS, $\overline{DQS}$ crossing		325	-	245	-	ps	
t_{WLH}	Write leveling hold time from rising DQS, $\overline{DQS}$ crossing to rising CK, $\overline{CK}$ crossing		325	-	245	-	ps	
t_{WLO}	Write leveling output delay		0	9	0	9	ns	
t_{WLOE}	Write levleing output error		0	2	0	2	ns	
t_{RFC}	REF command to ACT or REF command time		110		110		ns	
t_{REFI}	Average period refresh interval	0C<=t_{CASE}<=85C	7.8		7.8		us	
		85C<=t_{CASE}<=95C	3.9		3.9		us	

Symbol	Parameter	DDR3-1333 (-CF/-CG)		Unit	Notes
		min	max		
Clock Timing					
$t_{CK(DLL\_OFF)}$	Minimum Clock Cycle Time (DLL off mode)	8	-	ns	6
$t_{CK(avg)}$	Average Clock Period	Refer to “Standard Speed Bins”			
$t_{CH(avg)}$	Average high pulse width	0.47	0.53	$t_{CK(avg)}$	
$t_{CL(avg)}$	Average low pulse width	0.47	0.53	$t_{CK(avg)}$	
$t_{CK(abs)}$	Absolute Clock Period	tCK(avg)min +tJIT(per)min	tCK(avg)max +tJIT(per)max	ps	
$t_{CH(abs)}$	Absolute high pulse width	0.43	-	tCK(avg)	25
$t_{CL(abs)}$	Absolute low pulse width	0.43	-	tCK(avg)	26
JIT(per)	Clock Period Jitter	-80	80	ps	
$t_{JIT(per,lck)}$	Clock Period Jitter during DLL locking period	-70	70	ps	
$t_{JIT(cc)}$	Cycle to Clcyle Period Jitter	160		ps	
$t_{JIT(cc,lck)}$	Cycle to Cycle Period Jitter	140		ps	
$t_{ERR(2per)}$	Cumulative error accross 2 cycles	-118	118	ps	
$t_{ERR(3per)}$	Cumulative error accross 3 cycles	-140	140	ps	
$t_{ERR(4per)}$	Cumulative error accross 4cycles	-155	155	ps	

Symbol	Parameter	DDR3-1333 (-CF/-CG)		Unit	Notes
		min	max		
$t_{ERR(5per)}$	Cumulative error accross 5cycles	-168	168	ps	
$t_{ERR(6per)}$	Cumulative error accross 6 cycles	-177	177	ps	
$t_{ERR(7per)}$	Cumulative error accross 7 cycles	-186	186	ps	
$t_{ERR(8per)}$	Cumulative error accross 8 cycles	-193	193	ps	
$t_{ERR(9per)}$	Cumulative error accross 9 cycles	-200	200	ps	
$t_{ERR(10per)}$	Cumulative error accross 10 cycles	-205	205	ps	
$t_{ERR(11per)}$	Cumulative error accross 11 cycles	-210	210	ps	
$t_{ERR(12per)}$	Cumulative error accross 12 cycles	-215	215	ps	
$t_{ERR(nper)}$	Cumulative error accross n=13,14,..,49,50 cycles	tERR(npr)min = (1+ 0.68ln(n)) * tJIT(per)min tERR(npr)max = (1+ 0.68ln(n)) * tJIT(per)max		ps	24
$t_{JIT(duty)}$	Duty Cycle Jitter	-	-	ps	
Data Timing					
t_{DQSQ}	DQS, $\overline{DQS}$ to DQ skew per group, per access	-	125	ps	13
t_{QH}	DQ output hold time from DQS, $\overline{DQS}$	0.38	-	$t_{CK(avg)}$	13,b
$t_{LZ(DQ)}$	DQ low-impedence time from CK / $\overline{CK}$	-500	250	ps	13,14,a
$t_{HZ(DQ)}$	DQ high-impedence time from CK / $\overline{CK}$	-	250	ps	13,14,a
$t_{DS(base)}$	Data Setup time to DQS, $\overline{DQS}$ referenced to Vih(ac)/ Vil(ac) levels	TBD		ps	d,17
$t_{DH(base)}$	Data Hold time to DQS, $\overline{DQS}$ referenced to Vih(dc)/ Vil(dc) levels	TBD		ps	d,17
Data Strobe Timing					
t_{RPRE}	DQS, $\overline{DQS}$ differential READ Preamble	0.9	Note 19	$t_{CK(avg)}$	13,19,b
t_{RPST}	DQS, $\overline{DQS}$ differential READ Postamble	0.3	Note 11	$t_{CK(avg)}$	11,13,b
t_{QSH}	DQS, $\overline{DQS}$ differential output high time	0.4	-	$t_{CK(avg)}$	13,b
t_{QSL}	DQS, $\overline{DQS}$ differential output low time	0.4	-	$t_{CK(avg)}$	13,b
t_{WPRE}	DQS, $\overline{DQS}$ differential WRITE Preamble	0.9	-	$t_{CK(avg)}$	
t_{WPST}	DQS, $\overline{DQS}$ differential WRITE Postamble	0.3	-	$t_{CK(avg)}$	
t_{DQSCK}	DQS, $\overline{DQS}$ rising edge output access time from rising CK, $\overline{CK}$	-255	255	ps	13,a
$t_{LZ(DQS)}$	DQS, $\overline{DQS}$ low-impedance time (Referenced from RL-1)	-500	250	ps	13,14,a
$t_{HZ(DQS)}$	DQS, $\overline{DQS}$ high-impedance time (Referenced from RL+BL/2)	-	250	ps	13,14,a
t_{DQSL}	DQS, $\overline{DQS}$ differential input low pulse width	0.4	0.6	$t_{CK(avg)}$	
t_{DQSH}	DQS, $\overline{DQS}$ differential input high pulse width	0.4	0.6	$t_{CK(avg)}$	
t_{DQSS}	DQS, $\overline{DQS}$ rising edge to CK, $\overline{CK}$ rising edge	-0.25	0.25	$t_{CK(avg)}$	c
t_{DSS}	DQS, $\overline{DQS}$ falling edge setup time to CK, $\overline{CK}$ rising edge	0.2	-	$t_{CK(avg)}$	c

Symbol	Parameter		DDR3-1333 (-CF/-CG)		Unit	Notes
			min	max		
t_{DSH}	DQS, $\overline{DQS}$ falling edge hold time to CK, $\overline{CK}$ rising edge		0.2	-	$t_{CK(avg)}$	c
Command and Address Timing						
t_{DLLK}	DLL Locking time		512	-	nCK	
t_{RTP}	Internal READ command to PRECHARGE Command delay		max(4nCK, 7.5ns)	-		e
t_{WTR}	Delay from start of internal write transaction to internal read command		max(4nCK, 7.5ns)	-		e,18
t_{WR}	WRITE recovery time		15	-	ns	e
t_{MRD}	Mode Register Set command cycle time		4	-	nCK	
t_{MOD}	Mode Register Set command update delay		max(12nCK, 15ns)	-		
t_{CCD}	$\overline{CAS}$ to $\overline{CAS}$ command delay		4	-	nCK	
t_{DAL}	Auto Precharge write recovery + precharge time		WR + roundup (tRP/tCK(avg))		nCK	
t_{MPRR}	End of MPR Read burst to MSR for MPR (exit)		1	-	nCK	22
t_{RAS}	ACTIVE to PRECHARGE command period		Refer to “Standard Speed Bins”			e
t_{RRD}	ACTIVE to ACTIVE command period	x4 & x8 (1k page size)	max(4nCK, 6ns)	-		e
		x16 (2k page size)	max(4nCK, 7.5ns)	-		e
t_{FAW}	Four activate window	x4 & x8 (1k page size)	30	-	ns	e
		x16 (2k page size)	45	-	ns	e
t_{IS}(base)	Command and Address setup time to CK, CK referenced Vih(ac) / Vil(ac) levels		65		ps	b,16
t_{IH}(base)	Command and Address hold time from CK, CK referenced Vih(ac) / Vil(ac) levels		140		ps	b,16
t_{IH}(base) AC150	Command and Address hold time from CK, CK referenced Vih(ac) / Vil(ac) levels		65+125		ps	b,16,27
Calibration Timing						
t_{ZQinit}	Power-up and RESET calibration time		512	-	nCK	
t_{ZQoper}	Normal operation Full calibration time		256		nCK	
t_{ZQCS}	normal operation Short calibration time		64	-	nCK	23
Reset Timing						
t_{XPR}	Exit Reset from CKE HIGH to a valid command		max(5nCK, tRFC(min) +10ns)	-		
Self RefreshTimings						
t_{XS}	Exit Self Refresh to Commands not requiring a locked DLL		max(5nCK, tRFC(min) +10ns)	-		
t_{XSDLL}	Exit Self Refresh to Commands requiring a locked DLL		tDLLK(min)	-	nCK	

Symbol	Parameter	DDR3-1333 (-CF/-CG)		Unit	Notes
		min	max		
t_{CKESR}	Minimum CKE low width for Self Refresh entry to exit timing	tCKE(min)+ 1nCK	-		
t_{CKSRE}	Valid Clock Requirement after Self Refresh Entry (SRE) or Power Down Entry (PDE)	max(5nCK, 10ns)	-		
t_{CKSRX}	Valid Clock Requirement before Self Refresh Exit(SRX) or Power-Down Exit (PDX) or Reset Exit	max(5nCK, 10ns)	-		
Power Down Timings					
t_{XP}	Exit Power Down with DLL on to any valid command; Exit Precharge Power Down with DLL frozen to commands not requiring a locked DLL	max(3nCK, 6ns)	-		
t_{XPDLL}	Exit Precharge Power Down with DLL frozen to commands requiring a locked DLL	max(10nCK, 24ns)	-		2
t_{CKE}	CKE minimm pulse width	max(3nCK, 5.625ns)	-		
t_{CPDED}	Command Pass disable delay	1	-	nCK	
t_{PD}	Power Down Entry to Exit Timing	tCKE(min)	9tREFI		15
$t_{ACTPDEN}$	Timing of ACT command to Power Down entry	1	-	nCK	20
t_{PRPDEN}	Timing of PRE or PREA command to Power Down entry	1	-	nCK	20
t_{RDPDEN}	Timing of RD/RDA command to Power Down entry	RL + 4 + 1	-	nCK	
t_{WRPDEN}	Timing of WR command to Power Down entry (BL8OTF, BL8MRS, BC4OTF)	WL + 4 + (tWR/tCK(avg))	-	nCK	9
$t_{WRAPDEN}$	Timing of WRA command to Power Down entry (BL8OTF, BL8MRS, BC4OTF)	WL + 4 + WR + 1	-	nCK	10
t_{WRPDEN}	Timing of WR command to Power Down entry (BC4MRS)	WL + 2 + (tWR/tCK(avg))	-	nCK	9
$t_{WRAPDEN}$	Timing of WRA command to Power Down entry (BC4MRS)	WL + 2 + WR + 1	-	nCK	10
$t_{REFPDEN}$	Timing of REF command to Power Down entry	1	-	nCK	20,21
$t_{MRSPDEN}$	Timing of MRS command to Power Down entry	tMOD(min)	-		
ODT Timings					
t_{ODTH4}	ODT high time without write command or with write command and BC4	4	-	nCK	
t_{ODTH8}	ODT high time without write command oand BL8	6	-	nCK	
t_{AONPD}	Asynchronous RTT turn-on delay (Power-Down with DLL frozen)	1	9	ns	
t_{AOFPD}	Asynchronous RTT turn-off delay (Power Down with DLL frozen)	1	9	ns	
t_{AON}	RTT turn-on	-250	250	ps	7,a

Symbol	Parameter		DDR3-1333 (-CF/-CG)		Unit	Notes
			min	max		
t_{AOF}	RTT_NOM and RTT_WR turn-off time from ODTLoff reference		0.3	0.7	$t_{CK(avg)}$	8,a
t_{ADC}	RTT dynamic change skew		0.3	0.7	$t_{CK(avg)}$	a
Write Leveling Timings						
t_{WLMRD}	First DQS/$\overline{DQS}$ rising edge after write leveling mode is programmed		40	-	nCK	3
$t_{WLDQSEN}$	DQS/$\overline{DQS}$ delay after write leveling mode is porgramed		25	-	nCK	3
t_{WLS}	Write leveling setup time from rising CK, $\overline{CK}$ crossing to rising DQS, $\overline{DQS}$ crossing		195	-	ps	
t_{WLH}	Write leveling hold time from rising DQS, $\overline{DQS}$ crossing to rising CK, $\overline{CK}$ crossing		195	-	ps	
t_{WLO}	Write leveling output delay		0	9	ns	
t_{WLOE}	Write levleing output error		0	2	ns	
t_{RFC}	REF command to ACT or REF command time		110		ns	
t_{REFI}	Average period refresh interval	0C<=t_{CASE}<=85C	7.8		us	
		85C<=t_{CASE}<=95C	3.9		us	

Jitter Notes

Specific Note a

When the device is operated with input clock jitter, this parameter needs to be derated by the actual tERR(nper) act of the input clock, where 2<=n<=12. (output deratings are relative to the SDRAM input clock.)
For example, if the measured jitter into a DDR3-800 SDRAM has tERR(nper),act,min = -172ps and tERR(nper),act,max = +193ps, then tDQSCK,min(derated) = tDQSCK,min - tERR(nper),act,max = -400ps - 193ps = -593ps and tDQSCK,max(derated) = tDQSCK,max - tERR(nper),act,min = 400ps + 172ps = +572ps. Similarly, tLZ(DQ) for DDR3-800 derates to tLZ(DQ),min(derated) = -800ps - 193ps = -993ps and tLZ(DQ),max(derated) = 400ps + 172ps = +572ps. (Caution on the min/max usage!)
Note that tERR(nper),act,min is the minimum measured value of tERR(nper) where 2<=n<=12, and tERR(nper),act,max is the maximum measured value of tERR(nper) where 2<=n<=12.

Specific Note b

When the device is operated with input clock jitter, this parameter needs to be derated by the actual tJIT(per),act of the input clock. (output deratings are relative to the SDRAM input clock.)
For example, if the measured jitter into a DDR3-800 SDRAM has tCK(avg),act = 2500ps, tJIT(per),act,min = -72ps and tJIT(per),act,max = +93ps, then tRPRE,min(derated) = tRPRE,min + tJIT(per),act,min = 0.9 x tCK(avg),act + tJIT(per),act,min = 0.9 x 2500ps - 72ps = +2178ps. Similarly, tQH,min(derated) = tQH,min + tJIT(per),act,min = 0.38 x tCK(avg),act + tJIT(per),act,min = 0.38 x 2500ps - 72ps = +878ps (Caition on the min/max usage!)

Specific Note c

These parameters are measured from a data strobe signal (DQS(L/U), $\overline{\text{DQS(L/U)}}$) crossing to its respective clock signal (CK, $\overline{\text{CK}}$) crossing. The spec values are not affected by the amount of clock jitter applied (i.e. tJIT(per), tJIT(cc), etc), as these are relative to the clock signal crossing. That is, these parameters should be met whether clock jitter is presetn or not.

Specific Note d

These parameters are measured from a data signal (DM(L/U), DQ(L/U)0, DQ(L/U)1, etc.) transition edge to its respective data strobe signal (DQS(L/U), $\overline{\text{DQS(L/U)}}$) crossing.

Specific Note e

For these parameters, the DDR3 SDRAM device supports tnPARAM [nCK] = RU{tPARAM[ns] / tCK(avg)[ns]}, which is in clock cycles, assuming all input clock jitter specifications are satisfied. For example, the device will support tnRP = RU{tRP/tCK(avg)}, which is in clock cycles, if all input clock jitter specifications are met. This means: For DDR3-800 6-6-6, of which tRP = 15ns, the device will support tnRP = RU{tRP/tCK(avg)} = 6, as long as the input clock jitter specifications are met, i.e. Precharge command at Tm and Active command at Tm+6 is valid even if (Tm+6-Tm) is less than 15ns due to input clock jitter.

Timing Parameter Notes

1. Actual value dependant upon measurement level definitions which are TBD.
2. Commands requiring a locked DLL are: READ (and RAP) are synchronous ODT commands.
3. The max values are system dependent.
4. WR as programmed in mode register.
5. Value must be rouned-up to next higher integer value.
6. There is no maximum cycle time limit besides the need to satisfy the refresh interval, tREFI.
7. For definition of RTT-on time tAON See “Timing Parameters”.
8. For definition of RTT-off time tAOF See “Timing Parameters”.
9. tWR is defined in ns, for calculation of tWRPDEN it is necessary to round up tWR / tCK to the next integer.
10. WR in clock cycles are programmed in MR0.
11. The maximum postamble is bonded by tHZDQS(max).
12. Output timing deratings are relative to the SDRAM input clock. When the device is operated with input clock jitter, this parameter needs to be derated by TBD.
13. Value is only valid for RON34.
14. Single ended signal parameter.
15. tREFI depends on TOPER.
16. tIS(base) and tIH(base) values are for 1V/ns CMD/ADD single-ended slew rate and 2V/ns CK, $\overline{CK}$ differential slew rate. Note for DQ and DM signals, VREF(DC)=VRefDQ(DC). For input only pins except $\overline{RESET}$, VRef(DC)=VRefCA(DC).
17. tDS(base) and tDH(base) values are for 1V/ns DQ single-ended slew rate and 2V/ns DQS, $\overline{DQS}$ differential slew rate. Note for DQ and DM signals, VREF(DC)=VRefDQ(DC). For input only pins except $\overline{RESET}$, VRef(DC)=VRefCA(DC).
18. Start of internal write transaction is defined as follows:
    For BL8 (fixed by MRS and on-the-fly): Rising clock edge 4 clock cycles after WL.
    For BC4 (on-the-fly): Rising clock edge 4 clock cycles after WL.
    For BC4 (fixed by MRS): Rising clock edge 2 clock cycles after WL.
19. The maximum preamble is bound by tLZDQS(max).
20. CKE is allowed to be registered low while operations such as row activation, precharge, autoprecharge or refresh are in progress, but power-down IDD spec will not be applied until finishing those operations.
21. Although CKE is allowed to be registered LOW after a REFRESH command once tREFPDEN(min) is satisfied, there are cases where additional time such as tXPDLL(min) is also required.
22. Defined between end of MPR read burst and MRS which reloads MPR or disables MPR function.
23. One ZQCS command can effectively correct a minimum of 0.5% (ZQCorrection) of RON and RTT impedance error within 64 nCK for all speed bins assuming the maximum sensitivities specified in the “Output Driver Voltage and Temperature Sensitivity” and “ODT Voltage and Temperature Sensitivity” tables. The appropriate interval between ZQCS commands can be determined from these tables and other application-specific parameters.

    One method for calculating the interval between ZQCS commands, given the temperature (Tdriftrate) and voltage (Vdrift-rate) drift rates that the SDRAM is subject to in the application, is illustrated. the interval could be defined by the following formula: ZQCorrection / [(TSens x Tdriftrate) + (VSens x Vdriftrate)] where TSens = max(dRTTdT, dRONdTM) and VSens = max(dRTTdV, dRONdVM) define the SDRAM temperature and voltage sensitivities.

    For example, if TSens = 1.5%/C, VSens = 0.15%/mV, Tdriftrate = 1 C/sec and Vdriftrate = 15mV/sec, then the interval between ZQCS commands is calculated as 0.5 / [(1.5x1)+(0.15x15)] = 0.133 ~ 128ms
24. n = from 13 cycles to 50 cycles. This row defines 38 parameters.
25. tCH(abs) is the absolute instantaneous clock high pulse width, as measured from one rising edge to the following falling edge.
26. tCL(abs) is the absolute instantaneous clock low pulse width, as measured from one falling edge to the following rising edge.

27. The tIS(base) AC150 specifications are adjusted from the tIS(base) specification by adding an additional 100ps of derating to accommodate for the lower altemate threshold of 150mV and another 25ps to account for the earlier reference point [(175mV - 150mV) / 1V/ns].

Address / Command Setup, Hold, and Derating

For all input signals the total tIS (setup time) and tIH (hold time) required is calculated by adding the data sheet tIS(base) and tIH(base) and tIH(base) value to the delta tIS and delta tIH derating value respectively.
Example: tIS (total setup time) = tIS(base) + delta tIS
Setup (tIS) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of Vref(dc) and the first crossing of VIH(ac)min. Setup (tIS) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of Vref(dc) and the first crossing of VIL(ac)max. If the actual signal is always earlier than the nominal slew rate line between shaded 'Vref(dc) to ac region', use nominal slew rate for derating value. If the actual signal is later than the nominal slew rate line anywhere between shaded 'Vref(dc) to ac region', the slew rate of the tangent line to the actual signal from the ac level to dc level is used for derating value.
Hold (tIH) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of VIL(dc)max and the first crossing of Vref(dc). Hold (tIH) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of VIH(dc)min and the first crossing of Vref(dc). If the actual signal is always later than the nominal slew rate line between shaded 'dc to Vref(dc) region', use nominal slew rate for derating value. If the actual signal is earlier than the nomial slew rate line anywhere between shaded 'dc to Vref(dc) region', the slew rate of a tangent line to the actual signal from the dc level to Vref(dc) level is used for derating value. For a valid transition the input signal has to remain above/below VIH/IL(ac) for some time tVAC. Although for slow slew rates the total setup time might be negative (i.e. a valid input signal will not have reached VIH/IL(ac) at the time of the rising clock transition) a valid input signal is still required to complete the transistion and reach VIH/IL(ac).

ADD/CMD Setup and Hold Base-Values for 1V/ns

Unit [ps]	DDR3-800 (-AC/-AD)	DDR3-1066 (-BE/-BF)	DDR3-1333 (-CF/-CG)	reference
tIS(base)	200	125	65	VIH/L(ac)
tIH(base)	275	200	140	VIH/L(dc)
tIH(base) AC150	-	-	65+125	VIH/L(dc)

Note:
1. (ac/dc referenced for 1V/ns DQ-slew rate and 2V/ns DQS slew rate
2. The tIS(base) AC150 specifications are adjusted from the tIS(base) specification by adding an additional 100ps of derating to accomodate for the lower altermate threshold of 150mV and another 25ps to account for the earlier reference point [(175mV - 150mV) / 1V/ns].

Derating values DDR3-800/1066/1333 tIS/tIH - ac/dc based

Delta tIS, Delta tIH derating in AC/DC based
AC175 Threshold -> VIH(ac) = Vref(dc)+175mV, VIL(ac)=Vref-175mV

CMD/ADD Slew rate (V/ns)	CK, CK Differential Slew Rate															
	4.0 V/ns		3.0 V/ns		2.0 V/ns		1.8 V/ns		1.6 V/ns		1.4 V/ns		1.2 V/ns		1.0 V/ns	
	D tIS	D tIH	D tIS	D tIH	D tIS	D tIH	D tIS	D tIH	D tIS	D tIH	D tIS	D tIH	D tIS	D tIH	D tIS	D tIH
2.0	88	50	88	50	88	50	96	58	104	66	112	74	120	84	128	100
1.5	59	34	59	34	59	34	67	42	75	50	83	58	91	68	99	84
1.0	0	0	0	0	0	0	8	8	16	16	24	24	32	34	40	50
0.9	-2	-4	-2	-4	-2	-4	6	4	14	12	22	20	30	30	38	46
0.8	-6	-10	-6	-10	-6	-10	2	-2	10	6	18	14	26	24	34	40
0.7	-11	-16	-11	-16	-11	-16	-3	-8	5	0	13	8	21	18	29	34
0.6	-17	-26	-17	-26	-17	-26	-9	-18	-1	-10	7	-2	15	8	23	24
0.5	-35	-40	-35	-40	-35	-40	-27	-32	-19	-24	-11	-16	-2	-6	5	10
0.4	-62	-60	-62	-60	-62	-60	-54	-52	-46	-44	-38	-36	-30	-26	-22	-10

Derating values DDR3-1333 tIS/tIH - ac/dc based - Alternate AC150 Threshold

Delta tIS, Delta tIH derating in AC/DC based
Alternate AC150 Threshold -> VIH(ac) = Vref(dc)+150mV, VIL(ac)=Vref-150mV

CMD/ADD Slew rate (V/ns)	CK, CK Differential Slew Rate															
	4.0 V/ns		3.0 V/ns		2.0 V/ns		1.8 V/ns		1.6 V/ns		1.4 V/ns		1.2 V/ns		1.0 V/ns	
	D tIS	D tIH	D tIS	D tIH	D tIS	D tIH	D tIS	D tIH	D tIS	D tIH	D tIS	D tIH	D tIS	D tIH	D tIS	D tIH
2.0	75	50	75	50	75	50	83	58	91	66	99	74	107	84	115	100
1.5	50	34	50	34	50	34	58	42	66	50	74	58	82	68	90	84
1.0	0	0	0	0	0	0	8	8	16	16	24	24	32	34	40	50
0.9	0	-4	0	-4	0	-4	8	4	16	12	24	20	32	30	40	46
0.8	0	-10	0	-10	0	-10	8	-2	16	6	24	14	32	24	40	40
0.7	0	-16	0	-16	0	-16	8	-8	16	0	24	8	32	18	40	34
0.6	-1	-26	-1	-26	-1	-26	7	-18	15	-10	23	-2	31	8	39	24
0.5	-10	-40	-10	-40	-10	-40	-2	-32	6	-24	14	-16	22	-6	30	10
0.4	-25	-60	-25	-60	-25	-60	-17	-52	-9	-44	-1	-36	7	-26	15	-10

Required time tVAC above VIH(ac) {below VIL(ac)} for valid transition

Slew Rate [V/ns]	tVAC@175mV [ps]		tVAC@175mV [ps]	
	min	max	min	max
>2.0	75	-	175	-
2.0	57	-	170	-
1.5	50	-	167	-
1.0	38	-	163	-
0.9	34	-	162	-
0.8	29	-	161	-
0.7	22	-	159	-
0.6	13	-	155	-
0.5	0	-	150	-
<0.5	0	-	150	-

Data Setup, Hold, and Slew Rate Derating

For all input signals the total tDS (setup time) and tDH (hold time) required is calculated by adding the data sheet tDH(base) and tDH(base) value to the delta tDS and delta tDH derating value respectively.
Example: tDS (total setup time) = tDS(base) + delta tDS
Setup (tDS) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of Vref(dc) and the first crossing of VIH(ac)min. Setup (tDS) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of Vref(dc) and the first crossing of VIL(ac)max. If the actual signal is always earlier than the nominal slew rate line between shaded 'Vref(dc) to ac region', use nominal slew rate for derating value. If the actual signal is later than the nominal slew rate line anywhere between shaded 'Vref(dc) to ac region', the slew rate of the tangent line to the actual signal from the ac level to dc level is used for derating value.
Hold (tDH) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of VIL(dc)max and the first crossing of Vref(dc). Hold (tDH) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of VIH(dc)min and the first crossing of Vref(dc). If the actual signal is always later than the nominal slew rate line between shaded 'dc level to Vref(dc) region', use nominal slew rate for derating value. If the actual signal is earlier than the nomial slew rate line anywhere between shaded 'dc to Vref(dc) region', the slew rate of a tangent line to the actual signal from the dc level to Vref(dc) level is used for derating value.
For a valid transition the input signal has to remain above/below VIH/IL(ac) for some time tVAC.
Although for slow slew rates the total setup time might be negative (i.e. a valid input signal will not have reached VIH/IL(ac) at the time of the rising clock transition) a valid input signal is still required to complete the transistion and reach VIH/IL(ac).
For slew rates in between the values listed in the following tables, the derating values may be obtained by linear interpolation.
These values are typically not subject to production test. They are verified by design and characterization.

Data Setup and Hold Base-Values

Unit [ps]	DDR3-800 (-AC/-AD)	DDR3-1066 (-BE/-BF)	DDR3-1333 (-CF/-CG)	reference
tDS(base)	75	25	-10	VIH/L(ac)
tDH(base)	150	100	65	VIH/L(dc)
Note: (ac/dc referenced for 1V/ns DQ-slew rate and 2V/ns DQS slew rate				

Derating values DDR3-800/1066 tDS/tDH - ac/dc based

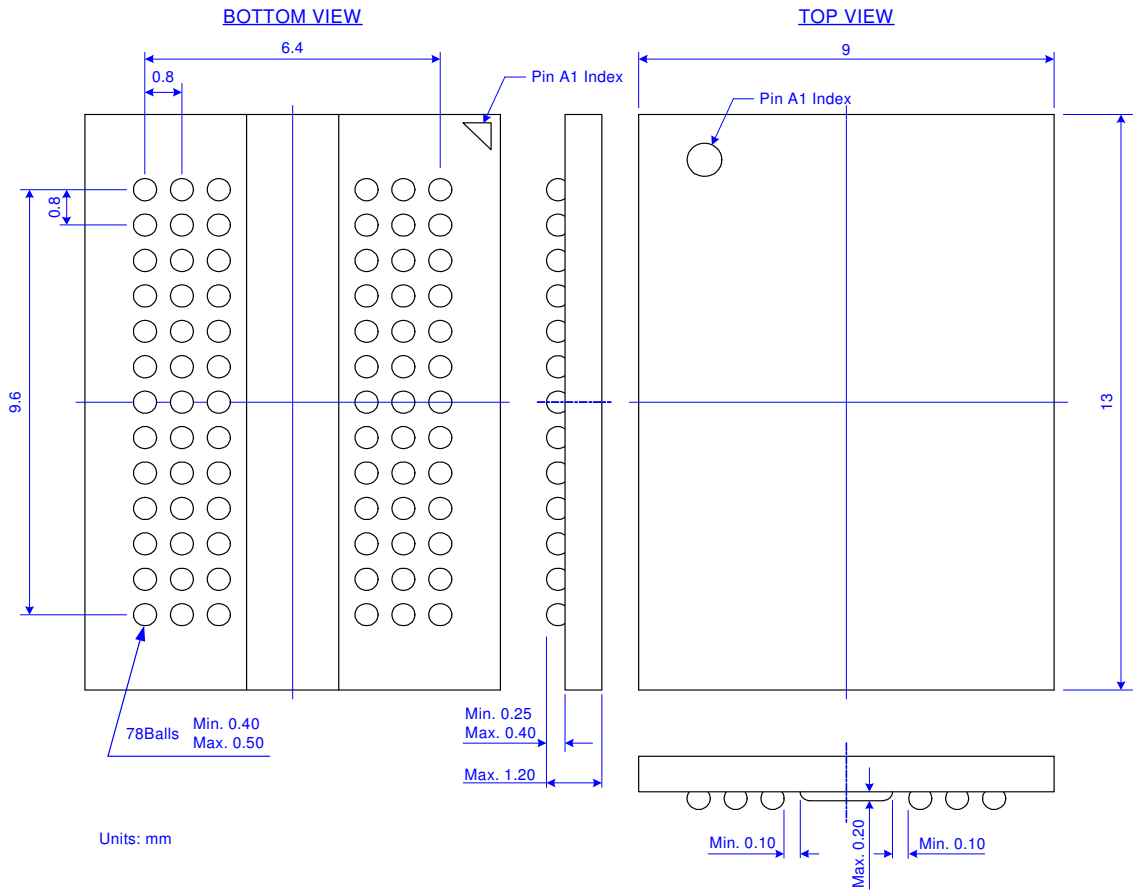
Delta tDS, Delta tDH derating in AC/DC based

		DQS, $\overline{DQS}$ Differential Slew Rate															
		4.0 V/ns		3.0 V/ns		2.0 V/ns		1.8 V/ns		1.6 V/ns		1.4 V/ns		1.2 V/ns		1.0 V/ns	
		D tDS	D tDH	D tDS	D tDH	D tDS	D tDH	D tDS	D tDH	D tDS	D tDH	D tDS	D tDH	D tDS	D tDH	D tDS	D tDH
DQ Slew rate (V/ns)	**2.0**	88	50	88	50	88	50	-	-	-	-	-	-	-	-	-	-
	1.5	59	34	59	34	59	34	67	42	-	-	-	-	-	-	-	-
	1.0	0	0	0	0	0	0	8	8	16	16	-	-	-	-	-	-
	0.9	-	-	-2	-4	-2	-4	6	4	14	12	22	20	-	-	-	-
	0.8	-	-	-	-	-6	-10	2	-2	10	6	18	14	26	24	-	-
	0.7	-	-	-	-	-	-	-3	-8	5	0	13	8	21	18	29	34
	0.6	-	-	-	-	-	-	-	-	-1	-10	7	-2	15	8	23	24
	0.5	-	-	-	-	-	-	-	-	-	-	-11	-16	-2	-6	5	10
	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-30	-26	-22	-10

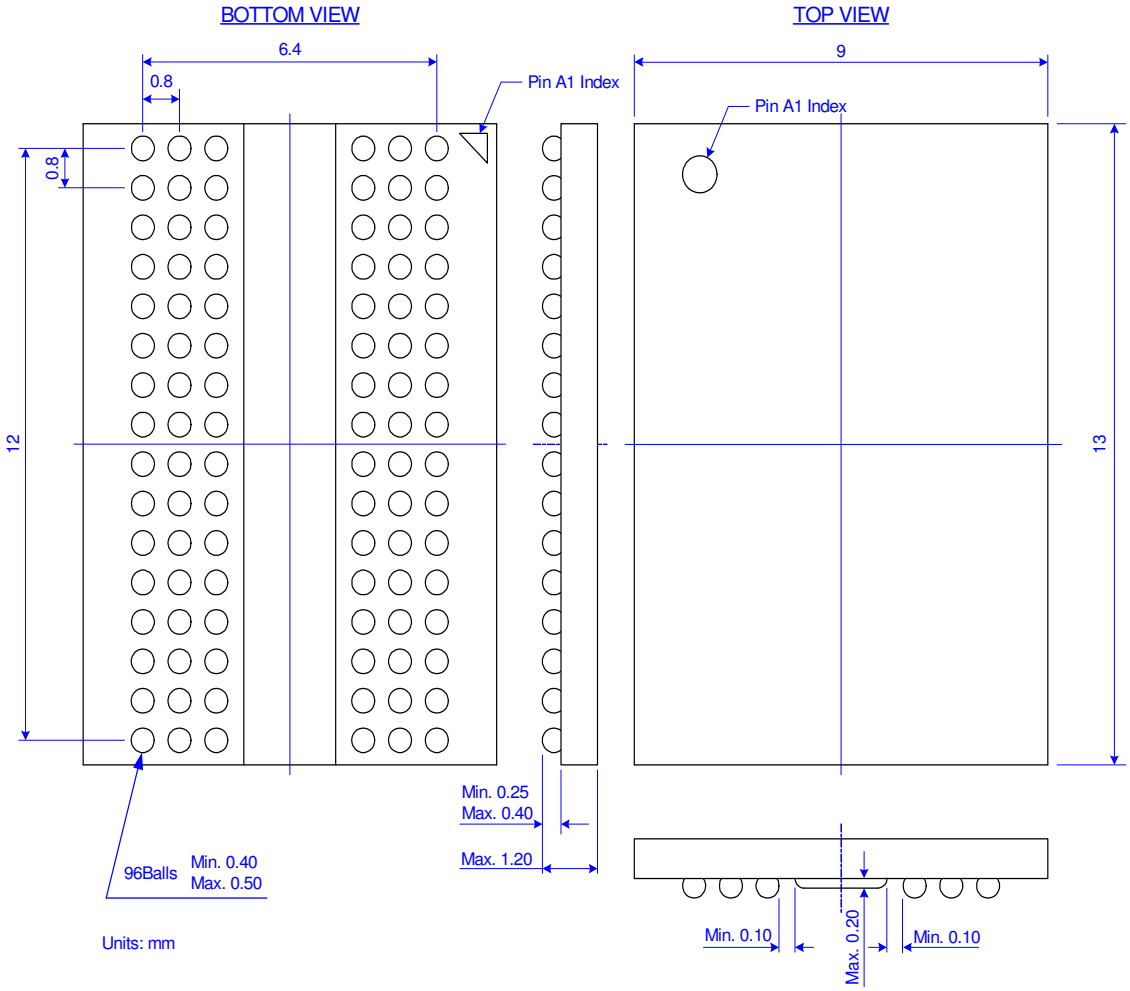
Required time tVAC above VIH(ac) {below VIL(ac)} for valid transition

Slew Rate [V/ns]	tVAC [ps]	
	min	max
>2.0	75	-
2.0	57	-
1.5	50	-
1.0	38	-
0.9	34	-
0.8	29	-
0.7	22	-
0.6	13	-
0.5	0	-
<0.5	0	-

Package Dimensions (x4/x8; 78 balls; 0.8mmx0.8mm Pitch; wBGA Package)



Package Dimensions (x16; 96 balls; 0.8mmx0.8mm Pitch; wBGA Package)



Revision Log

Rev	Date	Modification
0.1	04/2008	Preliminary Release

NANYA TECHNOLOGY CORPORATION
HWA YA Technology Park
669, FU HSING 3rd Rd., Kueishan,
Taoyuan, Taiwan, R.O.C.

The NANYA TECHNOLOGY CORPORATION

home page can be found at http:\\www.nanya.com