

JEDEC STANDARD

DDR3 SDRAM Specification

JESD79-3A

(Revision of JESD79-3)

September 2007

JEDEC SOLID STATE TECHNOLOGY ASSOCIATION



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1 Scope

This document defines the DDR3 SDRAM specification, including features, functionalities, AC and DC characteristics, packages, and ball/signal assignments. The purpose of this Specification is to define the minimum set of requirements for JEDEC compliant 512 Mb through 8 Gb for x4, x8, and x16 DDR3 SDRAM devices. This specification was created based on the DDR2 specification (JESD79-2) and some aspects of the DDR specification (JESD79). Each aspect of the changes for DDR3 SDRAM operation were considered and approved by committee ballot(s). The accumulation of these ballots were then incorporated to prepare this JESD79-3 specification, replacing whole sections and incorporating the changes into Functional Description and Operation.

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2 DDR3 SDRAM Package Pinout and Addressing

2.1 DDR3 SDRAM x4 Ballout using MO-207 (Top view: see balls through package)

	1	2	3	4	5	6	7	8	9	10	11
A	NC	NC		NC				NC		NC	NC
B											
C	NC	NC		NC				NC		NC	NC
D											
E											
F	NC	VSS	VDD	NC				NC	VSS	VDD	NC
G		VSS	VSSQ	DQ0				DM	VSSQ	VDDQ	
H		VDDQ	DQ2	DQS				DQ1	DQ3	VSSQ	
J		VSSQ	NC	DQS#				VDD	VSS	VSSQ	
K		VREFDQ	VDDQ	NC				NC	NC	VDDQ	
L		NC	VSS	RAS#				CK	VSS	NC	
M		ODT	VDD	CAS#				CK#	VDD	CKE	
N		NC	CS#	WE#				A10/AP	ZQ	NC	
P		VSS	BA0	BA2				A15	VREFCA	VSS	
R		VDD	A3	A0				A12/BC#	BA1	VDD	
T		VSS	A5	A2				A1	A4	VSS	
U		VDD	A7	A9				A11	A6	VDD	
V	NC	VSS	RESET#	A13				A14	A8	VSS	NC
W											
Y											
AA	NC	NC		NC				NC		NC	NC
AB											
AC	NC	NC		NC				NC		NC	NC
	1	2	3	4	5	6	7	8	9		

Note1: Green NC balls indicate mechanical support balls with no internal connection. Any of the support ball locations may or may not be populated with a ball.

MO-207 Variation DT-z (x4)

	1	2	3	4	5	6	7	8	9
A	○	○	○	+	+	+	○	○	○
B	○	○	○	+	+	+	○	○	○
C	○	○	○	+	+	+	○	○	○
D	○	○	○	+	+	+	○	○	○
E	○	○	○	+	+	+	○	○	○
F	○	○	○	+	+	+	○	○	○
G	○	○	○	+	+	+	○	○	○
H	○	○	○	+	+	+	○	○	○
J	○	○	○	+	+	+	○	○	○
K	○	○	○	+	+	+	○	○	○
L	○	○	○	+	+	+	○	○	○
M	○	○	○	+	+	+	○	○	○
N	○	○	○	+	+	+	○	○	○

○ Populated ball
+ Ball not populated

MO-207 Variation DW-z (x4)
with support balls

	1	2	3	4	5	6	7	8	9	10	11
A	○	○	+	○	+	+	+	○	+	○	○
B	+	+	+	+	+	+	+	+	+	+	+
C	○	○	+	○	+	+	+	○	+	○	○
D	+	+	+	+	+	+	+	+	+	+	+
E	+	+	+	+	+	+	+	+	+	+	+
F	○	○	○	○	+	+	+	○	○	○	○
G	+	○	○	○	+	+	+	○	○	○	+
H	+	○	○	○	+	+	+	○	○	○	+
J	+	○	○	○	+	+	+	○	○	○	+
K	+	○	○	○	+	+	+	○	○	○	+
L	+	○	○	○	+	+	+	○	○	○	+
M	+	○	○	○	+	+	+	○	○	○	+
N	+	○	○	○	+	+	+	○	○	○	+
P	+	○	○	○	+	+	+	○	○	○	+
R	+	○	○	○	+	+	+	○	○	○	+
T	+	○	○	○	+	+	+	○	○	○	+
U	+	○	○	○	+	+	+	○	○	○	+
V	○	○	○	○	+	+	+	○	○	○	○
W	+	+	+	+	+	+	+	+	+	+	+
X	+	+	+	+	+	+	+	+	+	+	+
AA	○	○	+	○	+	+	+	○	+	○	○
AB	+	+	+	+	+	+	+	+	+	+	+
AC	○	○	+	○	+	+	+	○	+	○	○

2 DDR3 SDRAM Package Pinout and Addressing (Cont'd)

2.2 DDR3 SDRAM x8 Ballout using MO-207 (Top view: see balls through package)

	1	2	3	4	5	6	7	8	9	10	11	
A	NC	NC		NC				NC		NC	NC	
B												
C	NC	NC		NC				NC		NC	NC	
D												
E												
F	NC	VSS	VDD	NC				NU/TDQS#	VSS	VDD	NC	A
G		VSS	VSSQ	DQ0				DM/TDQS	VSSQ	VDDQ		B
H		VDDQ	DQ2	DQS				DQ1	DQ3	VSSQ		C
J		VSSQ	DQ6	DQS#				VDD	VSS	VSSQ		D
K		VREFDQ	VDDQ	DQ4				DQ7	DQ5	VDDQ		E
L		NC	VSS	RAS#				CK	VSS	NC		F
M		ODT	VDD	CAS#				CK#	VDD	CKE		G
N		NC	CS#	WE#				A10/AP	ZQ	NC		H
P		VSS	BA0	BA2				A15	VREFCA	VSS		J
R		VDD	A3	A0				A12/BC#	BA1	VDD		K
T		VSS	A5	A2				A1	A4	VSS		L
U		VDD	A7	A9				A11	A6	VDD		M
V	NC	VSS	RESET#	A13				A14	A8	VSS	NC	N
W												
Y												
AA	NC	NC		NC				NC		NC	NC	
AB												
AC	NC	NC		NC				NC		NC	NC	
	1	2	3	4	5	6	7	8	9			

Note1: Green NC balls indicate mechanical support balls with no internal connection. Any of the support ball locations may or may not be populated with a ball.

MO-207 Variation DT-z (x8)

	1	2	3	4	5	6	7	8	9
A	○	○	○	+	+	+	○	○	○
B	○	○	○	+	+	+	○	○	○
C	○	○	○	+	+	+	○	○	○
D	○	○	○	+	+	+	○	○	○
E	○	○	○	+	+	+	○	○	○
F	○	○	○	+	+	+	○	○	○
G	○	○	○	+	+	+	○	○	○
H	○	○	○	+	+	+	○	○	○
J	○	○	○	+	+	+	○	○	○
K	○	○	○	+	+	+	○	○	○
L	○	○	○	+	+	+	○	○	○
M	○	○	○	+	+	+	○	○	○
N	○	○	○	+	+	+	○	○	○

○ Populated ball
+ Ball not populated

MO-207 Variation DW-z (x8)
with support balls

	1	2	3	4	5	6	7	8	9	10	11
A	○	○	+	○	+	+	+	○	+	○	○
B	+	+	+	+	+	+	+	+	+	+	+
C	○	○	+	○	+	+	+	○	+	○	○
D	+	+	+	+	+	+	+	+	+	+	+
E	+	+	+	+	+	+	+	+	+	+	+
F	○	○	○	○	○	○	○	○	○	○	○
G	+	○	○	○	○	+	+	+	+	○	+
H	+	○	○	○	○	+	+	+	+	○	+
J	+	○	○	○	○	+	+	+	+	○	+
K	+	○	○	○	○	+	+	+	+	○	+
L	+	○	○	○	○	+	+	+	+	○	+
M	+	○	○	○	○	+	+	+	+	○	+
N	+	○	○	○	○	+	+	+	+	○	+
P	+	○	○	○	○	+	+	+	+	○	+
R	+	○	○	○	○	+	+	+	+	○	+
T	+	○	○	○	○	+	+	+	+	○	+
U	+	○	○	○	○	+	+	+	+	○	+
V	○	○	○	○	○	+	+	+	+	○	○
W	+	+	+	+	+	+	+	+	+	+	+
X	+	+	+	+	+	+	+	+	+	+	+
AA	○	○	+	○	+	+	+	○	+	○	○
AB	+	+	+	+	+	+	+	+	+	+	+
AC	○	○	+	○	+	+	+	○	+	○	○

2 DDR3 SDRAM Package Pinout and Addressing (Cont'd)

2.3 DDR3 SDRAM x16 Ballout using MO-207 (Top view: see balls through package)

	1	2	3	4	5	6	7	8	9	10	11	
A	NC	NC		NC				NC		NC	NC	
B												
C												
D	NC	VDDQ	DQU5	DQU7				DQU4	VDDQ	VSS	NC	A
E		VSSQ	VDD	VSS				DQSU#	DQU6	VSSQ		B
F		VDDQ	DQU3	DQU1				DQSU	DQU2	VDDQ		C
G		VSSQ	VDDQ	DMU				DQU0	VSSQ	VDD		D
H		VSS	VSSQ	DQL0				DML	VSSQ	VDDQ		E
J		VDDQ	DQL2	DQSL				DQL1	DQL3	VSSQ		F
K		VSSQ	DQL6	DQSL#				VDD	VSS	VSSQ		G
L		VREFDQ	VDDQ	DQL4				DQL7	DQL5	VDDQ		H
M		NC	VSS	RAS#				CK	VSS	NC		J
N		ODT	VDD	CAS#				CK#	VDD	CKE		K
P		NC	CS#	WE#				A10/AP	ZQ	NC		L
R		VSS	BA0	BA2				A15	VREFCA	VSS		M
T		VDD	A3	A0				A12	BA1	VDD		N
U		VSS	A5	A2				A1	A4	VSS		P
V		VDD	A7	A9				A11	A6	VDD		R
W	NC	VSS	RESET#	A13				A14	A8	VSS	NC	T
Y												
AA												
AB	NC	NC		NC				NC		NC	NC	
	1	2	3	4	5	6	7	8	9			

Note1: Green NC balls indicate mechanical support balls with no internal connection. Any of the support ball locations may or may not be populated with a ball.

MO - 207 Variation DU-z (x16)

	1	2	3	4	5	6	7	8	9
A	○	○	○	+	+	+	○	○	○
B	○	○	○	+	+	+	○	○	○
C	○	○	○	+	+	+	○	○	○
D	○	○	○	+	+	+	○	○	○
E	○	○	○	+	+	+	○	○	○
F	○	○	○	+	+	+	○	○	○
G	○	○	○	+	+	+	○	○	○
H	○	○	○	+	+	+	○	○	○
J	○	○	○	+	+	+	○	○	○
K	○	○	○	+	+	+	○	○	○
L	○	○	○	+	+	+	○	○	○
M	○	○	○	+	+	+	○	○	○
N	○	○	○	+	+	+	○	○	○
P	○	○	○	+	+	+	○	○	○
R	○	○	○	+	+	+	○	○	○
T	○	○	○	+	+	+	○	○	○

○ Populated ball
+ Ball not populated

MO-207 Variation TBD (x16)
with support balls

	1	2	3	4	5	6	7	8	9	10	11
A	○	○	+	○	+	+	+	○	+	○	○
B	+	+	+	+	+	+	+	+	+	+	+
C	+	+	+	+	+	+	+	+	+	+	+
D	○	○	○	○	○	+	+	○	○	○	○
E	+	○	○	○	○	+	+	○	○	○	+
F	+	○	○	○	○	+	+	○	○	○	+
G	+	○	○	○	○	+	+	○	○	○	+
H	+	○	○	○	○	+	+	○	○	○	+
J	+	○	○	○	○	+	+	○	○	○	+
K	+	○	○	○	○	+	+	○	○	○	+
L	+	○	○	○	○	+	+	○	○	○	+
M	+	○	○	○	○	+	+	○	○	○	+
N	+	○	○	○	○	+	+	○	○	○	+
P	+	○	○	○	○	+	+	○	○	○	+
R	+	○	○	○	○	+	+	○	○	○	+
T	+	○	○	○	○	+	+	○	○	○	+
U	+	○	○	○	○	+	+	○	○	○	+
V	+	○	○	○	○	+	+	○	○	○	+
W	○	○	○	○	○	+	+	○	○	○	○
X	+	+	+	+	+	+	+	+	+	+	+
AA	+	+	+	+	+	+	+	+	+	+	+
AB	○	○	+	○	+	+	+	○	+	○	○

2 DDR3 SDRAM Package Pinout and Addressing (Cont'd)

2.4 Stacked / dual-die DDR3 SDRAM x4 Ballout using MO-207 (Top view: see balls through package)

	1	2	3	4	5	6	7	8	9	10	11	
A	NC	NC		NC				NC		NC	NC	
B												
C	NC	NC		NC				NC		NC	NC	
D												
E												
F	NC	VSS	VDD	NC				NC	VSS	VDD	NC	A
G		VSS	VSSQ	DQ0				DM	VSSQ	VDDQ		B
H		VDDQ	DQ2	DQS				DQ1	DQ3	VSSQ		C
J		VSSQ	NC	DQS#				VDD	VSS	VSSQ		D
K		VREFDQ	VDDQ	NC				NC	NC	VDDQ		E
L		ODT1	VSS	RAS#				CK	VSS	CKE1		F
M		ODT0	VDD	CAS#				CK#	VDD	CKE0		G
N		CS1#	CS0#	WE#				A10/AP	ZQ0	ZQ1		H
P		VSS	BA0	BA2				A15	VREFCA	VSS		J
R		VDD	A3	A0				A12/BC#	BA1	VDD		K
T		VSS	A5	A2				A1	A4	VSS		L
U		VDD	A7	A9				A11	A6	VDD		M
V	NC	VSS	RESET#	A13				A14	A8	VSS	NC	N
W												
X												
AA	NC	NC		NC				NC		NC	NC	
AB												
AC	NC	NC		NC				NC		NC	NC	
	1	2	3	4	5	6	7	8	9			

te1: Green NC balls indicate mechanical support balls with no internal connection.

Any of the support ball locations may or may not be populated with a ball.

te2: This stacked ballout is intended to use only with stacked/dual-die packages, and does not apply to non-stacked/single-die packages. This document (JESD79-3) focuses on non-stacked, single-die devices unless otherwise explicitly stated.

MO-207 Variation DT-z (x4)

	1	2	3	4	5	6	7	8	9
A	○	○	○	+	+	+	○	○	○
B	○	○	○	+	+	+	○	○	○
C	○	○	○	+	+	+	○	○	○
D	○	○	○	+	+	+	○	○	○
E	○	○	○	+	+	+	○	○	○
F	○	○	○	+	+	+	○	○	○
G	○	○	○	+	+	+	○	○	○
H	○	○	○	+	+	+	○	○	○
J	○	○	○	+	+	+	○	○	○
K	○	○	○	+	+	+	○	○	○
L	○	○	○	+	+	+	○	○	○
M	○	○	○	+	+	+	○	○	○
N	○	○	○	+	+	+	○	○	○

○ Populated ball
+ Ball not populated

MO-207 Variation DW-z (x4)
with support balls

	1	2	3	4	5	6	7	8	9	10	11
A	○	○	+	○	+	+	+	○	+	○	○
B	+	+	+	+	+	+	+	+	+	+	+
C	○	○	+	○	+	+	+	○	+	○	○
D	+	+	+	+	+	+	+	+	+	+	+
E	+	+	+	+	+	+	+	+	+	+	+
F	○	○	○	○	+	+	+	○	○	○	○
G	+	○	○	○	+	+	+	○	○	○	+
H	+	○	○	○	+	+	+	○	○	○	+
J	+	○	○	○	+	+	+	○	○	○	+
K	+	○	○	○	+	+	+	○	○	○	+
L	+	○	○	○	+	+	+	○	○	○	+
M	+	○	○	○	+	+	+	○	○	○	+
N	+	○	○	○	+	+	+	○	○	○	+
P	+	○	○	○	+	+	+	○	○	○	+
R	+	○	○	○	+	+	+	○	○	○	+
T	+	○	○	○	+	+	+	○	○	○	+
U	+	○	○	○	+	+	+	○	○	○	+
V	○	○	○	○	+	+	+	○	○	○	○
W	+	+	+	+	+	+	+	+	+	+	+
X	+	+	+	+	+	+	+	+	+	+	+
AA	○	○	+	○	+	+	+	○	+	○	○
AB	+	+	+	+	+	+	+	+	+	+	+
AC	○	○	+	○	+	+	+	○	+	○	○

2 DDR3 SDRAM Package Pinout and Addressing (Cont'd)

2.5 Stacked / dual-die DDR3 SDRAM x8 Ballout using MO-207 (Top view: see balls through package)

	1	2	3	4	5	6	7	8	9	10	11
A	NC	NC		NC				NC		NC	NC
B											
C	NC	NC		NC				NC		NC	NC
D											
E											
F	NC	VSS	VDD	NC				NU/TDQS#	VSS	VDD	NC
G		VSS	VSSQ	DQ0				DM/TDQS	VSSQ	VDDQ	
H		VDDQ	DQ2	DQS				DQ1	DQ3	VSSQ	
J		VSSQ	DQ6	DQS#				VDD	VSS	VSSQ	
K		VREFDQ	VDDQ	DQ4				DQ7	DQ5	VDDQ	
L		ODT1	VSS	RAS#				CK	VSS	CKE1	
M		ODT0	VDD	CAS#				CK#	VDD	CKE0	
N		CS1#	CS0#	WE#				A10/AP	ZQ0	ZQ1	
P		VSS	BA0	BA2				A15	VREFCA	VSS	
R		VDD	A3	A0				A12/BC#	BA1	VDD	
T		VSS	A5	A2				A1	A4	VSS	
U		VDD	A7	A9				A11	A6	VDD	
V	NC	VSS	RESET#	A13				A14	A8	VSS	NC
W											
X											
AA	NC	NC		NC				NC		NC	NC
AB											
AC	NC	NC		NC				NC		NC	NC
	1	2	3	4	5	6	7	8	9		

Note1: Green NC balls indicate mechanical support balls with no internal connection.

Any of the support ball locations may or may not be populated with a ball.

Note2: This stacked ballout is intended to use only with stacked/dual-die packages, and does not apply to non-stacked/single-die packages. This document (JESD79-3) focuses on non-stacked, single-die devices unless otherwise explicitly stated.

MO-207 Variation DT-z (x8)

	1	2	3	4	5	6	7	8	9
A	○	○	○	+	+	+	○	○	○
B	○	○	○	+	+	+	○	○	○
C	○	○	○	+	+	+	○	○	○
D	○	○	○	+	+	+	○	○	○
E	○	○	○	+	+	+	○	○	○
F	○	○	○	+	+	+	○	○	○
G	○	○	○	+	+	+	○	○	○
H	○	○	○	+	+	+	○	○	○
J	○	○	○	+	+	+	○	○	○
K	○	○	○	+	+	+	○	○	○
L	○	○	○	+	+	+	○	○	○
M	○	○	○	+	+	+	○	○	○
N	○	○	○	+	+	+	○	○	○

○ Populated ball
+ Ball not populated

MO - 207 Variation DW-z (x8)
with support balls

	1	2	3	4	5	6	7	8	9	10	11
A	○	○	+	○	+	+	+	○	+	○	○
B	+	+	+	+	+	+	+	+	+	+	+
C	○	○	+	○	+	+	+	○	+	○	○
D	+	+	+	+	+	+	+	+	+	+	+
E	+	+	+	+	+	+	+	+	+	+	+
F	○	○	○	○	+	+	+	○	○	○	○
G	+	○	○	○	+	+	+	○	○	○	+
H	+	○	○	○	+	+	+	○	○	○	+
J	+	○	○	○	+	+	+	○	○	○	+
K	+	○	○	○	+	+	+	○	○	○	+
L	+	○	○	○	+	+	+	○	○	○	+
M	+	○	○	○	+	+	+	○	○	○	+
N	+	○	○	○	+	+	+	○	○	○	+
P	+	○	○	○	+	+	+	○	○	○	+
R	+	○	○	○	+	+	+	○	○	○	+
T	+	○	○	○	+	+	+	○	○	○	+
U	+	○	○	○	+	+	+	○	○	○	+
V	○	○	○	○	+	+	+	○	○	○	○
W	+	+	+	+	+	+	+	+	+	+	+
X	+	+	+	+	+	+	+	+	+	+	+
AA	○	○	+	○	+	+	+	○	+	○	○
AB	+	+	+	+	+	+	+	+	+	+	+
AC	○	○	+	○	+	+	+	○	+	○	○

2 DDR3 SDRAM Package Pinout and Addressing (Cont'd)

2.6 Stacked / dual-die DDR3 SDRAM x16 Ballout using MO-207 (Top view: see balls through package)

	1	2	3	4	5	6	7	8	9	10	11	
A	NC	NC		NC				NC		NC	NC	
B												
C												
D	NC	VDDQ	DQU5	DQU7				DQU4	VDDQ	VSS	NC	A
E		VSSQ	VDD	VSS				DQSU#	DQU6	VSSQ		B
F		VDDQ	DQU3	DQU1				DQSU	DQU2	VDDQ		C
G		VSSQ	VDDQ	DMU				DQU0	VSSQ	VDD		D
H		VSS	VSSQ	DQL0				DML	VSSQ	VDDQ		E
J		VDDQ	DQL2	DQSL				DQL1	DQL3	VSSQ		F
K		VSSQ	DQL6	DQSL#				VDD	VSS	VSSQ		G
L		VREFDQ	VDDQ	DQL4				DQL7	DQL5	VDDQ		H
M		ODT1	VSS	RAS#				CK	VSS	CKE1		J
N		ODT0	VDD	CAS#				CK#	VDD	CKE0		K
P		CS1#	CS0#	WE#				A10/AP	ZQ0	ZQ1		L
R		VSS	BA0	BA2				A15	VREFCA	VSS		M
T		VDD	A3	A0				A12	BA1	VDD		N
U		VSS	A5	A2				A1	A4	VSS		P
V		VDD	A7	A9				A11	A6	VDD		R
W	NC	VSS	RESET#	A13				A14	A8	VSS	NC	T
Y												
AA												
AB	NC	NC		NC				NC		NC	NC	
	1	2	3	4	5	6	7	8	9			

te1: Green NC balls indicate mechanical support balls with no internal connection.

Any of the support ball locations may or may not be populated with a ball.

te2: This stacked ballout is intended to use only with stacked/dual-die packages, and does not apply to non-stacked/single-die packages. This document (JESD79-3) focuses on non-stacked, single-die devices unless otherwise explicitly stated.

MO - 207 Variation DU-z (x16)

1 2 3 4 5 6 7 8 9

A	○	○	○	+	+	+	○	○	○
B	○	○	○	+	+	+	○	○	○
C	○	○	○	+	+	+	○	○	○
D	○	○	○	+	+	+	○	○	○
E	○	○	○	+	+	+	○	○	○
F	○	○	○	+	+	+	○	○	○
G	○	○	○	+	+	+	○	○	○
H	○	○	○	+	+	+	○	○	○
J	○	○	○	+	+	+	○	○	○
K	○	○	○	+	+	+	○	○	○
L	○	○	○	+	+	+	○	○	○
M	○	○	○	+	+	+	○	○	○
N	○	○	○	+	+	+	○	○	○
P	○	○	○	+	+	+	○	○	○
R	○	○	○	+	+	+	○	○	○
T	○	○	○	+	+	+	○	○	○

○ Populated ball
+ Ball not populated

MO - 207 Variation TBD
(x16) with support balls

	1	2	3	4	5	6	7	8	9	10	11
A	○	○	+	○	+	+	+	○	+	○	○
B	+	+	+	+	+	+	+	+	+	+	+
C	+	+	+	+	+	+	+	+	+	+	+
D	○	○	+	○	+	+	+	○	+	○	○
E	+	○	○	○	+	+	+	○	○	○	+
F	+	○	○	○	+	+	+	○	○	○	+
G	+	○	○	○	+	+	+	○	○	○	+
H	+	○	○	○	+	+	+	○	○	○	+
J	+	○	○	○	+	+	+	○	○	○	+
K	+	○	○	○	+	+	+	○	○	○	+
L	+	○	○	○	+	+	+	○	○	○	+
M	+	○	○	○	+	+	+	○	○	○	+
N	+	○	○	○	+	+	+	○	○	○	+
P	+	○	○	○	+	+	+	○	○	○	+
R	+	○	○	○	+	+	+	○	○	○	+
T	+	○	○	○	+	+	+	○	○	○	+
U	+	○	○	○	+	+	+	○	○	○	+
V	+	○	○	○	+	+	+	○	○	○	+
W	○	○	○	○	+	+	+	○	○	○	○
X	+	+	+	+	+	+	+	+	+	+	+
AA	+	+	+	+	+	+	+	+	+	+	+
AB	○	○	+	○	+	+	+	○	+	○	○

2 DDR3 SDRAM Package Pinout and Addressing (Cont'd)

2.7 Pinout Description

Table 1 — Input / output functional description

Symbol	Type	Function
CK, CK#	Input	Clock: CK and 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 CK#.
CKE, (CKE0), (CKE1)	Input	Clock Enable: CKE HIGH activates, and CKE Low deactivates, internal clock signals and 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 during all operations (including Self-Refresh). CKE must be maintained high throughout read and write accesses. Input buffers, excluding CK, CK#, ODT and CKE are disabled during power-down. Input buffers, excluding CKE, are disabled during Self-Refresh.
CS#, (CS0#), (CS1#)	Input	Chip Select: All commands are masked when CS# is registered HIGH. CS# provides for external Rank selection on systems with multiple Ranks. CS# is considered part of the command code.
ODT, (ODT0), (ODT1)	Input	On Die Termination: ODT (registered HIGH) enables termination resistance internal to the DDR3 SDRAM. When enabled, ODT is only applied to each DQ, DQS, DQS# and DM/TDQS, NU/TDQS# (When TDQS is enabled via Mode Register A11=1 in MR1) signal for x4/x8 configurations. For x16 configuration ODT is applied to each DQ, DQSU, DQSU#, DQSL, DQSL#, DMU, and DML signal. The ODT pin will be ignored if MR1 and MR2 are programmed to disable RTT.
RAS#. CAS#. WE#	Input	Command Inputs: RAS#, CAS# and WE# (along with CS#) define the command being entered.
DM, (DMU), (DML)	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/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 - A15	Input	Address Inputs: Provide the row address for Active 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/BC# have additional functions, see below).The address inputs also provide the op-code during Mode Register Set commands.
A10 / AP	Input	Auto-precharge: A10 is sampled during Read/Write commands to determine whether Autoprecharge should be performed to the accessed bank after the Read/Write operation. (HIGH: Autoprecharge; LOW: no Autoprecharge).A10 is sampled during a Precharge command to determine whether the Precharge applies to one bank (A10 LOW) or all banks (A10 HIGH). If only one bank is to be precharged, the bank is selected by bank addresses.
A12 / BC#	Input	Burst Chop: A12 / 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). See command truth table for details.
RESET#	Input	Active Low Asynchronous Reset: Reset is active when RESET# is LOW, and inactive when RESET# is HIGH. RESET# must be HIGH during normal operation. RESET# is a CMOS rail to rail signal with DC high and low at 80% and 20% of V _{DD} , i.e. 1.20V for DC high and 0.30V for DC low.
DQ	Input / Output	Data Input/ Output: Bi-directional data bus.

2 DDR3 SDRAM Package Pinout and Addressing (Cont'd)**2.7 Pinout Description (Cont'd)****Table 1 — Input / output functional description**

Symbol	Type	Function
DQU, DQL, DQS, DQS#, DQSU, DQSU#, DQSL, DQSL#	Input / Output	Data Strobe: output with read data, input with write data. Edge-aligned with read data, centered in write data. For the x16, DQSL corresponds to the data on DQL0-DQL7; DQSU corresponds to the data on DQU0-DQU7. The data strobe DQS, DQSL, and DQSU are paired with differential signals DQS#, DQSL#, and DQSU#, respectively, to provide differential pair signaling to the system during reads and writes. DDR3 SDRAM supports differential data strobe only and does not support single-ended.
TDQS, TDQS#	Output	Termination Data Strobe: TDQS/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/TDQS# that is applied to DQS/DQS#. When disabled via mode register A11 = 0 in MR1, DM/TDQS will provide the data mask function and TDQS# is not used. x4/x16 DRAMs must disable the TDQS function via mode register A11 = 0 in MR1.
NC		No Connect: No internal electrical connection is present.
V _{DDQ}	Supply	DQ Power Supply: 1.5 V +/- 0.075 V
V _{SSQ}	Supply	DQ Ground
V _{DD}	Supply	Power Supply: 1.5 V +/- 0.075 V
V _{SS}	Supply	Ground
V _{REFDQ}	Supply	Reference voltage for DQ
V _{REFCA}	Supply	Reference voltage
ZQ, (ZQ0), (ZQ1)	Supply	Reference Pin for ZQ calibration
Note: Input only pins (BA0-BA2, A0-A15, RAS#, CAS#, WE#, CS#, CKE, ODT, and RESET#) do not supply termination.		

2 DDR3 SDRAM Package Pinout and Addressing (Cont'd)

2.8 DDR3 SDRAM Addressing

2.8.1 512Mb

Configuration	128Mb x 4	64Mb x 8	32Mb x 16
# of Banks	8	8	8
Bank Address	BA0 - BA2	BA0 - BA2	BA0 - BA2
Auto precharge	A10/AP	A10/AP	A10/AP
BC switch on the fly	A12/BC#	A12/BC#	A12/BC#
Row Address	A0 - A12	A0 - A12	A0 - A11
Column Address	A0 - A9,A11	A0 - A9	A0 - A9
Page size ¹	1 KB	1 KB	2 KB

2.8.2 1Gb

Configuration	256Mb x 4	128Mb x 8	64Mb x 16
# of Banks	8	8	8
Bank Address	BA0 - BA2	BA0 - BA2	BA0 - BA2
Auto precharge	A10/AP	A10/AP	A10/AP
BC switch on the fly	A12/BC#	A12/BC#	A12/BC#
Row Address	A0 - A13	A0 - A13	A0 - A12
Column Address	A0 - A9,A11	A0 - A9	A0 - A9
Page size ¹	1 KB	1 KB	2 KB

2.8.3 2Gb

Configuration	512Mb x 4	256Mb x 8	128Mb x 16
# of Banks	8	8	8
Bank Address	BA0 - BA2	BA0 - BA2	BA0 - BA2
Auto precharge	A10/AP	A10/AP	A10/AP
BC switch on the fly	A12/BC#	A12/BC#	A12/BC#
Row Address	A0 - A14	A0 - A14	A0 - A13
Column Address	A0 - A9,A11	A0 - A9	A0 - A9
Page size ¹	1 KB	1 KB	2 KB

2.8.4 4Gb

Configuration	1Gb x 4	512Mb x 8	256Mb x 16
# of Banks	8	8	8
Bank Address	BA0 - BA2	BA0 - BA2	BA0 - BA2
Auto precharge	A10/AP	A10/AP	A10/AP
BC switch on the fly	A12/BC#	A12/BC#	A12/BC#
Row Address	A0 - A15	A0 - A15	A0 - A14
Column Address	A0 - A9,A11	A0 - A9	A0 - A9
Page size ¹	1 KB	1 KB	2 KB

2 DDR3 SDRAM Package Pinout and Addressing (Cont'd)

2.8 DDR3 SDRAM Addressing (Cont'd)

2.8.5 8Gb

Configuration	2Gb x 4	1Gb x 8	512Mb x 16
# of Banks	8	8	8
Bank Address	BA0 - BA2	BA0 - BA2	BA0 - BA2
Auto precharge	A10/AP	A10/AP	A10/AP
BC switch on the fly	A12/BC#	A12/BC#	A12/BC#
Row Address	A0 - A15	A0 - A15	A0 - A15
Column Address	A0 - A9, A11, A13	A0 - A9, A11	A0 - A9
Page size ¹	2 KB	2 KB	2 KB

Notes: 1. Page size is the number of bytes 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:

$$\text{page size} = 2^{\text{COLBITS}} * \text{ORG} \div 8$$

where

COLBITS = the number of column address bits

ORG = the number of I/O (DQ) bits

3 Functional Description

3.1 Simplified State Diagram

This simplified State Diagram is intended to provide an overview of the possible state transitions and the commands to control them. In particular, situations involving more than one bank, the enabling or disabling of on-die termination, and some other events are not captured in full detail.

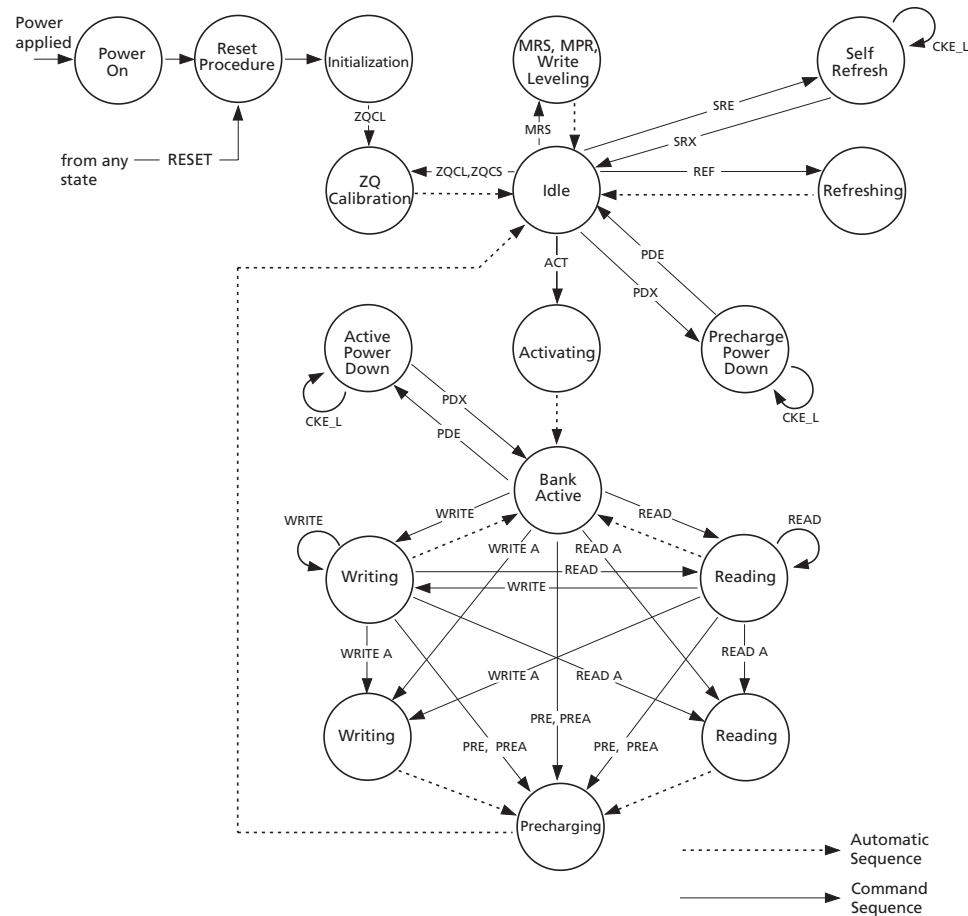


Figure 1 — Simplified State Diagram

Table 2 — State Diagram Command Definitions

Abbreviation	Function	Abbreviation	Function	Abbreviation	Function
ACT	Active	Read	RD, RDS4, RDS8	PDE	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	RESET	Start RESET Procedure	MPR	Multi-Purpose Register
ZQCL	ZQ Calibration Long	ZQCS	ZQ Calibration Short	-	-

Note: See "Command Truth Table" on page 29 for more details.

3 Functional Description (Cont'd)

3.2 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 four in 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-A15 select the row; refer to "DDR3 SDRAM Addressing" on page 11 for specific requirements). The address bits 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 BL8 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 covering device reset and initialization, register definition, command descriptions and device operation.

3 Functional Description (Cont'd)

3.3 RESET and Initialization Procedure

3.3.1 Power-up Initialization Sequence

The following sequence is required for POWER UP and Initialization.

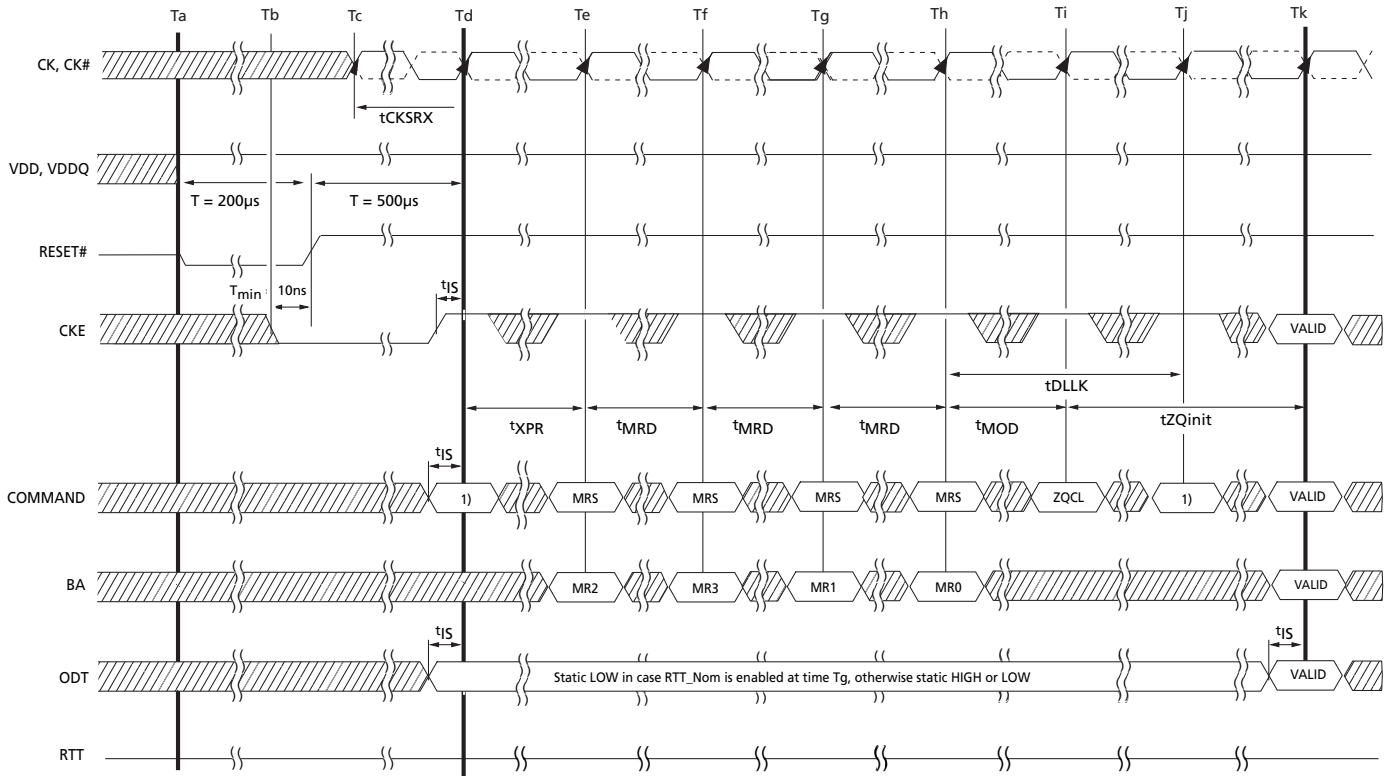
1. Apply power (RESET# is recommended to be maintained below $0.2 \times VDD$, (all other inputs may be undefined). RESET# needs to be maintained for minimum 200 us with stable power. CKE is pulled "Low" anytime before RESET# being de-asserted (min. time 10 ns). The power voltage ramp time between 300 mv to VDDmin must be no greater than 200 ms; 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 0.95 V 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 RESET# is de-asserted, wait for another 500 us until CKE becomes active. During this time, the DRAM will start internal state initialization; this will be done independently of external clocks.
 3. Clocks (CK, CK#) need to be started and stabilized for at least 10 ns or 5 tCK (which is larger) before CKE goes active. Since CKE is a synchronous signal, the corresponding set up time to clock (tIS) must be met. Also a NOP or Deselect command must be registered (with tIS set up time to clock) before CKE goes active. Once the CKE is 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 SDRAM keeps its on-die termination in high-impedance state as long as RESET# is asserted. Further, the SDRAM 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 is being registered high, wait minimum of Reset CKE Exit time, tXPR, before issuing the first MRS command to load mode register. ($tXPR = \max(tXS; 5 \times tCK)$)
 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 settings and DLL enabled. (To issue "DLL Enable" command, provide "Low" to A0, "High" to BA0 and "Low" to BA1 – 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 BA0-2).
 10. Issue ZQCL command to starting ZQ calibration.

3.3 RESET and Initialization Procedure (Cont'd)**3.3.1 Power-up Initialization Sequence (Cont'd)**

11. Wait for both t_{DLLK} and t_{ZQinit} completed.
12. The DDR3 SDRAM is now ready for normal operation.



NOTE 1. From time point "Td" until "Tk" NOP or DES commands must be applied between MRS and ZQCL commands.

TIME BREAK DON'T CARE

Figure 2 — Reset and Initialization Sequence at Power-on Ramping

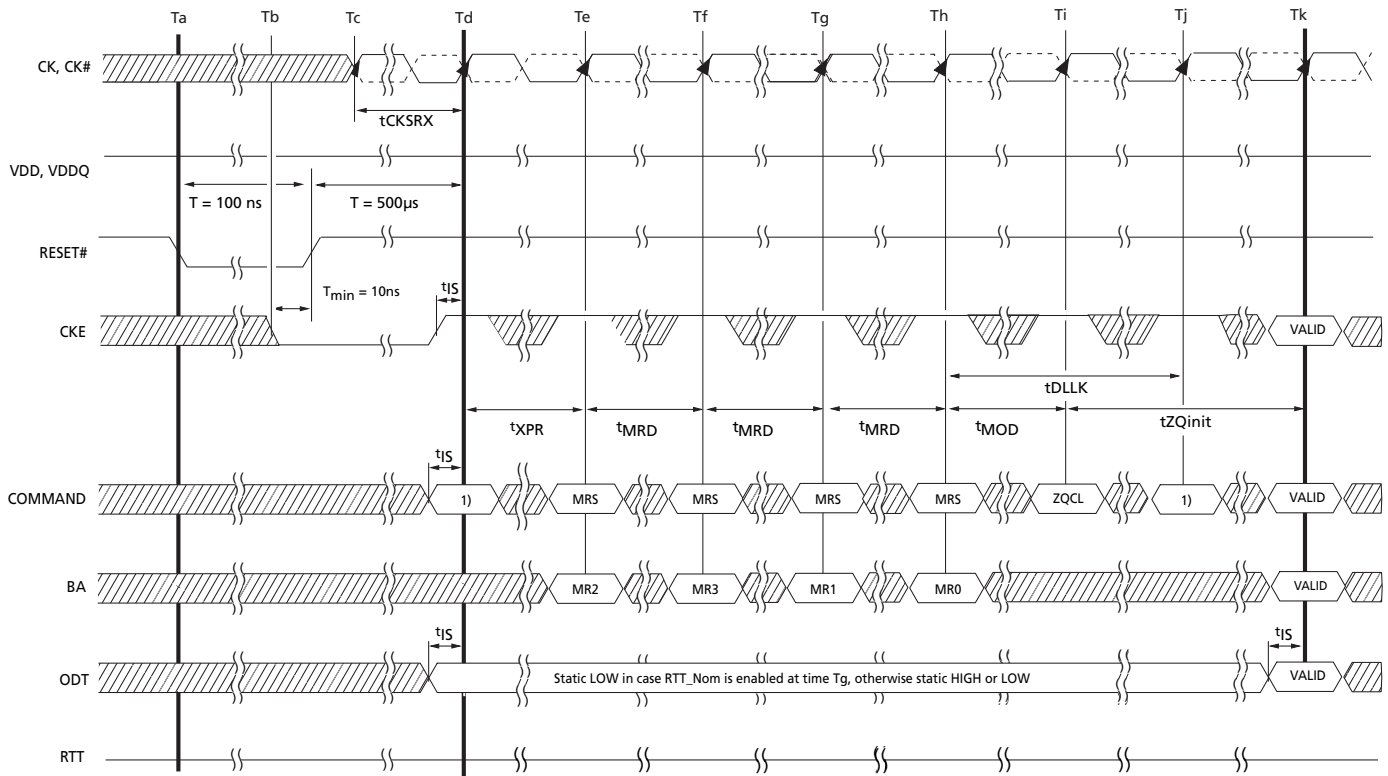
3 Functional Description (Cont'd)

3.3 RESET and Initialization Procedure (Cont'd)

3.3.2 Reset Initialization with Stable Power

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

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



NOTE 1. From time point "Td" until "Tk" NOP or DES commands must be applied between MRS and ZQCL commands.

TIME BREAK

DON'T CARE

Figure 3 — Reset Procedure at Power Stable Condition

3 Functional Description (Cont'd)

3.4 Register Definition

3.4.1 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, t_{MRD} is required to complete the write operation to the mode register and is the minimum time required between two MRS commands shown in Figure 4.

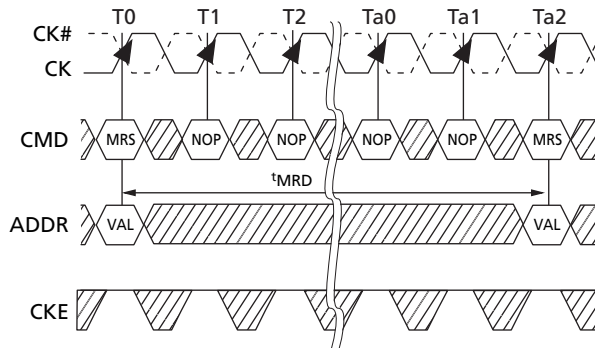


Figure 4 — t_{MRD} Timing

The MRS command to Non-MRS command delay, t_{MOD} , is required 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 in Figure 5.

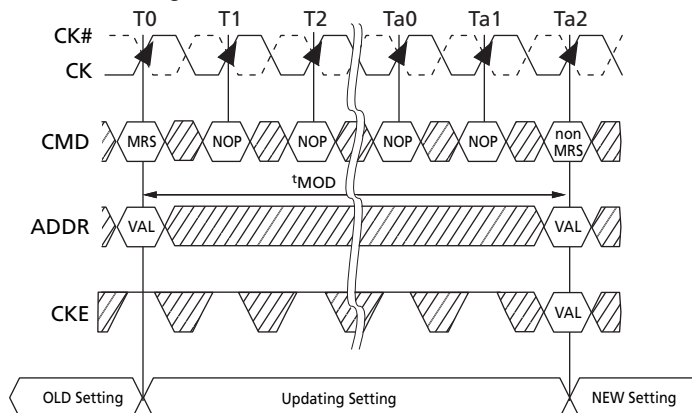


Figure 5 — t_{MOD} Timing

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 t_{RP} 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.

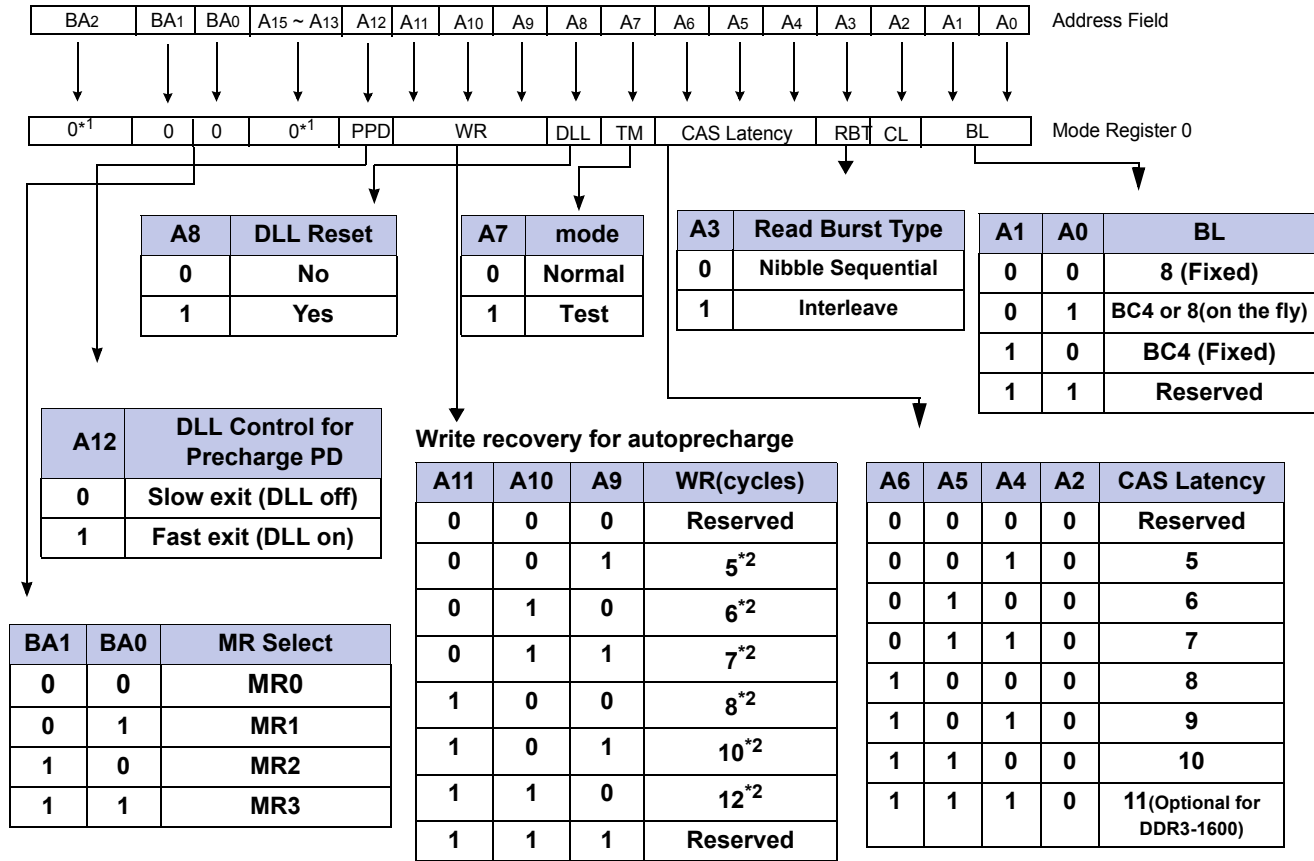
3.4.2 Mode Register MR0

The mode register MR0 stores the 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

3.4 Register Definition (Cont'd)

3.4.2 Mode Register MR0 (Cont'd)

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 CS#, RAS#, CAS#, WE#, BA0, BA1, and BA2, while controlling the states of address pins according to Figure 6.



*1 : BA2 and A13~A15 are RFU and must be programmed to 0 during MRS.

*2 : WR(write recovery for autoprecharge)min in clock cycles is calculated by dividing tWR(in ns) by tCK(in ns) and rounding up to the next integer: $WR_{min}[\text{cycles}] = \text{Roundup}(tWR[\text{ns}] / tCK[\text{ns}])$. The WR 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.

Figure 6 — MR0 Definition

3.4.2.1 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 Figure 6. The ordering of accesses within a burst is determined by the burst length, burst type, and the starting column address as shown in Table 3. The burst length is defined by bits A0-A1. Burst length options include fixed BC4, fixed BL8, and 'on the fly' which allows BC4 or BL8 to be selected coincident with the registration of a Read or Write command via A12/BC#.

3.4 Register Definition (Cont'd)**3.4.2 Mode Register MR0 (Cont'd)****Table 3 — 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	Notes
4 Chop	READ	0 0 0	0,1,2,3,T,T,T,T	0,1,2,3,T,T,T,T	1, 2, 3
		0 0 1	1,2,3,0,T,T,T,T	1,0,3,2,T,T,T,T	1, 2, 3
		0 1 0	2,3,0,1,T,T,T,T	2,3,0,1,T,T,T,T	1, 2, 3
		0 1 1	3,0,1,2,T,T,T,T	3,2,1,0,T,T,T,T	1, 2, 3
		1 0 0	4,5,6,7,T,T,T,T	4,5,6,7,T,T,T,T	1, 2, 3
		1 0 1	5,6,7,4,T,T,T,T	5,4,7,6,T,T,T,T	1, 2, 3
		1 1 0	6,7,4,5,T,T,T,T	6,7,4,5,T,T,T,T	1, 2, 3
		1 1 1	7,4,5,6,T,T,T,T	7,6,5,4,T,T,T,T	1, 2, 3
	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	1, 2, 4, 5
8	READ	0 0 0	0,1,2,3,4,5,6,7	0,1,2,3,4,5,6,7	2
		0 0 1	1,2,3,0,5,6,7,4	1,0,3,2,5,4,7,6	2
		0 1 0	2,3,0,1,6,7,4,5	2,3,0,1,6,7,4,5	2
		0 1 1	3,0,1,2,7,4,5,6	3,2,1,0,7,6,5,4	2
		1 0 0	4,5,6,7,0,1,2,3	4,5,6,7,0,1,2,3	2
		1 0 1	5,6,7,4,1,2,3,0	5,4,7,6,1,0,3,2	2
		1 1 0	6,7,4,5,2,3,0,1	6,7,4,5,2,3,0,1	2
		1 1 1	7,4,5,6,3,0,1,2	7,6,5,4,3,2,1,0	2
	WRITE	V,V,V	0,1,2,3,4,5,6,7	0,1,2,3,4,5,6,7	2, 4
Notes: 1. In case of burst length being fixed to 4 by MR0 setting, the internal write operation starts two clock cycles earlier than for 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-the-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: Don't Care.					

3.4.2.2 CAS Latency

The CAS Latency is defined by MR0 (bits A9-A11) as shown in Figure 6. 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); $RL = AL + CL$. For more information on the supported CL and AL settings based on the operating clock frequency, refer to "Standard Speed Bins" on page 144. For detailed Read operation refer to "READ Operation" on page 52.

3.4.2.3 Test Mode

The normal operating mode is selected by MR0 (bit A7 = 0) and all other bits set to the desired values shown in Figure 6. 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 specified if A7 = 1.

3.4 Register Definition (Cont'd)

3.4.2 Mode Register MR0 (Cont'd)

3.4.2.4 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. Any time 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).

3.4.2.5 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(in ns) by tCK(in ns) and rounding up to the next integer: $WR_{min}[cycles] = \text{Roundup}(tWR[ns]/tCK[ns])$. The WR must be programmed to be equal or larger than tWR(min).

3.4.2.6 Precharge PD DLL

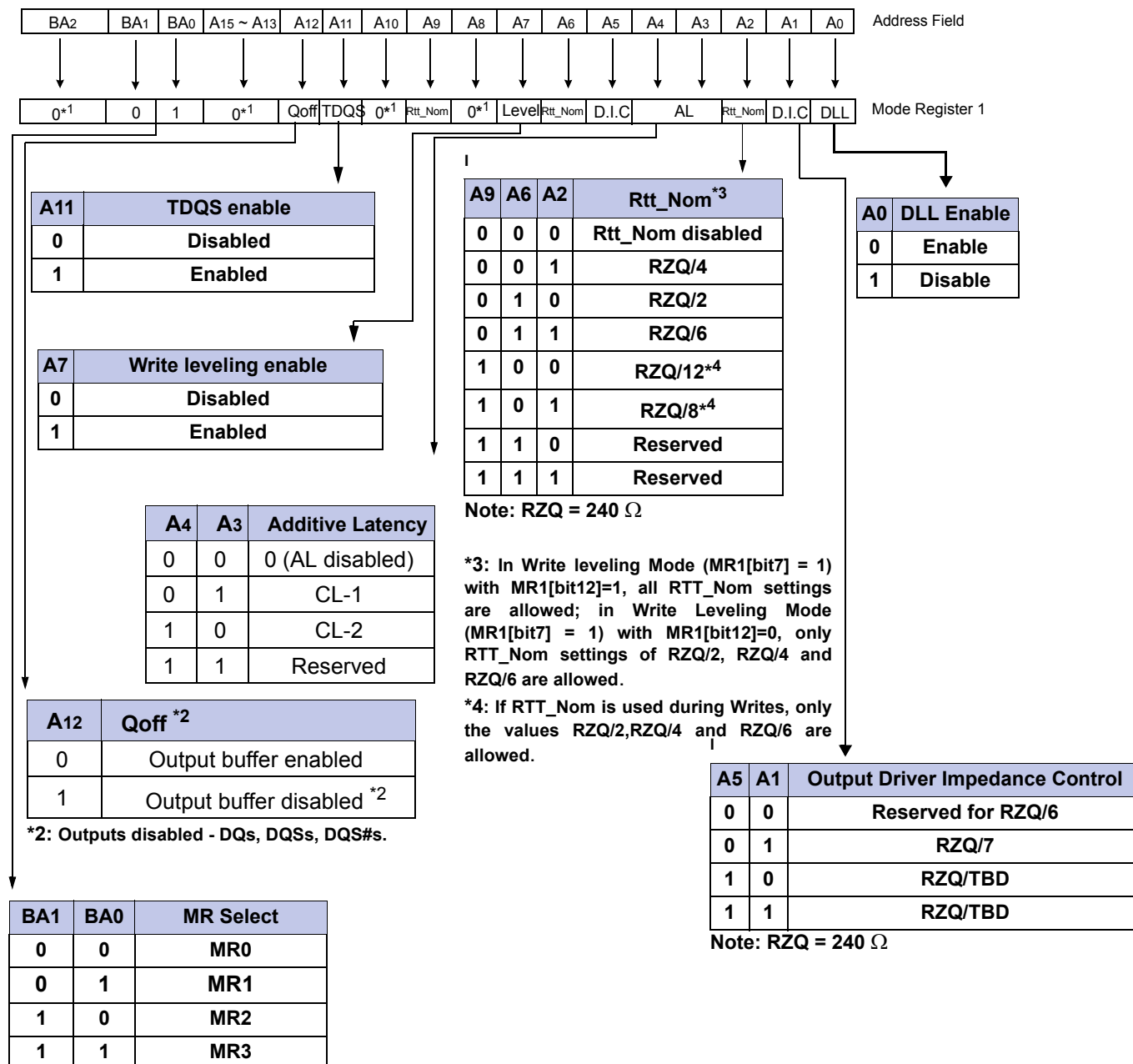
MR0 (bit A12) is used to select the DLL usage during precharge power-down mode. When MR0 (A12 = 0), or 'slow-exit', the DLL is frozen after entering precharge power-down (for potential power savings) and upon exit requires tXPLL to be met prior to the next valid command. When MR0 (A12 = 1), or 'fast-exit',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

3 Functional Description (Cont'd)

3.4 Register Definition (Cont'd)

3.4.3 Mode Register MR1

The Mode Register MR1 stores the data for enabling or disabling the DLL, output driver strength, Rtt_Nom impedance, additive latency, Write leveling enable, TDQS 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 Figure 7.



* 1 : BA2 and A8, A10, and A13 ~ A15 are RFU and must be programmed to 0 during MRS.

Figure 7 — MR1 Definition

3.4.3.1 DLL Enable/Disable

The DLL must be enabled for normal operation. DLL enable is required during power up initialization, and upon returning to normal operation after having the DLL disabled. During normal operation (DLL-on) with

3.4 Register Definition (Cont'd)

3.4.3 Mode Register MR1 (Cont'd)

MR1 (A0 = 0), the DLL is automatically disabled when entering Self-Refresh operation and is automatically re-enabled 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 tDQSK, tAON or tAOF parameters. During tDLLK, CKE must continuously be registered high. DDR3 SDRAM does not require DLL for any Write operation, except when RTT_WR is enabled and the DLL is required for proper ODT operation. For more detailed information on DLL Disable operation refer to “DLL-off Mode” on page 33.

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.

3.4.3.2 Output Driver Impedance Control

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

3.4.3.3 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 programmed in MR1. A separate value (Rtt_WR) may be programmed 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.

3.4.3.4 Additive Latency (AL)

Additive Latency (AL) operation is supported to make command and data bus efficient for sustainable bandwidths 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 in Table .

Table 4 — Additive Latency (AL) Settings

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

Note: AL has a value of CL - 1 or CL - 2 as per the CL values programmed in the MR0 register.

3.4.3.5 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 it difficult for the Controller to maintain tDQSS, tDSS and tDSH specification. Therefore, the DDR3 SDRAM supports a ‘write leveling’ feature to allow the controller to compensate for skew. See 4.8 “Write Leveling” on page 38 for more details.

3.4 Register Definition (Cont'd)

3.4.3 Mode Register MR1 (Cont'd)

3.4.3.6 Output Disable

The DDR3 SDRAM outputs may be enabled/disabled by MR1 (bit A12) as shown in Figure 7. When this feature is enabled (A12 = 1), all output pins (DQs, DQS, DQS#, etc.) are disconnected from the device removing any loading of the output drivers. This feature may be useful when measuring module power for example. For normal operation, A12 should be set to '0'.

3.4.3.7 TDQS, 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 or X16 configurations. When enabled via the mode register, the same termination resistance function is applied to the TDQS/TDQS# pins that is applied to the DQS/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 TDQS# pin is not used. See Table 5 for details.

The TDQS function is available in X8 DDR3 SDRAM only and must be disabled via the mode register A11=0 in MR1 for X4 and X16 configurations.

Table 5 — TDQS, TDQS# Function Matrix

MR1 (A11)	DM / TDQS	NU / TDQS
0 (TDQS Disabled)	DM	Hi-Z
1 (TDQS Enabled)	TDQS	TDQS#

- Notes:
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.

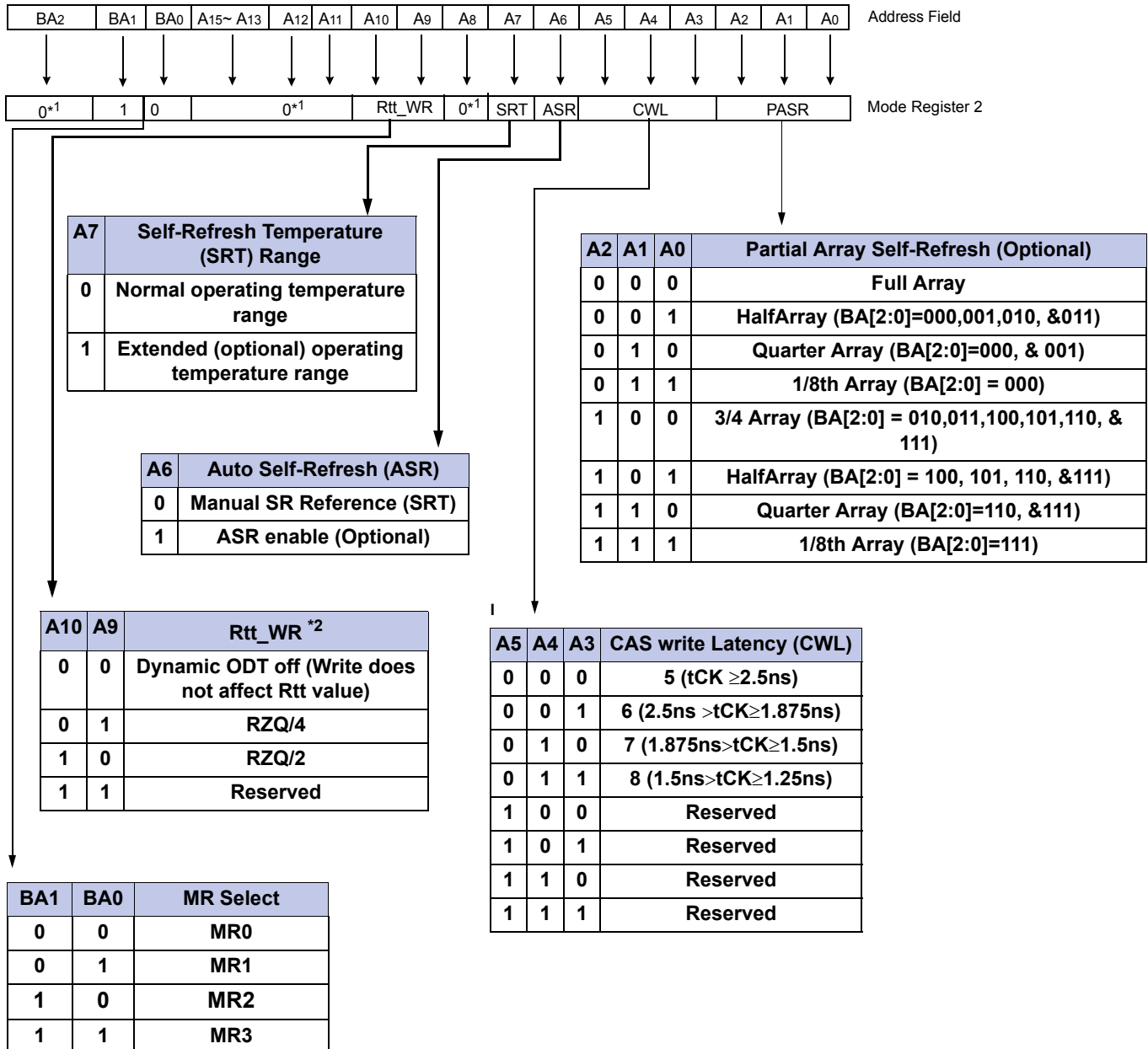
3 Functional Description (Cont'd)

3.4 Register Definition (Cont'd)

3.4.4 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 CS#, RAS#, CAS#, WE#, high on BA1 and low on BA0 and BA2, while controlling the states of address pins according to the table below.

MR2 Programming



* 1 : BA2, A5, A8, A11 ~ A15 are RFU and must be programmed to 0 during MRS.

* 2 : The Rtt_WR value can be applied during writes even when Rtt_Nom is disabled.
During write leveling, Dynamic ODT is not available.

Figure 8 — MR2 Definition

3.4 Register Definition (Cont'd)

3.4.4 Mode Register MR2 (Cont'd)

3.4.4.1 Partial Array Self-Refresh (PASR)

Optional in DDR3 SDRAM: Users should refer to the DRAM supplier data sheet and/or the DIMM SPD to determine if DDR3 SDRAM devices support the following options or requirements referred to in this material. If PASR (Partial Array Self-Refresh) is enabled, data located in areas of the array beyond the specified address range shown in Figure 8 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.

3.4.4.2 CAS Write Latency (CWL)

The CAS Write Latency is defined by MR2 (bits A3-A5), as shown in Figure . 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 SDRAM does not support any half clock latencies. The overall Write Latency (WL) is defined as Additive Latency (AL) + CAS Write Latency (CWL); $WL = AL + CWL$. For more information on the supported CWL and AL settings based on the operating clock frequency, refer to "Standard Speed Bins" on page 144. For detailed Write operation refer to "WRITE Operation" on page 62.

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

Optional in DDR3 SDRAM: Users should refer to the DRAM supplier data sheet and/or the DIMM SPD to determine if DDR3 SDRAM devices support the following options or requirements referred to in this material. For more details refer to "Extended Temperature Usage" on page 42. DDR3 SDRAM's must support Self-Refresh operation at all supported temperatures. Applications requiring Self-Refresh operation in the Extended Temperature Range must use the optional ASR function or program the SRT bit appropriately.

3.4.4.4 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 desirable 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. In Write leveling mode, only RTT_Nom is available. For details on Dynamic ODT operation, refer to "Dynamic ODT" on page 85.

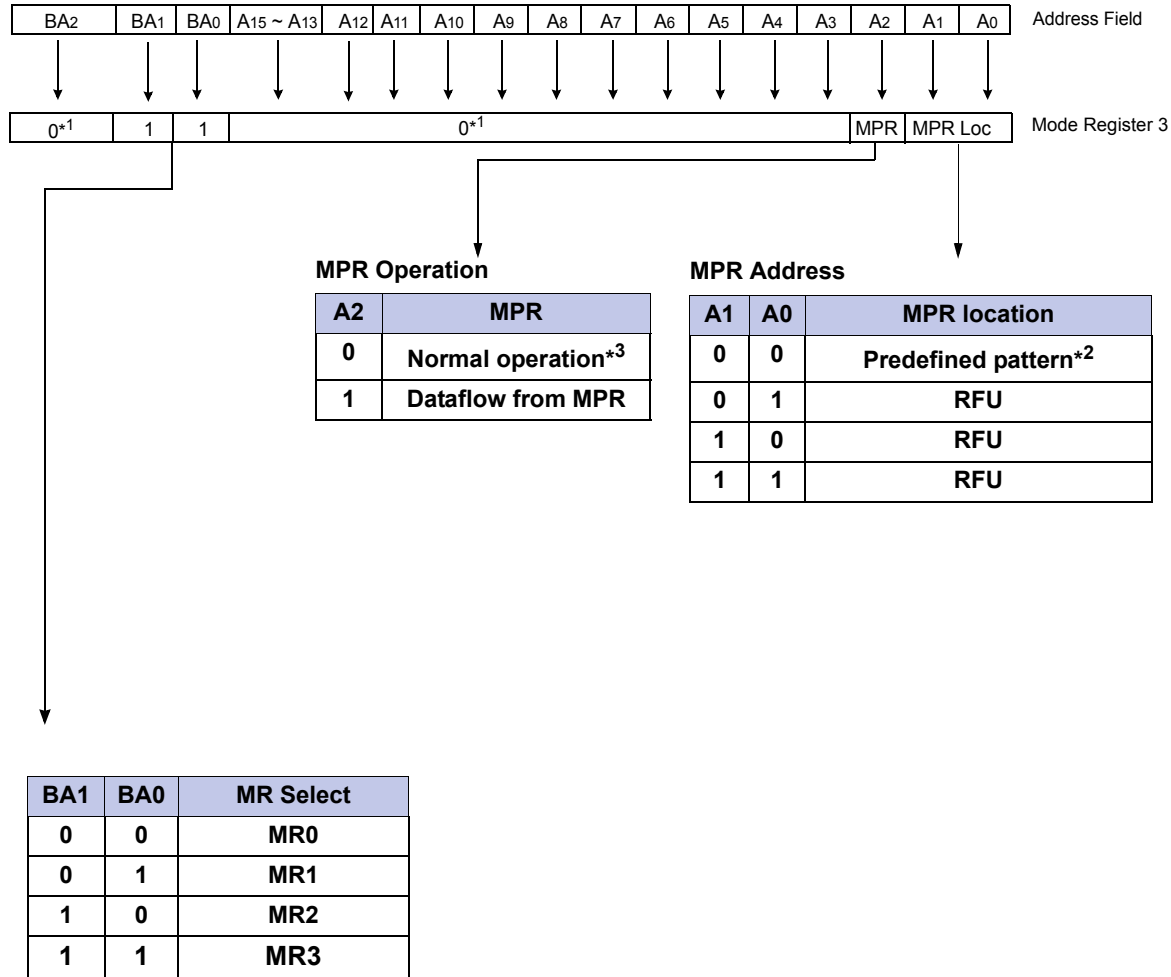
3 Functional Description (Cont'd)

3.4 Register Definition (Cont'd)

3.4.5 Mode Register MR3

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

MR3 Programming



* 1 : BA2, A3 - A15 are RFU and must be programmed to 0 during MRS.

* 2 : The predefined pattern will be used for read synchronization.

* 3 : When MPR control is set for normal operation (MR3 A[2] = 0) then MR3 A[1:0] will be ignored.

Figure 9 — MR3 Definition

3.4.5.1 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 pre-

3.4 Register Definition (Cont'd)

3.4.5 Mode Register MR3 (Cont'd)

charged 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. For detailed MPR operation refer to “Multi Purpose Register” on page 44.

4 DDR3 SDRAM Command Description and Operation

4.1 Command Truth Table

(a) note 1,2,3,4 apply to the entire Command Truth Table

(b) Note 5 applies to all Read/Write command

[BA=Bank Address, RA=Row Address, CA=Column Address, BC#=Burst Chop, X=Don't Care, V=Valid]

Table 6 — Command Truth Table

Function	Abbreviation	CKE		CS#	RAS#	CAS#	WE#	BA0-BA3	A13-A15	A12-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 BC4)	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	
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	

4 DDR3 SDRAM Command Description and Operation (Cont'd)**4.1 Command Truth Table (Cont'd)**

Function	Abbreviation	CKE		CS#	RAS#	CAS#	WE#	BA0-BA3	A13-A15	A12-BC#	A10-AP	A0-A9, A11	Notes
		Previous Cycle	Current Cycle										
ZQ Calibration Short	ZQCS	H	H	L	H	H	L	X	X	X	L	X	
Notes: 1. All DDR3 SDRAM commands are defined by states of CS#, RAS#, CAS#, WE# and CKE at the rising edge of the clock. The MSB of BA, RA and CA are device density and configuration dependant. 2. RESET# is Low enable command which will be used only for asynchronous reset so must be maintained HIGH during any function. 3. Bank addresses (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 previous 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.													

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.2 CKE Truth Table

Table 7 — CKE Truth Table

- a) Notes 1-7 apply to the entire CKE Truth Table.
b) For Power-down entry and exit parameters See 4.16 "Power-Down Modes" on page 72.
c) CKE low is allowed only if tMRD and tMOD are satisfied.

Current State ²	CKE		Command (N) ³ RAS#, CAS#, WE#, CS#	Action (N) ³	Notes
	Previous Cycle ¹ (N-1)	Current Cycle ¹ (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
For more details with all signals See 4.1 "Command Truth Table" on page 29.					10

- Notes:
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 not 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 registration. 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. For a detailed list of restrictions See 4.15 "Self-Refresh Operation" on page 70 and See 4.16 "Power-Down Modes" on page 72.
 14. The Power-Down does not perform any refresh operations.
 15. "X" means "don't 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 closed (tRP, tDAL, etc. satisfied), 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).

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.3 No Operation (NOP) Command

The No Operation (NOP) command is used to instruct the selected DDR3 SDRAM to perform a NOP (CS# LOW and RAS#, CAS#, and WE# HIGH). This prevents unwanted commands from being registered during idle or wait states. Operations already in progress are not affected.

4.4 Deselect Command

The DESELECT function (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.

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.5 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. Refer to “Input clock frequency change” on page 36

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. tDQSCK(DLL_off) values are vendor specific.

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

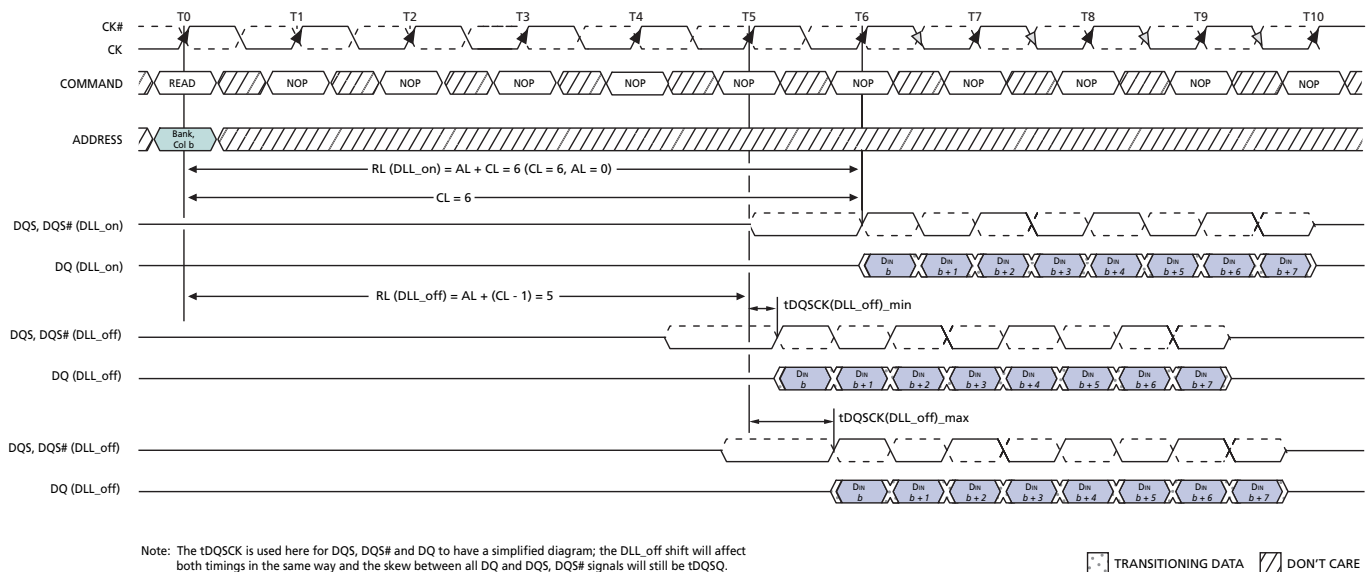


Figure 10 — DLL-off mode READ Timing Operation

4 DDR3 SDRAM Command Description and Operation (Cont'd)

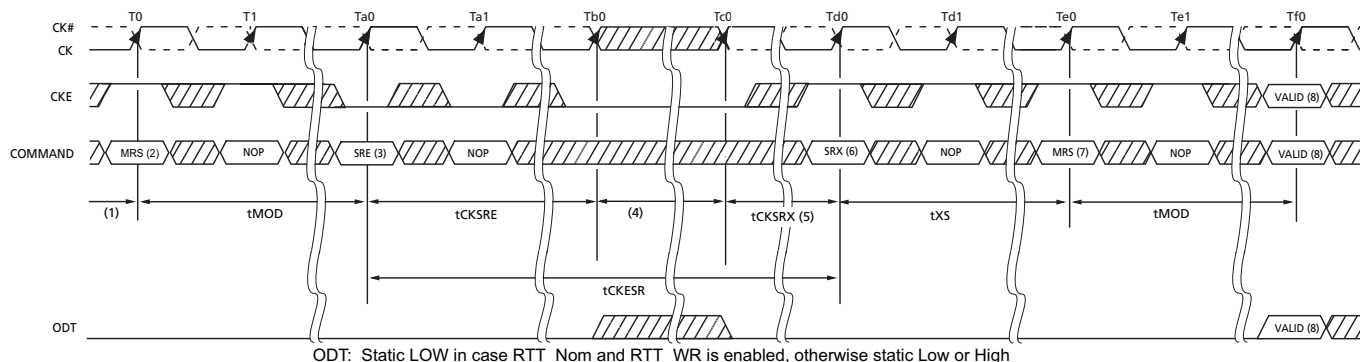
4.6 DLL on/off switching procedure

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

4.6.1 DLL “on” to DLL “off” Procedure

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

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 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) is satisfied.
5. Change frequency, in guidance with “Input clock frequency change” on page 36.
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 Registers 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.



- NOTES:
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 tCKSRX
 6. Exit SR
 7. Update Mode registers with DLL off parameters setting
 8. Any valid command



TIME BREAK



DON'T CARE

Figure 11 — DLL Switch Sequence from DLL-on to DLL-off

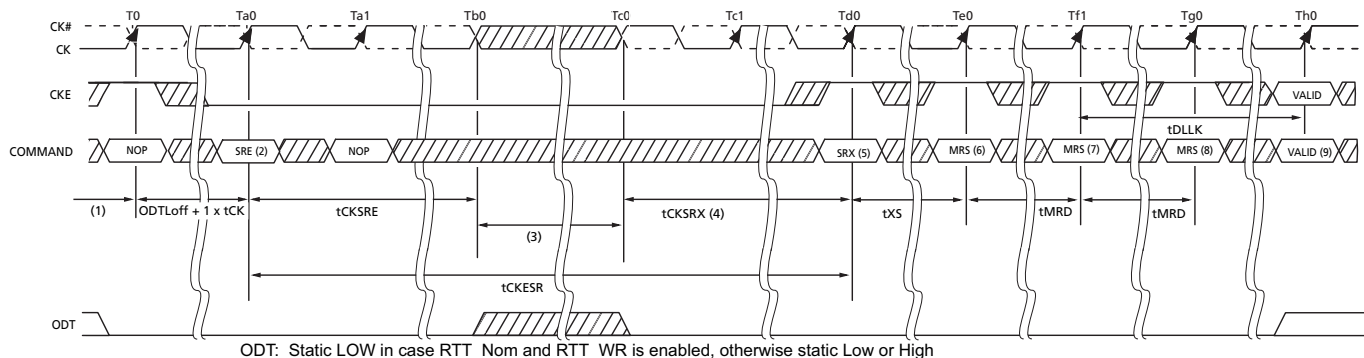
4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.6 DLL on/off switching procedure (Cont'd)

4.6.2 DLL "off" to DLL "on" Procedure

To switch from DLL "off" to DLL "on" (with required 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 t_{CKSRE} satisfied.
3. Change frequency, in guidance with "Input clock frequency change" on page 36.
4. Wait until a stable clock is available for at least (t_{CKSRX}) at DRAM inputs.
5. Starting with the Self Refresh Exit command, CKE must continuously be registered HIGH until t_{DLLK} 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 t_{DLLK} 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 t_{XS} , then set MR1 bit A0 to "0" to enable the DLL.
7. Wait t_{MRD} , then set MR0 bit A8 to "1" to start DLL Reset.
8. Wait t_{MRD} , then set Mode Registers with appropriate values (especially an update of CL, CWL and WR may be necessary. After t_{MOD} satisfied from any proceeding MRS command, a ZQCL command may also be issued during or after t_{DLLK} .)
9. Wait for t_{MOD} , then DRAM is ready for next command (Remember to wait t_{DLLK} after DLL Reset before applying command requiring a locked DLL!). In addition, wait also for t_{ZQoper} in case a ZQCL command was issued.



- NOTES:
1. Starting with Idle State
 2. Enter SR
 3. Change Frequency
 4. Clock must be stable t_{CKSRX}
 5. Exit SR
 6. Set DLL on by MR1 A0=0
 7. Update Mode registers
 8. Any valid command

}} TIME BREAK DON'T CARE

Figure 12 — DLL Switch Sequence from DLL Off to DLL On

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.7 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) specifications.

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 t_{CKSRE} 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 t_{CKSRX} . When entering and exiting Self-Refresh mode for the sole purpose of changing the clock frequency, the Self-Refresh entry and exit specifications must still be met as outlined in See 4.15 “Self-Refresh Operation” on page 70. The DDR3 SDRAM input clock frequency is allowed to change only within the minimum and maximum operating frequency specified for the particular speed grade. Any frequency change below the minimum operating frequency would require the use of DLL_on- mode -> DLL_off -mode transition sequence, refer to “DLL on/off switching procedure” on page 34.

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 entering 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 t_{CKSRE} 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 t_{CKSRX} before Precharge Power-down may be exited; after Precharge Power-down is exited and t_{XP} 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

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.7 Input clock frequency change (Cont'd)

remain HIGH. After the DLL lock time, the DRAM is ready to operate with new clock frequency. This process is depicted in Figure 13 on page 37.

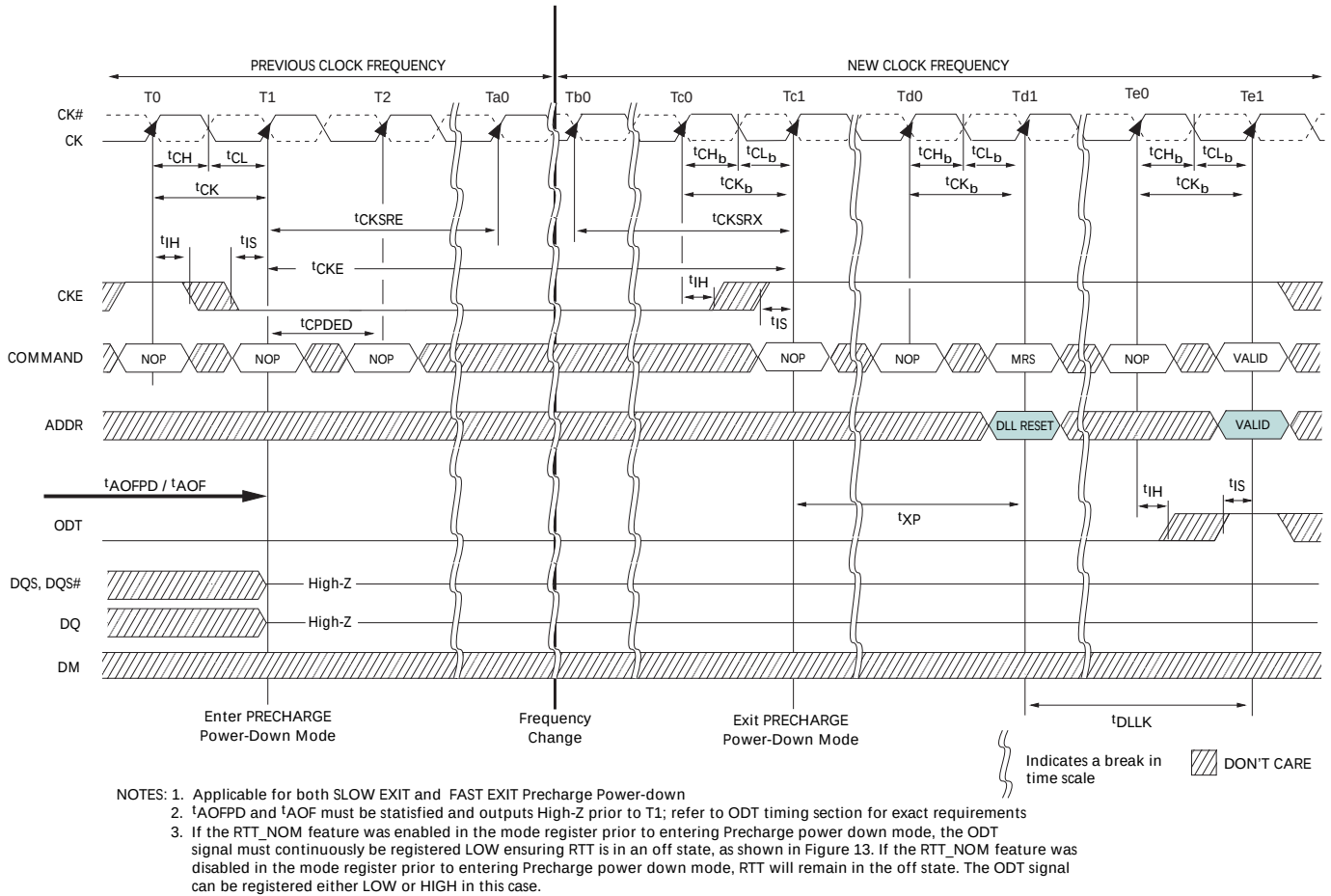


Figure 13 — Change Frequency during Precharge Power-down

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.8 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 it difficult for the Controller to maintain tDQSS, tDSS and tDSH specification. Therefore, the DDR3 SDRAM supports a 'write leveling' feature to allow the controller to compensate for skew.

The memory controller can use the 'write leveling' feature and feedback from the DDR3 SDRAM to adjust the DQS - DQS# to CK - CK# relationship. The memory controller involved in the leveling must have adjustable delay setting on DQS - DQS# to align the rising edge of DQS - DQS# with that of the clock at the DRAM pin. DRAM asynchronously feeds back CK - CK#, sampled with the rising edge of DQS - DQS#, through the DQ bus. The controller repeatedly delays DQS - DQS# until a transition from 0 to 1 is detected. The DQS - DQS# delay established through 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 - 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 limits provided in the chapter "AC Timing Parameters" in order to satisfy tDSS and tDSH specification. A conceptual timing of this scheme is shown in Figure 14.

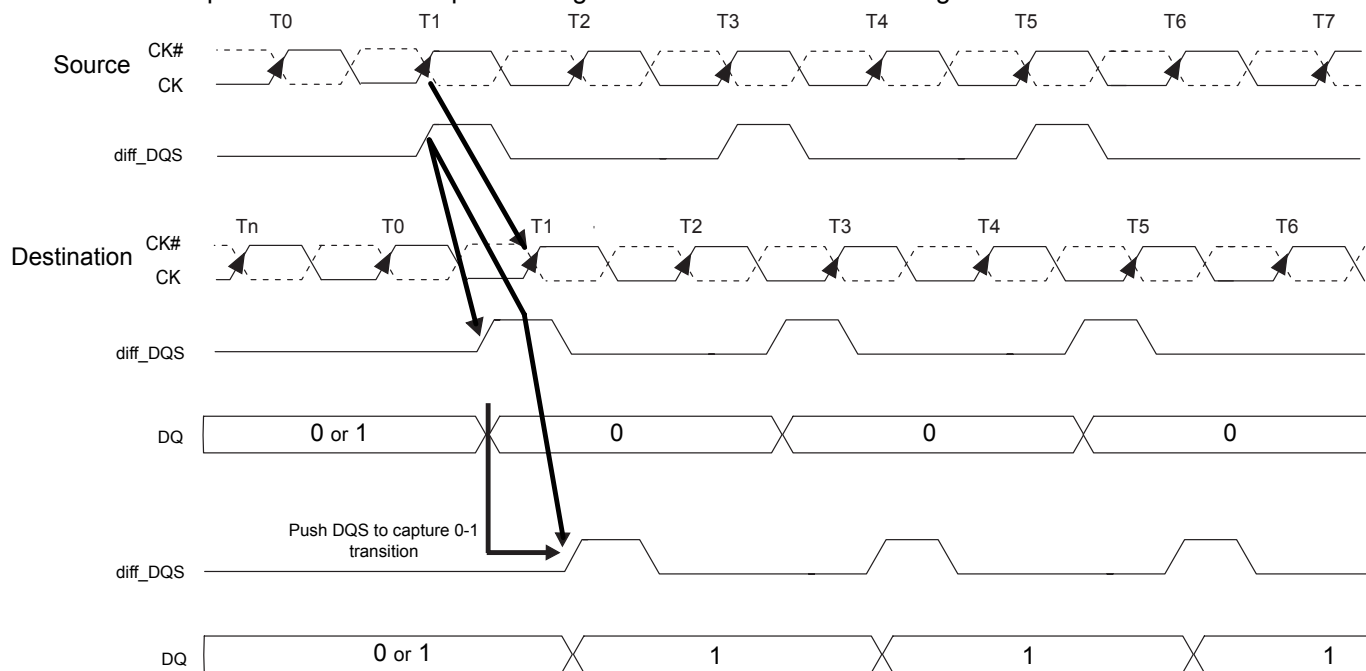


Figure 14 — Write Leveling Concept

DQS - DQS# driven by the controller during leveling mode must be terminated 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 available 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.

4.8.1 DRAM setting for write leveling & 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' (Table 8). Note that in write leveling mode, only DQS/DQS# terminations are activated and deactivated via ODT pin not like normal operation (Table 9).

4.8 Write Leveling (Cont'd)

4.8.1 DRAM setting for write leveling & DRAM termination function in that mode (Cont'd)

Table 8 — MR setting involved in the leveling procedure

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

Table 9 — DRAM termination function in the leveling mode

ODT pin @DRAM	DQS/DQS# termination	DQs termination
De-asserted	Off	Off
Asserted	On	Off

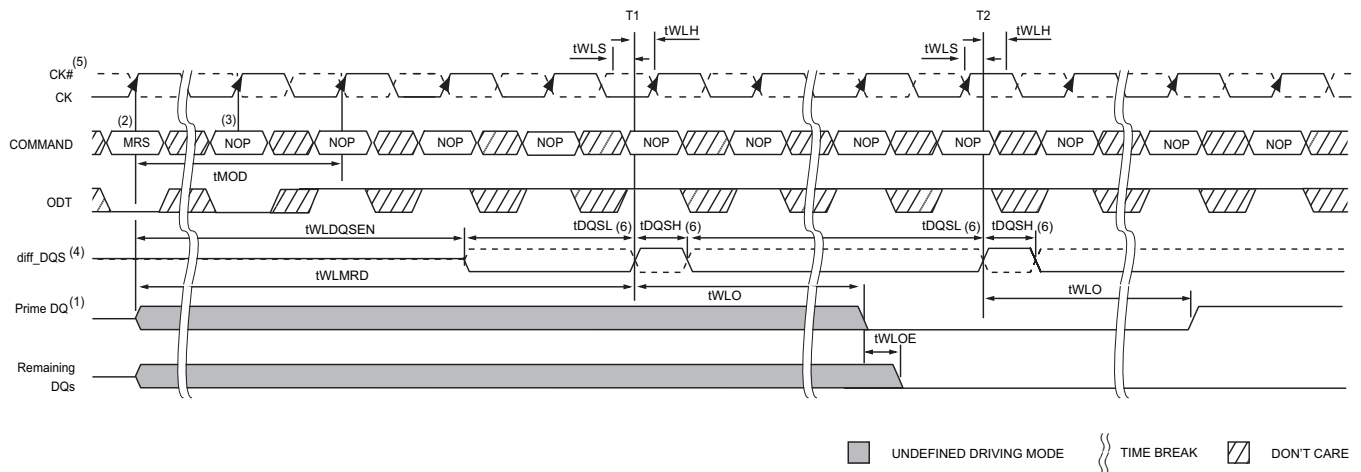
Note: In Write Leveling Mode with its output buffer disabled (MR1[bit7] = 1 with MR1[bit12] = 1) all RTT_Nom settings are allowed; in Write Leveling Mode with its output buffer enabled (MR1[bit7] = 1 with MR1[bit12] = 0) only RTT_Nom settings of RZQ/2, RZQ/4 and RZQ/6 are allowed.

4.8.2 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 DESELECT 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 ranks 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 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, DQS# edge which is used by the DRAM to sample CK - CK# driven from controller. tWLMRD(max) timing is controller dependent.

DRAM samples CK - CK# status with rising edge of DQS - 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/DQS#) needed for these DQs. Controller samples incoming DQ and decides to increment or decrement DQS - DQS# delay setting and launches the next DQS/DQS# pulse after some time, which is controller dependent. Once a 0 to 1 transition is detected, the controller locks DQS - DQS# delay setting and write leveling is achieved for the device. Figure 15 describes the timing diagram and parameters for the overall Write Leveling procedure.

4.8 Write Leveling (Cont'd)**4.8.2 Procedure Description (Cont'd)**

- NOTES: 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, DQS#). Timing reference points are the zero crossings. DQS is shown with solid line, DQS# is shown with dotted line.
5. CK, CK# : CK is shown with solid dark line, where as CK# is drawn with dotted line.
6. DQS, 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.

Figure 15 — Timing details of Write leveling sequence [DQS - DQS# is capturing CK - CK# low at T1 and CK - CK# high at T2]

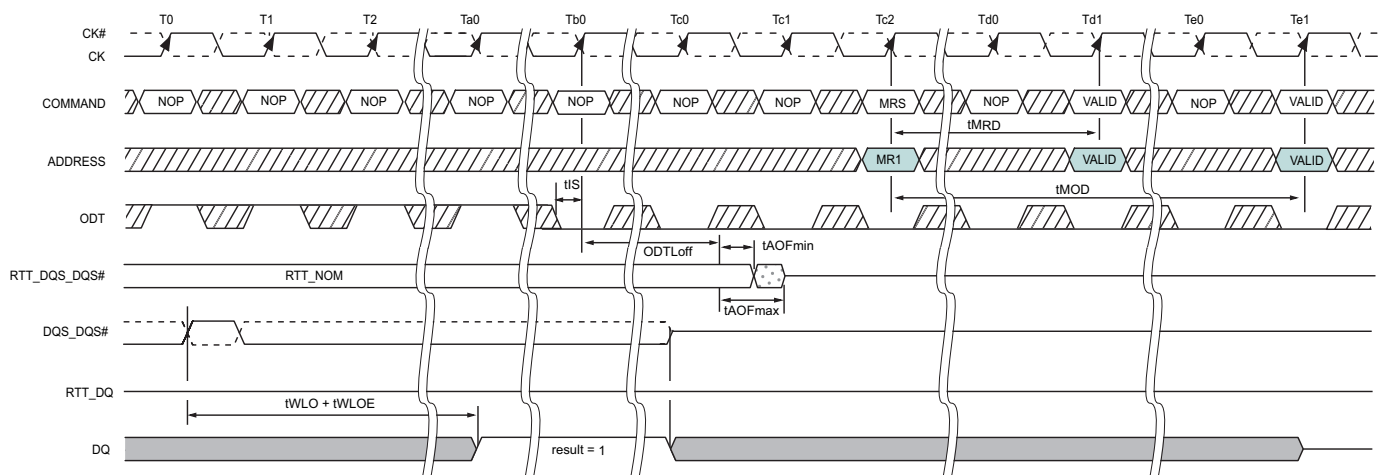
4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.8 Write Leveling (Cont'd)

4.8.3 Write Leveling Mode Exit

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

1. After the last rising strobe edge (see $\sim T_0$), stop driving the strobe signals (see $\sim T_{c0}$). Note: From now on, DQ pins are in undefined driving mode, and will remain undefined, until t_{MOD} after the respective MR command (T_{e1}).
2. Drive ODT pin low (t_{IS} must be satisfied) and continue registering low. (see T_{b0}).
3. After the RTT is switched off, disable Write Level Mode via MRS command (see T_{c2}).
4. After t_{MOD} is satisfied (T_{e1}), any valid command may be registered. (MR commands may be issued after t_{MRD} (T_{d1})).



NOTE: The DQ result = 1 between Ta0 and Tc0 is a result of the DQS, DQS# signals capturing CK high just after the T0 state.

■ UNDEFINED DRIVING MODE □ TRANSITIONING } TIME BREAK ▨ DON'T CARE

Figure 16 — Timing details of Write leveling exit

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.9 Extended Temperature Usage

Users should refer to the DRAM supplier data sheet and/or the DIMM SPD to determine if DDR3 SDRAM devices support the following options or requirements referred to in this material:

- a. Auto Self-refresh supported
- b. Extended Temperature Range supported
- c. Double refresh required for operation in the Extended Temperature Range (applies only for devices supporting the Extended Temperature Range)

Table 10 — Mode Register Description

Field	Bits	Description
ASR	MR2 (A6)	Auto Self-Refresh (ASR) (Optional) 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 (optional)
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 _b 0 = Normal operating temperature range 1 = Extended (optional) operating temperature range

4.9.0.1 Auto Self-Refresh mode - ASR Mode (optional)

DDR3 SDRAM provides an Auto Self-Refresh mode (ASR) for application ease. ASR mode is enabled by setting MR2 bit A6 = 1_b and MR2 bit A7 = 0_b. The DRAM will manage Self-Refresh entry in either the Normal or Extended (optional) 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 the DRAM, MR2 bit A6 must be set to 0_b.

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

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

Please refer to the supplier data sheet and/or the DIMM SPD for Extended Temperature Range and Auto Self-Refresh option availability.

4.9.1 Self-Refresh Temperature Range - SRT

SRT applies to devices supporting Extended Temperature Range only. If ASR = 0_b, the Self-Refresh Temperature (SRT) Range bit must be programmed to guarantee proper self-refresh operation. If SRT = 0_b, then the DRAM will set an appropriate refresh rate for Self-Refresh operation in the Normal Temperature Range. If SRT = 1_b then the DRAM will set an appropriate, 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 the IDD table for details.

For parts that do not support the Extended Temperature Range, MR2 bit A7 must be set to 0_b and the DRAM should not be operated outside the Normal Temperature Range.

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.9 Extended Temperature Usage (Cont'd)

Please refer to the supplier data sheet and/or the DIMM SPD for Extended Temperature Range availability.

Table 11 — 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 - 85 °C)
0	1	Self-refresh rate 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 - 95 °C)
1	0	ASR enabled (for devices supporting ASR and Normal Temperature Range). Self-Refresh power consumption is temperature dependent	Normal (0 - 85 °C)
1	0	ASR enabled (for devices supporting ASR and Extended Temperature Range). Self-Refresh power consumption is temperature dependent	Normal and Extended (0 - 95 °C)
1	1	Illegal	

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.10 Multi Purpose Register

The Multi Purpose Register (MPR) function is used to Read out a predefined system timing calibration bit sequence. The basic concept of the MPR is shown in Figure 17.

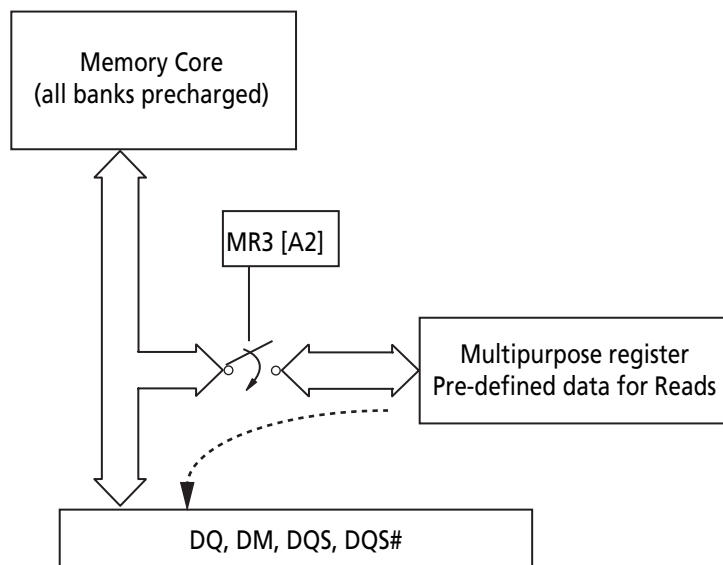


Figure 17 — MPR Block Diagram

To enable the MPR, a MODE Register Set (MRS) command must be issued to MR3 Register with bit A2 = 1, as shown in Table 12. 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. The resulting operation when a RD or RDA command is issued is defined by MR3 bits A[1:0] when the MPR is enabled as shown in Table 13. 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). Note that in MPR mode RDA has the same functionality as a READ command which means the auto precharge part of RDA is ignored. 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.

Table 12 — MPR MR3 Register Definition

MR3 A[2]	MR3 A[1:0]	Function
MPR	MPR-Loc	
0b	don't care (0b or 1b)	Normal operation, no MPR transaction. All subsequent Reads will come from DRAM array. All subsequent Write will go to DRAM array.
1b	See Table 13	Enable MPR mode, subsequent RD/RDA commands defined by MR3 A[1:0].

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.10 Multi Purpose Register (Cont'd)

4.10.1 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 0b.
- Register Read on x8:
 - DQ[0] drives information from MPR.
 - DQ[7:1] either drive the same information as DQ[0], or they drive 0b.
- 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 0b.
- 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'b. Data read burst order in nibble is fixed
 - A[2]: For BL=8, A[2] must be equal to 0b, 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]=0b, Burst order: 0,1,2,3 *) A[2]=1b, 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,... (if available): don't care
- Regular interface functionality during register reads:
 - Support two Burst Ordering which are switched with A2 and A[1:0]=00b.
 - Support of read burst chop (MRS and on-the-fly via A12/BC)
 - All other address bits (remaining column address 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.

4 DDR3 SDRAM Command Description and Operation (Cont'd)**4.10 Multi Purpose Register (Cont'd)****4.10.2 MPR Register Address Definition**

Table 13 provides an overview of the available data locations, 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.

Table 13 — MPR MR3 Register Definition

MR3 A[2]	MR3 A[1:0]	Function	Burst Length	Read Address A[2:0]	Burst Order and Data Pattern
1b	00b	Read Predefined Pattern for System Calibration	BL8	000b	Burst order 0,1,2,3,4,5,6,7 Pre-defined Data Pattern [0,1,0,1,0,1,0,1]
			BC4	000b	Burst order 0,1,2,3 Pre-defined Data Pattern [0,1,0,1]
			BC4	100b	Burst order 4,5,6,7 Pre-defined Data Pattern [0,1,0,1]
1b	01b	RFU	BL8	000b	Burst order 0,1,2,3,4,5,6,7
			BC4	000b	Burst order 0,1,2,3
			BC4	100b	Burst order 4,5,6,7
1b	10b	RFU	BL8	000b	Burst order 0,1,2,3,4,5,6,7
			BC4	000b	Burst order 0,1,2,3
			BC4	100b	Burst order 4,5,6,7
1b	11b	RFU	BL8	000b	Burst order 0,1,2,3,4,5,6,7
			BC4	000b	Burst order 0,1,2,3
			BC4	100b	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.					

4.10.3 Relevant Timing Parameters

The following AC timing parameters are important for operating the Multi Purpose Register: tRP, tMRD, tMOD, and tMPRR. For more details refer to “Electrical Characteristics & AC Timing for DDR3-800 to DDR3-1600” on page 142.

4.10.4 Protocol Example

Protocol Example (This is one example):

Read out predetermined read-calibration pattern.

Description: Multiple reads from Multi Purpose Register, in order to do system level read timing calibration based on predetermined and standardized pattern.

Protocol Steps:

- Precharge All.
- Wait until tRP is satisfied.
- MRS MR3, Opcode “A2 = 1b” and “A[1:0] = 00b”
 - Redirect all subsequent reads into the Multi Purpose Register, and load Pre-defined pattern into MPR.
- Wait until tMRD and tMOD are satisfied (Multi Purpose Register is then ready to be read). During the period MR3 A2 = 1, no data write operation is allowed.
- Read:
 - A[1:0] = ‘00’b (Data burst order is fixed starting at nibble, always 00b here)
 - A[2] = ‘0’b (For BL=8, burst order is fixed as 0,1,2,3,4,5,6,7)
 - A12/BC = 1 (use regular burst length of 8)
 - All other address pins (including BA[2:0] and A10/AP): don’t care

- After $RL = AL + CL$, DRAM bursts out the predefined Read Calibration Pattern.
- Memory controller repeats these calibration reads until read data capture at memory controller is optimized.
- After end of last MPR read burst, wait until $tMPRR$ is satisfied.
- MRS MR3, Opcode "A2 = 0b" and "A[1:0] = valid data but value are don't care"
 - All subsequent read and write accesses will be regular reads and writes from/to the DRAM array.
- Wait until $tMRD$ and $tMOD$ are satisfied.
- Continue with "regular" DRAM commands, like activate a memory bank for regular read or write access,...

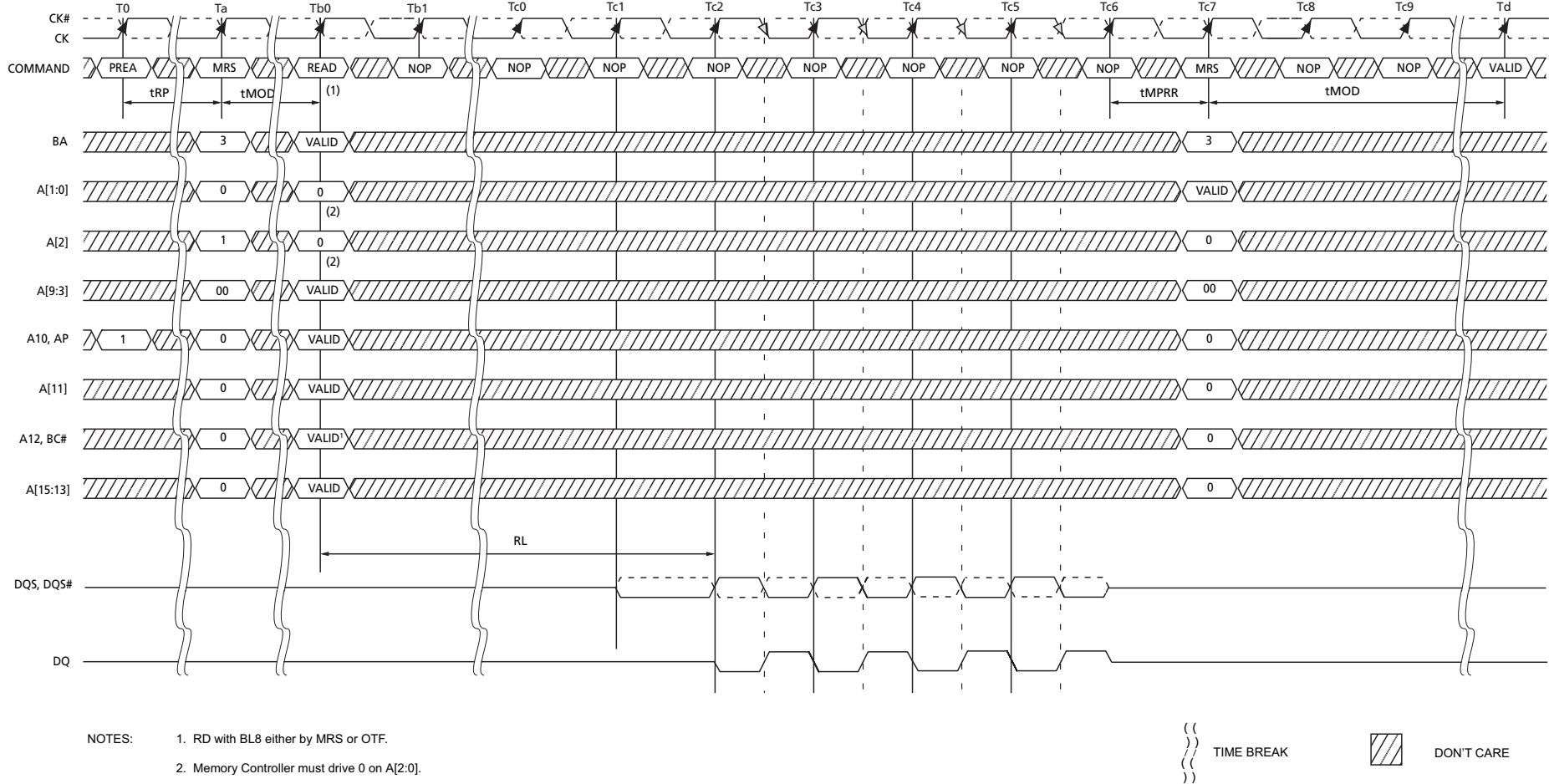
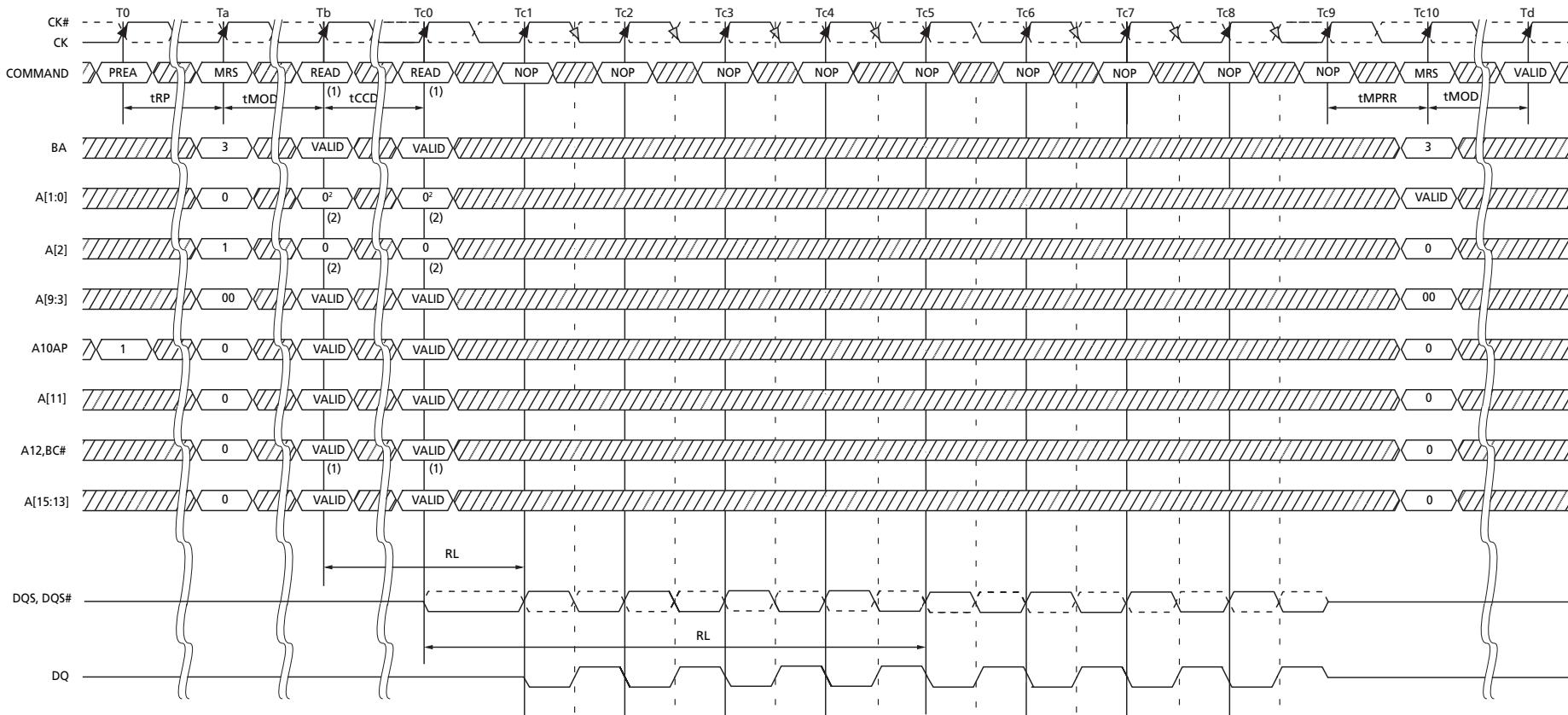


Figure 18 — MPR Readout of predefined pattern, BL8 fixed burst order, single readout

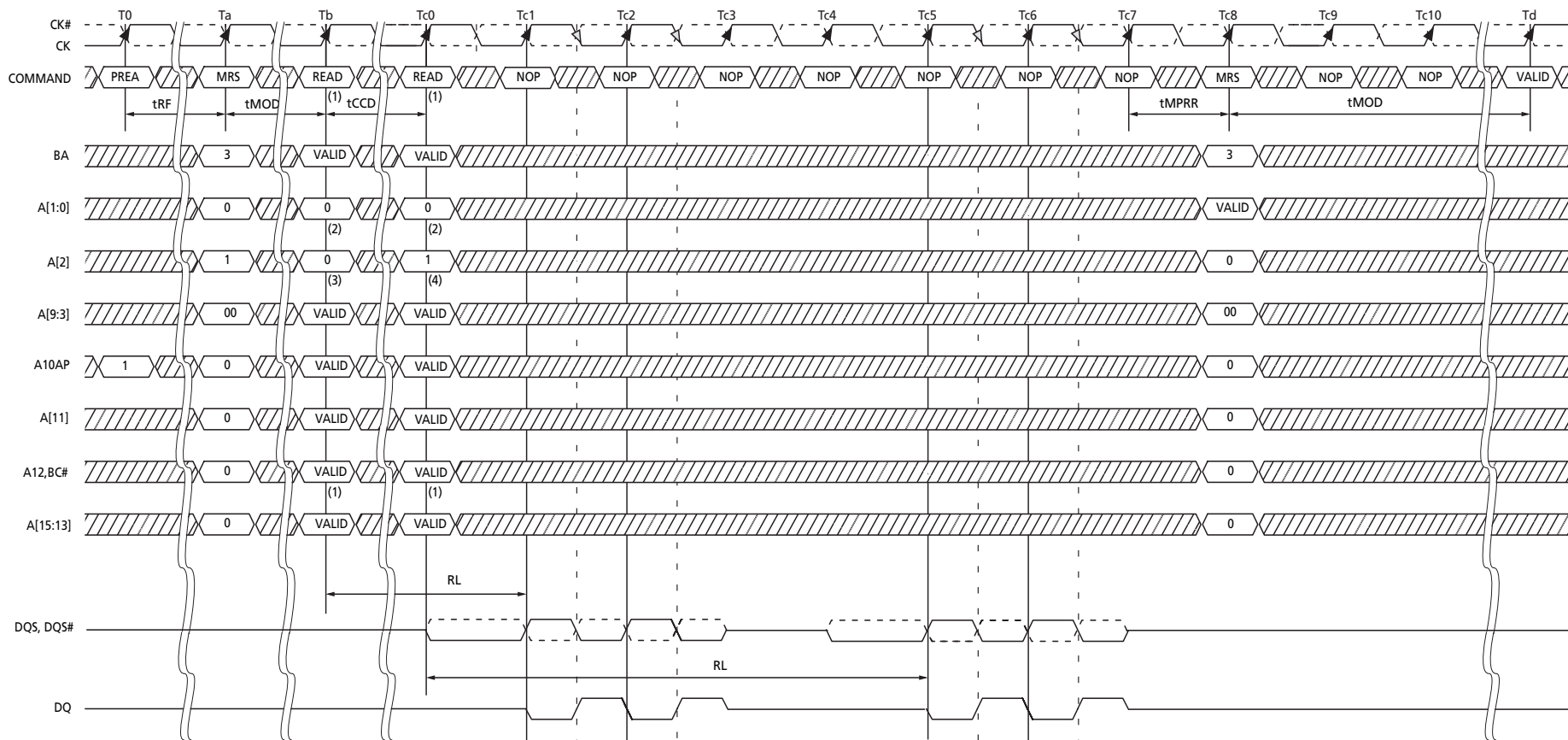
4.10 Multi Purpose Register (Cont'd)
4.10.4 Protocol Example Cont'd)



- NOTES:
1. RD with BL8 either by MRS or OTF.
 2. Memory Controller must drive 0 on A[2:0].

((TIME BREAK))
 DON'T CARE

Figure 19 — MPR Readout of predefined pattern, BL8 fixed burst order, back-to-back readout



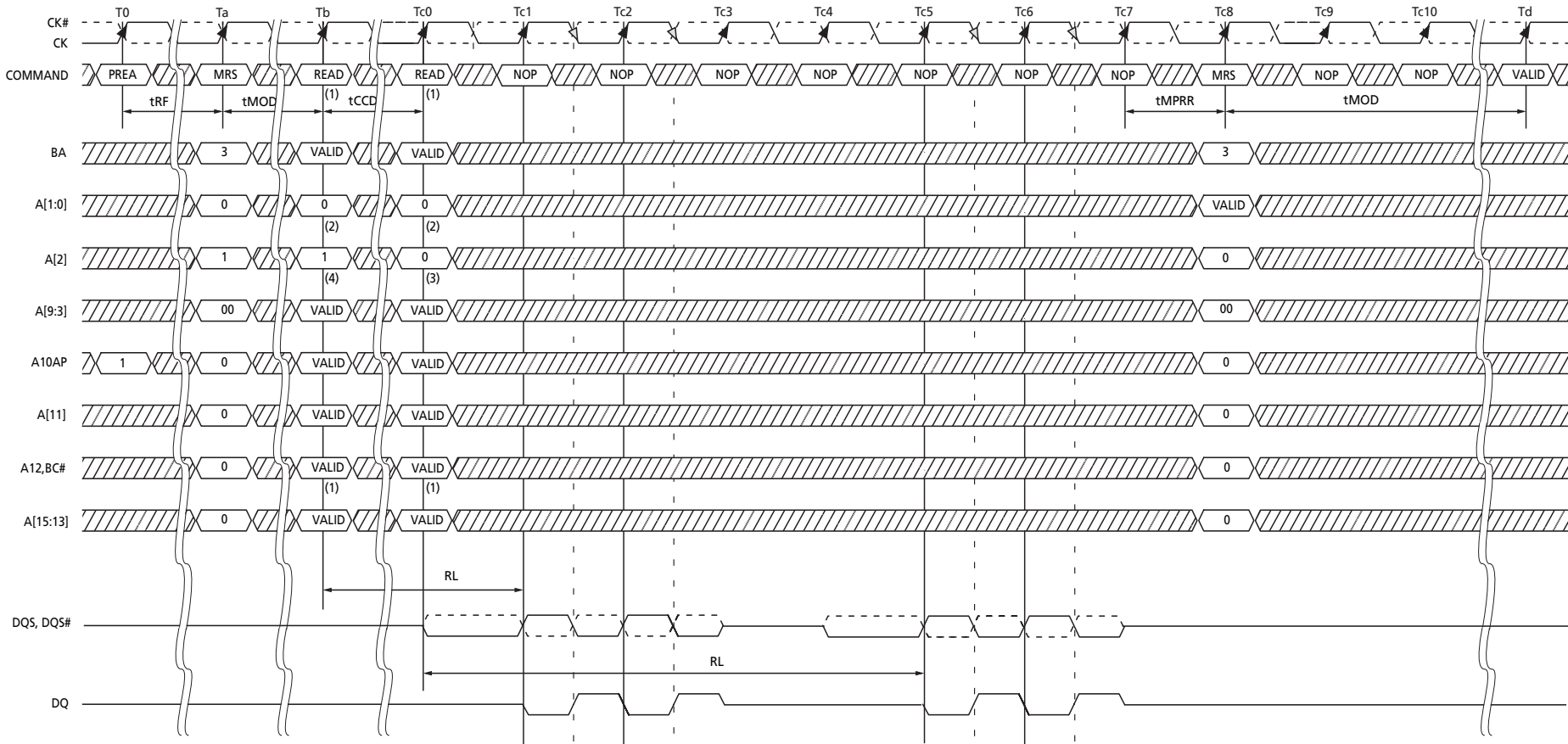
- NOTES:
1. RD with BC4 either by MRS or OTF.
 2. Memory Controller must drive 0 on A[1:0].
 3. A[2]=0 selects lower 4 nibble bits 0....3.
 4. A[2]=1 selects upper 4 nibble bits 4....7.

TIME BREAK

DON'T CARE

Figure 20 — MPR Readout predefined pattern, BC4, lower nibble then upper nibble

4.10 Multi Purpose Register (Cont'd)
4.10.4 Protocol Example Cont'd



- NOTES:
1. RD with BC4 either by MRS or OTF.
 2. Memory Controller must drive 0 on A[1:0].
 3. A[2]=0 selects lower 4 nibble bits 0....3.
 4. A[2]=1 selects upper 4 nibble bits 4....7.

((
)) TIME BREAK
((
))
DONT CARE

Figure 21 — MPR Readout of predefined pattern, BC4, upper nibble then lower nibble

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.11 ACTIVE Command

The ACTIVE command is used to open (or activate) a row in a particular bank for a subsequent access. The value on the BA0-BA2 inputs selects the bank, and the address provided on inputs A0-A15 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.

4.12 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 state) or if the previously open row is already in the process of precharging. However, the precharge period will be determined by the last PRECHARGE command issued to the bank.

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.13 READ Operation

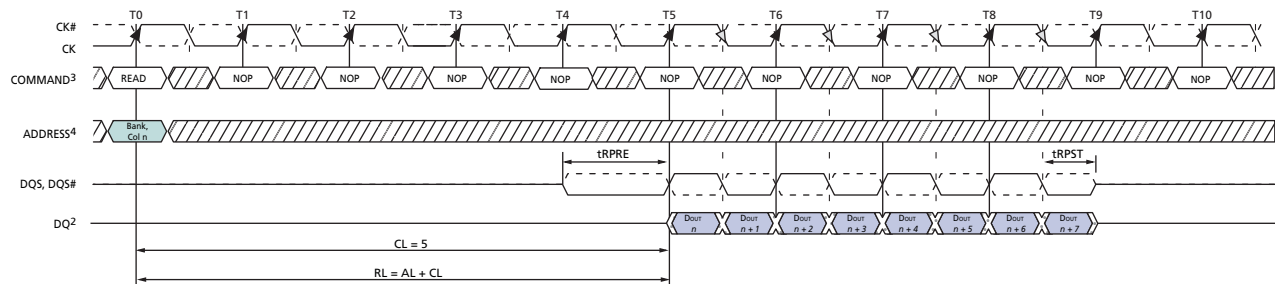
4.13.1 READ Burst Operation

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

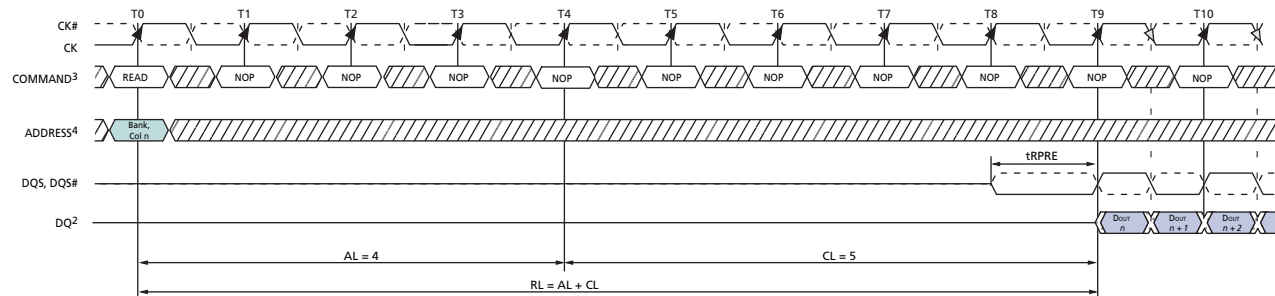
A12 is used only for burst length control, not as a column address.



- NOTES: 1. BL8, RL = 5, AL = 0, CL = 5.
 2. Dout n = data-out from column n.
 3. NOP commands are shown for ease of illustration; other commands 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 READ command at T0.

TRANSITIONING DATA DON'T CARE

Figure 22 — READ Burst Operation RL = 5 (AL = 0, CL = 5, BL8)



- NOTES: 1. BL8, RL = 9, AL = (CL - 1), CL = 5.
 2. Dout n = data-out from column n.
 3. NOP commands are shown for ease of illustration; other commands 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 READ command at T0.

TRANSITIONING DATA DON'T CARE

Figure 23 — READ Burst Operation RL = 9 (AL = 4, CL = 5, BL8)

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.13 READ Operation (Cont'd)

4.13.2 READ Timing Definitions

Read timing is shown in Figure 24 and is applied when the DLL is enabled and locked.

Rising data strobe edge parameters:

- t_{DQSCK} min/max describes the allowed range for a rising data strobe edge relative to CK, CK#.
- t_{DQSCK} is the actual position of a rising strobe edge relative to CK, CK#.
- t_{QSH} describes the DQS, DQS# differential output high time.
- t_{DQSQ} describes the latest valid transition of the associated DQ pins.
- t_{QH} describes the earliest invalid transition of the associated DQ pins.

Falling data strobe edge parameters:

- t_{QSL} describes the DQS, DQS# differential output low time.
- t_{DQSQ} describes the latest valid transition of the associated DQ pins.
- t_{QH} describes the earliest invalid transition of the associated DQ pins.

t_{DQSQ} ; both rising/falling edges of DQS, no t_{AC} defined.

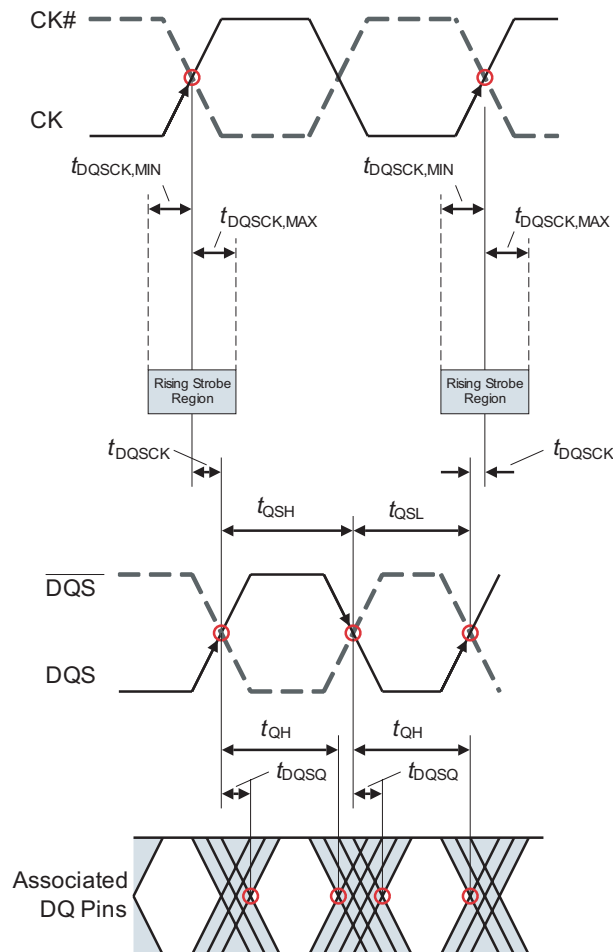


Figure 24 — READ Timing Definition

4.13 READ Operation (Cont'd)**4.13.2 READ Timing Definitions (Cont'd)****4.13.2.1 READ Timing; Clock to Data Strobe relationship**

Clock to Data Strobe relationship is shown in Figure 25 and is applied when the DLL is enabled and locked.

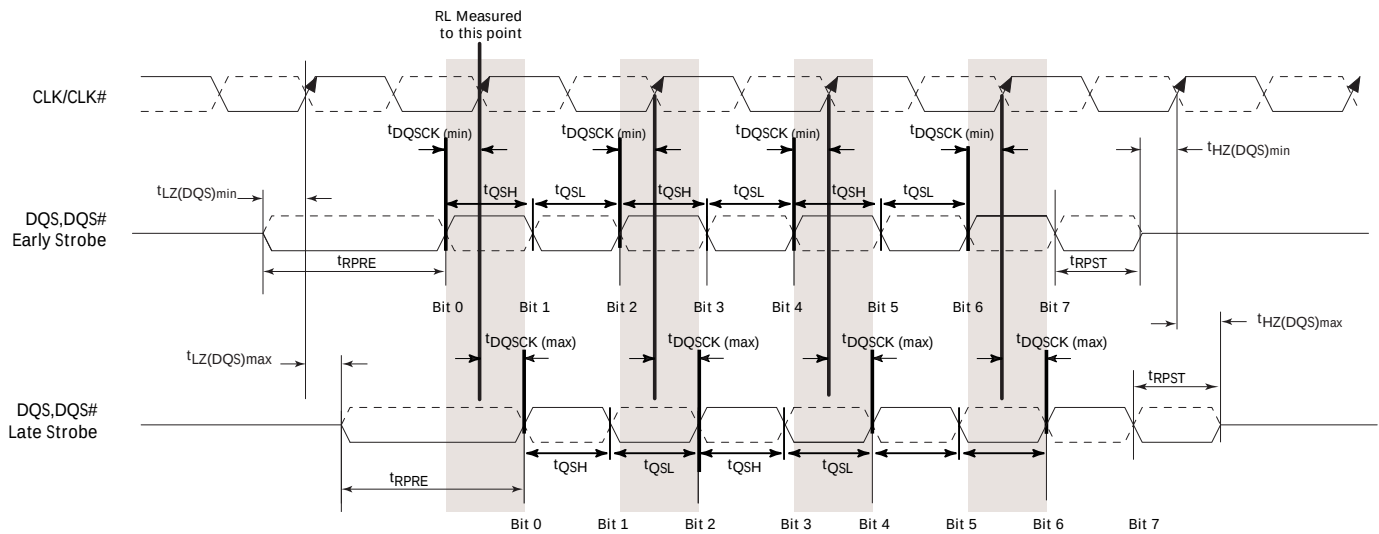
Rising data strobe edge parameters:

- t_{DQSCK} min/max describes the allowed range for a rising data strobe edge relative to CK, CK#.
- t_{DQSCK} is the actual position of a rising strobe edge relative to CK, CK#.
- t_{QSH} describes the data strobe high pulse width.

Falling data strobe edge parameters:

- t_{QSL} describes the data strobe low pulse width.

$t_{LZ}(DQS)$, $t_{HZ}(DQS)$ for preamble/postamble (see 4.13.2.3 and Figure 27)



- NOTES:**
1. Within a burst, rising strobe edge is not necessarily fixed to be always at $t_{DQSCK}(\text{min})$ or $t_{DQSCK}(\text{max})$. Instead, rising strobe edge can vary between $t_{DQSCK}(\text{min})$ and $t_{DQSCK}(\text{max})$.
 2. The DQS, DQS# differential output high time is defined by t_{QSH} and the DQS, DQS# differential output low time is defined by t_{QSL} .
 3. Likewise, $t_{LZ}(DQS)\text{min}$ and $t_{HZ}(DQS)\text{min}$ are not tied to $t_{DQSCK}\text{min}$ (early strobe case) and $t_{LZ}(DQS)\text{max}$ and $t_{HZ}(DQS)\text{max}$ are not tied to $t_{DQSCK}\text{max}$ (late strobe case); However, they will tend to track each other.
 4. The minimum pulse width of read preamble is defined by $t_{RPRE}(\text{min})$. The minimum pulse width of read postamble is defined by $t_{RPST}(\text{min})$.

Figure 25 — Clock to Data Strobe Relationship

4.13 READ Operation (Cont'd)

4.13.2 READ Timing Definitions (Cont'd)

4.13.2.2 READ Timing; Data Strobe to Data relationship

The Data Strobe to Data relationship is shown in Figure 26 and is applied when the DLL is enabled and locked.

Rising data strobe edge parameters:

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

tDQSQ; both rising/falling edges of DQS, no tAC defined

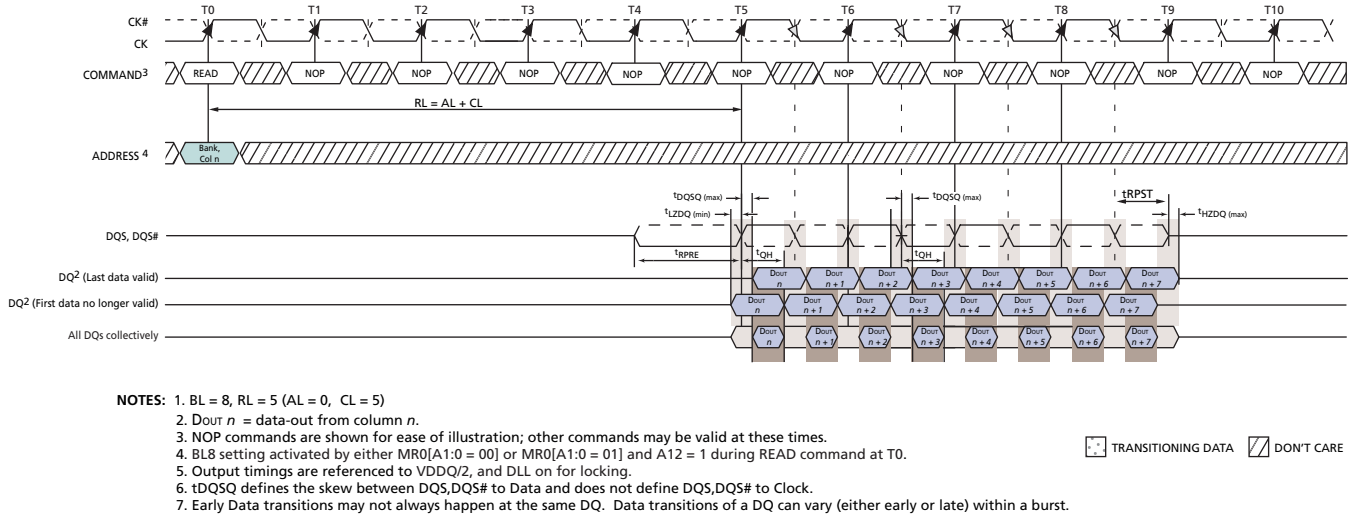


Figure 26 — Data Strobe to Data Relationship

4.13.2.3 tLZ(DQS), tLZ(DQ), tHZ(DQS), tHZ(DQ) Calculation

tHZ and tLZ transitions occur in the same access time as valid data transitions. These parameters are referenced to a specific voltage level which specifies when the device output is no longer driving tHZ(DQS) and tHZ(DQ), or begins driving tLZ(DQS), tLZ(DQ). Figure 27 shows a method to calculate the point when device is no longer driving tHZ(DQS) and tHZ(DQ), or begins driving tLZ(DQS), tLZ(DQ) by measuring the signal at two different voltages. The actual voltage measurement points are not critical as long as the cal-

4.13 READ Operation (Cont'd)

4.13.2 READ Timing Definitions (Cont'd)

ulation is consistent. The parameters tLZ(DQS), tLZ(DQ), tHZ(DQS), and tHZ(DQ) are defined as singled ended.

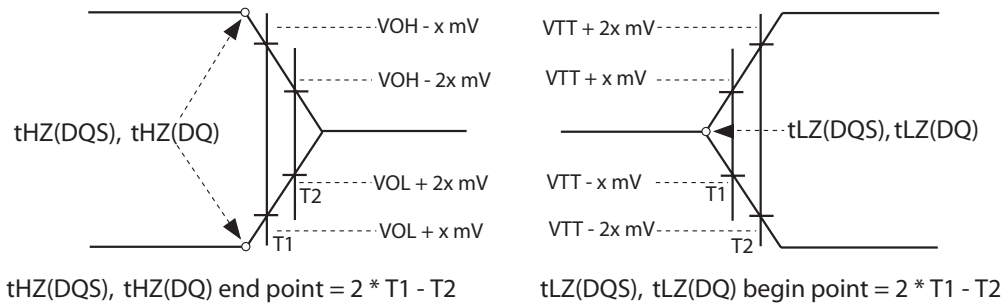


Figure 27 — tLZ and tHZ method for calculating transitions and endpoints

4.13 READ Operation (Cont'd)

4.13.2 READ Timing Definitions (Cont'd)

4.13.2.4 tRPRE Calculation

Method for calculating differential pulse widths for tRPRE is shown in Figure 28.

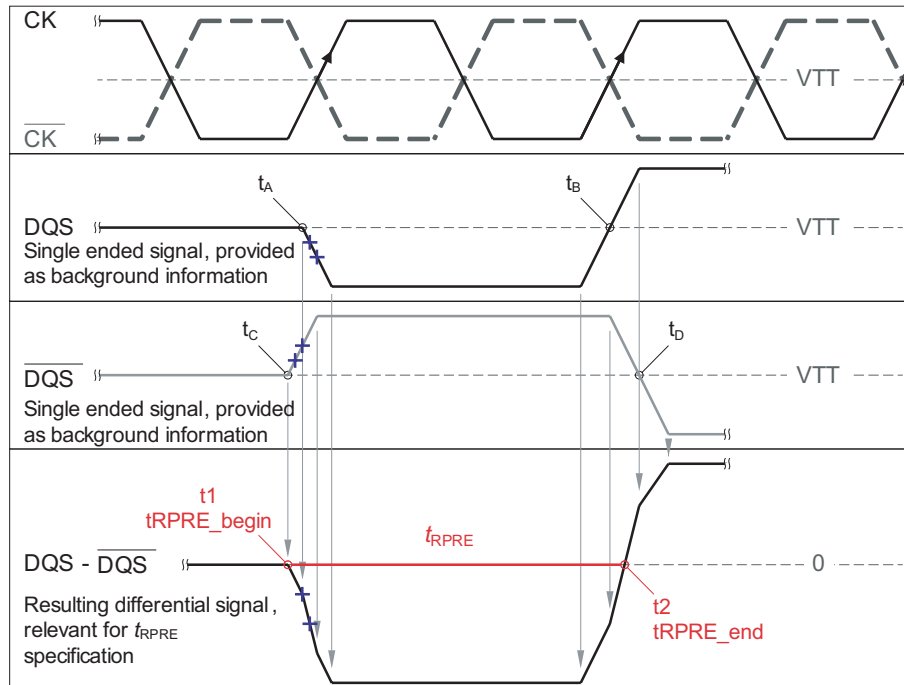


Figure 28 — Method for calculating tRPRE transitions and endpoints

4.13.2.5 tRPST Calculation

Method for calculating differential pulse widths for tRPST.

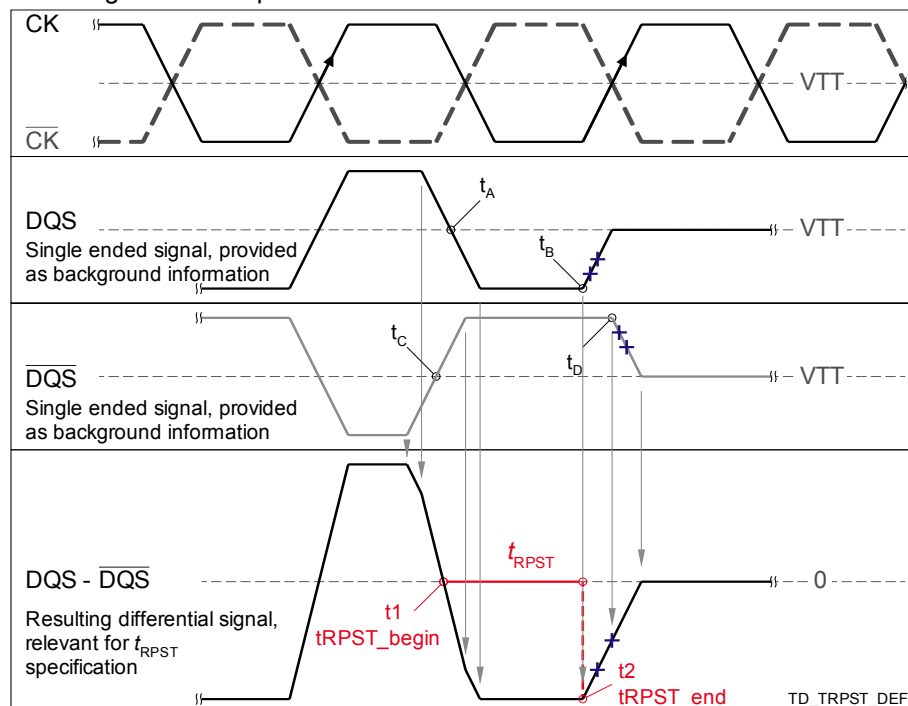


Figure 29 — Method for calculating tRPST transitions and endpoints

4.13 READ Operation (Cont'd)
4.13.2 READ Timing Definitions (Cont'd)

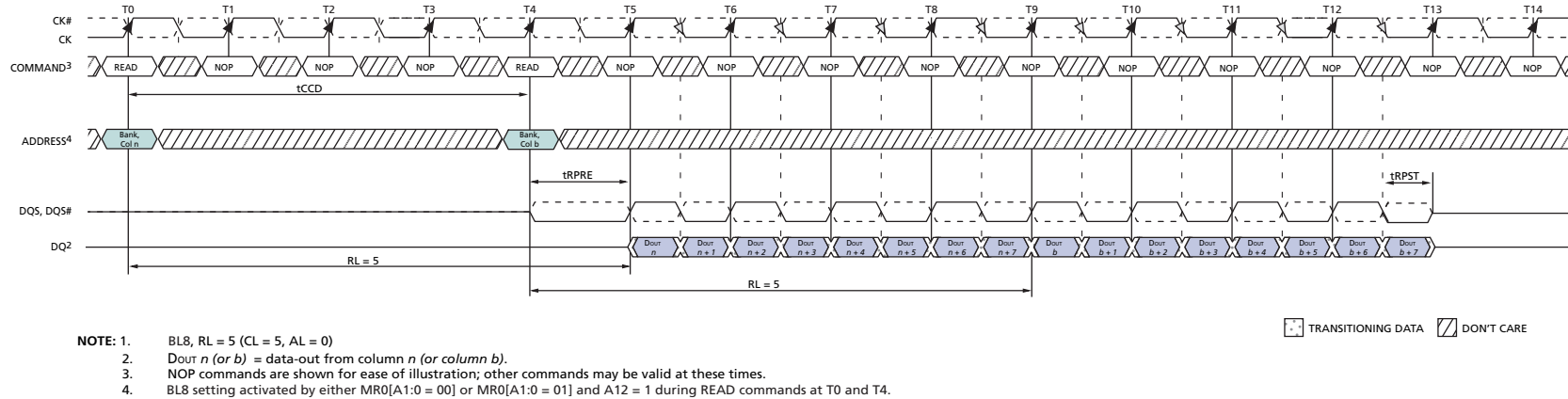


Figure 30 — READ (BL8) to READ (BL8)

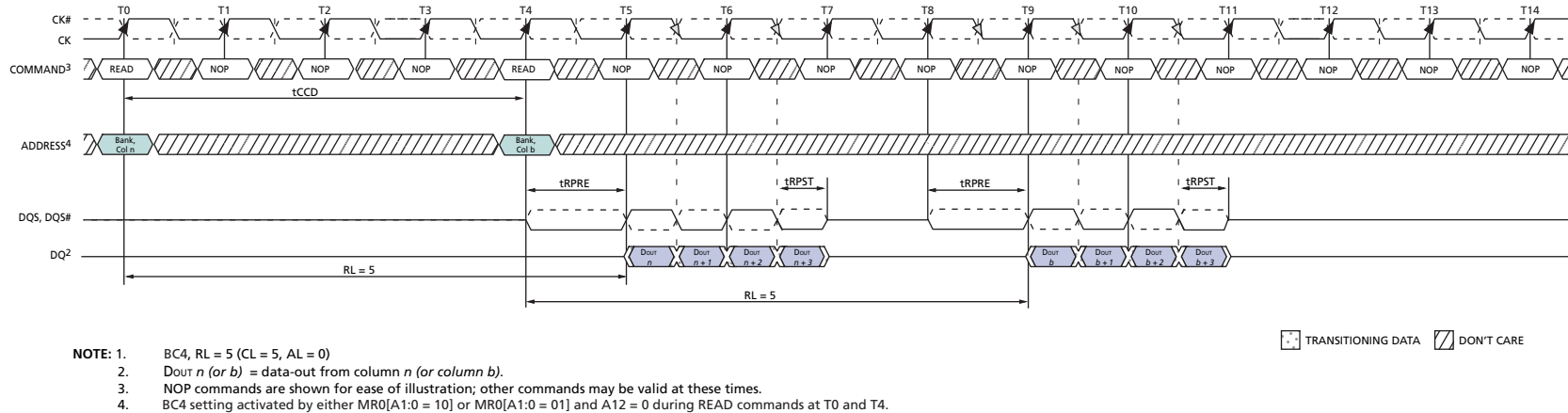
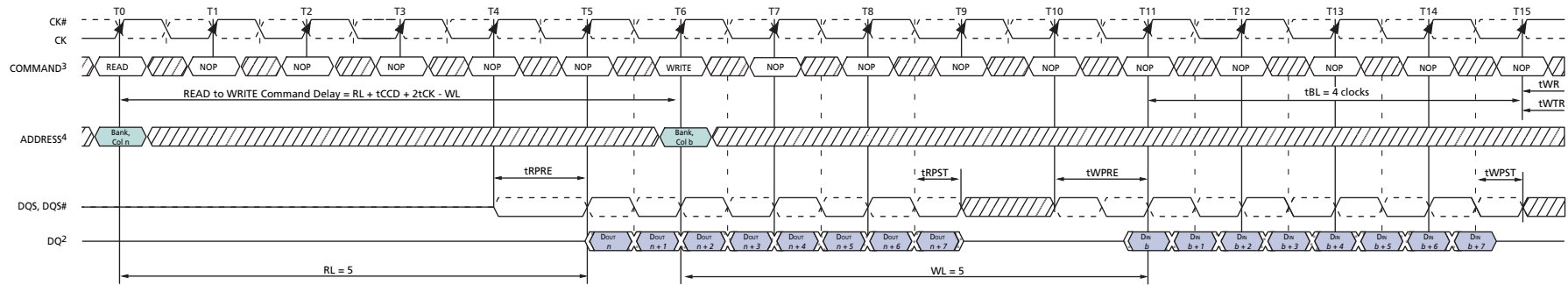


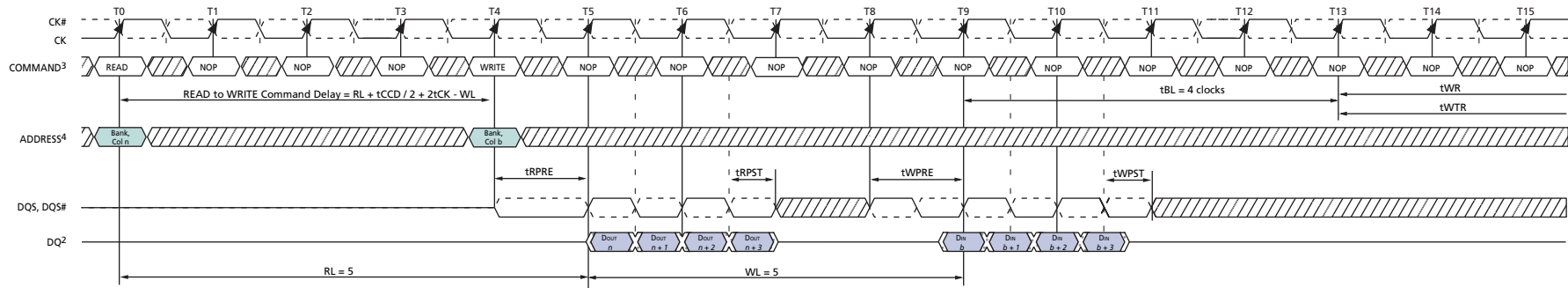
Figure 31 — READ (BC4) to READ (BC4)



- NOTE:** 1. BL8, RL = 5 (CL = 5, AL = 0), WL = 5 (CWL = 5, AL = 0)
2. Dout *n* = data-out from column, Din *b* = data-in from column *b*.
3. NOP commands are shown for ease of illustration; other commands 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 READ command at T0 and WRITE command at T6.

TRANSITIONING DATA DONT CARE

Figure 32 — READ (BL8) to WRITE (BL8)

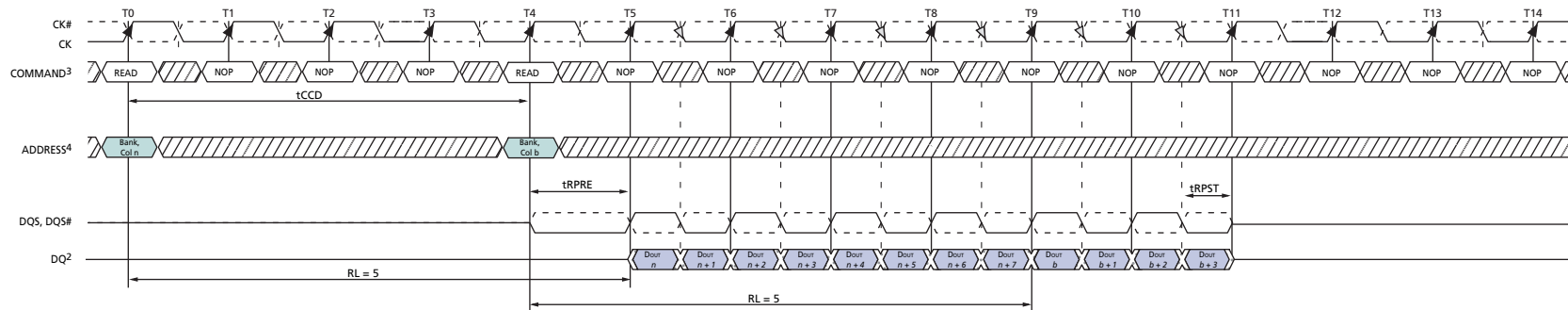


- NOTE:** 1. BC4, RL = 5 (CL = 5, AL = 0), WL = 5 (CWL = 5, AL = 0)
2. Dout *n* = data-out from column, Din *b* = data-in from column *b*.
3. NOP commands are shown for ease of illustration; other commands may be valid at these times.
4. BC4 setting activated by MR0[A1:0 = 01] and A12 = 0 during READ command at T0 and WRITE command at T4.

TRANSITIONING DATA DONT CARE

Figure 33 — READ (BC4) to WRITE (BC4) OTF

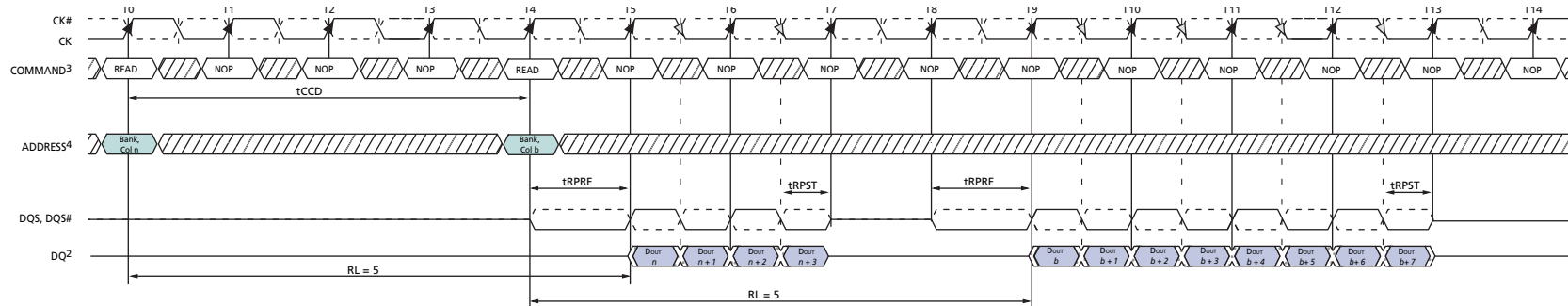
4.13 READ Operation (Cont'd)
4.13.2 READ Timing Definitions (Cont'd)



- NOTE:** 1. $RL = 5$ ($CL = 5$, $AL = 0$)
2. $Dout\ n$ (or b) = data-out from column n (or column b).
3. NOP commands are shown for ease of illustration; other commands may be valid at these times.
4. BL8 setting activated by $MR0[A1:0 = 01]$ and $A12 = 1$ during READ command at $T0$.
BC4 setting activated by $MR0[A1:0 = 01]$ and $A12 = 0$ during READ command at $T4$.

TRANSITIONING DATA / DON'T CARE

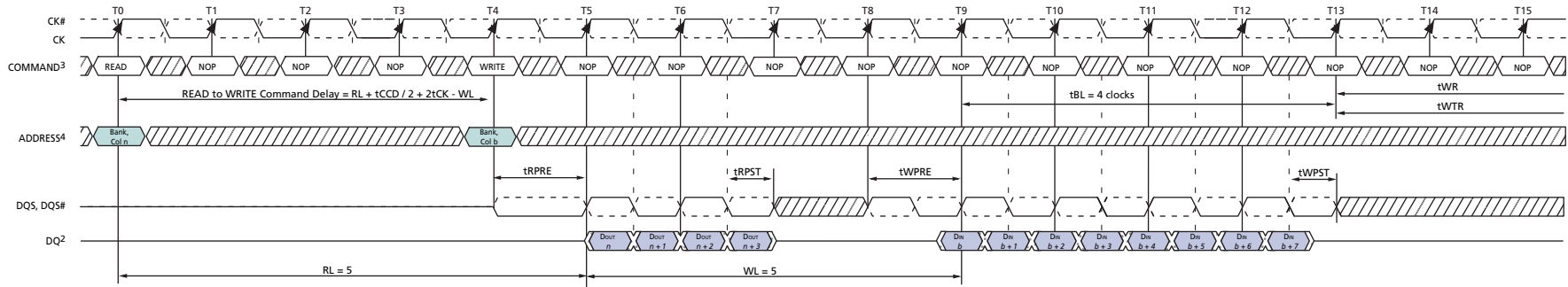
Figure 34 — READ (BL8) to READ (BC4) OTF



- NOTE:** 1. $RL = 5$ ($CL = 5$, $AL = 0$)
2. $Dout\ n$ (or b) = data-out from column n (or column b).
3. NOP commands are shown for ease of illustration; other commands may be valid at these times.
4. BC4 setting activated by $MR0[A1:0 = 01]$ and $A12 = 0$ during READ command at $T0$.
BL8 setting activated by $MR0[A1:0 = 01]$ and $A12 = 1$ during READ command at $T4$.

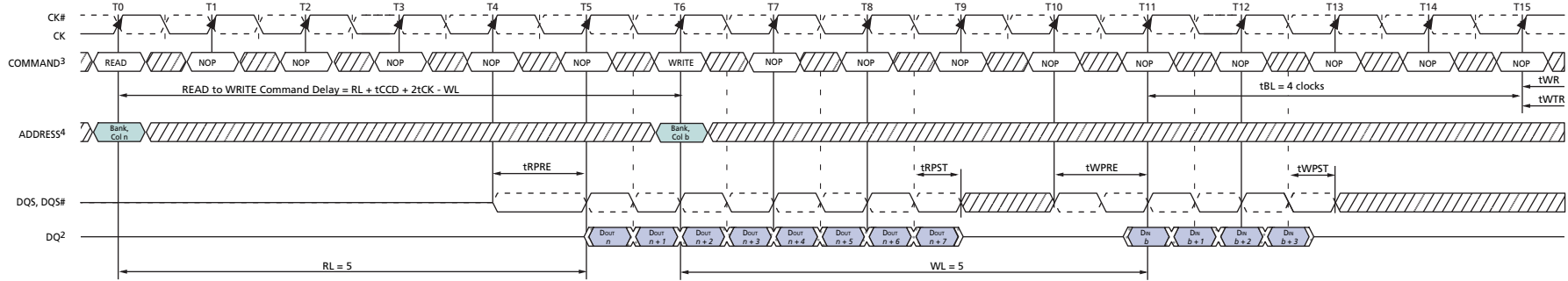
TRANSITIONING DATA / DON'T CARE

Figure 35 — READ (BC4) to READ (BL8) OTF



- NOTE:** 1. RL = 5 (CL = 5, AL = 0), WL = 5 (CWL = 1, AL = 0)
2. Dout n = data-out from column, Din b = data-in from column b.
3. NOP commands are shown for ease of illustration; other commands may be valid at these times.
4. BC4 setting activated by MR0[A1:0 = 01] and A12 = 0 during READ command at T0.
BL8 setting activated by MR0[A1:0 = 01] and A12 = 1 during WRITE command at T4.

Figure 36 — READ (BC4) to WRITE (BL8) OTF



- NOTE:** 1. RL = 5 (CL = 5, AL = 0), WL = 5 (CWL = 5, AL = 0)
2. Dout n = data-out from column, Din b = data-in from column b.
3. NOP commands are shown for ease of illustration; other commands may be valid at these times.
4. BL8 setting activated by MR0[A1:0 = 01] and A12 = 1 during READ command at T0.
BC4 setting activated by MR0[A1:0 = 01] and A12 = 0 during WRITE command at T6.

Figure 37 — READ (BL8) to WRITE (BC4) OTF

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.14 WRITE Operation

4.14.1 DDR3 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 is used only for burst length control, not as a column address.

4.14.2 WRITE Timing Violations

4.14.2.1 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 desirable 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.

4.14.2.2 Data Setup and Hold Violations

Should the data to strobe timing requirements (tDS, tDH) 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 this WRITE command.

In the example (Figure 38 on page 63), the relevant strobe edges for write burst A are associated with the clock edges: T5, T5.5, T6, T6.5, T7, T7.5, T8, T8.5.

Subsequent reads from that location might result in unpredictable read data, however the DRAM will work properly otherwise.

4.14.2.3 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.

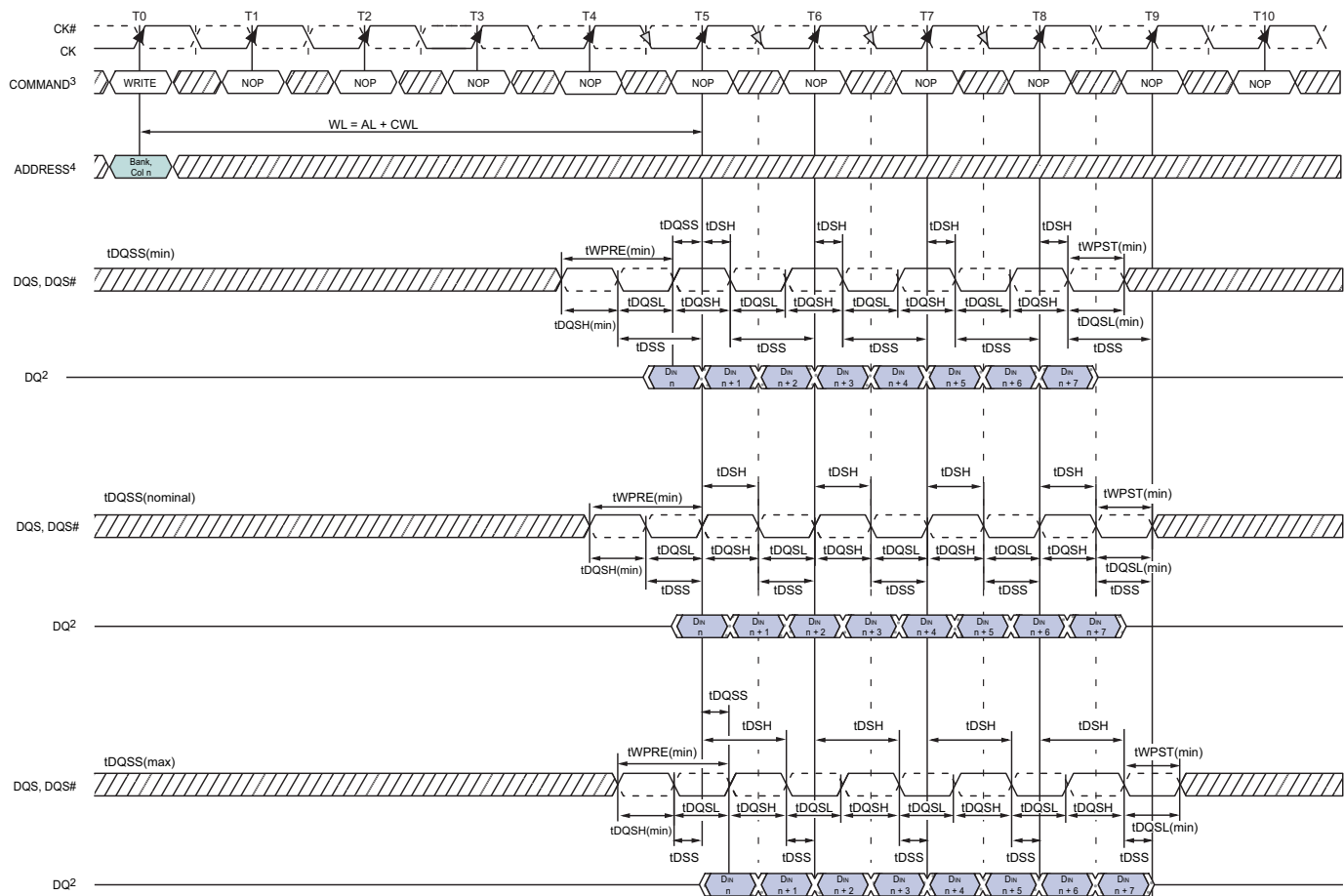
In the example (Figure 4.14.2.4 on page 62) the relevant strobe edges for Write burst A are associated with the clock edges: T4, T4.5, T5, T5.5, T6, T6.5, T7, T7.5, T8, T8.5 and T9. Any timing requirements starting or ending on one of these strobe edges need to be fulfilled for a valid burst. For Write burst B the relevant edges are T8, T8.5, T9, T9.5, T10, T10.5, T11, T11.5, T12, T12.5 and T13. Some edges are associated with both bursts.

4.14.2.4 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).]

4.14 WRITE Operation (Cont'd)

4.14.2 Write Timing Parameters (Cont'd)



- NOTE: 1. BL8, WL = 5 (AL = 0, CWL = 5)
2. DIN n = data-in from column n.
3. NOP commands are shown for ease of illustration; other commands 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.
5. tDQSS must be met at each rising clock edge.

 TRANSITIONING DATA DON'T CARE

Figure 38 — Write Timing Definition and Parameters

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.14 WRITE Operation (Cont'd)

4.14.3 tWPRE Calculation

Method for calculating differential pulse widths for tWPRE is shown in Figure 1.

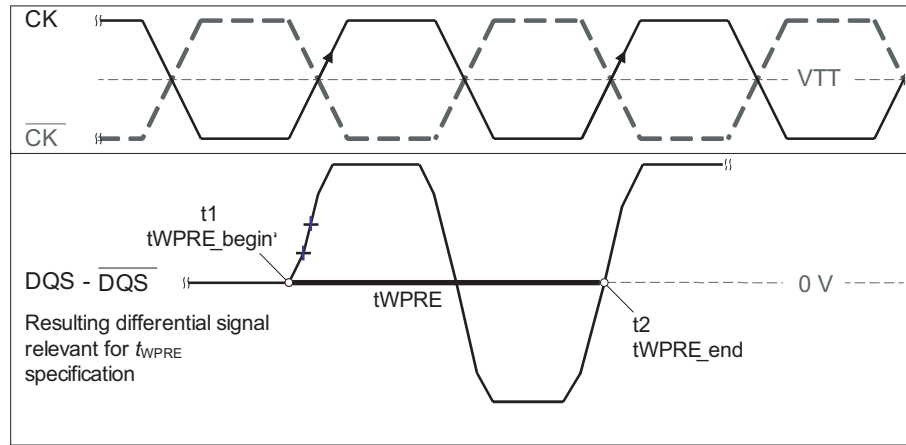


Figure 39 — Method for calculating tWPRE transitions and endpoints

4.14.4 tWPST Calculation

Method for calculating differential pulse widths for tWPST is shown in Figure 2.

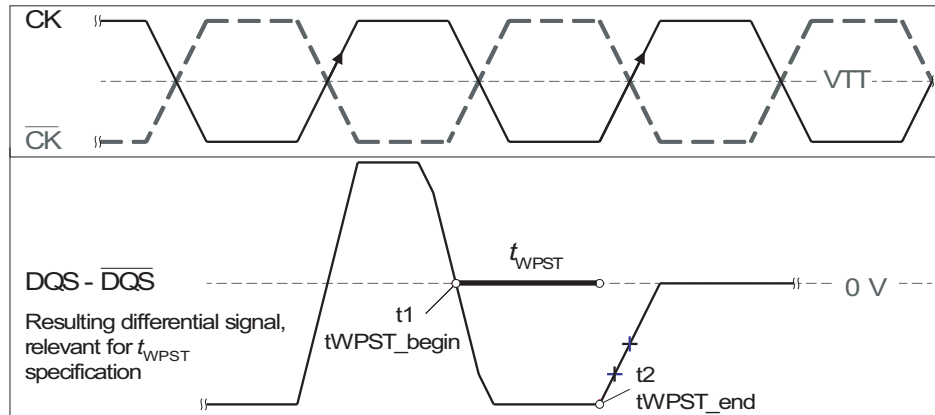
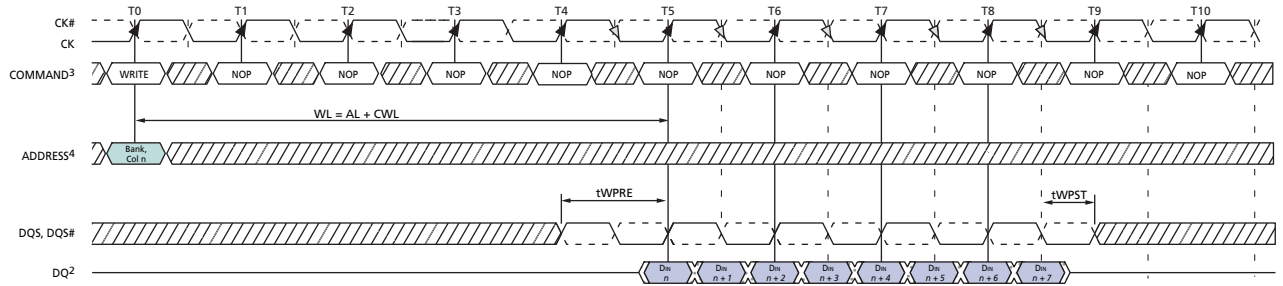


Figure 40 — Method for calculating tWPST transitions and endpoints

4.14 WRITE Operation (Cont'd)

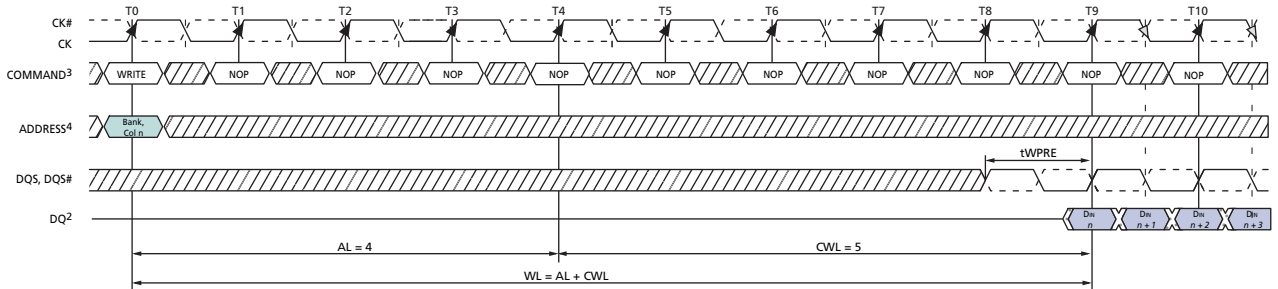
4.14.4 tWPST Calculation (Cont'd)



- NOTE: 1. BL8, WL = 5; AL = 0, CWL = 5.
2. Din n = data-in from column n.
3. NOP commands are shown for ease of illustration; other commands 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.

TRANSITIONING DATA DON'T CARE

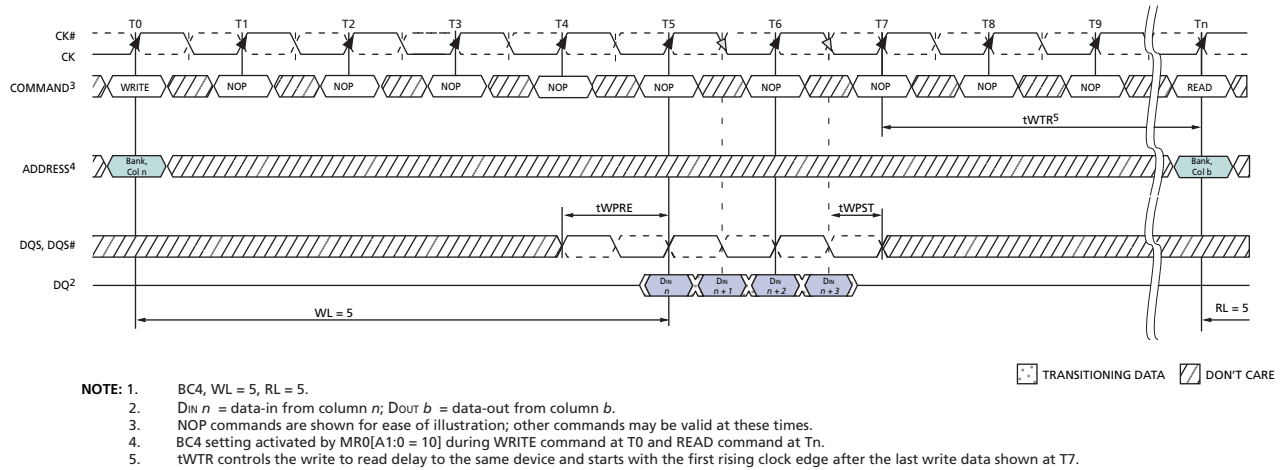
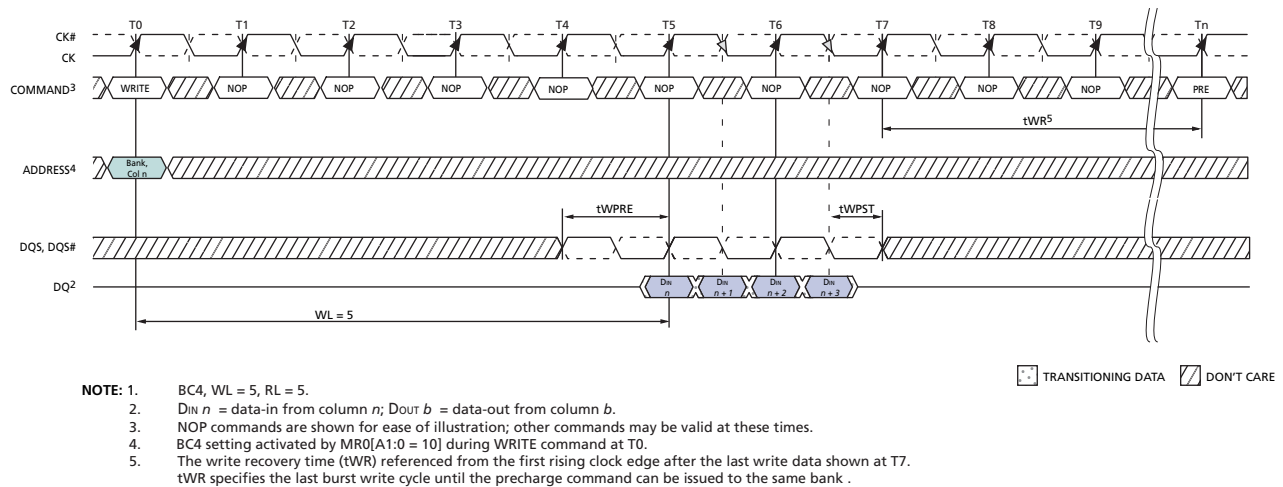
Figure 41 — WRITE Burst Operation WL = 5 (AL = 0, CWL = 5, BL8)

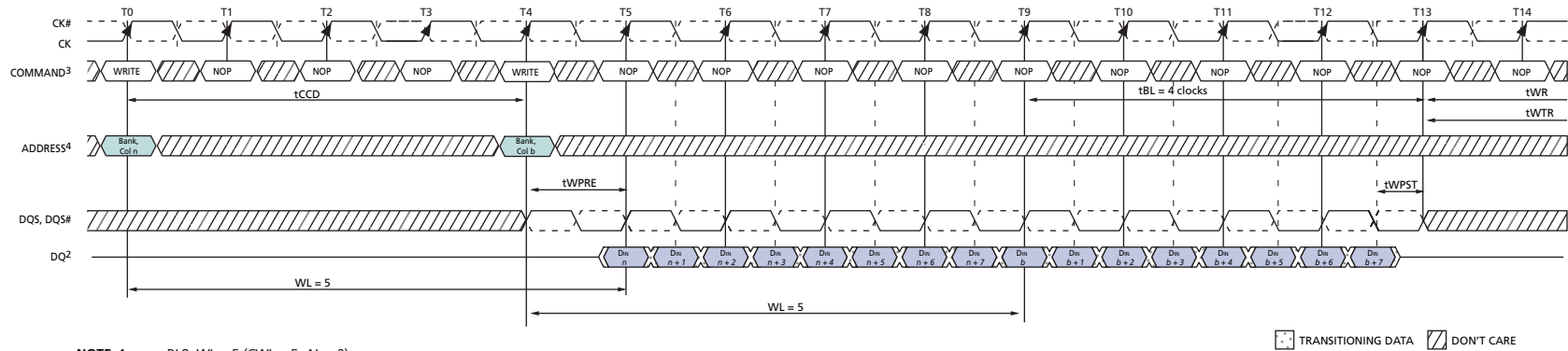


- NOTE: 1. BL8, WL = 9; AL = (CL - 1), CL = 5, CWL = 5.
2. Din n = data-in from column n.
3. NOP commands are shown for ease of illustration; other commands may be valid at these times.
4. BL8 setting activated by either MR0[A1:0 = 00] or MR0[A1:0 = 01] and A12 = 1 during WRITE command at T0.

TRANSITIONING DATA DON'T CARE

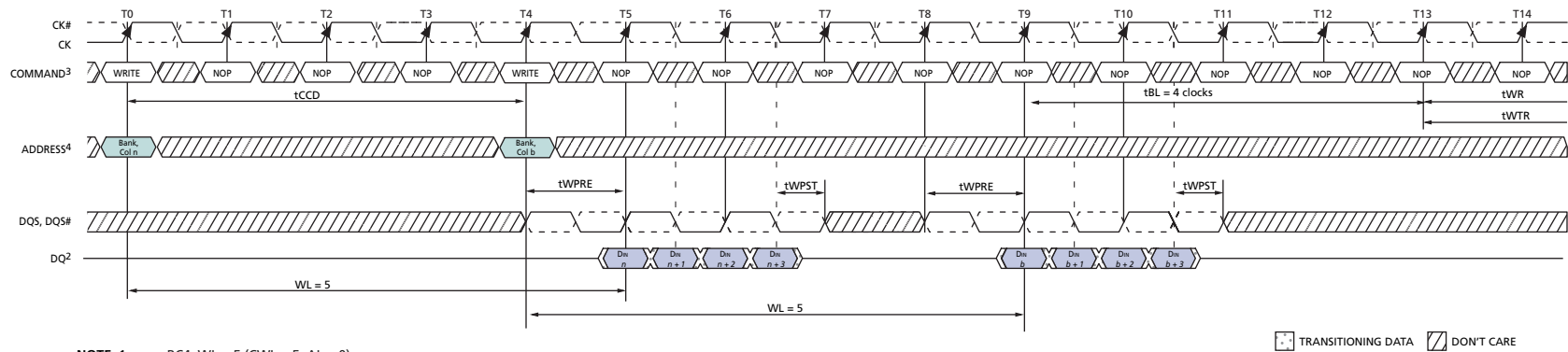
Figure 42 — WRITE Burst Operation WL = 9 (AL = CL-1, CWL = 5, BL8)

4.14 WRITE Operation (Cont'd)**4.14.4 tWPST Calculation (Cont'd)****Figure 43 — WRITE (BC4) to READ (BC4) Operation****Figure 44 — WRITE (BC4) to PRECHARGE Operation**



- NOTE:** 1. BL8, WL = 5 (CWL = 5, AL = 0)
2. $D_{IN\ n}$ (or b) = data-in from column n (or column b).
3. NOP commands are shown for ease of illustration; other commands 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 and T4.

Figure 45 — WRITE (BL8) to WRITE (BL8)



- NOTE:** 1. BC4, WL = 5 (CWL = 5, AL = 0)
2. $D_{IN\ n}$ (or b) = data-in from column n (or column b).
3. NOP commands are shown for ease of illustration; other commands may be valid at these times.
4. BC4 setting activated by $MR0[A1:0 = 01]$ and $A12 = 0$ during WRITE command at T0 and T4.

Figure 46 — WRITE (BC4) to WRITE (BC4) OTF

4.14 WRITE Operation (Cont'd)
4.14.4 tWPST Calculation (Cont'd)

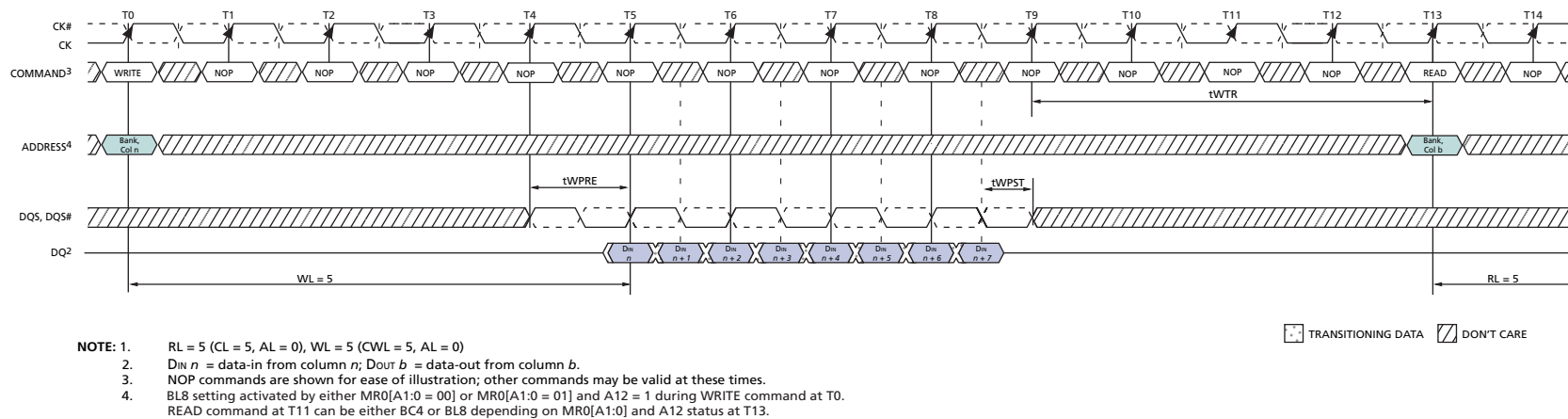


Figure 47 — WRITE (BL8) to READ (BC4/BL8) OTF

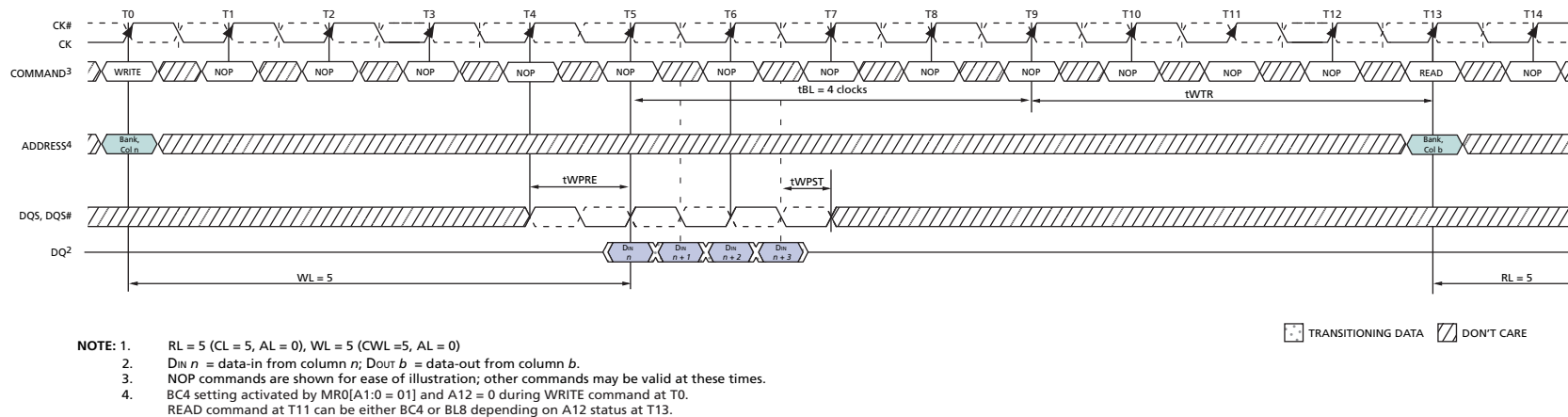
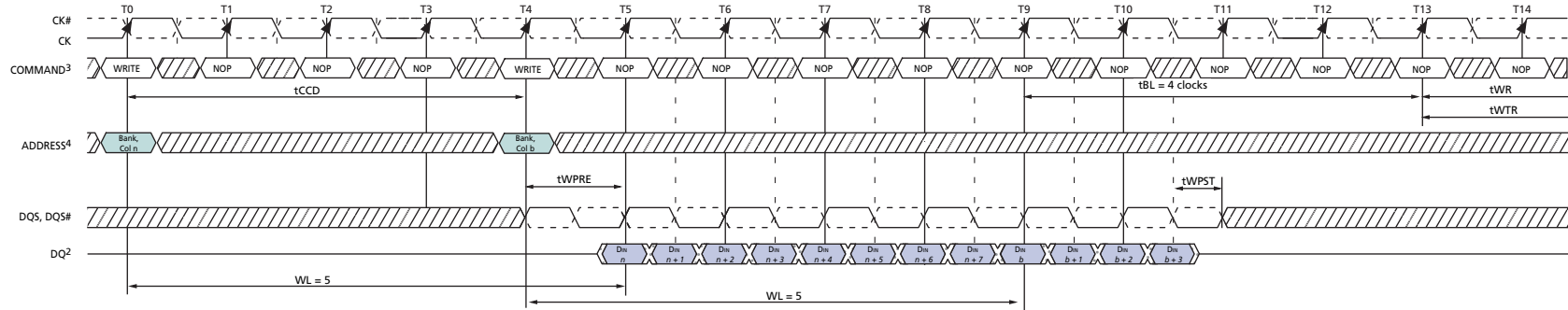


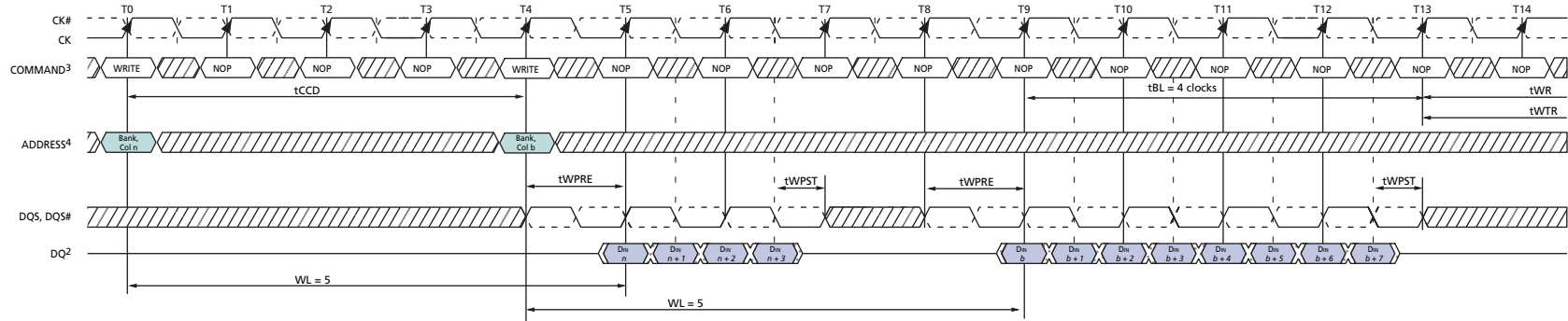
Figure 48 — WRITE (BC4) to READ (BC4/BL8) OTF



- NOTE:** 1. WL = 5 (CWL = 5, AL = 0)
2. D_{IN} *n* (or *b*) = data-in from column *n* (or column *b*).
3. NOP commands are shown for ease of illustration; other commands may be valid at these times.
4. BL8 setting activated by MR0[A1:0 = 01] and A12 = 1 during WRITE command at T0.
BC4 setting activated by MR0[A1:0 = 01] and A12 = 0 during WRITE command at T4.

TRANSITIONING DATA / DON'T CARE

Figure 49 — WRITE (BL8) to WRITE (BC4) OTF



- NOTE:** 1. WL = 5 (CWL = 5, AL = 0)
2. D_{IN} *n* (or *b*) = data-in from column *n* (or column *b*).
3. NOP commands are shown for ease of illustration; other commands may be valid at these times.
4. BC4 setting activated by MR0[A1:0 = 01] and A12 = 0 during WRITE command at T0.
BL8 setting activated by MR0[A1:0 = 01] and A12 = 1 during WRITE command at T4.

TRANSITIONING DATA / DON'T CARE

Figure 50 — WRITE (BC4) to WRITE (BL8) OTF

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.15 Self-Refresh Operation

The Self-Refresh command can be used to retain data in the DDR3 SDRAM, even if the rest 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 CS#, RAS#, CAS#, and CKE held low with WE# high at the rising edge of the clock.

Before issuing the Self-Refresh-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, except CKE and 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 operation.

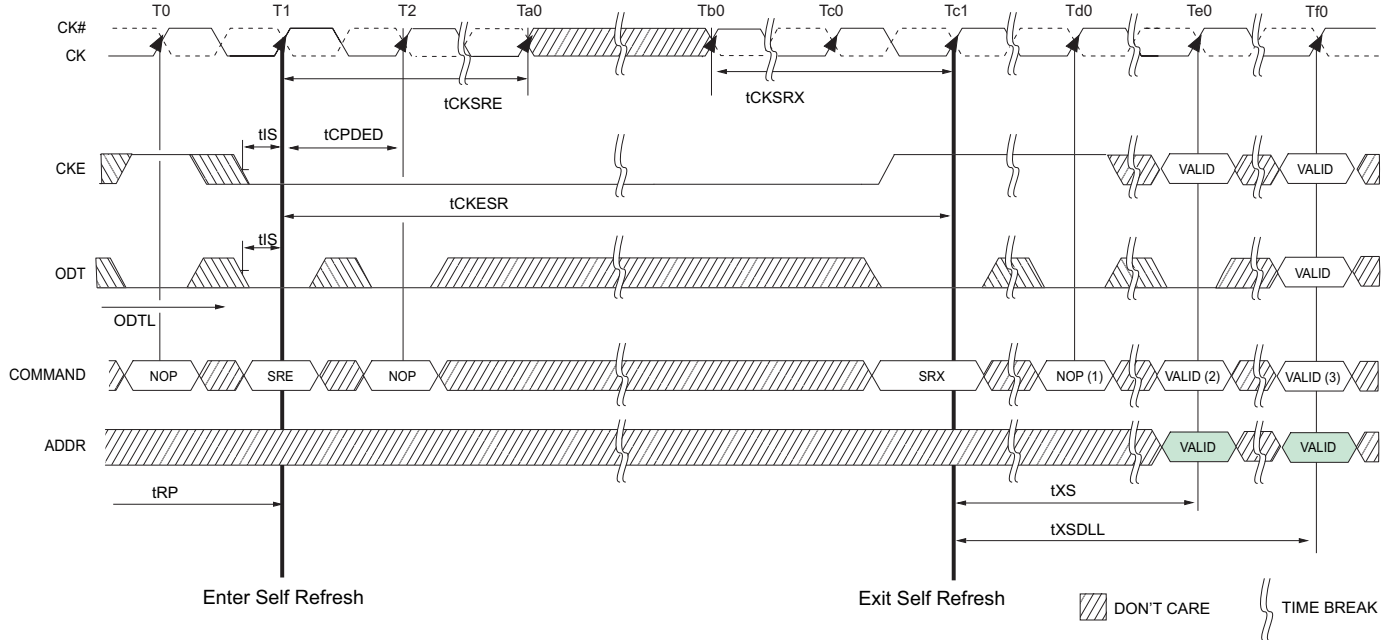
The procedure for exiting Self-Refresh requires a sequence of events. First, the clock must be stable prior to CKE going back HIGH. Once a Self-Refresh Exit command (SRX, combination of CKE going high and either NOP or Deselect on command bus) is registered, a delay of at least tXS must be satisfied 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.

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.15 Self-Refresh Operation (Cont'd)

The use of Self-Refresh mode introduces the possibility that an internally timed 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.



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

Figure 51 — Self-Refresh Entry/Exit Timing

4 DDR3 SDRAM Command Description and Operation (Cont'd)

4.16 Power-Down Modes

4.16.1 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 operations 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 operations. Timing diagrams are shown in Figures 52 through Figures 64 with details for entry and exit of Power-Down.

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, CK#, ODT, CKE and 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.

Table 14 — 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 Precharged)	0	Off	Slow	tXP to any valid command. Since it is in precharge state, commands here will be ACT, REF, MRS, PRE or PREA. tXPDLL to commands that need the DLL to operate, such as RD, RDA or ODT control line.
Precharged (All banks Precharged)	1	On	Fast	tXP to any valid command.

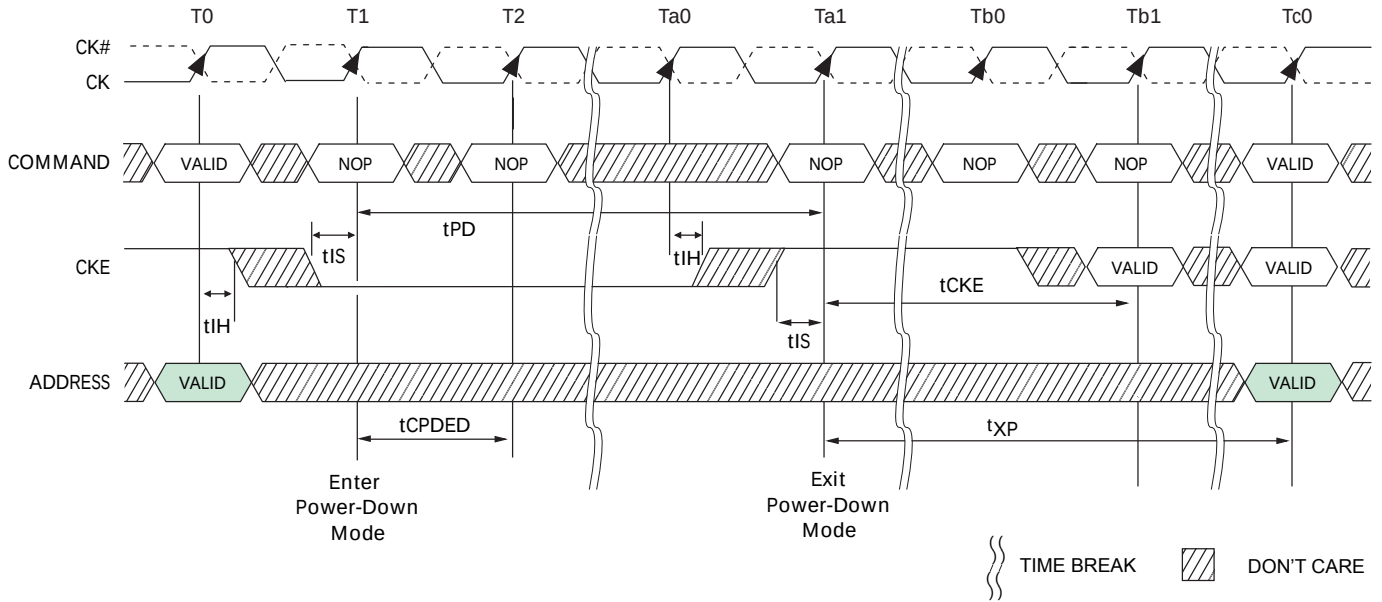
Also, the DLL is disabled upon entering precharge power-down (Slow Exit Mode), but the DLL is kept enabled during precharge power-down (Fast Exit Mode) or active power-down. In power-down mode, CKE low, RESET# high and a stable clock signal must be maintained at the inputs of the DDR3 SDRAM, and ODT should be in a valid state but all other input signals are "Don't Care" (If RESET# goes low during Power-Down, the DRAM will be out of PD mode and into reset state.) CKE low must be maintained 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 data sheet.

Active Power Down Entry and Exit timing diagram example is shown in Figure 52. Timing Diagrams for CKE with PD Entry, PD Exit with Read and Read with Auto Precharge, Write, Write with Auto Precharge, Activate, Precharge, Refresh, and MRS are shown in Figure 53 through Figure 61. Additional clarifications are shown in Figure 62 through Figure 64.

4.16 Power-Down Modes (Cont'd)

4.16.1 Power-Down Entry and Exit (Cont'd)



Note: VALID command at T0 is ACT, NOP, DES or PRE with still one bank remaining open after completion of the precharge command.

Figure 52 — Active Power-Down Entry and Exit Timing Diagram

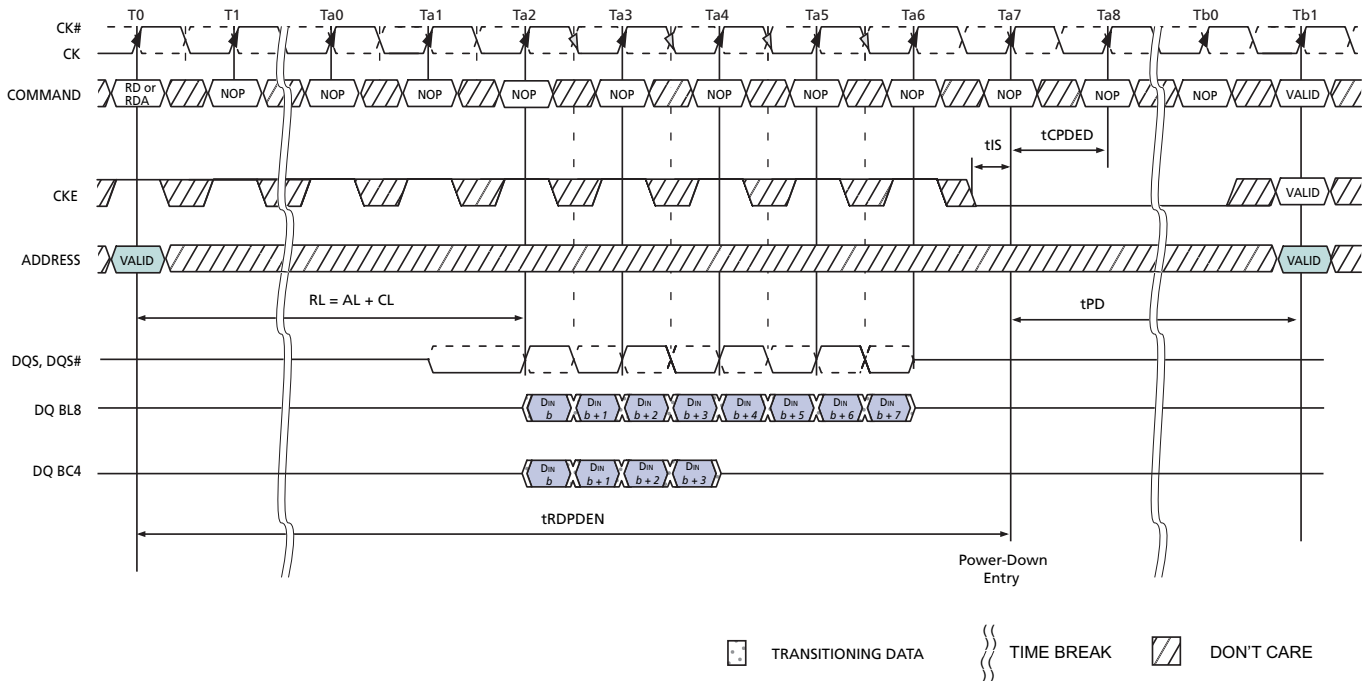
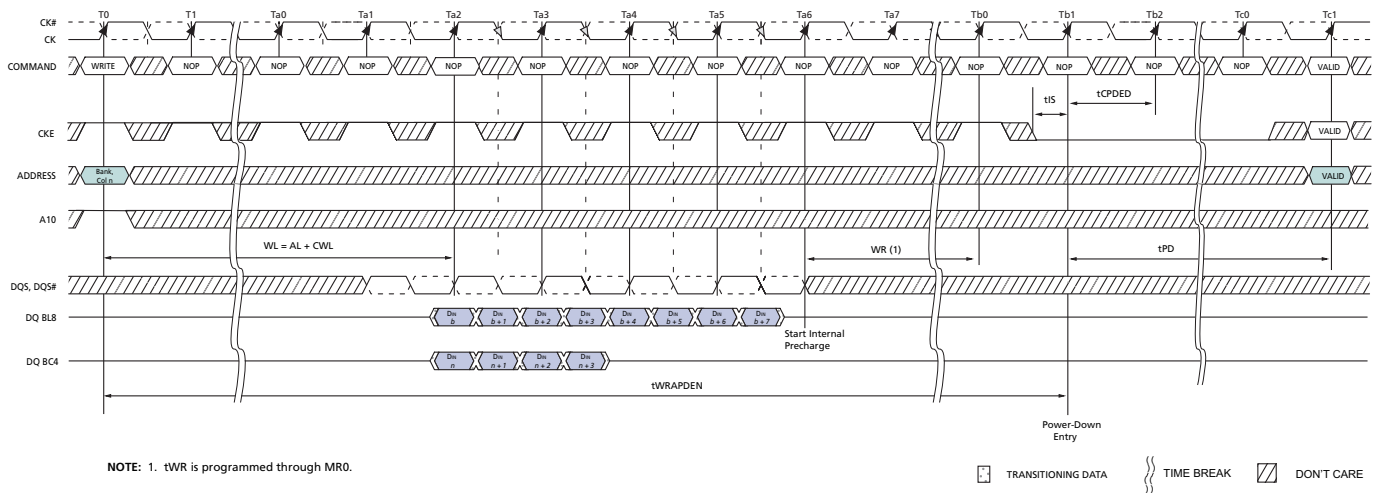
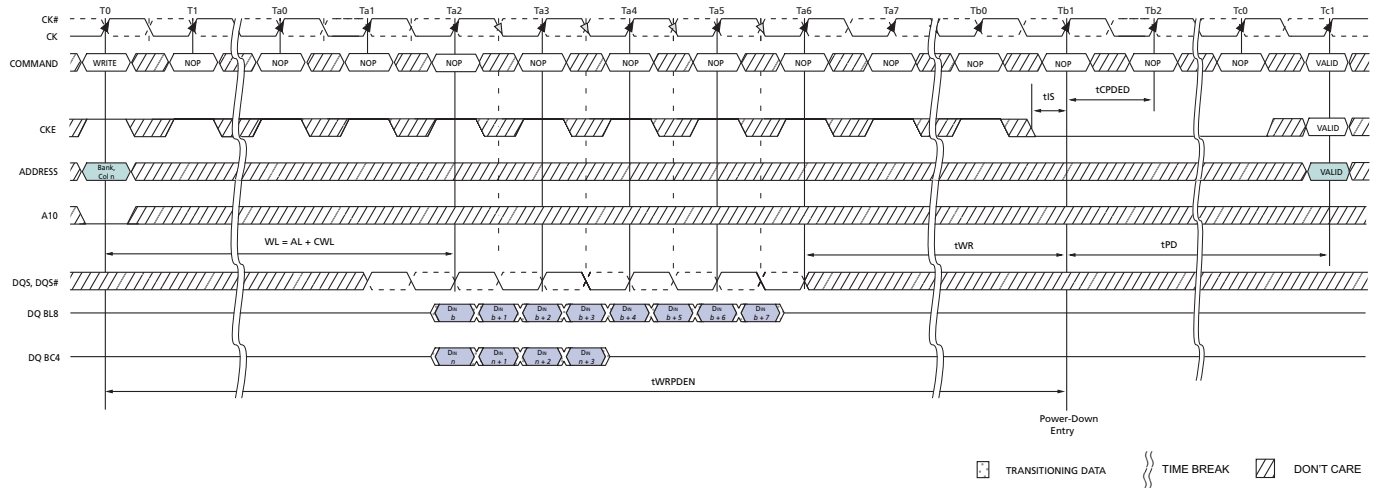


Figure 53 — Power-Down Entry after Read and Read with Auto Precharge

4.16 Power-Down Modes (Cont'd)**4.16.1 Power-Down Entry and Exit (Cont'd)****Figure 54 — Power-Down Entry after Write with Auto Precharge****Figure 55 — Power-Down Entry after Write**

4.16 Power-Down Modes (Cont'd)

4.16.1 Power-Down Entry and Exit (Cont'd)

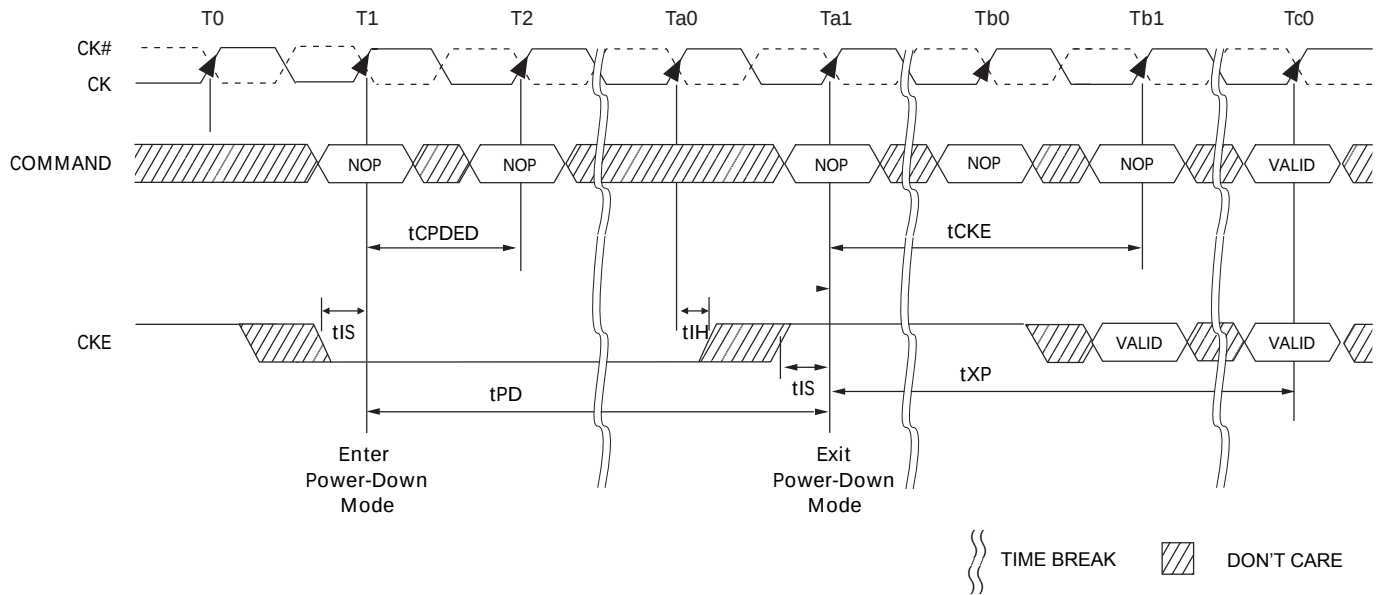


Figure 56 — Precharge Power-Down (Fast Exit Mode) Entry and Exit

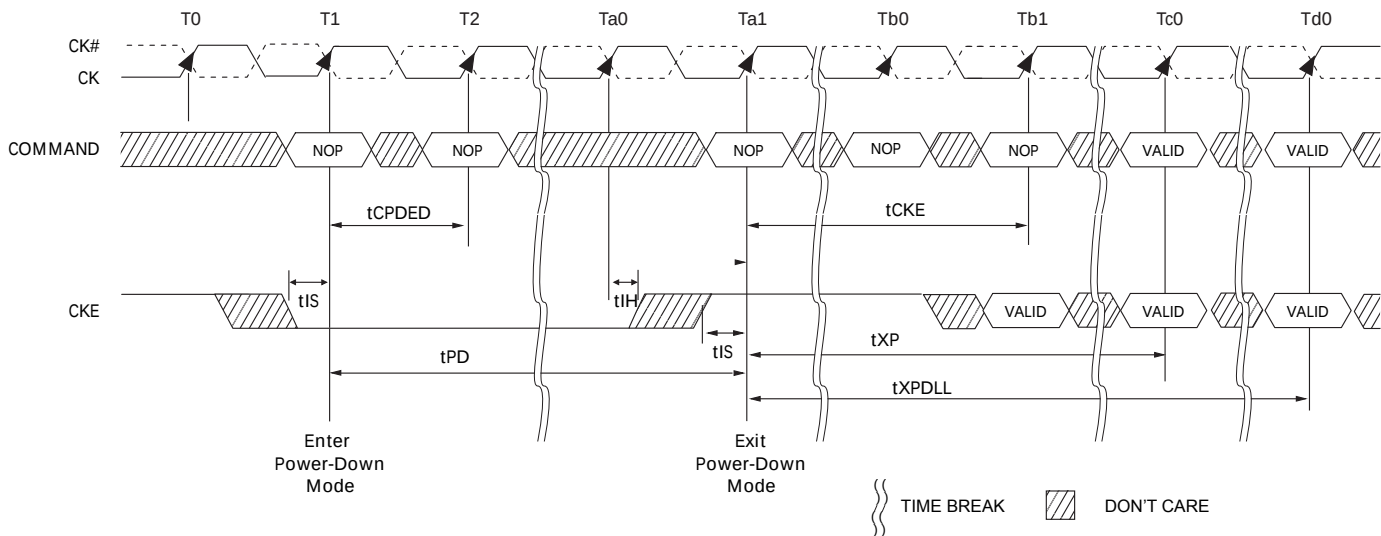


Figure 57 — Precharge Power-Down (Slow Exit Mode) Entry and Exit

4.16 Power-Down Modes (Cont'd)

4.16.1 Power-Down Entry and Exit (Cont'd)

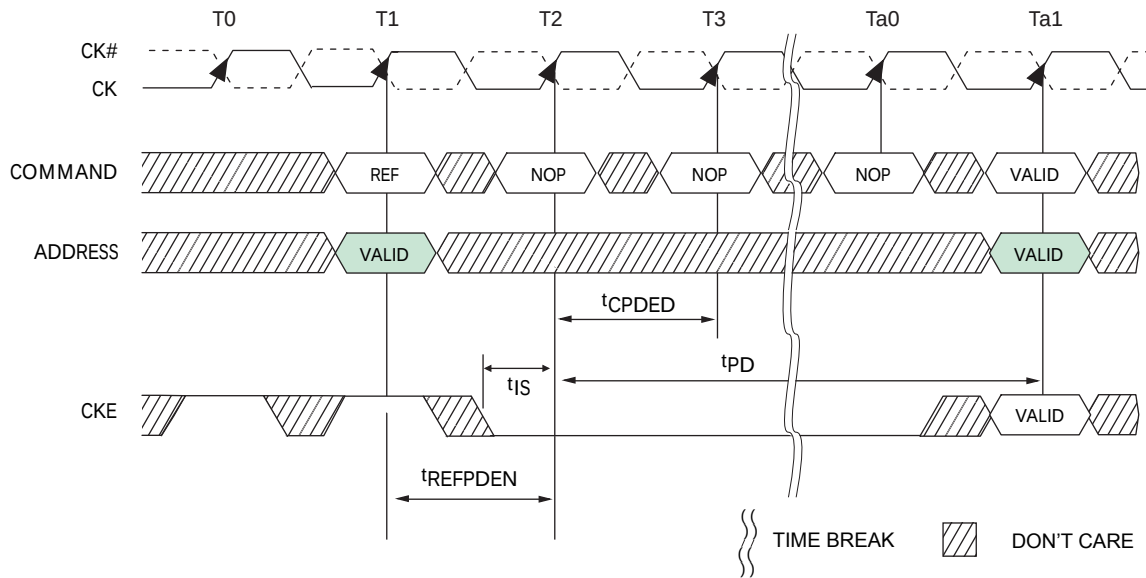


Figure 58 — Refresh Command to Power-Down Entry

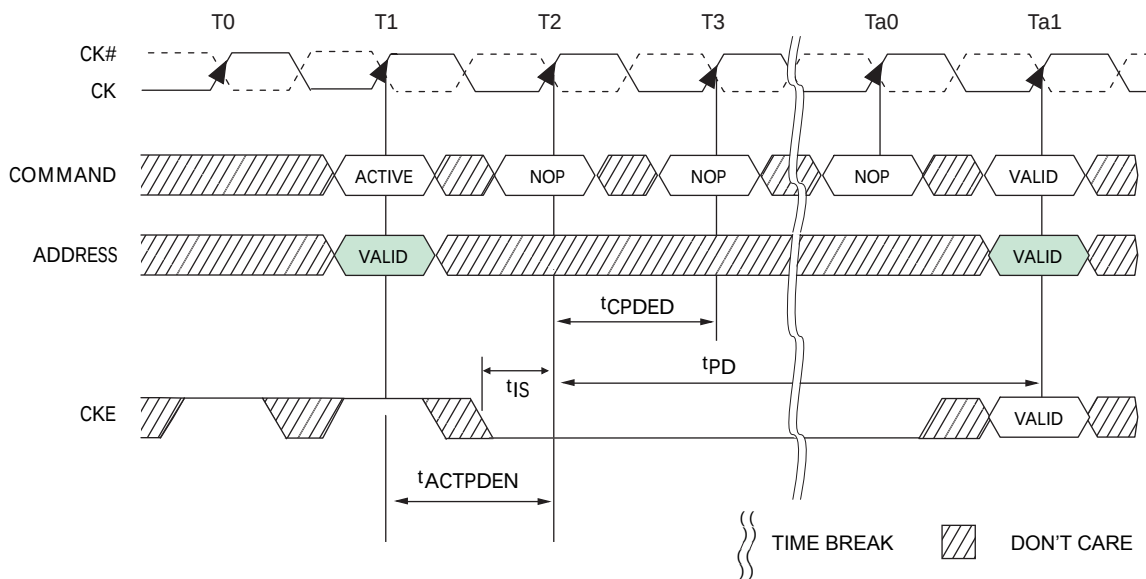


Figure 59 — Active Command to Power-Down Entry

4.16 Power-Down Modes (Cont'd)

4.16.1 Power-Down Entry and Exit (Cont'd)

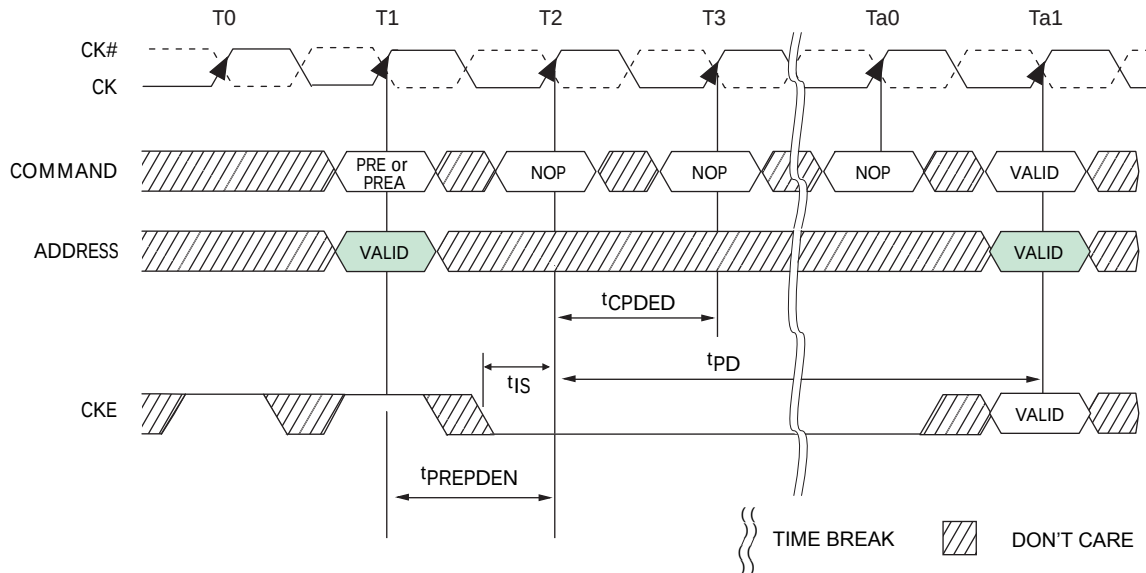


Figure 60 — Precharge / Precharge all Command to Power-Down Entry

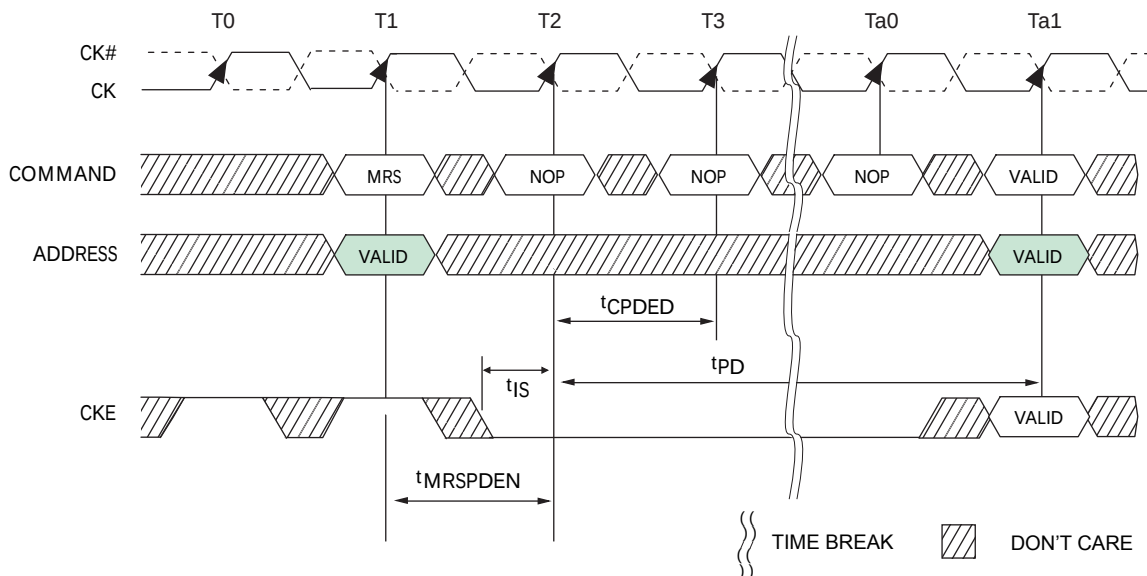


Figure 61 — MRS Command to Power-Down Entry

4.16.2 Power-Down clarifications - Case 1

When CKE is registered low for power-down entry, $t_{PD}(\text{min})$ must be satisfied before CKE can be registered high for power-down exit. The minimum value of parameter $t_{PD}(\text{min})$ is equal to the minimum value

4.16 Power-Down Modes (Cont'd)**4.16.2 Power-Down clarifications - Case 1 (Cont'd)**

of parameter $t_{CKE(min)}$ as shown in Table 67, Timing Parameters by Speed Bin. A detailed example of Case 1 is shown in Figure 62.)

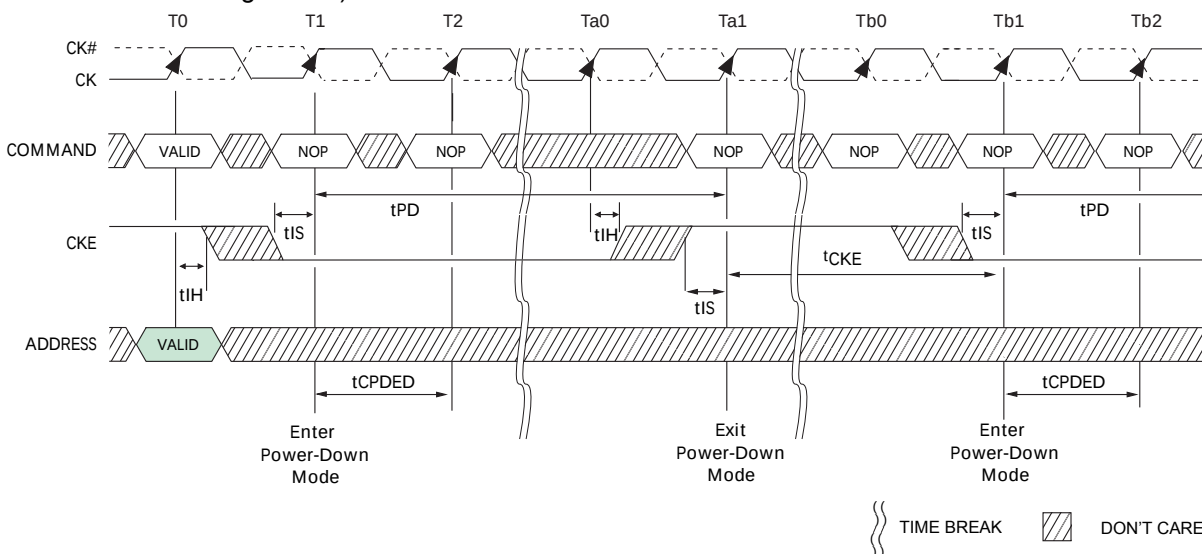


Figure 62 — Power-Down Entry/Exit Clarifications - Case 1

4.16.3 Power-Down clarifications - Case 2

For certain CKE intensive operations, for example, repeated 'PD Exit - Refresh - PD Entry' sequence, the number of clock cycles between PD Exit and PD Entry may be insufficient to keep the DLL updated. Therefore the following conditions must be met in addition to t_{CKE} in order to maintain proper DRAM operation when the Refresh command is issued between PD Exit and PD Entry. Power-down mode can be used in conjunction with the Refresh command if the following conditions are met: 1) t_{XP} must be satisfied before issuing the command. 2) t_{XPDLL} must be satisfied (referenced to the registration of PD Exit) before the next power-down can be entered. A detailed example of Case 2 is shown in Figure 63.

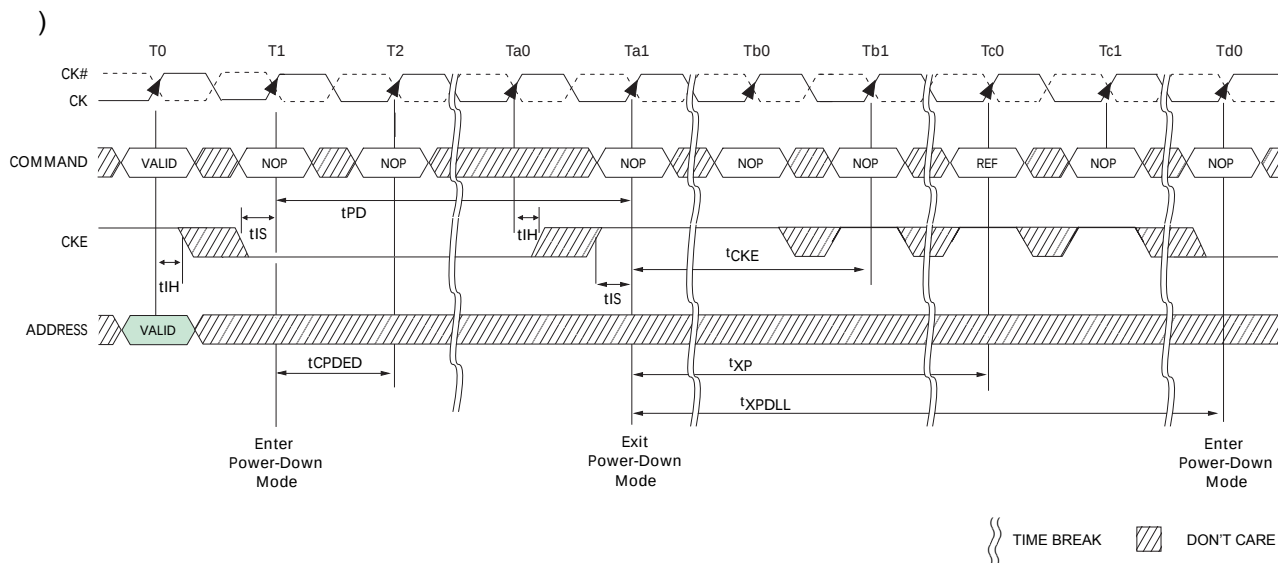


Figure 63 — Power-Down Entry/Exit Clarifications - Case 2

4.16 Power-Down Modes (Cont'd)

4.16.3 Power-Down clarifications - Case 2 (Cont'd)

4.16.4 Power-Down clarifications - Case 3

If an early PD Entry is issued after a Refresh command, once PD Exit is issued, NOP or DES with CKE High must be issued until $t_{RFC}(\min)$ from the Refresh command is satisfied. This means CKE can not be registered low twice within a $t_{RFC}(\min)$ window. A detailed example of Case 3 is shown in Figure 64.

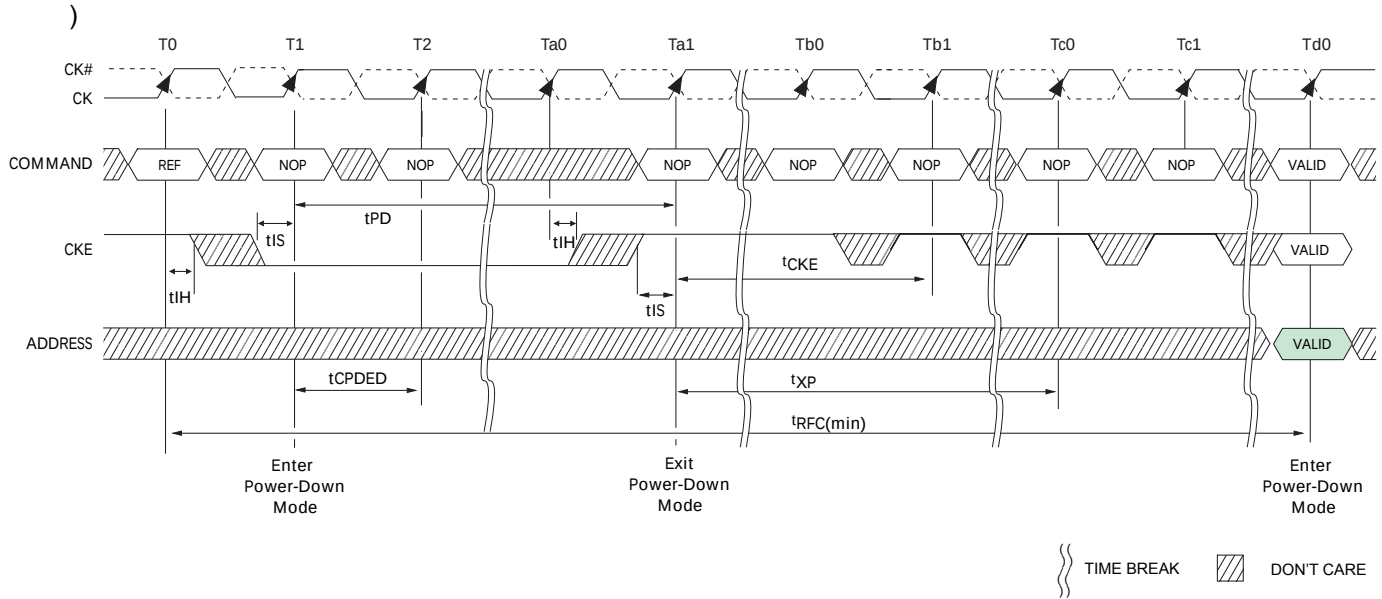


Figure 64 — Power-Down Entry/Exit Clarifications - Case 3

5 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, DQS# and DM for x4 and x8 configuration (and *TDQS, TDQS# for X8 configuration, when enabled via A11=1 in MR1*) via the ODT control pin. For x16 configuration, ODT is applied to each DQU, DQL, DQSU, DQSU#, DQSL, 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. More details about ODT control modes and ODT timing modes can be found further down in this document:

- The ODT control modes are described in 5.1.
- The ODT synchronous mode is described in 5.2
- The dynamic ODT feature is described in 5.3
- The ODT asynchronous mode is described in 5.4
- The transitions between ODT synchronous and asynchronous are described in 5.4.1 through 5.4.4

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

A simple functional representation of the DRAM ODT feature is shown in Figure 65.

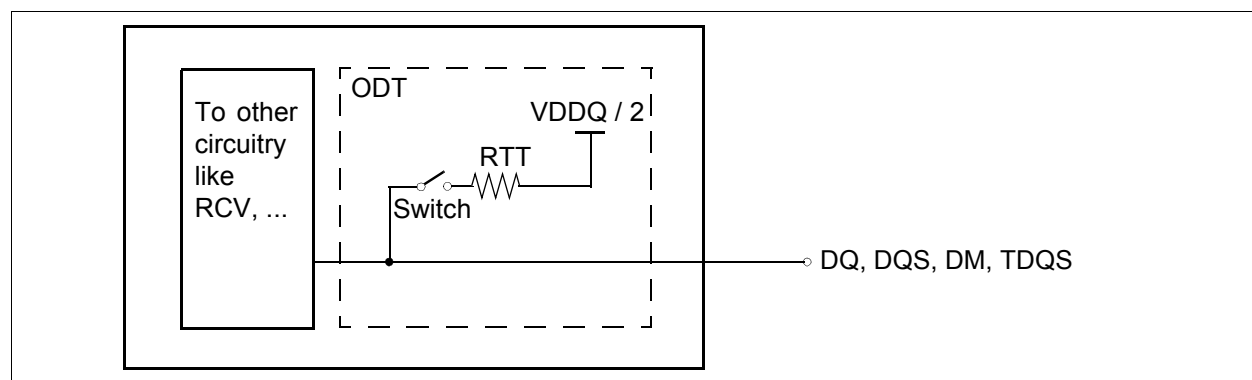


Figure 65 — Functional Representation of ODT

The switch is enabled by the internal ODT control logic, which uses the external ODT pin and other control information, see below. The value of RTT is determined by the settings of Mode Register bits (see Figure 7 on page 22 and Figure 8 on page 25). The ODT pin will be ignored if the Mode Registers MR1 and MR2 are programmed to disable ODT and in self-refresh mode.

5.1 ODT Mode Register and ODT Truth Table

The ODT Mode is enabled if any of MR1 {A9, A6, A2} or MR2 {A10, A9} are non zero. In this case, the value of RTT is determined by the settings of those bits (see Figure on page 22).

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.
- The Termination Truth Table is shown in Table 15.

Table 15 — Termination Truth Table

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

5 On-Die Termination (ODT) (Cont'd)

5.2 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)
- Precharge 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: ODTLon = WL - 2; ODTLoff = WL - 2 .

5.2.1 ODT Latency and Posted ODT

In Synchronous 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.

Table 16 — ODT Latency

Symbol	Parameter	DDR3-800	DDR3-1066	DDR3-1333	DDR3-1600	Unit
ODTLon	ODT turn on Latency	WL - 2 = CWL + AL - 2				t_{CK}
ODTLoff	ODT turn off Latency	WL - 2 = CWL + AL - 2				

5.2.2 Timing Parameters

In synchronous ODT mode, the following timing parameters apply (see also Figures 66):

ODTLon, ODTLoff, $t_{AON,min,max}$, $t_{AOF,min,max}$.

Minimum RTT turn-on time (t_{AONmin}) is the point in time when the device leaves high impedance and ODT resistance begins to turn on. Maximum RTT turn on time (t_{AONmax}) is the point in time when the ODT resistance is fully on. Both are measured from ODTLon.

Minimum RTT turn-off time (t_{AOFmin}) is the point in time when the device starts to turn off the ODT resistance. Maximum RTT turn off time (t_{AOFmax}) 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 ODTL4 is satisfied. If a Write command is registered by the SDRAM with ODT high, then ODT must remain high until ODTL4 (BL = 4) or ODTL8 (BL = 8) after the Write command (see Figure 67). ODTL4 and ODTL8 are measured from ODT registered high to ODT registered low or from the registration of a Write command until ODT is registered low.

5.2 Synchronous ODT Mode (Cont'd)
5.2.2 Timing Parameters (Cont'd)

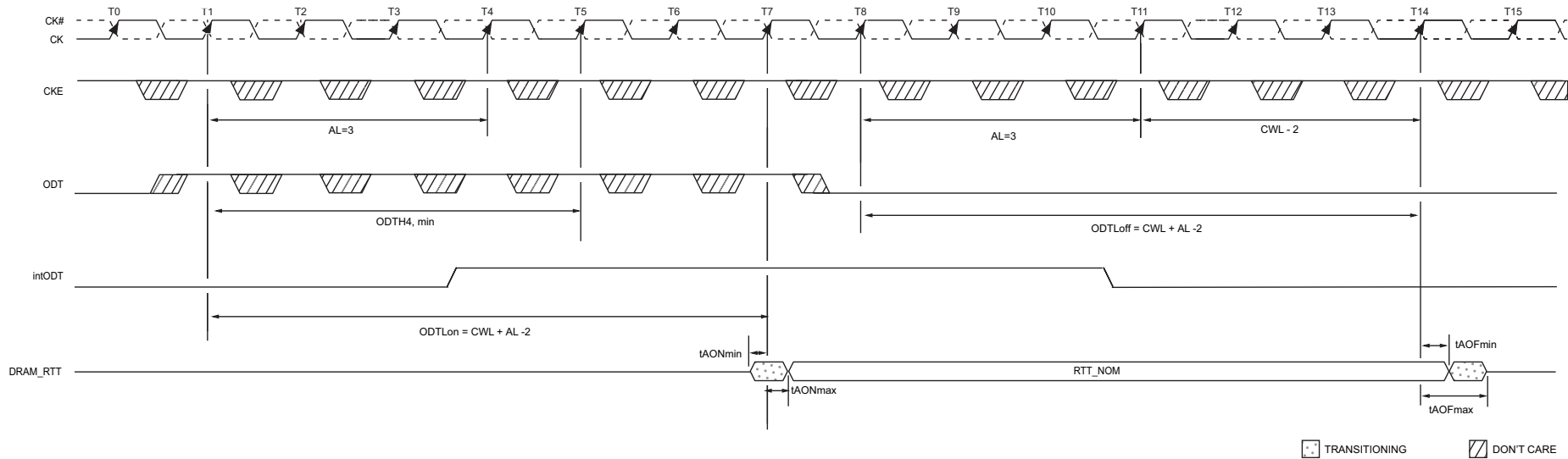


**Figure 66 — Synchronous ODT Timing Example for $AL = 3$; $CWL = 5$; $ODTLon = AL + CWL - 2 = 6.0$;
 $ODTLoff = AL + CWL - 2 = 6$**

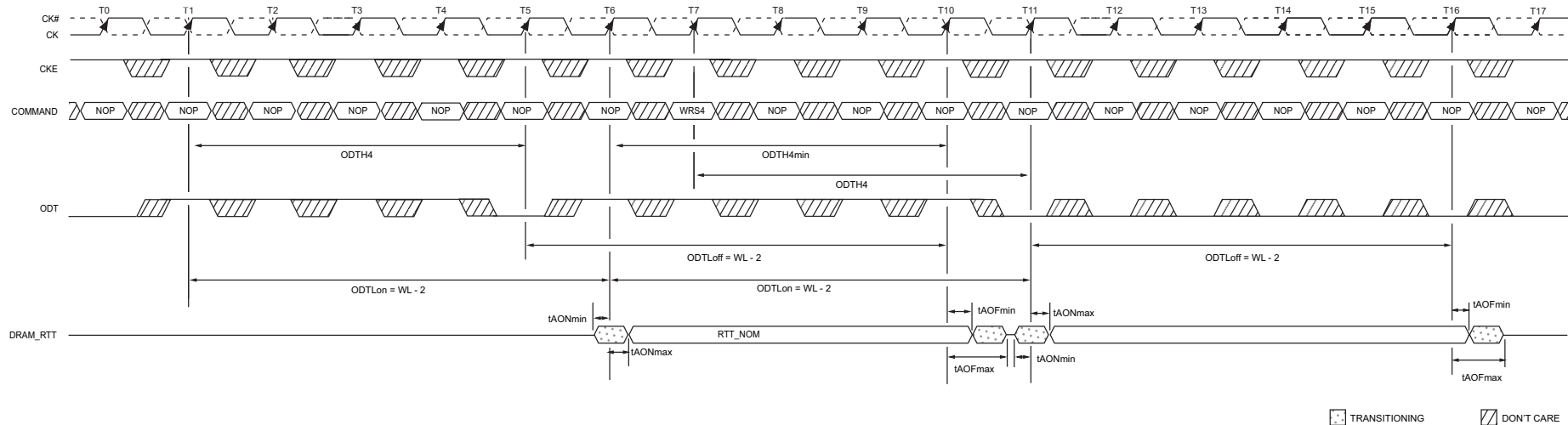


Figure 67 — Synchronous ODT example with BL = 4, WL = 7.

ODT must be held high for at least ODTL4 after assertion (T1); ODT must be kept high ODTL4 (BL = 4) or ODTL8 (BL = 8) after Write command (T7). ODTL 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 ODTL4 is satisfied from ODT registered high at T6 ODT must not go low before T11 as ODTL4 must also be satisfied from the registration of the Write command at T7.

5.2.3 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 example below. As shown in Figure 68 below at cycle T15, 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 timing 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 in Figure 68.

5.2 Synchronous ODT Mode (Cont'd)
5.2.2 Timing Parameters (Cont'd)

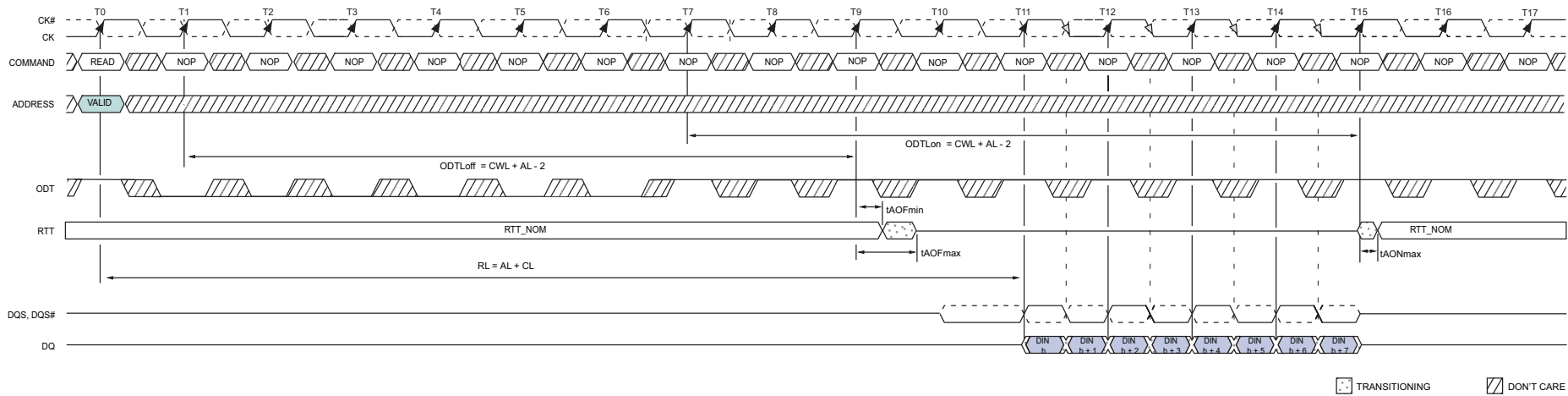


Figure 68 — ODT must be disabled externally during Reads by driving ODT low. (example: CL = 6; AL = CL - 1 = 5; RL = AL + CL = 11; CWL = 5; ODTLon = CWL + AL - 2 = 8; ODTLoFF = CWL + AL - 2 = 8)

5 On-Die Termination (ODT) (Cont'd)

5.3 Dynamic ODT

In certain application cases and to further enhance signal integrity on the data bus, it is desirable 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:

5.3.1 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.

Table 17 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 ODT4 is satisfied. If a Write command is registered by the SDRAM with ODT high, then ODT must remain high until ODT4 (BL = 4) or ODT8 (BL = 8) after the Write command (see Figure 67). ODT4 and ODT8 are measured from ODT registered high to ODT registered low or from the registration of a Write command until ODT is registered low.

Table 17 — Latencies and timing parameters relevant for Dynamic ODT

Name and Description	Abbr.	Defined from	Defined to	Definition for all DDR3 speed bins	Unit
ODT turn-on Latency	ODTLon	registering external ODT signal high	turning termination on	ODTLon = WL – 2	t_{CK}
ODT turn-off Latency	ODTLoff	registering external ODT signal low	turning termination off	ODTLoff = WL – 2	t_{CK}
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	t_{CK}
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	t_{CK}

5.3 Dynamic ODT (Cont'd)**5.3.1 Functional Description (Cont'd)****Table 17 — Latencies and timing parameters relevant for Dynamic ODT**

Name and Description	Abbr.	Defined from	Defined to	Definition for all DDR3 speed bins	Unit
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)
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 registered low	ODTH8 = 6	tCK(avg)
RTT change skew	t _{ADC}	ODTLcnw ODTLcwn	RTT valid	t _{ADC(min)} = 0.3 * tCK(avg) t _{ADC(max)} = 0.7 * tCK(avg)	tCK(avg)

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

5.3.2 ODT Timing Diagrams

The following pages provide exemplary timing diagrams as described in Table 18:

Table 18 — Timing Diagrams for “Dynamic ODT”

Figure and Page	Description
Figure 69 on page 87	Figure 69, Dynamic ODT: Behavior with ODT being asserted before and after the write.
Figure 70 on page 87	Figure 70, Dynamic ODT: Behavior without write command, AL = 0, CWL = 5.
Figure 71 on page 88	Figure 71, Dynamic ODT: Behavior with ODT pin being asserted together with write command for a duration of 6 clock cycles.
Figure 72 on page 89	Figure 72, 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.
Figure 73 on page 90	Figure 73, Dynamic ODT: Behavior with ODT pin being asserted together with write command for a duration of 4 clock cycles.

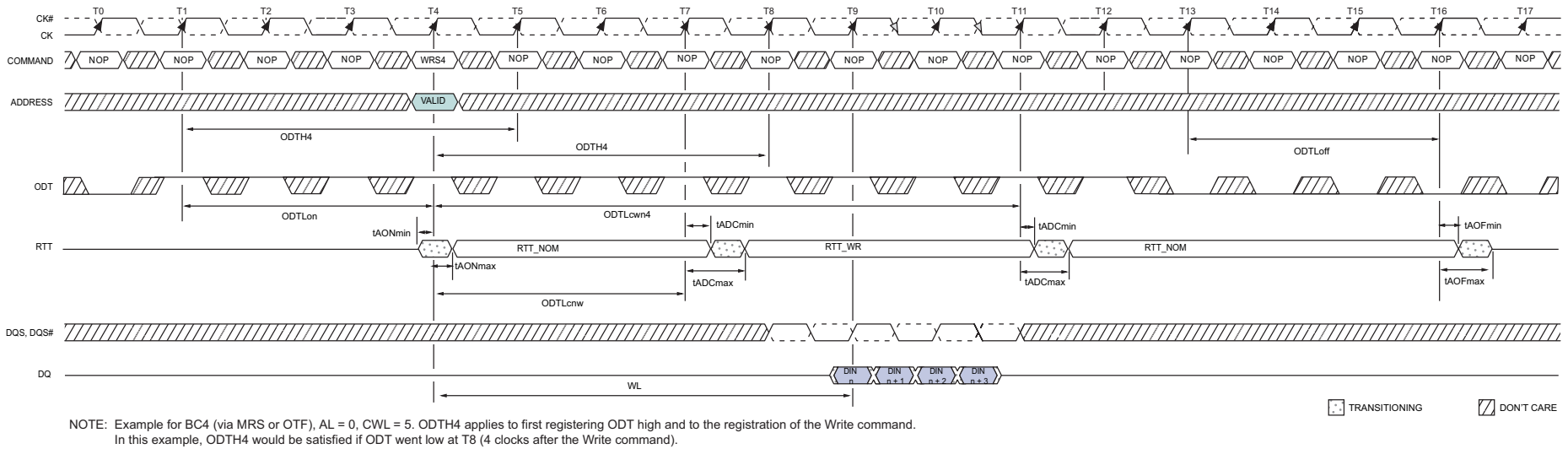


Figure 69 — Dynamic ODT: Behavior with ODT being asserted before and after the write

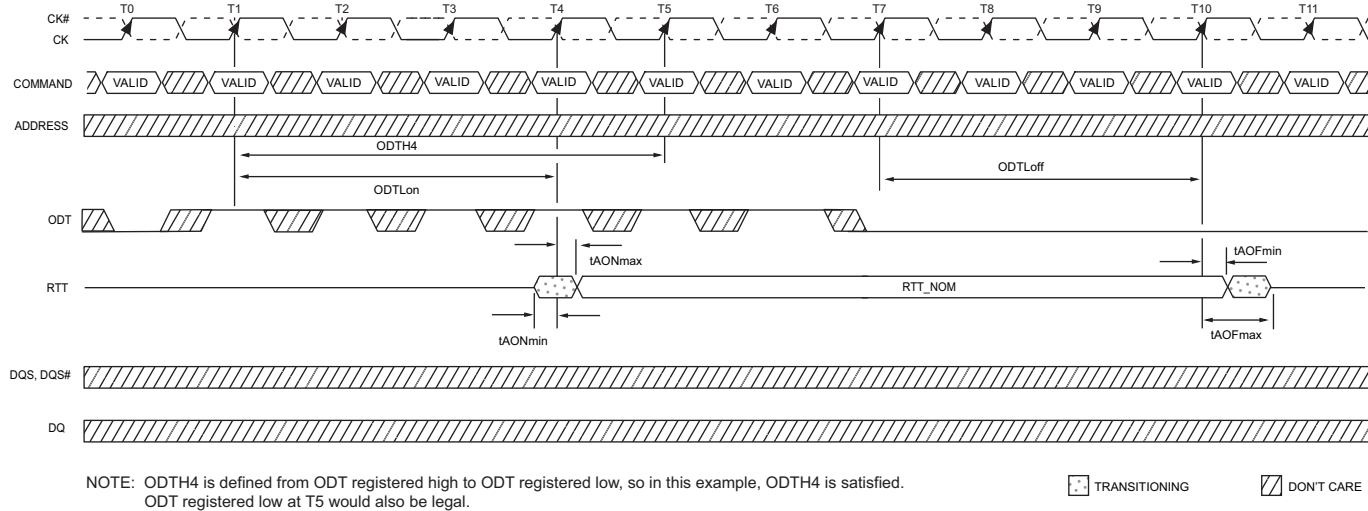


Figure 70 — Dynamic ODT: Behavior without write command, AL = 0, CWL = 5

5.3 Dynamic ODT (Cont'd)
5.3.2 ODT Timing Diagrams (Cont'd)

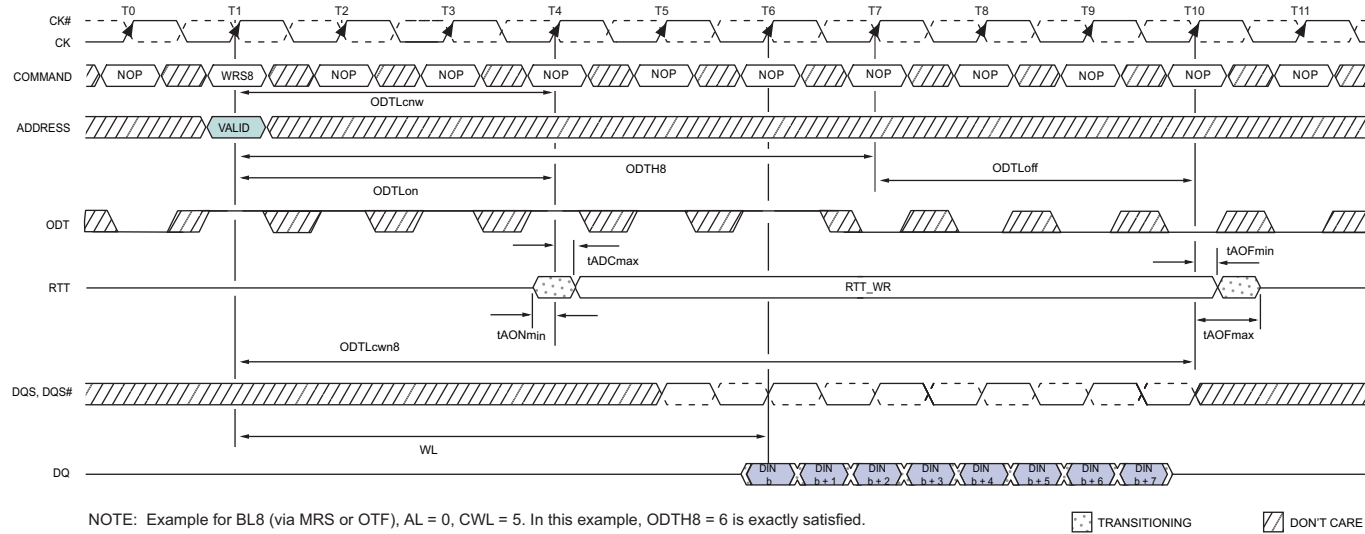


Figure 71 — Dynamic ODT: Behavior with ODT pin being asserted together with write command for a duration of 6 clock cycles

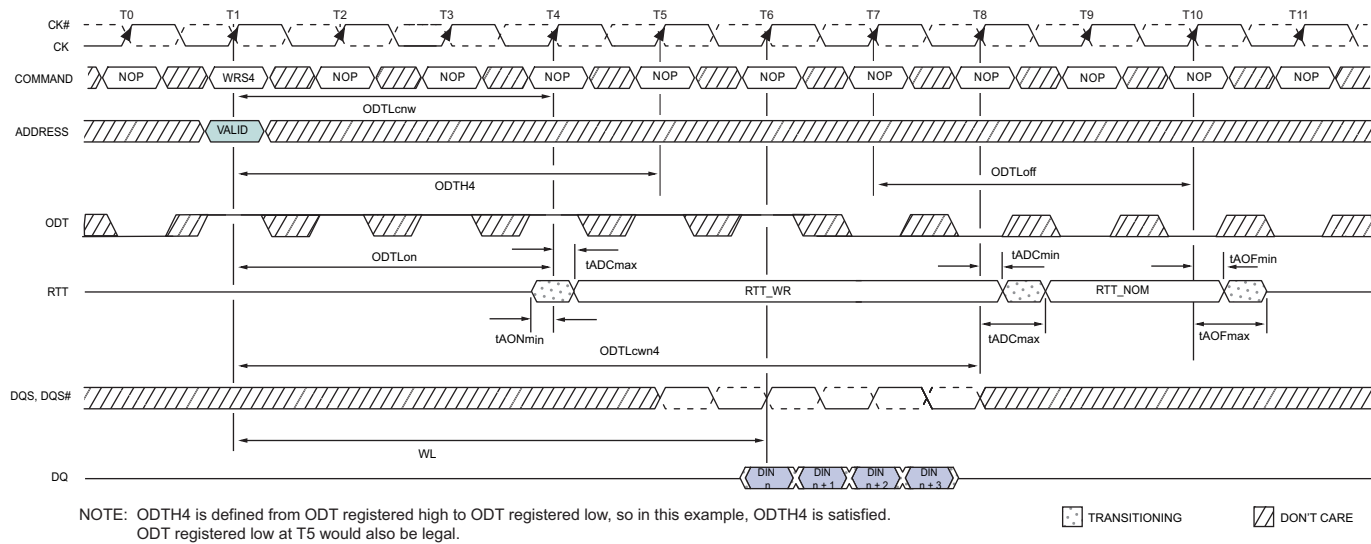


Figure 72 — Dynamic ODT: Behavior with ODT pin being asserted together with write command for a duration of 6 clock cycles, example for BC4 (via MRS or OTF), AL = 0, CWL = 5.



5.4 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 (comment: update editorially after everything is set and done...): 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 (see Figure 74): $t_{AONPD,min,max}$, $t_{AOFPD,min,max}$.

Minimum RTT turn-on time ($t_{AONPD,min}$) 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 ($t_{AONPD,max}$) is the point in time when the ODT resistance is fully on.

$t_{AONPD,min}$ and $t_{AONPD,max}$ are measured from ODT being sampled high.

Minimum RTT turn-off time ($t_{AOFPD,min}$) is the point in time when the devices termination circuit starts to turn off the ODT resistance. Maximum ODT turn off time ($t_{AOFPD,max}$) is the point in time when the on-die termination has reached high impedance. $t_{AOFPD,min}$ and $t_{AOFPD,max}$ are measured from ODT being sampled low.

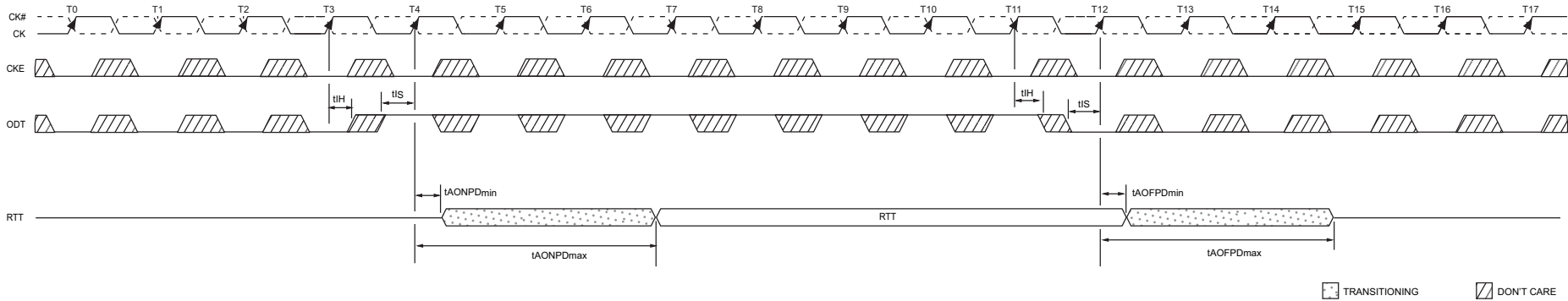


Figure 74 — Asynchronous ODT Timings on DDR3 SDRAM with fast ODT transition: AL is ignored

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.

Table 19 — Asynchronous ODT Timing Parameters for all Speed Bins

Symbol	Description	min	max	Unit
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

5 On-Die Termination (ODT) (Cont'd)

5.4 Asynchronous ODT Mode (Cont'd)

5.4.1 Synchronous to Asynchronous ODT Mode Transitions

Table 20 — ODT timing parameters for Power Down (with DLL frozen) entry and exit transition period

Description	min	max
ODT to RTT turn-on delay	$\min\{ \text{ODTLon} * t_{CK} + t_{AONmin}; t_{AONPDmin} \}$	$\max\{ \text{ODTLon} * t_{CK} + t_{AONmax}; t_{AONPDmax} \}$
	$\min\{ (WL - 2) * t_{CK} + t_{AONmin}; t_{AONPDmin} \}$	$\max\{ (WL - 2) * t_{CK} + t_{AONmax}; t_{AONPDmax} \}$
ODT to RTT turn-off delay	$\min\{ \text{ODTLo}ff * t_{CK} + t_{AOFmin}; t_{AOFDPDmin} \}$	$\max\{ \text{ODTLo}ff * t_{CK} + t_{AOFmax}; t_{AOFDPDmax} \}$
	$\min\{ (WL - 2) * t_{CK} + t_{AOFmin}; t_{AOFDPDmin} \}$	$\max\{ (WL - 2) * t_{CK} + t_{AOFmax}; t_{AOFDPDmax} \}$
tANPD	WL -1	

5.4.2 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(min) 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 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 tAOFDPDmin and (ODTLo*ff*tCK + tAOFmin) and as late as the larger of tAOFDPDmax and (ODTLo*ff*tCK + tAOFmax). See Figure 20 and Figure 75. Note that, if AL has a large value, the range where RTT is uncertain becomes quite large. Figure 75 shows the three different cases: ODT_A, synchronous behavior before tANPD; ODT_B has a state change during the transition period; ODT_C shows a state change after the transition period.

5.4 Asynchronous ODT Mode (Cont'd)
5.4.2 Synchronous to Asynchronous ODT Mode Transition during Power-Down Entry (Cont'd)

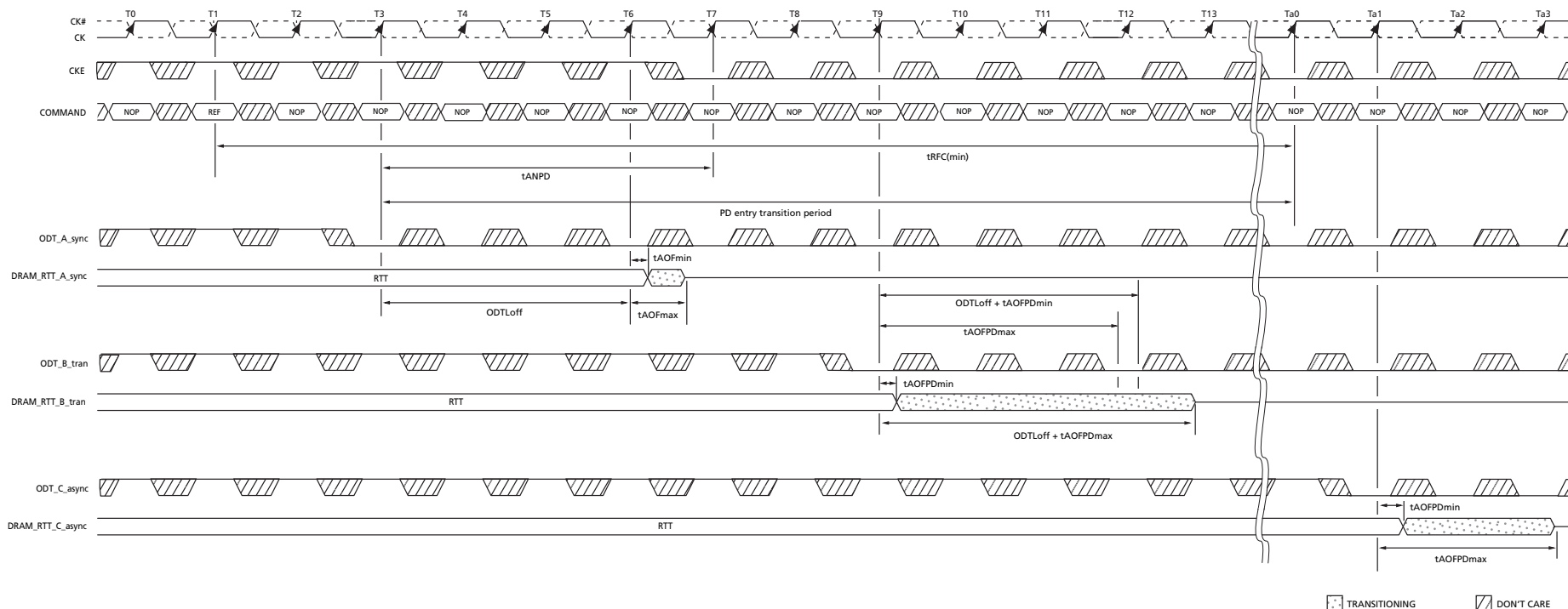


Figure 75 — Synchronous to asynchronous transition during Precharge Power Down (with DLL frozen) entry (AL = 0; CWL = 5; $t_{ANPD} = WL - 1 = 4$)

5.4.3 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 t_{ANPD} before CKE is first registered high, and ends t_{XPDLL} after CKE is first registered high. t_{ANPD} 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 $t_{AONPDmin}$ and $(ODTL_{on} * t_{CK} + t_{AONmin})$ and as late as the larger of $t_{AONPDmax}$ and $(ODTL_{on} * t_{CK} + t_{AONmax})$. ODT de-assertion during the transition period may result in an RTT change as early as the smaller of $t_{AOFPDmin}$ and $(ODTL_{off} * t_{CK} + t_{AOFmin})$ and as late as the larger of $t_{AOFPDmax}$ and $(ODTL_{off} * t_{CK} + t_{AOFmax})$. See Table 20.

Note that, if AL has a large value, the range where RTT is uncertain becomes quite large. Figure 76 shows the three different cases: ODT_C, asynchronous response before t_{ANPD} ; 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 synchronous response.

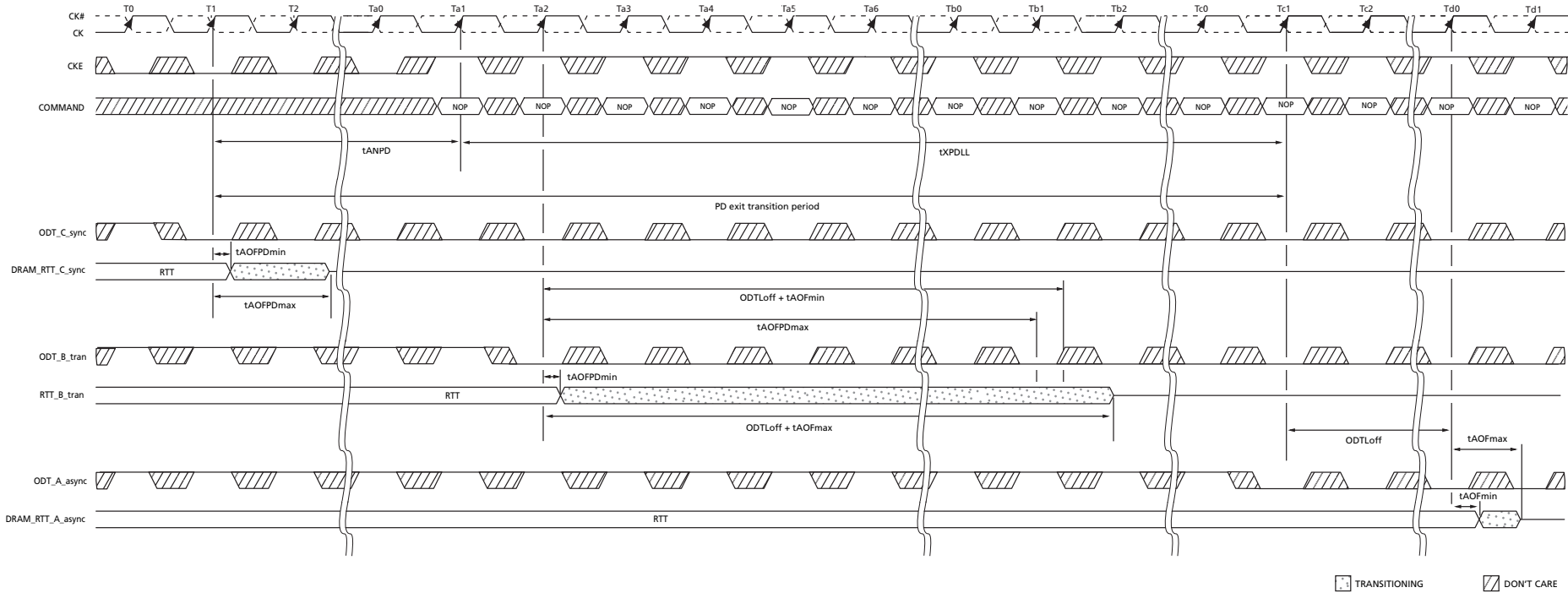


Figure 76 — Asynchronous to synchronous transition during Precharge Power Down (with DLL frozen) exit (CL = 6; AL = CL - 1; CWL = 5; tANPD = WL - 1 = 9)

5.4.4 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 (see Figure 77). 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 start of the PD entry transition period to the end of the PD exit transition period (even if the entry period 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 start of the PD exit transition period to the end of the PD entry transition period. Note that in the bottom part of Figure 77 it is assumed that there was no Refresh command in progress when Idle state was entered.

5.4 Asynchronous ODT Mode (Cont'd)
5.4.4 Asynch to Synch ODT Mode during short CKE high and short CKE low periods (Cont'd)

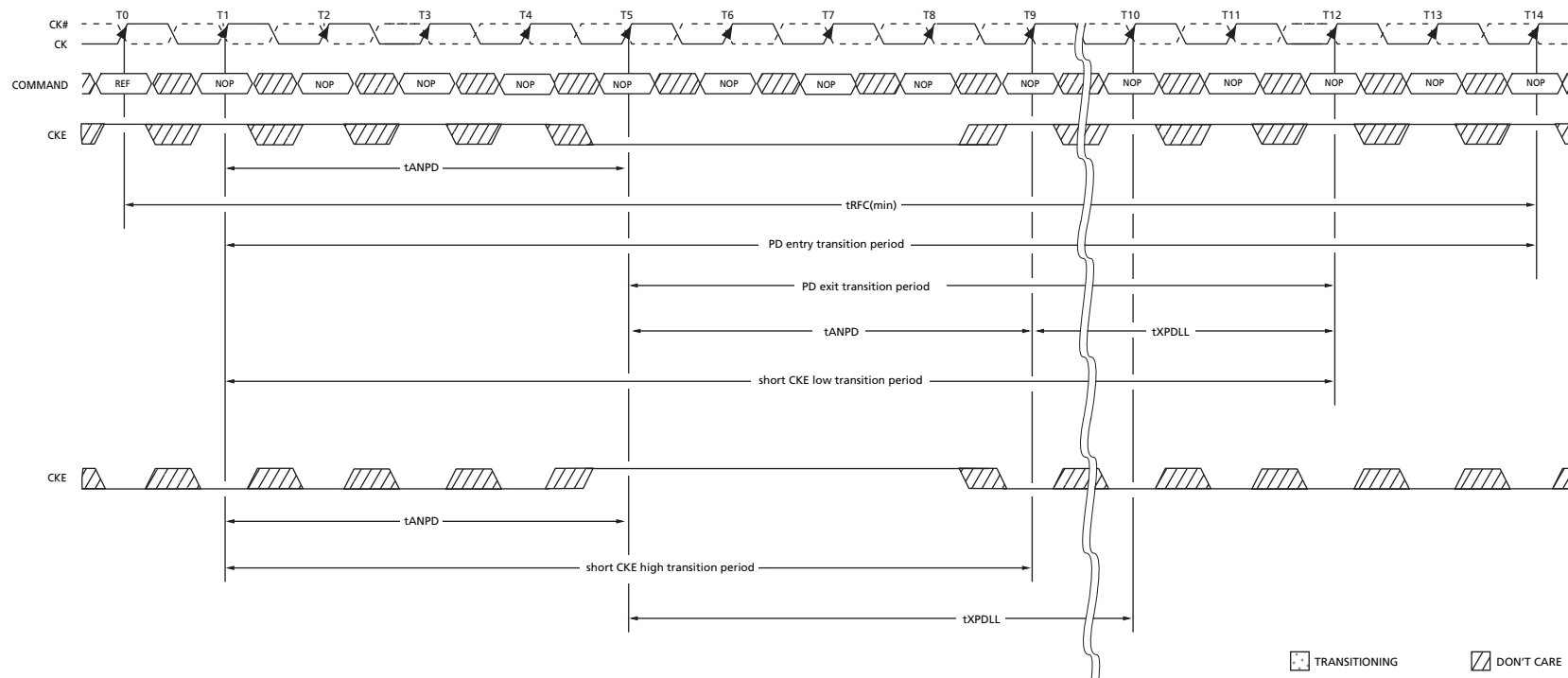


**Figure 77 — Transition period for short CKE cycles, entry and exit period overlapping
(AL = 0, WL = 5, $t_{ANPD} = WL - 1 = 4$)**

5 On-Die Termination (ODT) (Cont'd)

5.5 ZQ Calibration Commands

5.5.1 ZQ Calibration Description

ZQ Calibration command is used to calibrate DRAM Ron & 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 t_{ZQinit} 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 t_{ZQoper} .

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

No other activities should be performed on the DRAM channel by the controller for the duration of t_{ZQinit} , t_{ZQoper} or t_{ZQCS} . The quiet time on the DRAM channel allows accurate 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 t_{RP} met before ZQCL or ZQCS commands are issued by the controller. See Table 6 — “Command Truth Table” on page 29 for a description of the ZQCL and ZQCS commands.

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 t_{XS} .

In systems that share the ZQ resistor between devices, the controller must not allow any overlap of t_{ZQoper} , t_{ZQinit} , or t_{ZQCS} between the devices.

5 On-Die Termination (ODT) (Cont'd)

5.5 ZQ Calibration Commands (Cont'd)

5.5.2 ZQ Calibration Timing

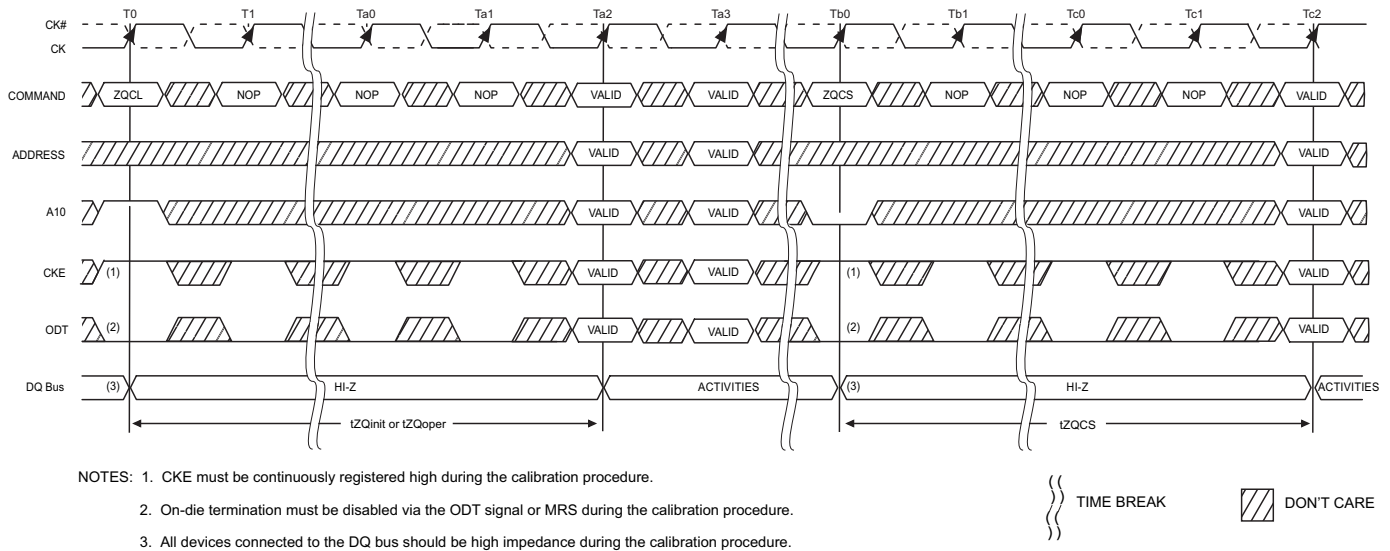


Figure 78 — ZQ Calibration Timing

5.5.3 ZQ External Resistor Value, Tolerance, and Capacitive loading

In order to use the ZQ Calibration function, a 240 ohm +/- 1% tolerance external resistor must be 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 (See Table 61 — “Input / Output Capacitance” on page 141).

6 Absolute Maximum Ratings

6.1 Absolute Maximum DC Ratings

Table 21 — Absolute Maximum DC Ratings

Symbol	Parameter	Rating	Units	Notes
VDD	Voltage on VDD pin relative to Vss	-0.4 V ~ 1.975 V	V	1,3
VDDQ	Voltage on VDDQ pin relative to Vss	-0.4 V ~ 1.975 V	V	1,3
V _{IN} , V _{OUT}	Voltage on any pin relative to Vss	-0.4 V ~ 1.975 V	V	1
T _{STG}	Storage Temperature	-55 to +100	°C	1,2
Notes: 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 operational sections of this specification is not 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. For the measurement conditions, please refer to JEDEC51-2 standard. 3. VDD and VDDQ must be within 300 mV of each other at all times; and VREF must be not greater than 0.6 x VDDQ, When VDD and VDDQ are less than 500 mV; VREF may be equal to or less than 300 mV				

6 Absolute Maximum Ratings (Cont'd)

6.2 DRAM Component Operating Temperature Range

Table 22 — Temperature Range

Symbol	Parameter	Rating	Units	Notes
T _{OPER}	Normal Operating Temperature Range	0 to 85	°C	1, 2
	Extended Temperature Range (Optional)	85 to 95	°C	1, 3
Notes: 1. Operating Temperature T_{OPER} is the case surface temperature on the center / top side of the DRAM. For measurement conditions, please refer to the JEDEC document JESD51-2. 2. The Normal Temperature Range specifies the temperatures where all DRAM specifications will be supported. During operation, the DRAM case temperature must be maintained between 0 to 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 supported in this range, but the following additional conditions apply: a) Refresh commands must be doubled in frequency, therefore reducing the Refresh interval tREFI to 3.9 μs. It is also possible to specify a component with 1X refresh (tREFI to 7.8μs) in the Extended Temperature Range. Please refer to supplier data sheet and/or the DIMM SPD for option availability. 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_b and MR2 A7 = 1_b) or enable the optional Auto Self-Refresh mode (MR2 A6 = 1_b and MR2 A7 = 0_b). Please refer to the supplier data sheet and/or the DIMM SPD for Auto Self-Refresh option availability, Extended Temperature Range support and tREFI requirements in the Extended Temperature Range.				

7 AC & DC Operating Conditions

7.1 Recommended DC Operating Conditions

Table 23 — Recommended DC Operating Conditions

Symbol	Parameter	Rating			Unit	Notes
		Min	Typ	Max		
V _{DD}	Supply Voltage	1.425	1.5	1.575	V	1, 2
V _{DDQ}	Supply Voltage for Output	1.425	1.5	1.575	V	1, 2
Notes: 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.						

8 AC and DC Input Measurement Levels

8.1 AC and DC Logic Input Levels for Single-Ended Signals

Table 24 — Single Ended AC and DC Input Levels

Symbol	Parameter	DDR3-800, DDR3-1066, DDR3-1333, DDR3-1600		Unit	Notes
		Min	Max		
VIH(DC)	DC input logic high	$V_{ref} + 0.100$	VDD	V	1
VIL(DC)	DC input logic low	VSS	$V_{ref} - 0.100$	V	1
VIH(AC)	AC input logic high	$V_{ref} + 0.175$	-	V	1, 2
VIL(AC)	AC input logic low	-	$V_{ref} - 0.175$	V	1, 2
$V_{RefDQ(DC)}$	Reference Voltage for DQ, DM inputs	$0.49 * VDD$	$0.51 * VDD$	V	3, 4
$V_{RefCA(DC)}$	Reference Voltage for ADD, CMD inputs	$0.49 * VDD$	$0.51 * VDD$	V	3, 4
Notes: 1. For DQ and DM, $V_{ref} = V_{refDQ}$. For input only pins except RESET#, $V_{ref} = V_{refCA}$. 2. See 9.6 "Overshoot and Undershoot Specifications" on page 113. 3. The ac peak noise on V_{Ref} may not allow V_{Ref} to deviate from $V_{Ref(DC)}$ by more than $\pm 1\% VDD$ (for reference: approx. ± 15 mV). 4. For reference: approx. $VDD/2 \pm 15$ mV.					

The dc-tolerance limits and ac-noise limits for the reference voltages V_{RefCA} and V_{RefDQ} are illustrated in Figure 79. It shows a valid reference voltage $V_{Ref}(t)$ as a function of time. (V_{Ref} stands for V_{RefCA} and V_{RefDQ} likewise).

$V_{Ref(DC)}$ is the linear average of $V_{Ref}(t)$ over a very long period of time (e.g. 1 sec). This average has to meet the min/max requirements in Table 24. Furthermore $V_{Ref}(t)$ may temporarily deviate from $V_{Ref(DC)}$ by no more than $\pm 1\% VDD$.

8 AC and DC Input Measurement Levels (Cont'd)**8.1 AC and DC Logic Input Levels for Single-Ended Signals (Cont'd)**

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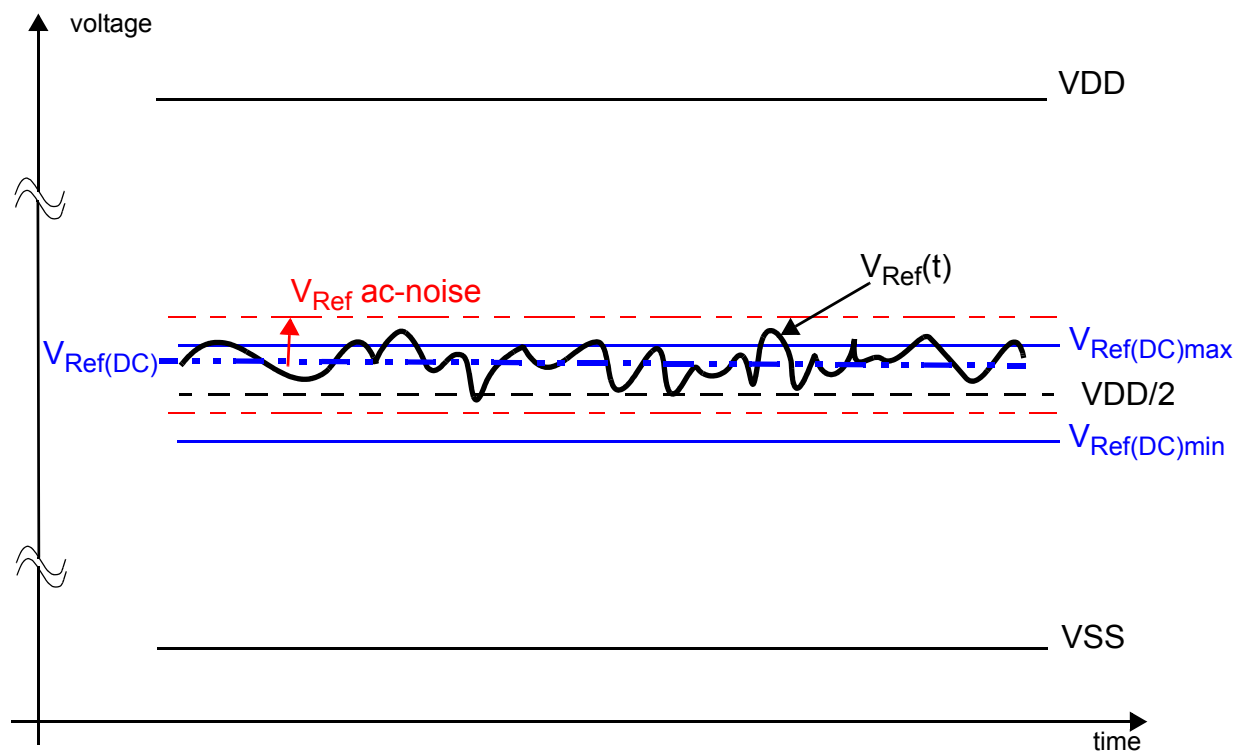


Figure 79 — Illustration of $V_{\text{Ref(DC)}}$ tolerance and V_{Ref} ac-noise limits

The voltage levels for setup and hold time measurements $V_{\text{IH(AC)}}$, $V_{\text{IH(DC)}}$, $V_{\text{IL(AC)}}$ and $V_{\text{IL(DC)}}$ are dependent on V_{Ref} .

“ V_{Ref} ” shall be understood as $V_{\text{Ref(DC)}}$, as defined in Figure 79.

This clarifies that dc-variations of V_{Ref} affect the absolute voltage a signal has to reach to achieve a valid high or low level and therefore the time to which setup and hold is measured. System timing and voltage budgets need to account for $V_{\text{Ref(DC)}}$ deviations from the optimum position within the data-eye of the input signals.

This also clarifies that the DRAM setup/hold specification and derating values need to include time and voltage associated with V_{Ref} ac-noise. Timing and voltage effects due to ac-noise on V_{Ref} up to the specified limit ($\pm 1\%$ of VDD) are included in DRAM timings and their associated deratings.

8 AC and DC Input Measurement Levels (Cont'd)

8.2 AC and DC Logic Input Levels for Differential Signals

8.2.1 Differential signal definition

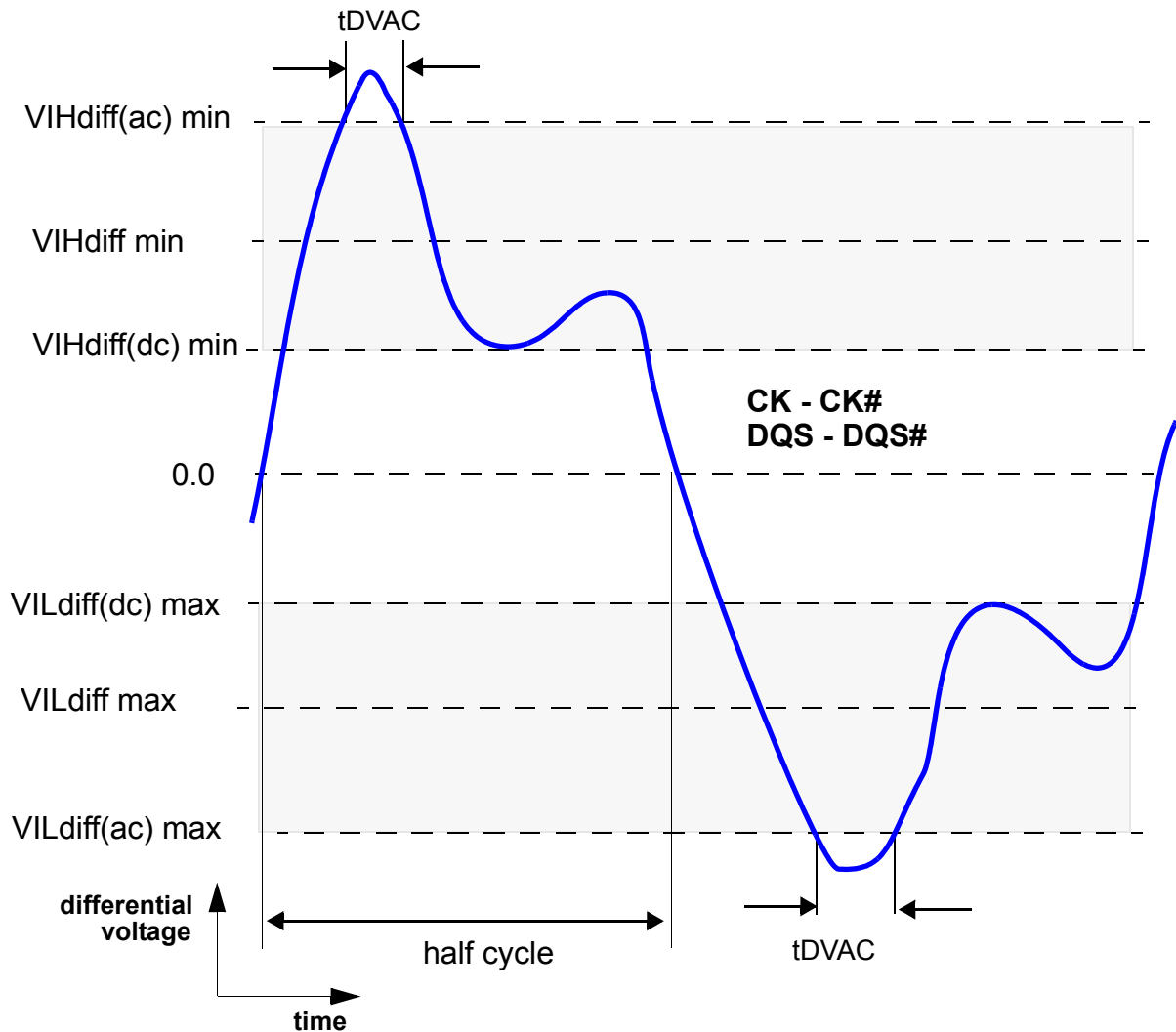


Figure 80 — Definition of differential ac-swing and "time above ac-level" t_{DVAC}

8 AC and DC Input Measurement Levels (Cont'd)**8.2 AC and DC Logic Input Levels for Differential Signals (Cont'd)****8.2.2 Differential swing requirements for clock (CK - CK#) and strobe (DQS - DQS#)****Table 25 — Differential AC and DC Input Levels**

Symbol	Parameter	DDR3-800, 1066, 1333, & 1600		Unit	Notes
		Min	Max		
V_{IHdiff}	Differential input high	+ 0.200	note 3	V	1
V_{ILdiff}	Differential input logic low	Note 3	- 0.200	V	1
$V_{IHdiff(ac)}$	Differential input high ac	2 x ($V_{IH(ac)}$ - V_{ref})	Note 3	V	2
$V_{ILdiff(ac)}$	Differential input low ac	note 3	2 x (V_{ref} - $V_{IL(ac)}$)	V	2
1. Used to define a differential signal slew-rate. 2. For CK - CK# use $V_{IH}/V_{IL(ac)}$ of ADD/CMD and V_{REFCA} ; for DQS - DQS#, DQSL, DQSL#, DQSU, DQSU# use $V_{IH}/V_{IL(ac)}$ of DQs and V_{REFDQ} ; if a reduced ac-high or ac-low level is used for a signal group, then the reduced level applies also here. 3. These values are not defined, however the single-ended signals CK, CK#, DQS, DQS#, DQSL, DQSL#, DQSU, DQSU# need to be within the respective limits ($V_{IH(dc)}$ max, $V_{IL(dc)}$ min) for single-ended signals as well as the limitations for overshoot and undershoot. Refer to "Overshoot and Undershoot Specifications" on page 113					

Table 26 — Allowed time before ringback (t_{DVAC}) for CK - CK# and DQS - DQS#

Slew Rate [V/ns]	t_{DVAC} [ps] @ $ V_{IH}/L_{diff(ac)} = 350mV$		t_{DVAC} [ps] @ $ V_{IH}/L_{diff(ac)} = 300mV$	
	min	max	min	max
> 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	-

8.2.3 Single-ended requirements for differential signals

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

CK and CK# have to approximately reach V_{SEHmin} / V_{SELmax} (approximately equal to the ac-levels ($V_{IH(ac)}$ / $V_{IL(ac)}$) for ADD/CMD signals) in every half-cycle.

DQS, DQSL, DQSU, DQS#, DQSL# have to reach V_{SEHmin} / V_{SELmax} (approximately the ac-levels ($V_{IH(ac)}$ / $V_{IL(ac)}$) for DQ signals) in every half-cycle preceeding and following a valid transition.

8.2 AC and DC Logic Input Levels for Differential Signals (Cont'd)

8.2.3 Single-ended requirements for differential signals (Cont'd)

Note that the applicable ac-levels for ADD/CMD and DQ's might be different per speed-bin etc. E.g. if VIH150(ac)/VIL150(ac) is used for ADD/CMD signals, then these ac-levels apply also for the single-ended signals CK and CK#

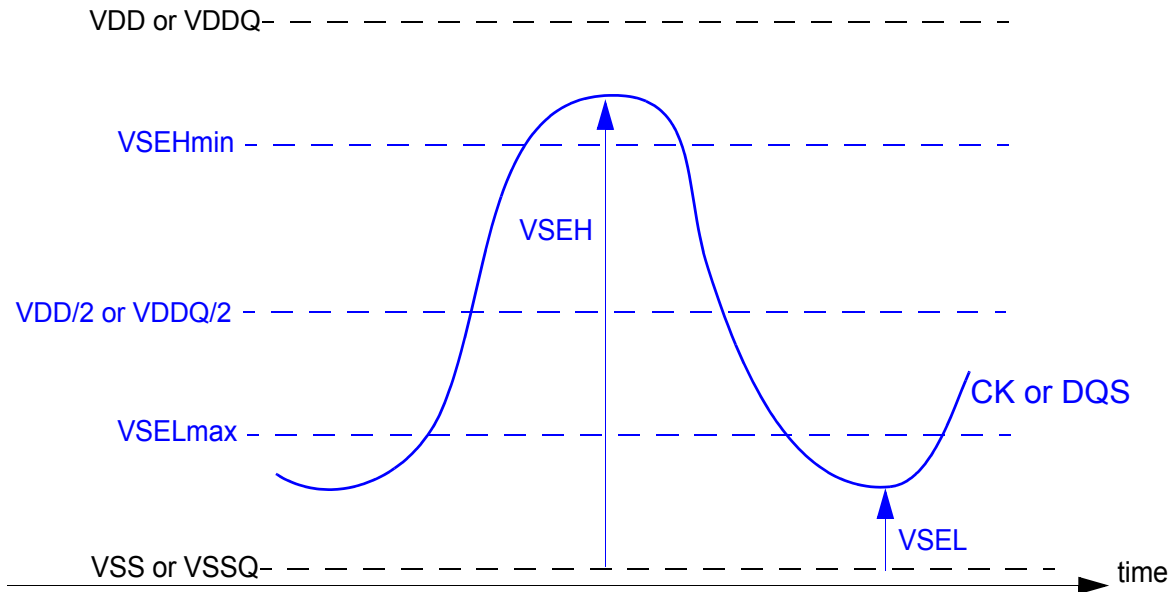


Figure 81 — Single-ended requirement for differential signals.

Note that while ADD/CMD and DQ signal requirements are with respect to Vref, the single-ended components of differential signals have a requirement with respect to $VDD / 2$; this is nominally the same. The transition of single-ended signals through the ac-levels is used to measure setup time. For single-ended components of differential signals the requirement to reach VSELmax, VSEHmin has no bearing on timing, but adds a restriction on the common mode characteristics of these signals.

Table 27 — Single-ended levels for CK, DQS, DQSL, DQSU, CK#, DQS#, DQSL# or DQSU#

Symbol	Parameter	DDR3-800, 1066, 1333, & 1600		Unit	Notes
		Min	Max		
VSEH	Single-ended highlevel for strobes	$V_{IH}(ac) - V_{REFDQ} + VDDQ / 2$	note 3	V	1, 2
	Single-ended high-level for CK, CK#	$V_{IH}(ac) - V_{REFCA} + VDD / 2$	note 3	V	1, 2
VSEL	Single-ended lowlevel for strobes	note 3	$V_{IL}(ac) + V_{REFDQ} - VDDQ / 2$	V	1, 2
	Single-ended lowlevel for CK, CK#	note 3	$V_{IL}(ac) + V_{REFCA} - VDD / 2$	V	1, 2

8.2 AC and DC Logic Input Levels for Differential Signals (Cont'd)

8.2.3 Single-ended requirements for differential signals (Cont'd)

Table 27 — Single-ended levels for CK, DQS, DQSL, DQSU, CK#, DQS#, DQSL# or DQSU#

Symbol	Parameter	DDR3-800, 1066, 1333, & 1600		Unit	Notes
		Min	Max		
	1. For CK, CK# use VIH/VIL(ac) of ADD/CMD; for strobes (DQS, DQS#, DQSL, DQSL#, DQSU, 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 signal group, then the reduced level applies also here 3. These values are not defined, however they single-ended signals CK, CK#, DQS, DQS#, DQSL, DQSL#, DQSU, DQSU# need to be within the respective limits (VIH(dc) max, VIL(dc)min) for single-ended signals as well as the limitations for overshoot and undershoot. Refer to “Overshoot and Undershoot Specifications” on page 113				

8.3 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, CK# and DQS, DQS#) must meet the requirements in Table 28. The differential input cross point voltage V_{IX} is measured from the actual cross point of true and complement signals to the midlevel between of VDD and VSS.

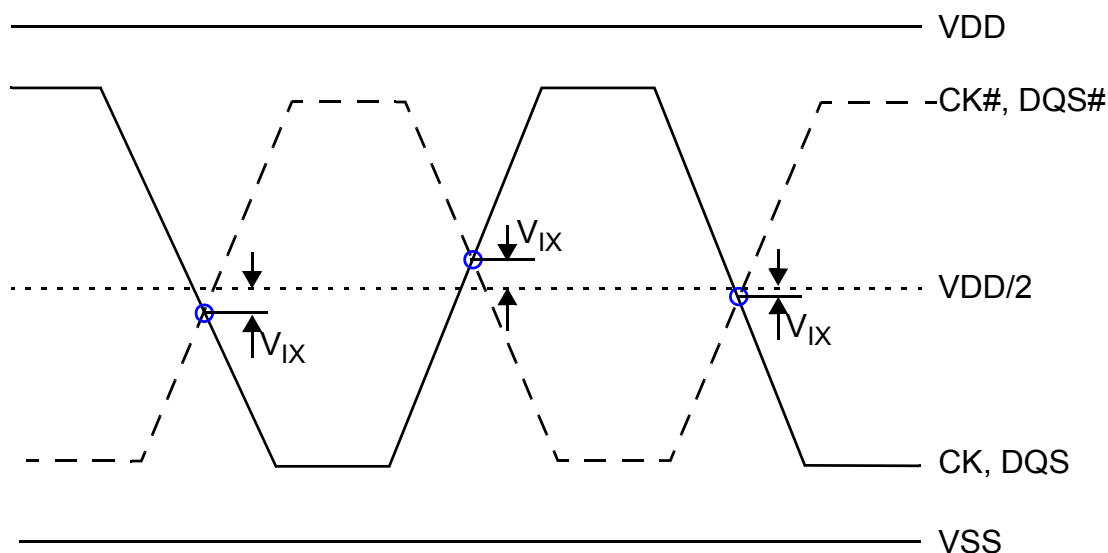


Figure 82 — Vix Definition

Table 28 — Cross point voltage for differential input signals (CK, DQS)

Symbol	Parameter	DDR3-800, DDR3-1066, DDR3-1333, DDR3-1600		Unit	Notes
		Min	Max		
V_{IX}	Differential Input Cross Point Voltage relative to VDD/2	- 150	150	mV	

8 AC and DC Input Measurement Levels (Cont'd)

8.4 Slew Rate Definitions for Single Ended Input Signals

8.4.1 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.

8.4.2 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.

Table 29 — Single-ended Input Slew Rate Definition

Description	Measured		Defined by	Applicable for
	from	to		
Input slew rate for rising edge	V _{Ref}	V _{IH(AC)min}	$\frac{V_{IH(AC)min} - V_{Ref}}{\Delta TRS}$	Setup (t _{IS} , t _{DS})
Input slew rate for falling edge	V _{Ref}	V _{IL(AC)max}	$\frac{V_{Ref} - V_{IL(AC)max}}{\Delta TFS}$	
Input slew rate for rising edge	V _{IL(DC)max}	V _{Ref}	$\frac{V_{Ref} - V_{IL(DC)max}}{\Delta TFH}$	Hold (t _{IH} , t _{DH})
Input slew rate for falling edge	V _{IH(DC)min}	V _{Ref}	$\frac{V_{IH(DC)min} - V_{Ref}}{\Delta TRH}$	

This nominal slew rate applies for linear signal waveforms.

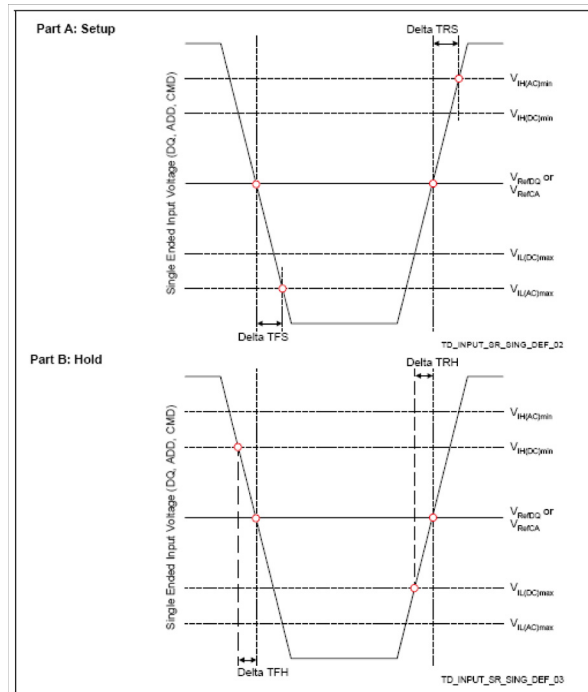


Figure 83 — Input Nominal Slew Rate Definition for Single-Ended Signals

8 AC and DC Input Measurement Levels (Cont'd)

8.5 Slew Rate Definitions for Differential Input Signals

Input slew rate for differential signals (CK, CK# and DQS, DQS#) are defined and measured as shown in Table 30 and Figure 84.

Table 30 — Differential Input Slew Rate Definition

Description	Measured		Defined by
	from	to	
Differential input slew rate for rising edge (CK - CK# and DQS - DQS#).	$V_{ILDiffmax}$	$V_{ILDiffmin}$	$\frac{V_{IHDiffmin} - V_{ILDiffmax}}{\Delta TR_{diff}}$
Differential input slew rate for falling edge (CK - CK# and DQS - DQS#).	$V_{IHDiffmin}$	$V_{IHDiffmax}$	$\frac{V_{IHDiffmin} - V_{ILDiffmax}}{\Delta TF_{diff}}$
Note: The differential signal (i.e. CK - CK# and DQS - DQS#) must be linear between these thresholds.			

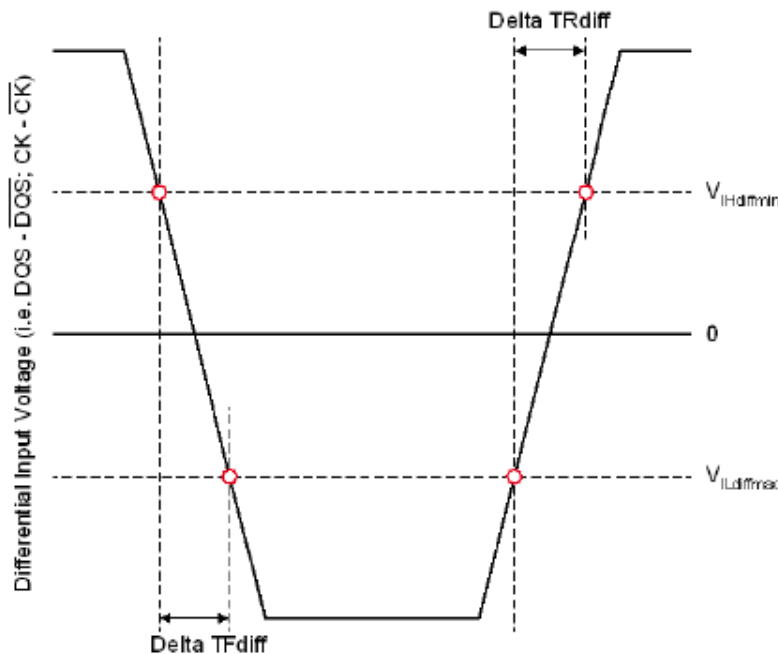


Figure 84 — Differential Input Slew Rate Definition for DQS, DQS# and CK, CK#

9 AC and DC Output Measurement Levels

9.1 Single Ended AC and DC Output Levels

Table 31 shows the output levels used for measurements of single ended signals.

Table 31 — Single-ended AC and DC Output Levels

Symbol	Parameter	DDR3-800, 1066, 1333, and 1600	Unit	Notes
$V_{OH(DC)}$	DC output high measurement level (for IV curve linearity)	$0.8 \times V_{DDQ}$	V	
$V_{OM(DC)}$	DC output mid measurement level (for IV curve linearity)	$0.5 \times V_{DDQ}$	V	
$V_{OL(DC)}$	DC output low measurement level (for IV curve linearity)	$0.2 \times V_{DDQ}$	V	
$V_{OH(AC)}$	AC output high measurement level (for output SR)	$V_{TT} + 0.1 \times V_{DDQ}$	V	1
$V_{OL(AC)}$	AC output low measurement level (for output SR)	$V_{TT} - 0.1 \times V_{DDQ}$	V	1
Notes: 1. The swing of $\pm 0.1 \times V_{DDQ}$ is based on approximately 50% of the static single-ended output high or low swing with a driver impedance of 40Ω and an effective test load of 25Ω to $V_{TT} = V_{DDQ}/2$.				

9.2 Differential AC and DC Output Levels

Table 32 shows the output levels used for measurements of differential signals.

Table 32 — Differential AC and DC Output Levels

Symbol	Parameter	DDR3-800, 1066, 1333, and 1600	Unit	Notes
$V_{OHdiff(AC)}$	AC differential output high measurement level (for output SR)	$+ 0.2 \times V_{DDQ}$	V	1
$V_{OLdiff(AC)}$	AC differential output low measurement level (for output SR)	$- 0.2 \times V_{DDQ}$	V	1
Notes: 1. The swing of $\pm 0.2 \times V_{DDQ}$ is based on approximately 50% of the static single-ended output high or low swing with a driver impedance of 40Ω and an effective test load of 25Ω to $V_{TT} = V_{DDQ}/2$ at each of the differential outputs.				

9 AC and DC Output Measurement Levels (Cont'd)

9.3 Single Ended Output Slew Rate

With the reference load for timing measurements, output slew rate for falling and rising edges is defined and measured between $V_{OL(AC)}$ and $V_{OH(AC)}$ for single ended signals as shown in Table 33 and Figure 85.

Table 33 — Single-ended Output Slew Rate Definition

Description	Measured		Defined by
	from	to	
Single-ended output slew rate for rising edge	$V_{OL(AC)}$	$V_{OH(AC)}$	$\frac{V_{OH(AC)} - V_{OL(AC)}}{\Delta t_{Rse}}$
Single-ended output slew rate for falling edge	$V_{OH(AC)}$	$V_{OL(AC)}$	$\frac{V_{OH(AC)} - V_{OL(AC)}}{\Delta t_{Fse}}$
Note: Output slew rate is verified by design and characterization, and may not be subject to production test.			

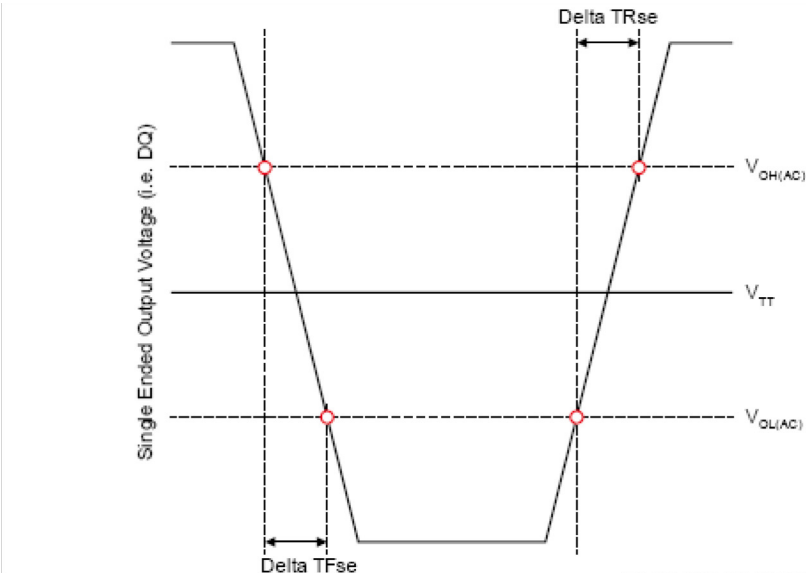


Figure 85 — Single Ended Output Slew Rate Definition

Table 34 — Output Slew Rate (single-ended)

		DDR3-800		DDR3-1066		DDR3-1333		DDR3-1600		Units
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Min	Max	
Single-ended Output Slew Rate	SRQse	2.5	5	2.5	5	2.5	5	TBD	5	V/ns
Description: 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										

9 AC and DC Output Measurement Levels (Cont'd)

9.4 Differential Output Slew Rate

With the reference load for timing measurements, output slew rate for falling and rising edges is defined and measured between VOLdiff(AC) and VOHdiff(AC) for differential signals as shown in Table 35 and Figure 86.

Table 35 — Differential Output Slew Rate Definition

Description	Measured		Defined by
	from	to	
Differential output slew rate for rising edge	V _{OLdiff(AC)}	V _{OHdiff(AC)}	$\frac{V_{OHdiff(AC)} - V_{OLdiff(AC)}}{\Delta T_{Rdiff}}$
Differential output slew rate for falling edge	V _{OHdiff(AC)}	V _{OLdiff(AC)}	$\frac{V_{OHdiff(AC)} - V_{OLdiff(AC)}}{\Delta T_{Fdiff}}$
Note: Output slew rate is verified by design and characterization, and may not be subject to production test.			

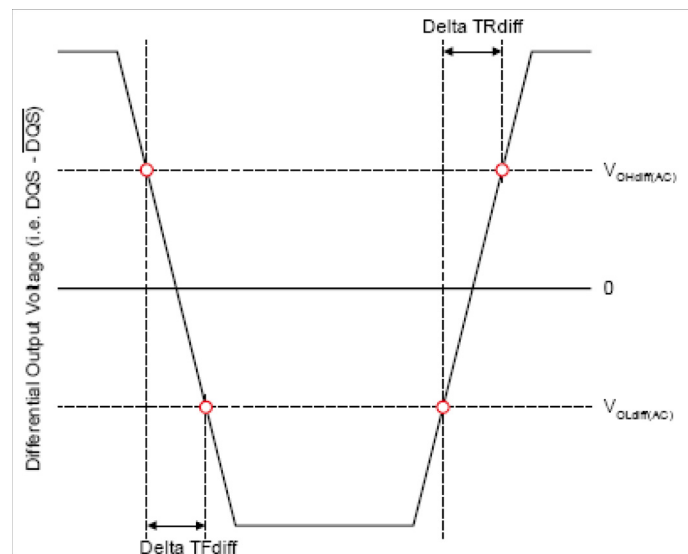


Figure 86 — Differential Output Slew Rate Definition

Table 36 — Differential Output Slew Rate

		DDR3-800		DDR3-1066		DDR3-1333		DDR3-1600		Units
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Min	Max	
Differential Output Slew Rate	SRQdiff	5	10	5	10	5	10	TBD	10	V/ns
Description: SR: Slew Rate Q: Query Output (like in DQ, which stands for Data-in, Query-Output) diff: Differential Signals For Ron = RZQ/7 setting										

9 AC and DC Output Measurement Levels (Cont'd)

9.5 Reference Load for AC Timing and Output Slew Rate

Figure 87 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 transmission lines terminated at the tester electronics.

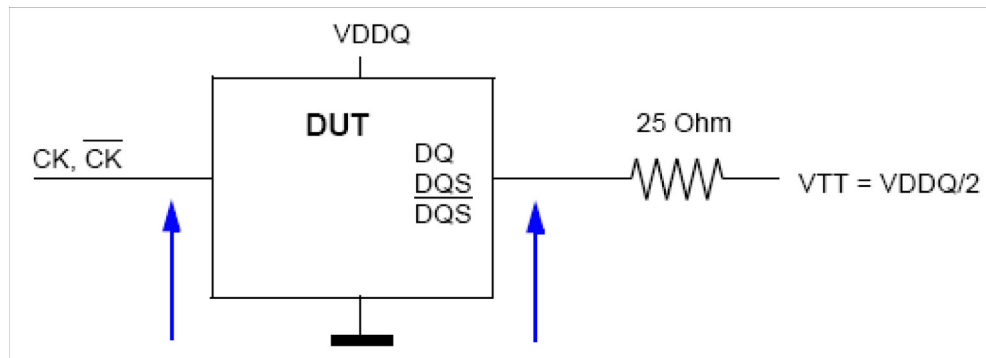


Figure 87 — Reference Load for AC Timing and Output Slew Rate

9 AC and DC Output Measurement Levels (Cont'd)

9.6 Overshoot and Undershoot Specifications

9.6.1 Address and Control Overshoot and Undershoot Specifications

Table 37 — AC Overshoot/Undershoot Specification for Address and Control Pins

	DDR3-800	DDR3-1066	DDR3-1333	DDR3-1600	Units
Maximum peak amplitude allowed for overshoot area. (See Figure 88)	0.4	0.4	0.4	0.4	V
Maximum peak amplitude allowed for undershoot area. (See Figure 88)	0.4	0.4	0.4	0.4	V
Maximum overshoot area above VDD (See Figure 88)	0.67	0.5	0.4	0.33	V-ns
Maximum undershoot area below VSS (See Figure 88)	0.67	0.5	0.4	0.33	V-ns
(A0-A15, BA0-BA3, CS#, RAS#, CAS#, WE#, CKE, ODT)					

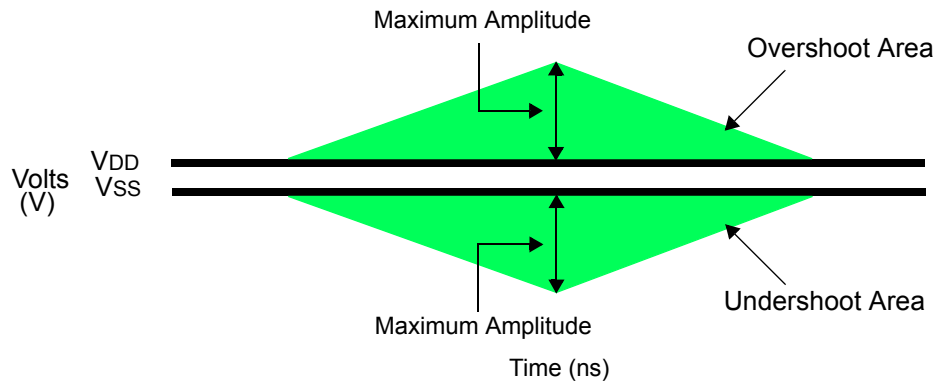


Figure 88 — Address and Control Overshoot and Undershoot Definition

9 AC and DC Output Measurement Levels (Cont'd)
9.6 Overshoot and Undershoot Specifications (Cont'd)

9.6.2 Clock, Data, Strobe and Mask Overshoot and Undershoot Specifications

Table 38 — AC Overshoot/Undershoot Specification for Clock, Data, Strobe and Mask

	DDR3-800	DDR3-1066	DDR3-1333	DDR3-1600	Units
Maximum peak amplitude allowed for overshoot area. (See Figure 89)	0.4	0.4	0.4	0.4	V
Maximum peak amplitude allowed for undershoot area. (See Figure 89)	0.4	0.4	0.4	0.4	V
Maximum overshoot area above VDDQ (See Figure 89)	0.25	0.19	0.15	0.13	V-ns
Maximum undershoot area below VSSQ (See Figure 89)	0.25	0.19	0.15	0.13	V-ns
(CK, CK#, DQ, DQS, DQS#, DM)					

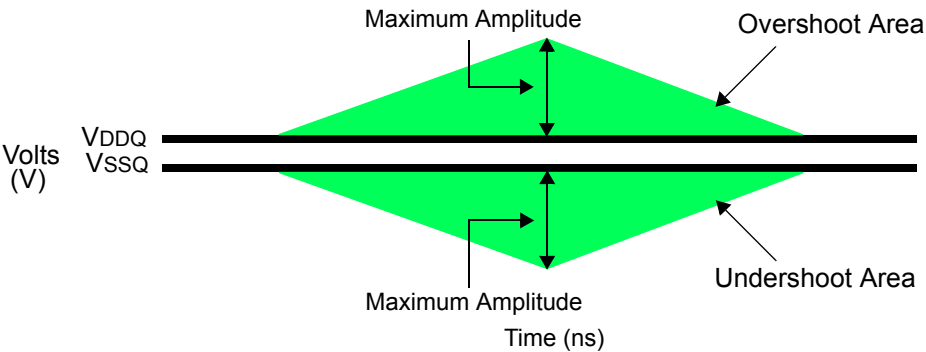


Figure 89 — Clock, Data, Strobe and Mask Overshoot and Undershoot Definition

9 AC and DC Output Measurement Levels (Cont'd)

9.7 34 ohm Output Driver DC Electrical Characteristics

A functional representation of the output buffer is shown in Figure 90. Output driver impedance R_{ON} is defined by the value of the external reference resistor R_{ZQ} as follows:

$$R_{ON_{34}} = R_{ZQ} / 7 \text{ (nominal } 34.3 \, \Omega \pm 10\% \text{ with nominal } R_{ZQ} = 240 \, \Omega \text{)}$$

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

$$R_{ON_{Pu}} = \frac{V_{DDQ} - V_{Out}}{|I_{Out}|} \quad \text{under the condition that } R_{ON_{Pd}} \text{ is turned off} \quad (1)$$

$$R_{ON_{Pd}} = \frac{V_{Out}}{|I_{Out}|} \quad \text{under the condition that } R_{ON_{Pu}} \text{ is turned off} \quad (2)$$

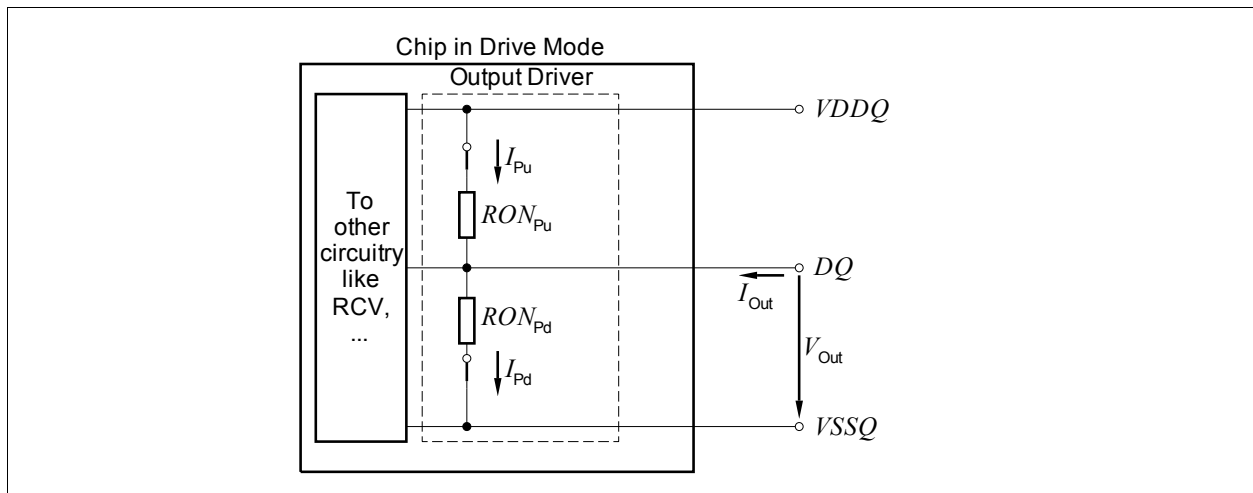


Figure 90 — Output Driver: Definition of Voltages and Currents

Table 39 — Output Driver DC Electrical Characteristics, assuming $R_{ZQ} = 240 \, \Omega$; entire operating temperature range; after proper ZQ calibration

$R_{ON_{Nom}}$	Resistor	V_{Out}	min	nom	max	Unit	Notes
34 Ω	$R_{ON_{34Pd}}$	$V_{OLdc} = 0.2 \times V_{DDQ}$	0.6	1.0	1.1	$R_{ZQ}/7$	1, 2, 3
		$V_{OMdc} = 0.5 \times V_{DDQ}$	0.9	1.0	1.1	$R_{ZQ}/7$	1, 2, 3
		$V_{OHdc} = 0.8 \times V_{DDQ}$	0.9	1.0	1.4	$R_{ZQ}/7$	1, 2, 3
	$R_{ON_{34Pu}}$	$V_{OLdc} = 0.2 \times V_{DDQ}$	0.9	1.0	1.4	$R_{ZQ}/7$	1, 2, 3
		$V_{OMdc} = 0.5 \times V_{DDQ}$	0.9	1.0	1.1	$R_{ZQ}/7$	1, 2, 3
		$V_{OHdc} = 0.8 \times V_{DDQ}$	0.6	1.0	1.1	$R_{ZQ}/7$	1, 2, 3
Mismatch between pull-up and pull-down, MM_{PuPd}		V_{OMdc} $0.5 \times V_{DDQ}$	-10		+10	%	1, 2, 4

Notes: 1. The tolerance limits are specified after calibration with stable voltage and temperature. For the behavior of the tolerance limits if temperature or volt-

9 AC and DC Output Measurement Levels (Cont'd)

9.7 34 ohm Output Driver DC Electrical Characteristics (Cont'd)

age changes after calibration, see following section on voltage and temperature sensitivity.

2. The tolerance limits are specified under the condition that $V_{DDQ} = V_{DD}$ and that $V_{SSQ} = V_{SS}$.
3. Pull-down and pull-up output driver impedances are recommended to be calibrated at $0.5 \times V_{DDQ}$. Other calibration schemes may be used to achieve the linearity spec shown above, e.g. calibration at $0.2 \times V_{DDQ}$ and $0.8 \times V_{DDQ}$.
4. Measurement definition for mismatch between pull-up and pull-down, MM_{PuPd} :

MM_{PuPd} :

Measure RON_{Pu} and RON_{Pd} , both at $0.5 \times V_{DDQ}$:

$$MM_{PuPd} = \frac{RON_{Pu} - RON_{Pd}}{RON_{Nom}} \times 100$$

9 AC and DC Output Measurement Levels (Cont'd)

9.7 34 ohm Output Driver DC Electrical Characteristics (Cont'd)

9.7.1 Output Driver Temperature and Voltage sensitivity

If temperature and/or voltage change after calibration, the tolerance limits widen according to Table 40 and Table 41.

$$\Delta T = T - T(@\text{calibration}); \Delta V = V_{DDQ} - V_{DDQ}(@\text{calibration}); V_{DD} = V_{DDQ}$$

Note: dR_{ONdT} and dR_{ONdV} are not subject to production test but are verified by design and characterization.

Table 40 — Output Driver Sensitivity Definition

	min	max	unit
$R_{ONPU}@ V_{OHdc}$	$0.6 - dR_{ONdTH} DT - dR_{ONdVH} DV $	$1.1 + dR_{ONdTH} DT + dR_{ONdVH} DV $	RZQ/7
$R_{ON}@ V_{OMdc}$	$0.9 - dR_{ONdTM} DT - dR_{ONdVM} DV $	$1.1 + dR_{ONdTM} DT + dR_{ONdVM} DV $	RZQ/7
$R_{ONPD}@ V_{OLdc}$	$0.6 - dR_{ONdTL} DT - dR_{ONdVL} DV $	$1.1 + dR_{ONdTL} DT + dR_{ONdVL} DV $	RZQ/7

Table 41 — Output Driver Voltage and Temperature Sensitivity

	min	max	unit
dR_{ONdTM}	0	1.5	%/°C
dR_{ONdVM}	0	0.15	%/mV
dR_{ONdTL}	0	1.5	%/°C
dR_{ONdVL}	0	TBD	%/mV
dR_{ONdTH}	0	1.5	%/°C
dR_{ONdVH}	0	TBD	%/mV

These parameters may not be subject to production test. They are verified by design and characterization.

9 AC and DC Output Measurement Levels (Cont'd)

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

9.8.1 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/DQS# and TDQS/TDQS# (x8 devices only) pins.

A functional representation of the on-die termination is shown in Figure 91. The individual pull-up and pull-down resistors (RTT_{Pu} and RTT_{Pd}) are defined as follows:

$$RTT_{Pu} = \frac{V_{DDQ} - V_{Out}}{|I_{Out}|} \text{ under the condition that } RTT_{Pd} \text{ is turned off} \quad (3)$$

$$RTT_{Pd} = \frac{V_{Out}}{|I_{Out}|} \text{ under the condition that } RTT_{Pu} \text{ is turned off} \quad (4)$$

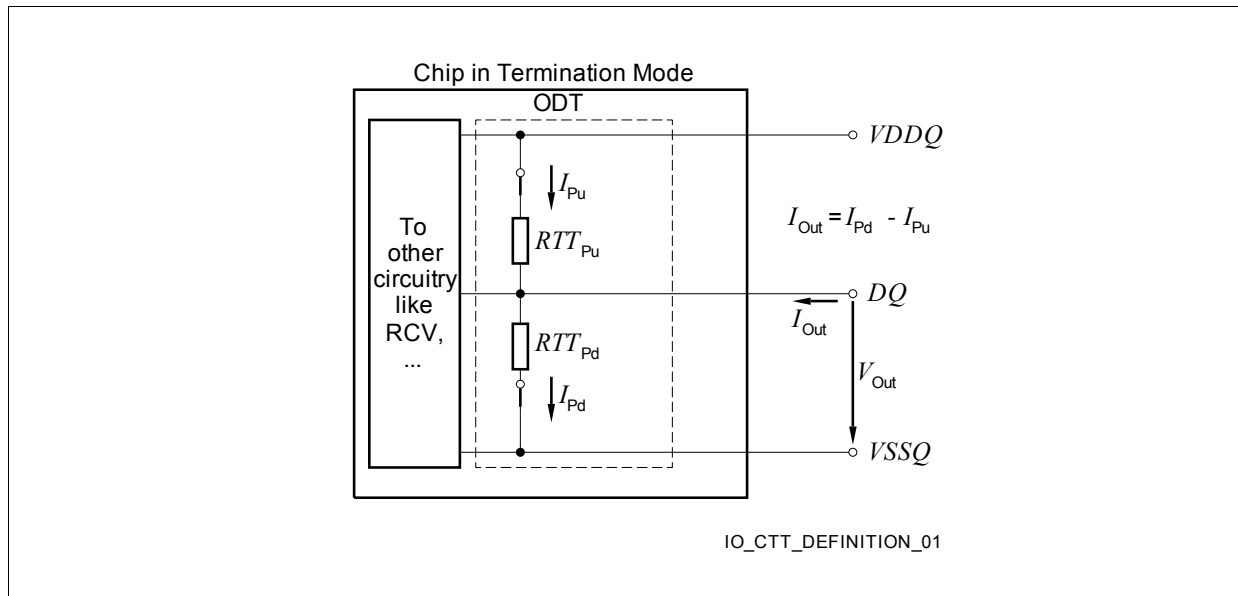


Figure 91 — On-Die Termination: Definition of Voltages and Currents

9 AC and DC Output Measurement Levels (Cont'd)

9.8 On-Die Termination (ODT) Levels and I-V Characteristics (Cont'd)

9.8.2 ODT DC Electrical Characteristics

Table 42 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:

Table 42 — ODT DC Electrical Characteristics, assuming $R_{ZQ} = 240 \Omega \pm 1\%$ entire operating temperature range; after proper ZQ calibration

MR1 A9, A6, A2	RTT	Resistor	V_{Out}	min	nom	max	Unit	Notes
0, 1, 0	120 Ω	$RTT_{120Pd240}$	V_{OLdc} $0.2 \times V_{DDQ}$	0.6	1.00	1.1	R_{ZQ}	1, 2, 3, 4,
			$0.5 \times V_{DDQ}$	0.9	1.00	1.1	R_{ZQ}	1, 2, 3, 4,
			V_{OHdc} $0.8 \times V_{DDQ}$	0.9	1.00	1.4	R_{ZQ}	1, 2, 3, 4,
		$RTT_{120Pu240}$	V_{OLdc} $0.2 \times V_{DDQ}$	0.9	1.00	1.4	R_{ZQ}	1, 2, 3, 4,
			$0.5 \times V_{DDQ}$	0.9	1.00	1.1	R_{ZQ}	1, 2, 3, 4,
			V_{OHdc} $0.8 \times V_{DDQ}$	0.6	1.00	1.1	R_{ZQ}	1, 2, 3, 4,
		RTT_{120}	$V_{IL(ac)}$ to $V_{IH(ac)}$	0.9	1.00	1.6	$R_{ZQ}/2$	1, 2, 5,
		$RTT_{60Pd120}$	V_{OLdc} $0.2 \times V_{DDQ}$	0.6	1.00	1.1	$R_{ZQ}/2$	1, 2, 3, 4,
			$0.5 \times V_{DDQ}$	0.9	1.00	1.1	$R_{ZQ}/2$	1, 2, 3, 4,
			V_{OHdc} $0.8 \times V_{DDQ}$	0.9	1.00	1.4	$R_{ZQ}/2$	1, 2, 3, 4,
0, 0, 1	60 Ω	$RTT_{60Pu120}$	V_{OLdc} $0.2 \times V_{DDQ}$	0.9	1.00	1.4	$R_{ZQ}/2$	1, 2, 3, 4,
			$0.5 \times V_{DDQ}$	0.9	1.00	1.1	$R_{ZQ}/2$	1, 2, 3, 4,
			V_{OHdc} $0.8 \times V_{DDQ}$	0.6	1.00	1.1	$R_{ZQ}/2$	1, 2, 3, 4,
		RTT_{60}	$V_{IL(ac)}$ to $V_{IH(ac)}$	0.9	1.00	1.6	$R_{ZQ}/4$	1, 2, 5,

9.8 On-Die Termination (ODT) Levels and I-V Characteristics (Cont'd)
9.8.2 ODT DC Electrical Characteristics (Cont'd)

Table 42 — ODT DC Electrical Characteristics, assuming $R_{ZQ} = 240\ \Omega \pm 1\%$ entire operating temperature range; after proper ZQ calibration

MR1 A9, A6, A2	RTT	Resistor	V _{Out}	min	nom	max	Unit	Notes		
0, 1, 1	40 Ω	RTT _{40Pd80}	V _{OLdc} 0.2 × V _{DDQ}	0.6	1.00	1.1	R _{ZQ} /3	1, 2, 3, 4,		
			0.5 × V _{DDQ}	0.9	1.00	1.1	R _{ZQ} /3	1, 2, 3, 4,		
			V _{OHdc} 0.8 × V _{DDQ}	0.9	1.00	1.4	R _{ZQ} /3	1, 2, 3, 4,		
		RTT _{40Pu80}	V _{OLdc} 0.2 × V _{DDQ}	0.9	1.00	1.4	R _{ZQ} /3	1, 2, 3, 4,		
			0.5 × V _{DDQ}	0.9	1.00	1.1	R _{ZQ} /3	1, 2, 3, 4,		
			V _{OHdc} 0.8 × V _{DDQ}	0.6	1.00	1.1	R _{ZQ} /3	1, 2, 3, 4,		
		RTT ₄₀	V _{IL(ac)} to V _{IH(ac)}	0.9	1.00	1.6	R _{ZQ} /6	1, 2, 5,		
		1, 0, 1	30 Ω	RTT _{30Pd60}	V _{OLdc} 0.2 × V _{DDQ}	0.6	1.00	1.1	R _{ZQ} /4	1, 2, 3, 4,
					0.5 × V _{DDQ}	0.9	1.00	1.1	R _{ZQ} /4	1, 2, 3, 4,
V _{OHdc} 0.8 × V _{DDQ}	0.9				1.00	1.4	R _{ZQ} /4	1, 2, 3, 4,		
RTT _{30Pu60}	V _{OLdc} 0.2 × V _{DDQ}			0.9	1.00	1.4	R _{ZQ} /4	1, 2, 3, 4,		
	0.5 × V _{DDQ}			0.9	1.00	1.1	R _{ZQ} /4	1, 2, 3, 4,		
	V _{OHdc} 0.8 × V _{DDQ}			0.6	1.00	1.1	R _{ZQ} /4	1, 2, 3, 4,		
RTT ₃₀	V _{IL(ac)} to V _{IH(ac)}			0.9	1.00	1.6	R _{ZQ} /8	1, 2, 5,		
1, 0, 0	20 Ω			RTT _{20Pd40}	V _{OLdc} 0.2 × V _{DDQ}	0.6	1.00	1.1	R _{ZQ} /6	1, 2, 3, 4,
					0.5 × V _{DDQ}	0.9	1.00	1.1	R _{ZQ} /6	1, 2, 3, 4,
		V _{OHdc} 0.8 × V _{DDQ}	0.9		1.00	1.4	R _{ZQ} /6	1, 2, 3, 4,		
		RTT _{20Pu40}	V _{OLdc} 0.2 × V _{DDQ}	0.9	1.00	1.4	R _{ZQ} /6	1, 2, 3, 4,		
			0.5 × V _{DDQ}	0.9	1.00	1.1	R _{ZQ} /6	1, 2, 3, 4,		
			V _{OHdc} 0.8 × V _{DDQ}	0.6	1.00	1.1	R _{ZQ} /6	1, 2, 3, 4,		
		RTT ₂₀	V _{IL(ac)} to V _{IH(ac)}	0.9	1.00	1.6	R _{ZQ} /12	1, 2, 5,		
		Deviation of V _M w.r.t. V _{DDQ} /2, DV _M				-5		+5	%	1, 2, 5, 6,

- Notes:
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 $V_{DDQ} = V_{DD}$ and that $V_{SSQ} = V_{SS}$.
 3. Pull-down and pull-up ODT resistors are recommended to be calibrated at $0.5 \times V_{DDQ}$. Other calibration schemes may be used to achieve the linearity spec shown above, e.g. calibration at $0.2 \times V_{DDQ}$ and $0.8 \times V_{DDQ}$.

9.8 On-Die Termination (ODT) Levels and I-V Characteristics (Cont'd)

9.8.2 ODT DC Electrical Characteristics (Cont'd)

4. Not a specification requirement, but a design guide line.
5. Measurement definition for R_{TT} :
Apply $V_{IH(ac)}$ to pin under test and measure current $I(V_{IH(ac)})$, then apply $V_{IL(ac)}$ to pin under test and measure current $I(V_{IL(ac)})$ respectively.

$$R_{TT} = \frac{V_{IH(ac)} - V_{IL(ac)}}{I(V_{IH(ac)}) - I(V_{IL(ac)})}$$

6. Measurement definition for V_M and DV_M :
Measure voltage (V_M) at test pin (midpoint) with no load:

$$\Delta V_M = \left(\frac{2 \times V_M}{V_{DDQ}} - 1 \right) \times 100$$

9 AC and DC Output Measurement Levels (Cont'd)

9.8 On-Die Termination (ODT) Levels and I-V Characteristics (Cont'd)

9.8.3 ODT Temperature and Voltage sensitivity

If temperature and/or voltage change after calibration, the tolerance limits widen according to Table 43 and Table 44.

$DT = T - T(@calibration)$; $DV = VDDQ - VDDQ(@calibration)$; $VDD = VDDQ$

Table 43 — ODT Sensitivity Definition

	min	max	unit
RTT	$0.9 - dR_{TT}dT* \Delta T - dR_{TT}dV* \Delta V $	$1.6 + dR_{TT}dT* \Delta T + dR_{TT}dV* \Delta V $	RZQ/2,4,6,8,12

Table 44 — ODT Voltage and Temperature Sensitivity

	min	max	unit
$dR_{TT}dT$	0	1.5	%/°C
$dR_{TT}dV$	0	0.15	%/mV

These parameters may not be subject to production test. They are verified by design and characterization

9 AC and DC Output Measurement Levels (Cont'd)

9.9 ODT Timing Definitions

9.9.1 Test Load for ODT Timings

Different than for timing measurements, the reference load for ODT timings is defined in Figure 92.

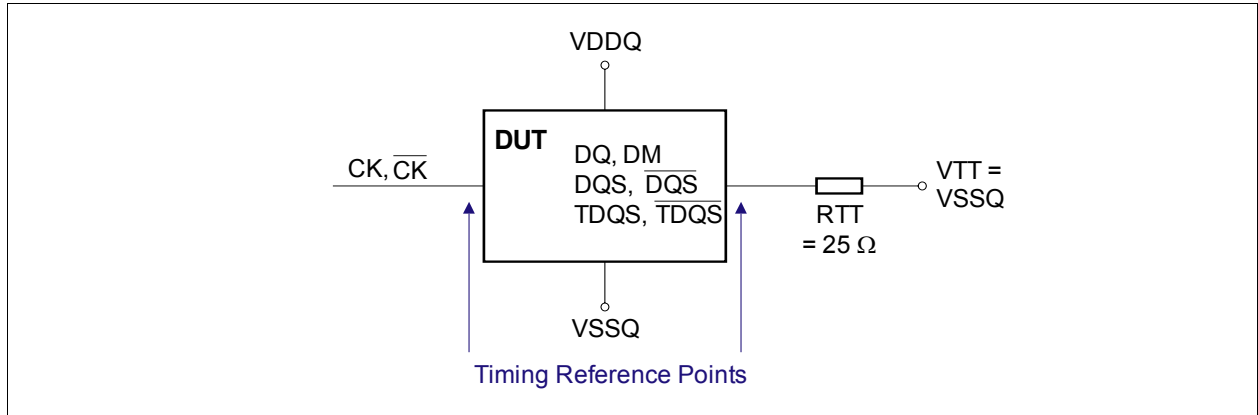


Figure 92: ODT Timing Reference Load

9.9.2 ODT Timing Definitions

Definitions for t_{AON} , t_{AONPD} , t_{AOF} , t_{AOFPD} and t_{ADC} are provided in Table 45 and subsequent figures. Measurement reference settings are provided in Table 46.

Table 45 — ODT Timing Definitions

Symbol	Begin Point Definition	End Point Definition	Figure
t_{AON}	Rising edge of CK - CK# defined by the end point of ODTLon	Extrapolated point at VSSQ	Figure 93
t_{AONPD}	Rising edge of CK - CK# with ODT being first registered high	Extrapolated point at VSSQ	Figure 94
t_{AOF}	Rising edge of CK - CK# defined by the end point of ODTLoff	End point: Extrapolated point at VRTT_Nom	Figure 95
t_{AOFPD}	Rising edge of CK - CK# with ODT being first registered low	End point: Extrapolated point at VRTT_Nom	Figure 96
t_{ADC}	Rising edge of CK - CK# defined by the end point of ODTLcnw, ODTLcwn4 or ODTLcwn8	End point: Extrapolated point at VRTT_Wr and VRTT_Nom respectively	Figure 97

Table 46 — Reference Settings for ODT Timing Measurements

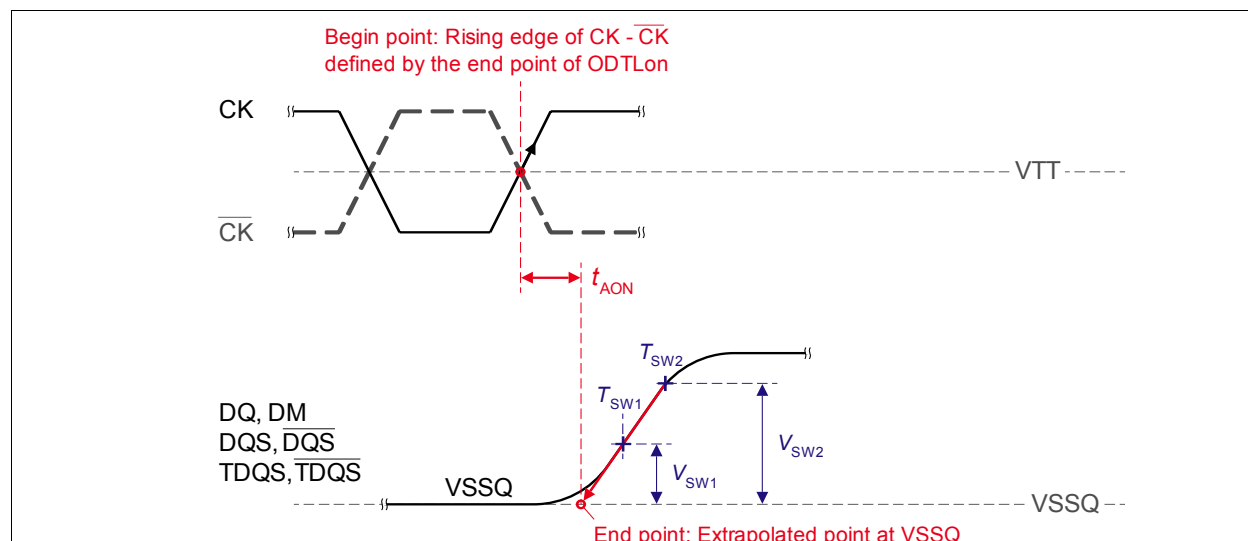
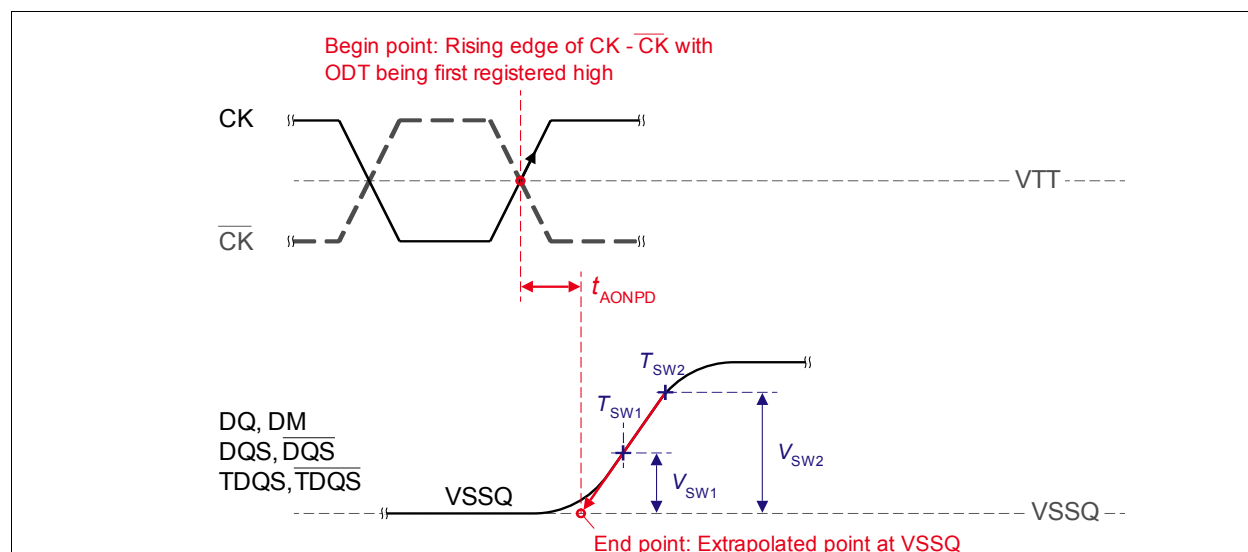
Measured Parameter	RTT_Nom Setting	RTT_Wr Setting	V_{sw1} [V]	V_{sw2} [V]	Note
t_{AON}	$R_{ZQ}/4$	NA	0.05	0.10	
	$R_{ZQ}/12$	NA	0.10	0.20	
t_{AONPD}	$R_{ZQ}/4$	NA	0.05	0.10	
	$R_{ZQ}/12$	NA	0.10	0.20	
t_{AOF}	$R_{ZQ}/4$	NA	0.05	0.10	
	$R_{ZQ}/12$	NA	0.10	0.20	

9.9 ODT Timing Definitions (Cont'd)

9.9.2 ODT Timing Definitions (Cont'd)

Table 46 — Reference Settings for ODT Timing Measurements (Cont.)

Measured Parameter	RTT_Nom Setting	RTT_Wr Setting	V_{SW1} [V]	V_{SW2} [V]	Note
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	

Figure 93 — Definition of t_{AON} Figure 94 — Definition of t_{AONPD}

9.9 ODT Timing Definitions (Cont'd)

9.9.2 ODT Timing Definitions (Cont'd)

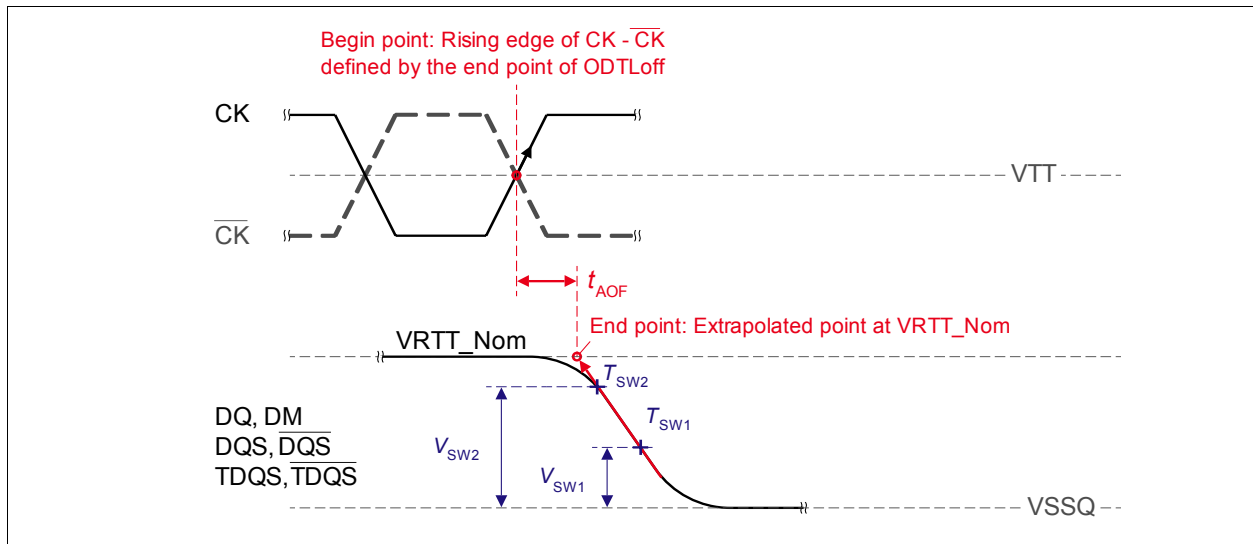


Figure 95 — Definition of t_{AOF}

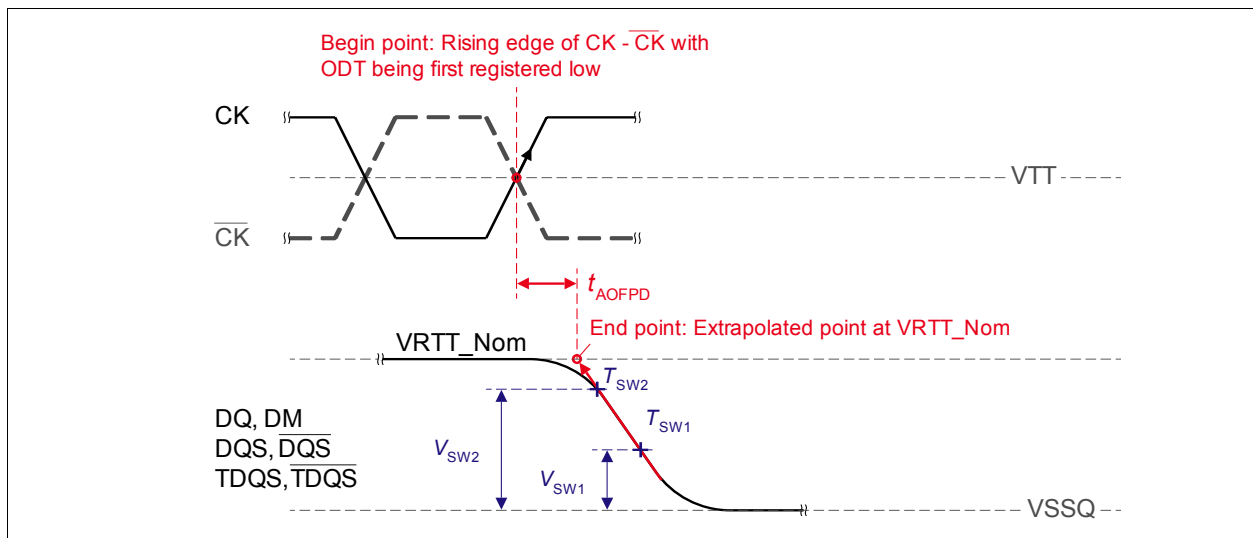


Figure 96 — Definition of t_{AOFPD}

9.9 ODT Timing Definitions (Cont'd)

9.9.2 ODT Timing Definitions (Cont'd)

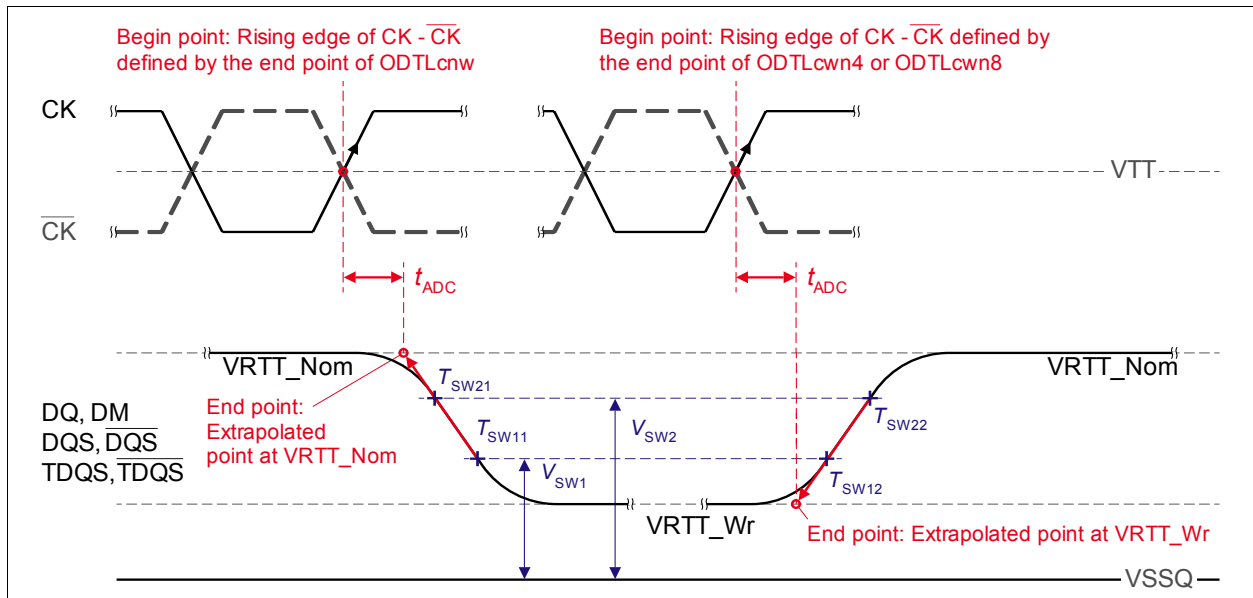


Figure 97 — Definition of t_{ADC}

10 IDD Specification Parameters and Test Conditions

10.1 IDD Measurement Conditions

The following tables provide an overview about the IDD measurement conditions is provided as follows:

Table 47 — Overview of Tables providing IDD Measurement Conditions and DRAM Behavior

Table number	Measurement Conditions
Table 51 on page 129	IDD0 and IDD1
Table 52 on page 131	IDD2N, IDD2Q, IDD2P(0), IDD2P(1)
Table 53 on page 133	IDD3N and IDD3P
Table 54 on page 134	IDD4R, IDD4W, IDD7
Table 55 on page 136	IDD7 for different Speed Grades and different tRRD, tFAW conditions
Table 56 on page 137	IDD5B
Table 57 on page 137	IDD6, IDD6ET (optional), IDD6TC (optional)

Within the tables about IDD measurement conditions, the following definitions are used:

- LOW is defined as $V_{IN} \leq V_{ILAC(max.)}$; HIGH is defined as $V_{IN} \geq V_{IHAC(min.)}$.
- STABLE is defined as inputs are stable at a HIGH or LOW level.
- FLOATING is defined as inputs are $V_{REF} = V_{DDQ} / 2$.
- SWITCHING is defined as described in Table 48 and Table 49.

Table 48 — Definition of SWITCHING for Address and Command Input Signals

SWITCHING for Address (row, column) and Command Signals (CS#, RAS#, CAS#, WE#) is defined as:	
Address (row, column):	If not otherwise mentioned the inputs are stable at HIGH or LOW during 4 clocks and change then to the opposite value _____ (e.g. Ax Ax Ax Ax $\overline{Ax}$ $\overline{Ax}$ $\overline{Ax}$ Ax Ax Ax Ax Ax Ax please see each IDDX definition for details
Bank address:	If not otherwise mentioned the bank addresses should be switched like the row/column addresses - please see each IDDX definition for details
Command (CS#, RAS#, CAS#, WE#):	Define $\underline{D} = \{CS\#, RAS\#, CAS\#, WE\# \} := \{HIGH, LOW, LOW, LOW\}$ Define $\overline{D} = \{CS\#, RAS\#, CAS\#, WE\# \} := \{HIGH, HIGH, HIGH, HIGH\}$ Define Command Background Pattern = $D \ D \ \overline{D} \ \overline{D} \ D \ D \ \overline{D} \ \overline{D} \ D \ D \ \overline{D} \ \overline{D} \ \dots$ If other commands are necessary (e.g. ACT for IDD0 or Read for IDD4R), the Background Pattern Command is substituted by the respective CS#, RAS#, CAS#, WE# levels of the necessary command. See each IDDX definition for details and Figure 98 through Figure 100 as examples.

10 IDD Specification Parameters and Test Conditions (Cont'd)**10.1 IDD Measurement Conditions (Cont'd)****Table 49 — Definition of SWITCHING for Data (DQ)**

SWITCHING for Data (DQ) is defined as	
Data (DQ)	Data DQ is changing between HIGH and LOW every other data transfer (once per clock) for DQ signals, which means that data DQ is stable during one clock; see each ID Dx definition for exceptions from this rule and for further details. See Figure 98 through Figure 100 as examples.
Data Masking (DM)	NO Switching; DM must be driven LOW all the time

Timing parameters are listed in the following table:

Table 50 — For IDD testing the following parameters are utilized.

Parameter Bin		DDR3-800		DDR3-1066			DDR3-1333			DDR3-1600			Unit
		5-5-5	6-6-6	6-6-6	7-7-7	8-8-8	7-7-7	8-8-8	9-9-9	8-8-8	9-9-9	10-10-10	
$t_{CKmin}(IDD)$		2.5		1.875			1.5			1.25			ns
CL(IDD)		5	6	6	7	8	7	8	9	8	9	10	
$t_{RCDmin}(IDD)$		12.5	15	11.25	13.13	15	10.5	12	13.5	10	11.25	12.5	ns
$t_{RCmin}(IDD)$		50	52.5	48.75	50.63	52.50	46.5	48	49.5	45	46.25	47.5	ns
$t_{RASmin}(IDD)$		37.5	37.5	37.5	37.5	37.5	36	36	36	35	35	35	ns
$t_{RPmin}(IDD)$		12.5	15	11.25	13.13	15	10.5	12	13.5	10	11.25	12.5	ns
$t_{FAW}(IDD)$	x4/ x8	40	40	37.5	37.5	37.5	30	30	30	30	30	30	ns
	x16	50	50	50	50	50	45	45	45	40	40	40	ns
$t_{RRD}(IDD)$	x4/ x8	10	10	7.5	7.5	7.5	6.0	6.0	6.0	6.0	6.0	6.0	ns
	x16	10	10	10	10	10	7.5	7.5	7.5	7.5	7.5	7.5	ns
$t_{RFC}(IDD) - 512Mb$		90	90	90	90	90	90	90	90	90	90	90	ns
$t_{RFC}(IDD) - 1Gb$		110	110	110	110	110	110	110	110	110	110	110	ns
$t_{RFC}(IDD) - 2Gb$		160	160	160	160	160	160	160	160	160	160	160	ns
$t_{RFC}(IDD) - 4Gb$		300	300	300	300	300	300	300	300	300	300	300	ns
$t_{RFC}(IDD) - 8Gb$		350	350	350	350	350	350	350	350	350	350	350	ns

The following conditions apply:

1. IDD specifications are tested after the device is properly initialized.
2. Input slew rate is specified by AC Parametric test conditions.
3. IDD parameters are specified with ODT and output buffer disabled (MR1 bit A12).

10 IDD Specification Parameters and Test Conditions (Cont'd)

10.1 IDD Measurement Conditions (Cont'd)

Table 51 — IDD Measurement Conditions for IDD0 and IDD1

Current	I_{DD0}	I_{DD1}
Name	Operating Current 0 -> One Bank Activate -> Precharge	Operating Current 1 -> One Bank Activate -> Read -> Precharge
Measurement Condition		
Timing Diagram Example		Figure 98
CKE	HIGH	HIGH
External Clock	on	on
t_{CK}	$t_{CKmin}(IDD)$	$t_{CKmin}(IDD)$
t_{RC}	$t_{RCmin}(IDD)$	$t_{RCmin}(IDD)$
t_{RAS}	$t_{RASmin}(IDD)$	$t_{RASmin}(IDD)$
t_{RCD}	n.a.	$t_{RCDmin}(IDD)$
t_{RRD}	n.a.	n.a.
CL	n.a.	CL(IDD)
AL	n.a.	0
CS#	HIGH between. Activate and Precharge Commands	HIGH between Activate, Read and Precharge
Command Inputs (CS#, RAS#, CAS#, WE#)	SWITCHING as described in Table 48; only exceptions are Activate and Precharge commands; example of IDD0 pattern: A0DDDDDDDDDDDDDDDD P0 (DDR3-800: $t_{RAS} = 37.5ns$ between (A)ctivate and (P)recharge to bank 0; Definition of D and $\bar{D}$: see Table 48)	SWITCHING as described in Table 48; only exceptions are Activate, Read and Precharge commands; example of IDD1 pattern: A0DDDDR0DDDDDDDDDD P0 (DDR3-800 -555: $t_{RCD} = 12.5ns$ between (A)ctivate and (R)ead to bank 0; Definition of D and $\bar{D}$: see Table 48)
Row, Column Addresses	Row addresses SWITCHING as described in Table 48; Address Input A10 must be LOW all the time!	Row addresses SWITCHING as described in Table 48; Address Input A10 must be LOW all the time!
Bank Addresses	bank address is fixed (bank 0)	bank address is fixed (bank 0)
Data I/O	SWITCHING as described in Table 49	Read Data: output data switches every clock, which means that Read data is stable during one clock cycle. To achieve $I_{out} = 0mA$, the output buffer should be switched off by MR1 bit A12 set to "1". When there is no read data burst from DRAM, the DQ I/O should be FLOATING.
Output Buffer DQ,DQS / MR1 bit A12	off / 1	off / 1
Rtt_Nom, Rtt_WR	disabled	disabled
Burst length	n.a.	8 fixed / MR0 bits [A1, A0] = {0,0}

10 IDD Specification Parameters and Test Conditions (Cont'd)

10.1 IDD Measurement Conditions (Cont'd)

Table 51 — IDD Measurement Conditions for IDD0 and IDD1

Current	I_{DD0}	I_{DD1}
Name	Operating Current 0 -> One Bank Activate -> Precharge	Operating Current 1 -> One Bank Activate -> Read -> Precharge
Active banks	one ACT-PRE loop	one ACT-RD-PRE loop
Idle banks	all other	all other
Precharge Power Down Mode / MR0 bit A12	n.a.	n.a.

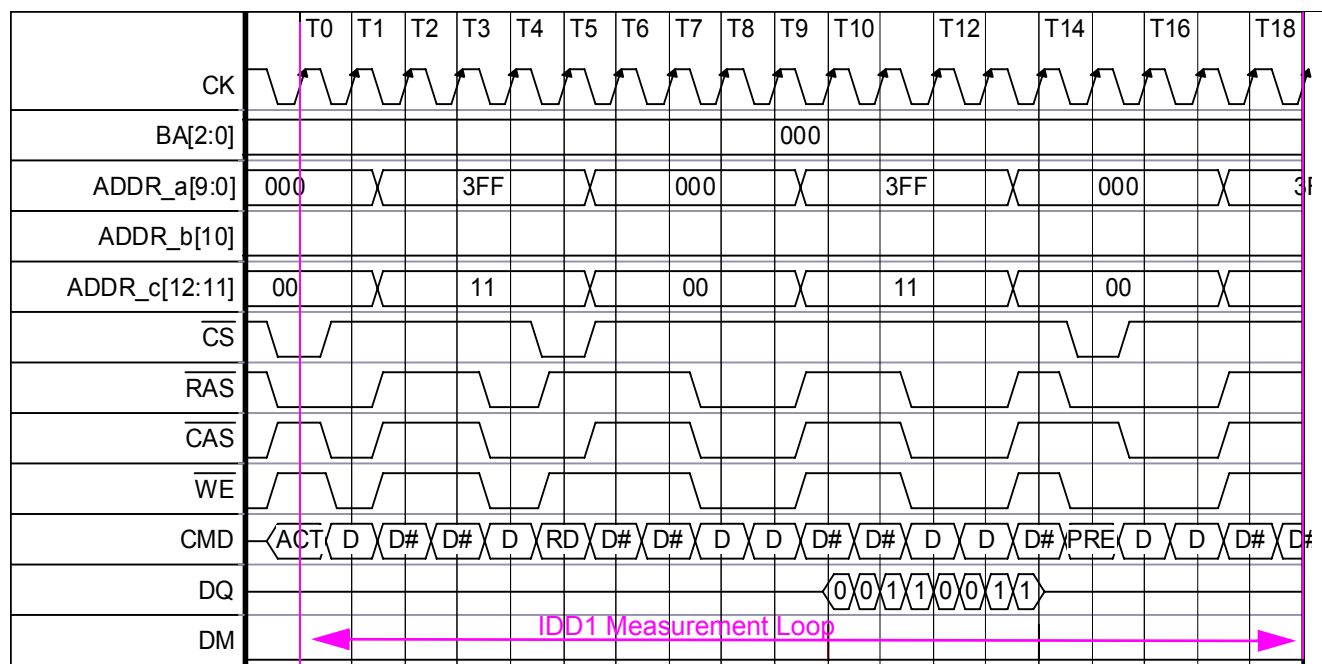


Figure 98 — IDD1 Example (DDR3-800-555, 512Mb x8): Data DQ is shown but the output buffer should be switched off (per MR1 bit A12 = "1") to achieve $I_{out} = 0\text{mA}$. Address inputs are split into 3 parts.

10 IDD Specification Parameters and Test Conditions (Cont'd)

10.1 IDD Measurement Conditions (Cont'd)

Table 52 — IDD Measurement Conditions for IDD2N, IDD2P(1), IDD2P(0) and IDD2Q

Current	I_{DD2N}	$I_{DD2P(1)}^1$	$I_{DD2P(0)}$	I_{DD2Q}
Name	Precharge Standby Current	Precharge Power Down Current Fast Exit - MR0 bit A12 = 1	Precharge Power Down Current Slow Exit - MR0 bit A12 = 0	Precharge Quiet Standby Current
Measurement Condition				
Timing Diagram Example	Figure 99			
CKE	HIGH	LOW	LOW	HIGH
External Clock	on	on	on	on
t_{CK}	$t_{CKmin}(IDD)$	$t_{CKmin}(IDD)$	$t_{CKmin}(IDD)$	$t_{CKmin}(IDD)$
t_{RC}	n.a.	n.a.	n.a.	n.a.
t_{RAS}	n.a.	n.a.	n.a.	n.a.
t_{RCD}	n.a.	n.a.	n.a.	n.a.
t_{RRD}	n.a.	n.a.	n.a.	n.a.
CL	n.a.	n.a.	n.a.	n.a.
AL	n.a.	n.a.	n.a.	n.a.
CS#	HIGH	STABLE	STABLE	HIGH
Bank Address, Row Addr. and Command Inputs	SWITCHING as described in Table 48	STABLE	STABLE	STABLE
Data inputs	SWITCHING	FLOATING	FLOATING	FLOATING
Output Buffer DQ,DQS / MR1 bit A12	off / 1	off / 1	off / 1	off / 1
Rtt_Nom, Rtt_WR	disabled	disabled	disabled	disabled
Burst length	n.a.	n.a.	n.a.	n.a.
Active banks	none	none	none	none
Idle banks	all	all	all	all
Precharge Power Down Mode / MR0 bit A12 ^a	n.a.	Fast Exit / 1 (any valid command after tXP ²)	Slow Exit / 0 Slow exit (RD and ODT commands must satisfy tXPDLL-AL)	n.a.

NOTE:

1. In DDR3, the MR0 bit A12 defines DLL on/off behaviour ONLY for precharge power down. There are 2 different Precharge Power Down states possible: one with DLL on (fast exit, bit 12 = 1) and one with DLL off (slow exit, bit 12 = 0).
2. Because it is an exit after precharge power down, the valid commands are: Activate, Refresh, Mode-Register Set, Enter - Self Refresh

10 IDD Specification Parameters and Test Conditions (Cont'd)
10.1 IDD Measurement Conditions (Cont'd)

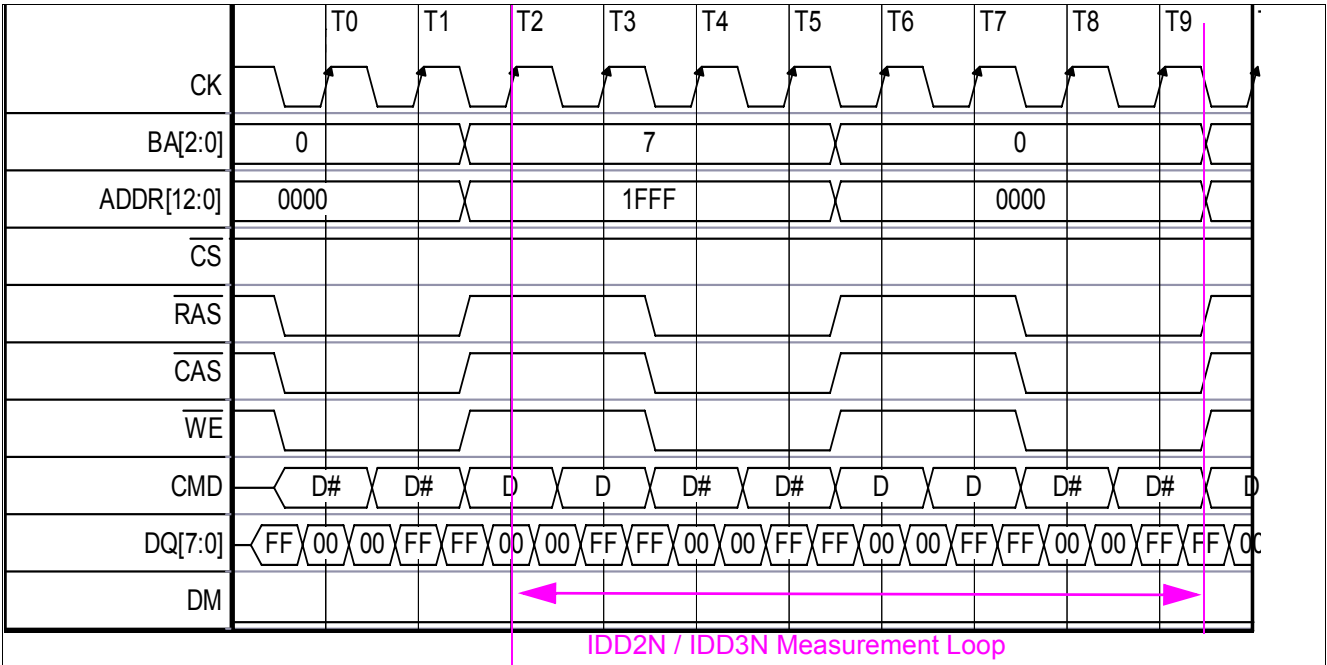


Figure 99 — IDD2N / IDD3N Example (DDR3-800-555, 512Mb x8)

10 IDD Specification Parameters and Test Conditions (Cont'd)
10.1 IDD Measurement Conditions (Cont'd)

Table 53 — IDD Measurement Conditions for IDD3N and IDD3P(fast exit)

Current	I_{DD3N}	I_{DD3P}
Name	Active Standby Current	Active Power-Down Current ¹ Always Fast Exit
Measurement Condition		
Timing Diagram Example	Figure 99	
CKE	HIGH	LOW
External Clock	on	on
t_{CK}	$t_{CKmin}(IDD)$	$t_{CKmin}(IDD)$
t_{RC}	n.a.	n.a.
t_{RAS}	n.a.	n.a.
t_{RCD}	n.a.	n.a.
t_{RRD}	n.a.	n.a.
CL	n.a.	n.a.
AL	n.a.	n.a.
CS#	HIGH	STABLE
Addr. and cmd Inputs	SWITCHING as described in Table 48	STABLE
Data inputs	SWITCHING as described in Table 49	FLOATING
Output Buffer DQ,DQS / MR1 bit A12	off / 1	off / 1
Rtt_Nom, Rtt_WR	disabled	disabled
Burst length	n.a.	n.a.
Active banks	all	all
Idle banks	none	none
Precharge Power Down Mode / MR0 bit A12 ^a	n.a.	n.a. (Active Power Down Mode is always "Fast Exit" with DLL on

NOTE:

1. DDR3 will offer only ONE active power down mode with DLL on (-> fast exit). MR0 bit A12 will not be used for active power down. Instead bit A12 will be used to switch between two different precharge power down modes.

10 IDD Specification Parameters and Test Conditions (Cont'd)

10.1 IDD Measurement Conditions (Cont'd)

Table 54 — IDD Measurement Conditions for IDD4R, IDD4W and IDD7

Current	I_{DD4R}	I_{DD4W}	I_{DD7}
Name	Operating Current Burst Read	Operating Current Burst Write	All Bank Interleave Read Current
Measurement Condition			
Timing Diagram Example	Figure 100		
CKE	HIGH	HIGH	HIGH
External Clock	on	on	on
t_{CK}	$t_{CKmin}(IDD)$	$t_{CKmin}(IDD)$	$t_{CKmin}(IDD)$
t_{RC}	n.a.	n.a.	$t_{RCmin}(IDD)$
t_{RAS}	n.a.	n.a.	$t_{RASmin}(IDD)$
t_{RCD}	n.a.	n.a.	$t_{RCDmin}(IDD)$
t_{RRD}	n.a.	n.a.	$t_{RRDmin}(IDD)$
CL	CL(IDD)	CL(IDD)	CL(IDD)
AL	0	0	$t_{RCDmin} - 1 t_{CK}$
CS#	HIGH btw. valid cmds	HIGH btw. valid cmds	HIGH btw. valid cmds
Command Inputs CS#, RAS#, CAS#, WE#	SWITCHING as described in Table 48; exceptions are Read commands => IDD4R Pattern: R0DDDR1DDDR2DDDR3 .DDD R4 Rx = Read from bank x; Definition of D and $\bar{D}$: see Table 48	SWITCHING as described in Table 48; exceptions are Write commands => IDD4W Pattern: W0DDDW1DDDW2DDDW3 DDD W4 ... Wx = Write to bank x; Definition of D and $\bar{D}$: see Table 48	For patterns see Table 55
Row, Column Addresses	column addresses SWITCHING as described in Table 48; Address Input A10 must be LOW all the time!	column addresses SWITCHING as described in Table 48; Address Input A10 must be LOW all the time!	STABLE during DESELECTs
Bank Addresses	bank address cycling (0 -> 1 -> 2 -> 3 ...)	bank address cycling (0 -> 1 -> 2 -> 3 ...)	bank address cycling (0 -> 1 -> 2 -> 3 ...), see pattern in Table 55
DQ I/O	Seamless Read Data Burst (BL8): output data switches every clock, which means that Read data is stable during one clock cycle. To achieve $I_{out} = 0mA$ the output buffer should be switched off by MR1 bit A12 set to "1".	Seamless Write Data Burst (BL8): input data switches every clock, which means that Write data is stable during one clock cycle. DM is low all the time.	Read Data (BL8): output data switches every clock, which means that Read data is stable during one clock cycle. To achieve $I_{out} = 0mA$ the output buffer should be switched off by MR1 bit A12 set to "1".
Output Buffer DQ,DQS / MR1 bit A12	off / 1	off / 1	off / 1
Rtt_Nom, Rtt_WR	disabled	disabled	disabled

10 IDD Specification Parameters and Test Conditions (Cont'd)
10.1 IDD Measurement Conditions (Cont'd)

Table 54 — IDD Measurement Conditions for IDD4R, IDD4W and IDD7

Current	I_{DD4R}	I_{DD4W}	I_{DD7}
Name	Operating Current Burst Read	Operating Current Burst Write	All Bank Interleave Read Current
Burst length	8 fixed / MR0 bits [A1, A0] = {0,0}	8 fixed / MR0 bits [A1, A0] = {0,0}	8 fixed / MR0 bits [A1, A0] = {0,0}
Active banks	all	all	all, rotational
Idle banks	none	none	none
Precharge Power Down Mode / MR0 bit A12	n.a.	n.a.	n.a.

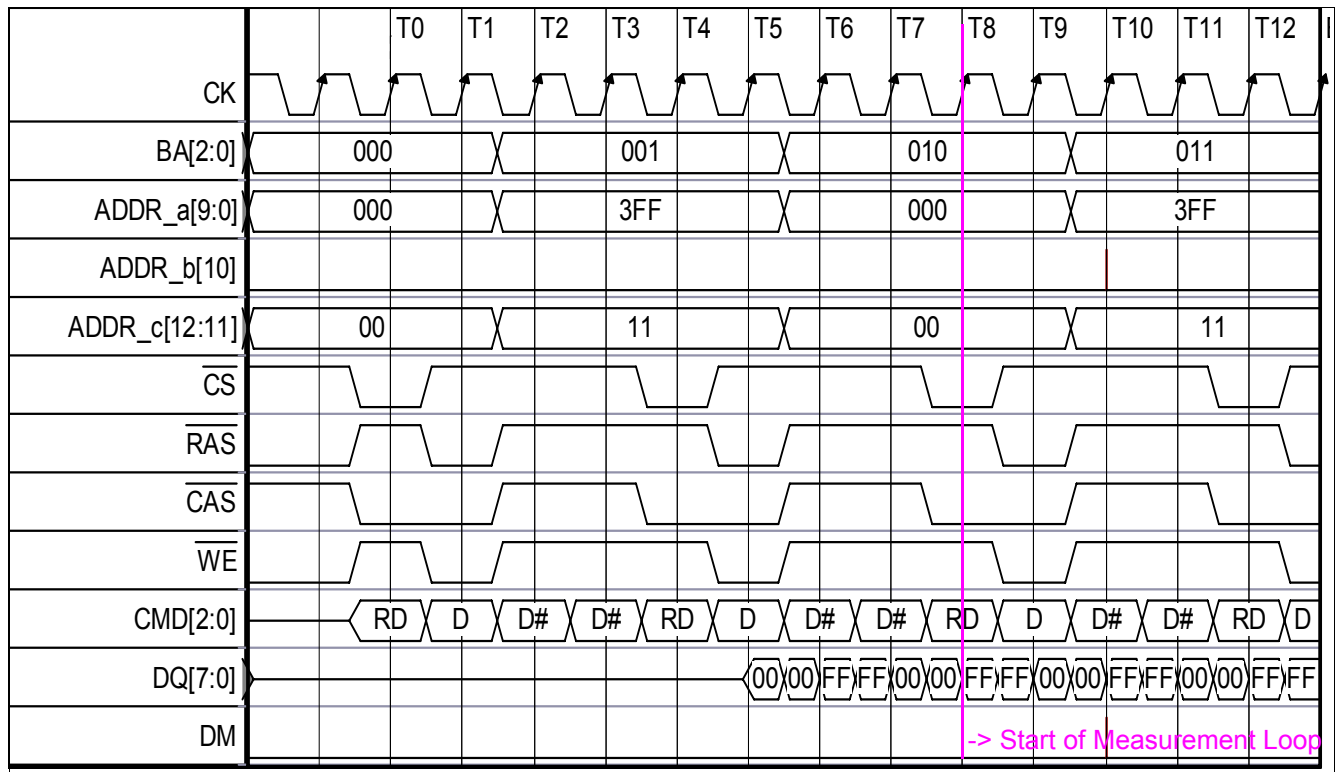


Figure 100 — IDD4R Example (DDR3-800-555, 512Mb x8): data DQ is shown but the output buffer should be switched off (per MR1 bit A12="1") to achieve $I_{out} = 0\text{mA}$. Address inputs are split into 3 parts.

10 IDD Specification Parameters and Test Conditions (Cont'd)
10.1 IDD Measurement Conditions (Cont'd)

Table 55 — IDD7 Pattern for different Speed Grades and different tRRD, tFAW conditions

Speed	Bin	Org.	tFAW	tFAW	tRRD	tRRD	IDD7 Pattern ¹
Mb/s			[ns]	[CLK]	[ns]	[CLK]	(Note this entire sequence is repeated.)
800	all	x4/x8	40	16	10	4	A0 RA0 D D A1 RA1 D D A2 RA2 D D A3 RA3 D D A4 RA4 D D A5 RA5 D D A6 RA6 D D A7 RA7 D D
	all	x16	50	20	10	4	A0 RA0 D D A1 RA1 D D A2 RA2 D D A3 RA3 D D D D D D A4 RA4 D D A5 RA5 D D A6 RA6 D D A7 RA7 D D D D D D
1066	all	x4/x8	37.5	20	7.5	4	A0 RA0 D D A1 RA1 D D A2 RA2 D D A3 RA3 D D D D D D A4 RA4 D D A5 RA5 D D A6 RA6 D D A7 RA7 D D D D D D
	all	x16	50	27	10	6	A0 RA0 D D D D A1 RA1 D D D D A2 RA2 D D D D A3 RA3 D D D D D D D D A4 RA4 D D D D A5 RA5 D D D D A6 RA6 D D D D A7 RA7 D D D D D D D D
1333	all	x4/x8	30	20	6	4	A0 RA0 D D A1 RA1 D D A2 RA2 D D A3 RA3 D D D D D D A4 RA4 D D A5 RA5 D D A6 RA6 D D A7 RA7 D D D D D D
	all	x16	45	30	7.5	5	A0 RA0 D D D A1 RA1 D D D A2 RA2 D D D A3 RA3 D D D D D D D D D D D D A4 RA4 D D D A5 RA5 D D D A6 RA6 D D D A7 RA7 D D D D D D D D D D D D
1600	all	x4/x8	30	24	6	5	A0 RA0 D D D A1 RA1 D D D A2 RA2 D D D A3 RA3 D D D D D D A4 RA4 D D D A5 RA5 D D D A6 RA6 D D D A7 RA7 D D D D D D
	all	x16	40	32	7.5	6	A0 RA0 D D D D A1 RA1 D D D D A2 RA2 D D D D A3 RA3 D D D D D D D D D D D D A4 RA4 D D D D A5 RA5 D D D D A6 RA6 D D D D A7 RA7 D D D D D D D D D D D D

NOTE:

1. A0 = Activation of Bank 0; RA0 = Read with Auto-Precharge of Bank 0; D = Deselect

10 IDD Specification Parameters and Test Conditions (Cont'd)

10.1 IDD Measurement Conditions (Cont'd)

Table 56 — IDD Measurement Conditions for IDD5B

Current	I_{DD5B}
Name	Burst Refresh Current
Measurement Condition	
CKE	HIGH
External Clock	on
t_{CK}	$t_{CKmin}(IDD)$
t_{RC}	n.a.
t_{RAS}	n.a.
t_{RCD}	n.a.
t_{RRD}	n.a.
t_{RFC}	$t_{RFCmin}(IDD)$
CL	n.a.
AL	n.a.
CS#	HIGH btw. valid cmds
Addr. and cmd Inputs	SWITCHING
Data inputs	SWITCHING
Output Buffer DQ,DQS / MR1 bit A12	off / 1
Rtt_Nom, Rtt_WR	disabled
Burst length	n.a.
Active banks	Refresh command every $t_{RFC}=t_{RFCmin}$
Idle banks	none
Precharge Power Down Mode / MR0 bit A12	n.a.

Table 57 — IDD Measurement Conditions for IDD6, IDD6ET, and IDD6TC

Current	I_{DD6}	I_{DD6ET} (optional)	I_{DD6TC} (optional)
Name	Self-Refresh Current Normal Temperature Range $T_{CASE} = 0 \dots 85^{\circ}C$	Self-Refresh Current Extended Temperature Range ¹ $T_{CASE} = 0 \dots 95^{\circ}C$	Auto Self-Refresh Current ^{1,2} T_{CASE} - See Table
Measurement Condition			
Temperature	$T_{CASE} = 85^{\circ}C$	$T_{CASE} = 95^{\circ}C$	T_{CASE} - See Table
Auto Self Refresh (ASR) / MR2 bit A6	Disabled / "0"	Disabled / "0"	Enabled / "1"
Self Refresh Temperature Range (SRT) / MR2 bit A7	Normal / "0"	Extended / "1"	Disabled / "0"
CKE	LOW	LOW	LOW

10 IDD Specification Parameters and Test Conditions (Cont'd)

10.1 IDD Measurement Conditions (Cont'd)

Table 57 — IDD Measurement Conditions for IDD6, IDD6ET, and IDD6TC

Current	I_{DD6}	I_{DD6ET} (optional)	I_{DD6TC} (optional)
Name	Self-Refresh Current Normal Temperature Range $T_{CASE} = 0 \dots 85 \text{ }^{\circ}\text{C}$	Self-Refresh Current Extended Temperature Range ¹ $T_{CASE} = 0 \dots 95 \text{ }^{\circ}\text{C}$	Auto Self-Refresh Current ^{1,2} T_{CASE} - See Table
External Clock	OFF; CK and $\overline{\text{CK}}$ at LOW	OFF; CK and $\overline{\text{CK}}$ at LOW	OFF; CK and $\overline{\text{CK}}$ at LOW
t_{CK}	n.a.	n.a.	n.a.
t_{RC}	n.a.	n.a.	n.a.
t_{RAS}	n.a.	n.a.	n.a.
t_{RCD}	n.a.	n.a.	n.a.
t_{RRD}	n.a.	n.a.	n.a.
CL	n.a.	n.a.	n.a.
AL	n.a.	n.a.	n.a.
CS#	FLOATING	FLOATING	FLOATING
Command Inputs (CS#, RAS#, CAS#, WE#)	FLOATING	FLOATING	FLOATING
Row, Column Addresses	FLOATING	FLOATING	FLOATING
Bank Addresses	FLOATING	FLOATING	FLOATING
Data I/O	FLOATING	FLOATING	FLOATING
Output Buffer DQ,DQS / MR1 bit A12	off / 1	off / 1	off / 1
Rtt_Nom, Rtt_WR	disabled	disabled	disabled
Burst length	n.a.	n.a.	n.a.
Active banks	all during self-refresh actions	all during self-refresh actions	all during self-refresh actions
Idle banks	all btw. Self-Refresh actions	all btw. Self-Refresh actions	all btw. Self-Refresh actions
Precharge Power Down Mode / MR0 bit A12	n.a.	n.a.	n.a.

NOTE:

1. Users should refer to the DRAM supplier data sheet and/or the DIMM SPD to determine if DDR3 SDRAM devices support the following options or requirements referred to in this material.
2. Users should refer to the DRAM supplier data sheet and/or the DIMM SPD to determine if DDR3 SDRAM devices supporting ASR support the Normal or Extended Temperature Range.

10 IDD Specification Parameters and Test Conditions (Cont'd)

10.2 IDD Specifications

IDD values are for full operating range of voltage and temperature unless otherwise noted.

Table 58 — I_{DD} Specification Example 512M DDR3

Speed Grade Bin	DDR3 - 800 5-5-5	DDR3 - 1066 7-7-7	DDR3 - 1333 8-8-8	DDR3 - 1600 9-9-9	Unit	Notes
Symbol	Max.	Max.	Max.	Max.		
I_{DD0}					mA	x4/x8
					mA	x16
I_{DD1}					mA	x4/x8
					mA	x16
I_{DD2P} (0) slow exit					mA	x4/x8/x16
I_{DD2P} (1) fast exit					mA	x4/x8/x16
I_{DD2N}					mA	x4/x8/x16
I_{DD2Q}					mA	x4/x8/x16
I_{DD3P} (fast exit)					mA	x4/x8/x16
I_{DD3N}					mA	x4/x8/x16
I_{DD4R}					mA	x4
					mA	x8
					mA	x16
I_{DD4W}					mA	x4
					mA	x8
					mA	x16
I_{DD5B}					mA	x4/x8/x16
I_{DD6}					mA	
I_{DD6ET}^1					mA	
I_{DD6TC}^1					mA	Refer to Table
I_{DD7}					mA	x4/x8
					mA	x16

NOTE:

- Users should refer to the DRAM supplier data sheet and/or the DIMM SPD to determine if DDR3 SDRAM devices support the following options or requirements referred to in this material.

Table 59 — I_{DD6} Current Definition

Symbol	Parameter/Condition
I_{DD6}	Normal Temperature Range Self-Refresh Current: $CKE \leq 0.2V$; external clock off, CK and CK# at 0V; Other control and address inputs are FLOATING; Data Bus inputs are FLOATING, PASR disabled. Applicable for MR2 settings A6 = 0 and A7 = 0.
I_{DD6ET}	Extended Temperature Range Self-Refresh Current: $CKE \leq 0.2V$; external clock off, CK and CK# at 0V; Other control and address inputs are FLOATING; Data Bus inputs are FLOATING, PASR disabled. Applicable for MR2 settings A6 = 0 and A7 = 1.

10 IDD Specification Parameters and Test Conditions (Cont'd)**10.2 IDD Specifications (Cont'd)****Table 59 — I_{DD6} Current Definition**

Symbol	Parameter/Condition
I_{DD6TC}	Auto Self-Refresh Current: $CKE \leq 0.2V$; external clock off, CK and CK# at 0V; Other control and address inputs are FLOATING; Data Bus inputs are FLOATING, PASR disabled. Applicable when ASR is enabled by MR2 settings A6 = 1 and A7 = 0.

Table 60 — I_{DD6} Specification

Symbol	Temperature Range	Value	Unit	Notes
I_{DD6}	0 - 85 °C		mA	3,4
I_{DD6ET}	0 - 95 °C		mA	5,6
I_{DD6TC}	0 °C ~ T_a		mA	6,7,8
	$T_b \sim T_y$		mA	6,7,8
	$T_z \sim T_{OPERmax}$		mA	6,7,8

1. Some I_{DD} currents are higher for x16 organization due to larger page-size architecture.
2. Max. values for I_{DD} currents considering worst case conditions of process, temperature and voltage.
3. Applicable for MR2 settings A6=0 and A7=0.
4. Supplier data sheets include a max value for I_{DD6} .
5. Applicable for MR2 settings A6=0 and A7=1. I_{DD6ET} is only specified for devices which support the Extended Temperature Range feature.
6. Refer to the supplier data sheet for the value specification method (e.g. max, typical) for I_{DD6ET} and I_{DD6TC} .
7. Applicable for MR2 settings A6=1 and A7=0. I_{DD6TC} is only specified for devices which support the Auto Self Refresh feature.
8. The number of discrete temperature ranges supported and the associated T_a - T_z values are supplier/design specific. Temperature ranges are specified for all supported values of T_{OPER} . Refer to supplier data sheet for more information.

11 Input/Output Capacitance

11.1 Input/Output Capacitance

Table 61 — Input / Output Capacitance

		DDR3-800		DDR3-1066		DDR3-1333		DDR3-1600			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Min	Max	Units	Notes
Input/output capacitance (DQ,DM,DQS,DQS#,TDQS,TDQS#)	C_{IO}	1.5	3.0	1.5	3.0	1.5	2.5	TBD	TBD	pF	1,2,3
Input capacitance, CK and CK#	C_{CK}	0.8	1.6	0.8	1.6	0.8	1.4	0.8	1.4	pF	2,3
Input capacitance delta, CK and CK#	C_{DCK}	0	0.15	0	0.15	0	0.15	0	0.15	pF	2,3,4
Input/output capacitance delta DQS and DQS#	C_{DDQS}	0	0.2	0	0.2	0	0.15	0	0.15	pF	2,3,5
Input capacitance, (CTRL, ADD, CMD input-only pins)	C_I	0.75	1.5	0.75	1.5	0.75	1.3	0.75	1.3	pF	2,3,6
Input capacitance delta, (All CTRL input-only pins)	C_{DI_CTRL}	-0.5	0.3	-0.5	0.3	-0.4	0.2	-0.4	0.2	pF	2,3,7,8
Input capacitance delta, (All ADD/CMD input-only pins)	$C_{DI\_ADD\_CMD}$	-0.5	0.5	-0.5	0.5	-0.4	0.4	-0.4	0.4	pF	2,3,9,10
Input/output capacitance delta, DQ, DM, DQS, DQS#, TDQS, TDQS#	C_{DIO}	-0.5	0.3	-0.5	0.3	-0.5	0.3	-0.5	0.3	pF	2,3,11
Input/output capacitance of ZQ pin	C_{ZQ}	-	3	-	3	-	3	-	3	pF	2,3,12
1. Although the DM, TDQS and 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. The capacitance is measured according to JEP147("PROCEDURE FOR MEASURING INPUT CAPACITANCE USING A VECTOR NETWORK ANALYZER(VNA)") with VDD, VDDQ, VSS, VSSQ applied and all other pins floating (except the pin under test, CKE, RESET# and ODT as necessary). VDD=VDDQ=1.5V, VBIAS=VDD/2 and on-die termination off. 3. This parameter applies to monolithic devices only; stacked/dual-die devices are not covered here 4. Absolute value of $C_{CK}-C_{CK\#}$ 5. Absolute value of $C_{IO}(DQS)-C_{IO}(DQS\#)$ 6. C_I applies to ODT, CS#, CKE, A0-A15, BA0-BA2, RAS#, CAS#, WE#. 7. C_{DI_CTRL} applies to ODT, CS# and CKE 8. $C_{DI\_CTRL}=C_I(CTRL)-0.5*(C_I(CLK)+C_I(CLK\#))$ 9. $C_{DI\_ADD\_CMD}$ applies to A0-A15, BA0-BA2, RAS#, CAS# and WE# 10. $C_{DI\_ADD\_CMD}=C_I(ADD\_CMD) - 0.5*(C_I(CLK)+C_I(CLK\#))$ 11. $C_{DIO}=C_{IO}(DQ,DM) - 0.5*(C_{IO}(DQS)+C_{IO}(DQS\#))$ 12. Maximum external load capacitance on ZQ pin: 5 pF.											

12 Electrical Characteristics & AC Timing for DDR3-800 to DDR3-1600

12.1 Clock Specification

The jitter specified is a random jitter meeting a Gaussian distribution. Input clocks violating the min/max values may result in malfunction of the DDR3 SDRAM device.

12.1.1 Definition for tCK(avg)

tCK(avg) is calculated as the average clock period across any consecutive 200 cycle window, where each clock period is calculated from rising edge to rising edge.

$$tCK(avg) = \left(\sum_{j=1}^N tCK_j \right) / N$$

where $N = 200$

12.1.2 Definition for tCK(abs)

tCK(abs) is defined as the absolute clock period, as measured from one rising edge to the next consecutive rising edge. tCK(abs) is not subject to production test.

12.1.3 Definition for tCH(avg) and tCL(avg)

tCH(avg) is defined as the average high pulse width, as calculated across any consecutive 200 high pulses.

$$tCH(avg) = \left(\sum_{j=1}^N tCH_j \right) / (N \times tCK(avg))$$

where $N = 200$

tCL(avg) is defined as the average low pulse width, as calculated across any consecutive 200 low pulses.

$$tCL(avg) = \left(\sum_{j=1}^N tCL_j \right) / (N \times tCK(avg))$$

where $N = 200$

12.1.4 Definition for tJIT(per) and tJIT(per,lck)

tJIT(per) is defined as the largest deviation of any signal tCK from tCK(avg).

tJIT(per) = Min/max of {tCK_i - tCK(avg) where i = 1 to 200}.

tJIT(per) defines the single period jitter when the DLL is already locked.

tJIT(per,lck) uses the same definition for single period jitter, during the DLL locking period only.

tJIT(per) and tJIT(per,lck) are not subject to production test.

12 Electrical Characteristics & AC Timing for DDR3-800 to DDR3-1600 (Cont'd)**12.1 Clock Specification (Cont'd)****12.1.5 Definition for tJIT(cc) and tJIT(cc,lck)**

tJIT(cc) is defined as the absolute difference in clock period between two consecutive clock cycles.

$$tJIT(cc) = \text{Max of } |tCK_{i+1} - tCK_i|.$$

tJIT(cc) defines the cycle to cycle jitter when the DLL is already locked.

tJIT(cc,lck) uses the same definition for cycle to cycle jitter, during the DLL locking period only.

tJIT(cc) and tJIT(cc,lck) are not subject to production test.

12.1.6 Definition for tERR(nper)

tERR is defined as the cumulative error across n multiple consecutive cycles from tCK(avg). tERR is not subject to production test.

12.2 Refresh parameters by device density**Table 62 — Refresh parameters by device density**

Parameter	Symbol		512Mb	1Gb	2Gb	4Gb	8Gb	Units	Notes
REF command to ACT or REF command time	tRFC		90	110	160	300	350	ns	
Average periodic refresh interval	tREFI	$0\text{ }^{\circ}\text{C} \leq T_{\text{CASE}} \leq 85\text{ }^{\circ}\text{C}$	7.8	7.8	7.8	7.8	7.8	μs	
		$85\text{ }^{\circ}\text{C} < T_{\text{CASE}} \leq 95\text{ }^{\circ}\text{C}$	3.9	3.9	3.9	3.9	3.9	μs	1

Notes: 1. Users should refer to the DRAM supplier data sheet and/or the DIMM SPD to determine if DDR3 SDRAM devices support the following options or requirements referred to in this material.

12 Electrical Characteristics & AC Timing for DDR3-800 to DDR3-1600 (Cont'd)

12.3 Standard Speed Bins

DDR3 SDRAM Standard Speed Bins include tCK, tRCD, tRP, tRAS and tRC for each corresponding bin.

Table 63 — DDR3-800 Speed Bins

For specific Notes See 12.3.1 “Speed Bin Table Notes” on page 148.								
Speed Bin			DDR3-800D		DDR3-800E		Unit	Notes
CL - nRCD - nRP			5-5-5		6-6-6			
Parameter		Symbol	min	max	min	max		
Internal read command to first data		t_{AA}	12.5	20	15	20	ns	
ACT to internal read or write delay time		t_{RCD}	12.5	—	15	—	ns	
PRE command period		t_{RP}	12.5	—	15	—	ns	
ACT to ACT or REF command period		t_{RC}	50	—	52.5	—	ns	
ACT to PRE command period		t_{RAS}	37.5	9 * tREFI	37.5	9 * tREFI	ns	
CL = 5	CWL = 5	$t_{CK(AVG)}$	2.5	3.3	Reserved		ns	1,2,3,4,
CL = 6	CWL = 5	$t_{CK(AVG)}$	2.5	3.3	2.5	3.3	ns	1,2,3,
Supported CL Settings			5, 6		6		n_{CK}	
Supported CWL Settings			5		5		n_{CK}	

12 Electrical Characteristics & AC Timing for DDR3-800 to DDR3-1600 (Cont'd)
12.3 Standard Speed Bins (Cont'd)

Table 64 — DDR3-1066 Speed Bins

For specific Notes See 12.3.1 “Speed Bin Table Notes” on page 148.										
Speed Bin		DDR3-1066E		DDR3-1066F		DDR3-1066G		Unit	Note	
CL - nRCD - nRP		6-6-6		7-7-7		8-8-8				
Parameter	Symbol	min	max	min	max	min	max			
Internal read command to first data	t_{AA}	11.25	20	13.125	20	15	20	ns		
ACT to internal read or write delay time	t_{RCD}	11.25	—	13.125	—	15	—	ns		
PRE command period	t_{RP}	11.25	—	13.125	—	15	—	ns		
ACT to ACT or REF command period	t_{RC}	48.75	—	50.625	—	52.5	—	ns		
ACT to PRE command period	t_{RAS}	37.5	9 * t_{REFI}	37.5	9 * t_{REFI}	37.5	9 * t_{REFI}	ns		
CL = 5	CWL = 5	$t_{CK(AVG)}$	2.5	3.3	Reserved		Reserved		ns	1,2,3,4,6,
	CWL = 6	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		ns	4,
CL = 6	CWL = 5	$t_{CK(AVG)}$	2.5	3.3	2.5	3.3	2.5	3.3	ns	1,2,3,6,
	CWL = 6	$t_{CK(AVG)}$	1.875	< 2.5	Reserved		Reserved		ns	1,2,3,4,
CL = 7	CWL = 5	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		ns	4,
	CWL = 6	$t_{CK(AVG)}$	1.875	< 2.5	1.875	< 2.5	Reserved		ns	1,2,3,4,
CL = 8	CWL = 5	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		ns	4,
	CWL = 6	$t_{CK(AVG)}$	1.875	< 2.5	1.875	< 2.5	1.875	< 2.5	ns	1,2,3,
Supported CL Settings		5, 6, 7, 8		6, 7, 8		6, 8		n_{CK}		
Supported CWL Settings		5, 6		5, 6		5, 6		n_{CK}		

12 Electrical Characteristics & AC Timing for DDR3-800 to DDR3-1600 (Cont'd)**12.3 Standard Speed Bins (Cont'd)****Table 65 — DDR3-1333 Speed Bins**

For specific Notes See 12.3.1 “Speed Bin Table Notes” on page 148.												
Speed Bin		DDR3-1333F (optional)		DDR3-1333G		DDR3-1333H		DDR3-1333J (optional)		Unit	Note	
CL - nRCD - nRP		7-7-7		8-8-8		9-9-9		10-10-10				
Parameter	Symbol	min	max	min	max	min	max	min	max			
Internal read command to first	t_{AA}	10.5	20	12	20	13.5	20	15	20	ns		
ACT to internal read or write delay time	t_{RCD}	10.5	—	12	—	13.5	—	15	—	ns		
PRE command period	t_{RP}	10.5	—	12	—	13.5	—	15	—	ns		
ACT to ACT or REF command period	t_{RC}	46.5	—	48	—	49.5	—	51	—	ns		
ACT to PRE command period	t_{RAS}	36	9 * t_{REFI}	36	9 * t_{REFI}	36	9 * t_{REFI}	36	9 * t_{REFI}	ns		
CL = 5	CWL = 5	$t_{CK(AVG)}$	2.5	3.3	2.5	3.3	Reserved		Reserved		ns	1,2,3,4,7
	CWL = 6, 7	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		Reserved		ns	4
CL = 6	CWL = 5	$t_{CK(AVG)}$	2.5	3.3	2.5	3.3	2.5	3.3	2.5	3.3	ns	1,2,3,7
	CWL = 6	$t_{CK(AVG)}$	1.875	< 2.5	Reserved		Reserved		Reserved		ns	1,2,3,4,7
	CWL = 7	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		Reserved		ns	4
CL = 7	CWL = 5	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		Reserved		ns	4
	CWL = 6	$t_{CK(AVG)}$	1.875	< 2.5	1.875	< 2.5	Reserved		Reserved		ns	1,2,3,4,7
	CWL = 7	$t_{CK(AVG)}$	1.5	<1.875	Reserved		Reserved		Reserved		ns	1,2,3,4
CL = 8	CWL = 5	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		Reserved		ns	4
	CWL = 6	$t_{CK(AVG)}$	1.875	< 2.5	1.875	< 2.5	1.875	< 2.5	1.875	< 2.5	ns	1,2,3,7
	CWL = 7	$t_{CK(AVG)}$	1.5	<1.875	1.5	<1.875	Reserved		Reserved		ns	1,2,3,4
CL = 9	CWL = 5, 6	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		Reserved		ns	4
	CWL = 7	$t_{CK(AVG)}$	1.5	<1.875	1.5	<1.875	1.5	<1.875	Reserved		ns	1,2,3,4
CL = 10	CWL = 5, 6	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		Reserved		ns	4
	CWL = 7	$t_{CK(AVG)}$	1.5	<1.875	1.5	<1.875	1.5	<1.875	1.5	<1.875	ns	1,2,3
			(Optional)		(Optional)		(Optional)				ns	5
Supported CL Settings		5, 6, 7, 8, 9		5, 6, 7, 8, 9		6, 8, 9		6, 8, 10		n_{CK}		
Supported CWL Settings		5, 6, 7		5, 6, 7		5, 6, 7		5, 6, 7		n_{CK}		

12 Electrical Characteristics & AC Timing for DDR3-800 to DDR3-1600 (Cont'd)
12.3 Standard Speed Bins (Cont'd)

Table 66 — DDR3-1600 Speed Bins

For specific Notes See 12.3.1 “Speed Bin Table Notes” on page 148.												
Speed Bin		DDR3-1600G (optional)		DDR3-1600H		DDR3-1600J		DDR3-1600K (optional)		Unit	Note	
CL - nRCD - nRP		8-8-8		9-9-9		10-10-10		11-11-11				
Parameter	Symbol	min	max	min	max	min	max	min	max			
Internal read command to first data	t_{AA}	10	20	11.25	20	12.5	20	13.75	20	ns		
ACT to internal read or write delay time	t_{RCD}	10	—	11.25	—	12.5	—	13.75	—	ns		
PRE command period	t_{RP}	10	—	11.25	—	12.5	—	13.75	—	ns		
ACT to ACT or REF command period	t_{RC}	45	—	46.25	—	47.5	—	48.75	—	ns		
ACT to PRE command period	t_{RAS}	35	9 * t_{REFI}	35	9 * t_{REFI}	35	9 * t_{REFI}	35	9 * t_{REFI}	ns		
CL = 5	CWL = 5	$t_{CK(AVG)}$	2.5	3.3	2.5	3.3	2.5	3.3	Reserved		ns	1,2,3,4,8
	CWL = 6, 7, 8	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		Reserved		ns	4
CL = 6	CWL = 5	$t_{CK(AVG)}$	2.5	3.3	2.5	3.3	2.5	3.3	2.5	3.3	ns	1,2,3,8
	CWL = 6	$t_{CK(AVG)}$	1.875	< 2.5	1.875	< 2.5	Reserved		Reserved		ns	1,2,3,4,8
	CWL = 7, 8	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		Reserved		ns	4
CL = 7	CWL = 5	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		Reserved		ns	4
	CWL = 6	$t_{CK(AVG)}$	1.875	< 2.5	1.875	< 2.5	1.875	< 2.5	Reserved		ns	1,2,3,4,8
	CWL = 7	$t_{CK(AVG)}$	1.5	<1.875	Reserved		Reserved		Reserved		ns	1,2,3,4,8
	CWL = 8	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		Reserved		ns	4
CL = 8	CWL = 5	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		Reserved		ns	4
	CWL = 6	$t_{CK(AVG)}$	1.875	< 2.5	1.875	< 2.5	1.875	< 2.5	1.875	< 2.5	ns	1,2,3,8
	CWL = 7	$t_{CK(AVG)}$	1.5	<1.875	1.5	<1.875	Reserved		Reserved		ns	1,2,3,4,8
	CWL = 8	$t_{CK(AVG)}$	1.25	< 1.5	Reserved		Reserved		Reserved		ns	1,2,3,4
CL = 9	CWL = 5, 6	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		Reserved		ns	4
	CWL = 7	$t_{CK(AVG)}$	1.5	<1.875	1.5	<1.875	1.5	<1.875	Reserved		ns	1,2,3,4,8
	CWL = 8	$t_{CK(AVG)}$	1.25	< 1.5	1.25	< 1.5	Reserved		Reserved		ns	1,2,3,4
CL = 10	CWL = 5, 6	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		Reserved		ns	4
	CWL = 7	$t_{CK(AVG)}$	1.5	<1.875	1.5	<1.875	1.5	<1.875	1.5	<1.875	ns	1,2,3,8
	CWL = 8	$t_{CK(AVG)}$	1.25	< 1.5	1.25	< 1.5	1.25	< 1.5	Reserved		ns	1,2,3,4

12 Electrical Characteristics & AC Timing for DDR3-800 to DDR3-1600 (Cont'd)**12.3 Standard Speed Bins (Cont'd)**

CL = 11	CWL = 5, 6, 7	$t_{CK(AVG)}$	Reserved		Reserved		Reserved		Reserved		ns	4
	CWL = 8	$t_{CK(AVG)}$	1.25	< 1.5	1.25	< 1.5	1.25	< 1.5	1.25	< 1.5	ns	1,2,3
			(Optional)		(Optional)		(Optional)				ns	5
			Supported CL Settings		5, 6, 7, 8, 9, 10	5, 6, 7, 8, 9, 10	5, 6, 7, 8, 9, 10	6, 8, 10, 11			n_{CK}	
Supported CWL Settings			5, 6, 7, 8		5, 6, 7, 8		5, 6, 7, 8		5, 6, 7, 8		n_{CK}	

12.3.1 Speed Bin Table Notes

Absolute Specification (T_{OPER} ; $V_{DDQ} = V_{DD} = 1.5V \pm 0.075V$);

Notes:

1. The CL setting and CWL setting result in $t_{CK(AVG).MIN}$ and $t_{CK(AVG).MAX}$ requirements. When making a selection of $t_{CK(AVG)}$, both need to be fulfilled: Requirements from CL setting as well as requirements from CWL setting.
2. $t_{CK(AVG).MIN}$ limits: Since CAS Latency is not purely analog - data and strobe output are synchronized by the DLL - all possible intermediate frequencies may not be guaranteed. An application should use the next smaller JEDEC standard $t_{CK(AVG)}$ value (2.5, 1.875, 1.5, or 1.25 ns) when calculating CL [n_{CK}] = t_{AA} [ns] / $t_{CK(AVG)}$ [ns], rounding up to the next 'Supported CL'.
3. $t_{CK(AVG).MAX}$ limits: Calculate $t_{CK(AVG)} = t_{AA}.MAX / CL$ SELECTED and round the resulting $t_{CK(AVG)}$ down to the next valid speed bin (i.e. 3.3ns or 2.5ns or 1.875 ns or 1.25 ns). This result is $t_{CK(AVG).MAX}$ corresponding to CL SELECTED.
4. 'Reserved' settings are not allowed. User must program a different value.
5. 'Optional' settings allow certain devices in the industry to support this setting, however, it is not a mandatory feature. Refer to supplier's data sheet and SPD information if and how this setting is supported.
6. Any DDR3-1066 speed bin also supports functional operation at lower frequencies as shown in the table which are not subject to Production Tests but verified by Design/Characterization.
7. Any DDR3-1333 speed bin also supports functional operation at lower frequencies as shown in the table which are not subject to Production Tests but verified by Design/Characterization.
8. Any DDR3-1600 speed bin also supports functional operation at lower frequencies as shown in the table which are not subject to Production Tests but verified by Design/Characterization.

13 Electrical Characteristics and AC Timing

Table 67 — Timing Parameters by Speed Bin

Note: The following general notes from page 156 apply to Table 67: a

		DDR3-800		DDR3-1066		DDR3-1333		DDR3-1600			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Min	Max	Units	Notes
Clock Timing											
Minimum Clock Cycle Time (DLL off mode)	tCK(DLL_OFF)	8	-	8	-	8	-	8	-	ns	6
Average Clock Period	tCK(avg)	See 12.3 “Standard Speed Bins” on page 144								ps	
Average high pulse width	tCH(avg)	0.47	0.53	0.47	0.53	0.47	0.53	0.47	0.53	tCK(avg)	
Average low pulse width	tCL(avg)	0.47	0.53	0.47	0.53	0.47	0.53	0.47	0.53	tCK(avg)	
Absolute Clock Period	tCK(abs)	tCK(avg) min + tJIT(per) min	tCK(avg) max + tJIT(per) max	tCK(avg) min + tJIT(per) min	tCK(avg) max + tJIT(per) max	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	
Absolute clock HIGH pulse width	tCH(abs)	0.43	-	0.43	-	0.43	-	0.43	-	tCK(avg)	25
Absolute clock LOW pulse width	tCL(abs)	0.43	-	0.43	-	0.43	-	0.43	-	tCK(avg)	26
Clock Period Jitter	JIT(per)	- 100	100	- 90	90	- 80	80	-70	70	ps	
Clock Period Jitter during DLL locking period	tJIT(per, lck)	- 90	90	- 80	80	- 70	70	-60	60	ps	
Cycle to Cycle Period Jitter	tJIT(cc)	200		180		160		140		ps	
Cycle to Cycle Period Jitter during DLL locking period	tJIT(cc, lck)	180		160		140		120		ps	
Duty Cycle Jitter	tJIT(duty)	-	-	-	-	-	-	-	-	ps	
Cumulative error across 2 cycles	tERR(2per)	- 147	147	- 132	132	- 118	118	- 103	103	ps	
Cumulative error across 3 cycles	tERR(3per)	- 175	175	- 157	157	- 140	140	- 122	122	ps	
Cumulative error across 4 cycles	tERR(4per)	- 194	194	- 175	175	- 155	155	- 136	136	ps	
Cumulative error across 5 cycles	tERR(5per)	- 209	209	- 188	188	- 168	168	- 147	147	ps	
Cumulative error across 6 cycles	tERR(6per)	- 222	222	- 200	200	- 177	177	- 155	155	ps	
Cumulative error across 7 cycles	tERR(7per)	- 232	232	- 209	209	- 186	186	- 163	163	ps	

Table 67 — Timing Parameters by Speed Bin (Cont.)

Note: The following general notes from page 156 apply to Table 67: a

		DDR3-800		DDR3-1066		DDR3-1333		DDR3-1600			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Min	Max	Units	Notes
Cumulative error across 8 cycles	tERR(8per)	- 241	241	- 217	217	- 193	193	- 169	169	ps	
Cumulative error across 9 cycles	tERR(9per)	- 249	249	- 224	224	- 200	200	- 175	175	ps	
Cumulative error across 10 cycles	tERR(10per)	- 257	257	- 231	231	- 205	205	- 180	180	ps	
Cumulative error across 11 cycles	tERR(11per)	- 263	263	- 237	237	- 210	210	- 184	184	ps	
Cumulative error across 12 cycles	tERR(12per)	- 269	269	- 242	242	- 215	215	- 188	188	ps	
Cumulative error across n = 13, 14 . . . 49, 50 cycles	tERR(nper)	$tERR(nper)_{min} = (1 + 0.68\ln(n)) * t_{JIT(per)min}$ $tERR(nper)_{max} = (1 + 0.68\ln(n)) * t_{JIT(per)max}$								ps	24
Data Timing											
DQS, DQS# to DQ skew, per group, per access	tDQSQ	-	200	-	150	-	125	-	100	ps	13
DQ output hold time from DQS, DQS#	tQH	0.38	-	0.38	-	0.38	-	0.38	-	tCK(avg)	13, b
DQ low-impedance time from CK, CK#	tLZ(DQ)	- 800	400	- 600	300	- 500	250	- 450	225	ps	13, 14, a
DQ high impedance time from CK, CK#	tHZ(DQ)	-	400	-	300	-	250	-	225	ps	13, 14, a
Data setup time to DQS, DQS# referenced to Vih(ac) / Vil(ac) levels	tDS(base)	75		25		TBD		TBD		ps	d, 17
Data hold time from DQS, DQS# referenced to Vih(dc) / Vil(dc) levels	tDH(base)	150		100		TBD		TBD		ps	d, 17
Data Strobe Timing											
DQS,DQS# differential READ Preamble	tRPRE	0.9	Note 19	0.9	Note 19	0.9	Note 19	0.9	Note 19	tCK(avg)	13, 19, b
DQS, DQS# differential READ Postamble	tRPST	0.3	Note 11	0.3	Note 11	0.3	Note 11	0.3	Note 11	tCK(avg)	11, 13, b
DQS, DQS# differential output high time	tQSH	0.38	-	0.38	-	0.40	-	0.40	-	tCK(avg)	13, b
DQS, DQS# differential output low time	tQSL	0.38	-	0.38	-	0.40	-	0.40	-	tCK(avg)	13, b
DQS, DQS# differential WRITE Preamble	tWPRE	0.9	-	0.9	-	0.9	-	0.9	-	tCK(avg)	
DQS, DQS# differential WRITE Postamble	tWPST	0.3	-	0.3	-	0.3	-	0.3	-	tCK(avg)	
DQS, DQS# rising edge output access time from rising CK, CK#	tDQCK	- 400	400	- 300	300	- 255	255	- 225	225	ps	13, a
DQS and DQS# low-impedance time (Referenced from RL - 1)	tLZ(DQS)	- 800	400	- 600	300	- 500	250	- 450	225	ps	13, 14, a
DQS and DQS# high-impedance time (Referenced from RL + BL/2)	tHZ(DQS)	-	400	-	300	-	250	-	225	ps	13, 14, a

Table 67 — Timing Parameters by Speed Bin (Cont.)**Note:** The following general notes from page 156 apply to Table 67: a

		DDR3-800		DDR3-1066		DDR3-1333		DDR3-1600			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Min	Max	Units	Notes
DQS, DQS# differential input low pulse width	tDQSL	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6	tCK(avg)	
DQS, DQS# differential input high pulse width	tDQSH	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6	tCK(avg)	
DQS, DQS# rising edge to CK, CK# rising edge	tDQSS	- 0.25	0.25	- 0.25	0.25	- 0.25	0.25	- 0.25	0.25	tCK(avg)	c
DQS, DQS# falling edge setup time to CK, CK# rising edge	tDSS	0.2	-	0.2	-	0.2	-	0.2	-	tCK(avg)	c
DQS, DQS# falling edge hold time from CK, CK# rising edge	tDSH	0.2	-	0.2	-	0.2	-	0.2	-	tCK(avg)	c
Command and Address Timing											
DLL locking time	tDLLK	512	-	512	-	512	-	512	-	nCK	
Internal READ Command to PRECHARGE Command delay	tRTP	max(4nC K, 7.5ns)	-	max(4nC K, 7.5ns)	-	max(4nC K, 7.5ns)	-	max(4nC K, 7.5ns)	-		e
Delay from start of internal write transaction to internal read command	tWTR	max(4nC K, 7.5ns)	-	max(4nC K, 7.5ns)	-	max(4nC K, 7.5ns)	-	max(4nC K, 7.5ns)	-		e, 18
WRITE recovery time	tWR	15	-	15	-	15	-	15	-	ns	e
Mode Register Set command cycle time	tMRD	4	-	4	-	4	-	4	-	nCK	
Mode Register Set command update delay	tMOD	max(12n CK, 15ns)	-	max(12n CK, 15ns)	-	max(12n CK, 15ns)	-	max(12n CK, 15ns)	-		
ACT to internal read or write delay time	tRCD	Refer to Table 63 to Table 66 on pages pages 144 to pages 147									e
PRE command period	tRP	Refer to Table 63 to Table 66 on pages pages 144 to pages 147									e
ACT to ACT or REF command period	tRC	Refer to Table 63 to Table 66 on pages pages 144 to pages 147									e
CAS# to CAS# command delay	tCCD	4	-	4	-	4	-	4	-	nCK	
Auto precharge write recovery + precharge time	tDAL(min)	WR + roundup(tRP / tCK(avg))								nCK	
Multi-Purpose Register Recovery Time	tMPRR	1	-	1	-	1	-	1	-	nCK	22
ACTIVE to PRECHARGE command period	tRAS	See 12.3 "Standard Speed Bins" on page 144									e
ACTIVE to ACTIVE command period for 1KB page size	tRRD	max(4nC K, 10ns)	-	max(4nC K, 7.5ns)	-	max(4nC K, 6ns)	-	max(4nC K, 6ns)	-		e

Table 67 — Timing Parameters by Speed Bin (Cont.)

Note: The following general notes from page 156 apply to Table 67: a

		DDR3-800		DDR3-1066		DDR3-1333		DDR3-1600			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Min	Max	Units	Notes
ACTIVE to ACTIVE command period for 2KB page size	tRRD	max(4nC K, 10ns)	-	max(4nC K, 10ns)	-	max(4nC K, 7.5ns)	-	max(4nC K, 7.5ns)	-		e
Four activate window for 1KB page size	tFAW	40	-	37.5	-	30	-	30	-	ns	e
Four activate window for 2KB page size	tFAW	50	-	50	-	45	-	40	-	ns	e
Command and Address setup time to CK, CK# referenced to Vih(ac) / Vil(ac) levels	tIS(base)	200		125		65		TBD		ps	b, 16
Command and Address hold time from CK, CK# referenced to Vih(dc) / Vil(dc) levels	tIH(base)	275		200		140		TBD		ps	b, 16
Command and Address setup time to CK, CK# referenced to Vih(ac) / Vil(ac) levels	tIS(base) AC150	-	-	-	-	65 + 125		TBD + 125		ps	b, 16, 27
Calibration Timing											
Power-up and RESET calibration time	tZQinit	512	-	512	-	512	-	512	-	nCK	
Normal operation Full calibration time	tZQoper	256	-	256	-	256	-	256	-	nCK	
Normal operation Short calibration time	tZQCS	64	-	64	-	64	-	64	-	nCK	23
Reset Timing											
Exit Reset from CKE HIGH to a valid command	tXPR	max(5nC K, tRFC(min) + 10ns)	-	max(5nC K, tRFC(min) + 10ns)	-	max(5nC K, tRFC(min) + 10ns)	-	max(5nC K, tRFC(min) + 10ns)	-		
Self Refresh Timings											
Exit Self Refresh to commands not requiring a locked DLL	tXS	max(5nC K, tRFC(min) + 10ns)	-	max(5nC K, tRFC(min) + 10ns)	-	max(5nC K, tRFC(min) + 10ns)	-	max(5nC K, tRFC(min) + 10ns)	-		
Exit Self Refresh to commands requiring a locked DLL	tXSDLL	tDLLK(min)	-	tDLLK(min)	-	tDLLK(min)	-	tDLLK(min)	-	nCK	
Minimum CKE low width for Self Refresh entry to exit timing	tCKESR	tCKE(min) + 1 nCK	-	tCKE(min) + 1 nCK	-	tCKE(min) + 1 nCK	-	tCKE(min) + 1 nCK	-		

Table 67 — Timing Parameters by Speed Bin (Cont.)**Note:** The following general notes from page 156 apply to Table 67: a

		DDR3-800		DDR3-1066		DDR3-1333		DDR3-1600			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Min	Max	Units	Notes
Valid Clock Requirement after Self Refresh Entry (SRE) or Power-Down Entry (PDE)	tCKSRE	max(5 nCK, 10 ns)	-	max(5 nCK, 10 ns)	-	max(5 nCK, 10 ns)	-	max(5 nCK, 10 ns)	-		
Valid Clock Requirement before Self Refresh Exit (SRX) or Power-Down Exit (PDX) or Reset Exit	tCKSRX	max(5 nCK, 10 ns)	-	max(5 nCK, 10 ns)	-	max(5 nCK, 10 ns)	-	max(5 nCK, 10 ns)	-		
Power Down Timings											
Exit Power Down with DLL on to any valid command; Exit Precharge Power Down with DLL frozen to commands not requiring a locked DLL	tXP	max(3nCK, 7.5ns)	-	max(3nCK, 7.5ns)	-	max(3nCK, 6ns)	-	max(3nCK, 6ns)	-		
Exit Precharge Power Down with DLL frozen to commands requiring a locked DLL	tXPDLL	max(10nCK, 24ns)	-	max(10nCK, 24ns)	-	max(10nCK, 24ns)	-	max(10nCK, 24ns)	-		2
CKE minimum pulse width	tCKE	max(3nCK, 7.5ns)	-	max(3nCK, 5.625ns)	-	max(3nCK, 5.625ns)	-	max(3nCK, 5ns)	-		
Command pass disable delay	tCPDED	1	-	1	-	1	-	1	-	nCK	
Power Down Entry to Exit Timing	tPD	tCKE(min)	9 * tREFI	tCKE(min)	9 * tREFI	tCKE(min)	9 * tREFI	tCKE(min)	9 * tREFI		15
Timing of ACT command to Power Down entry	tACTPDEN	1	-	1	-	1	-	1	-	nCK	20
Timing of PRE or PREA command to Power Down entry	tPRPDEN	1	-	1	-	1	-	1	-	nCK	20
Timing of RD/RDA command to Power Down entry	tRDPDEN	RL + 4 + 1	-	RL + 4 + 1	-	RL + 4 + 1	-	RL + 4 + 1	-	nCK	
Timing of WR command to Power Down entry (BL8OTF, BL8MRS, BC4OTF)	tWRPDEN	WL + 4 + (tWR / tCK(avg))	-	WL + 4 + (tWR / tCK(avg))	-	WL + 4 + (tWR / tCK(avg))	-	WL + 4 + (tWR / tCK(avg))	-	nCK	9
Timing of WRA command to Power Down entry (BL8OTF, BL8MRS, BC4OTF)	tWRAPDEN	WL + 4 + WR + 1	-	WL + 4 + WR + 1	-	WL + 4 + WR + 1	-	WL + 4 + WR + 1	-	nCK	10

Table 67 — Timing Parameters by Speed Bin (Cont.)

Note: The following general notes from page 156 apply to Table 67: a

		DDR3-800		DDR3-1066		DDR3-1333		DDR3-1600			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Min	Max	Units	Notes
Timing of WR command to Power Down entry (BC4MRS)	tWRPDEN	WL + 2 + (tWR / tCK(avg))	-	WL + 2 + (tWR / tCK(avg))	-	WL + 2 + (tWR / tCK(avg))	-	WL + 2 + (tWR / tCK(avg))	-	nCK	9
Timing of WRA command to Power Down entry (BC4MRS)	tWRAPDEN	WL + 2 + WR + 1	-	WL + 2 + WR + 1	-	WL + 2 + WR + 1	-	WL + 2 + WR + 1	-	nCK	10
Timing of REF command to Power Down entry	tREFPDEN	1	-	1	-	1	-	1	-	nCK	20, 21
Timing of MRS command to Power Down entry	tMRSPDEN	tMOD(min)	-	tMOD(min)	-	tMOD(min)	-	tMOD(min)	-		
ODT Timings											
ODT high time without write command or with write command and BC4	ODTH4	4	-	4	-	4	-	4	-	nCK	
ODT high time with Write command and BL8	ODTH8	6	-	6	-	6	-	6	-	nCK	
Asynchronous RTT turn-on delay (Power-Down with DLL frozen)	tAONPD	1	9	1	9	1	9	1	9	ns	
Asynchronous RTT turn-off delay (Power-Down with DLL frozen)	tAOFPD	1	9	1	9	1	9	1	9	ns	
RTT turn-on	tAON	-400	400	-300	300	-250	250	-225	225	ps	7, a
RTT_Nom and RTT_WR turn-off time from ODTLoff reference	tAOF	0.3	0.7	0.3	0.7	0.3	0.7	0.3	0.7	tCK(avg)	8, a
RTT dynamic change skew	tADC	0.3	0.7	0.3	0.7	0.3	0.7	0.3	0.7	tCK(avg)	a
Write Leveling Timings											
First DQS/DQS# rising edge after write leveling mode is programmed	tWLMRD	40	-	40	-	40	-	40	-	nCK	3
DQS/DQS# delay after write leveling mode is programmed	tWLDQSEN	25	-	25	-	25	-	25	-	nCK	3
Write leveling setup time from rising CK, CK# crossing to rising DQS, DQS# crossing	tWLS	325	-	245	-	195	-	TBD	-	ps	
Write leveling hold time from rising DQS, DQS# crossing to rising CK, CK# crossing	tWLH	325	-	245	-	195	-	TBD	-	ps	
Write leveling output delay	tWLO	0	9	0	9	0	9	0	7.5	ns	

Table 67 — Timing Parameters by Speed Bin (Cont.)

Note: The following general notes from page 156 apply to Table 67: a

		DDR3-800		DDR3-1066		DDR3-1333		DDR3-1600			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Min	Max	Units	Notes
Write leveling output error	tWLOE	0	2	0	2	0	2	0	2	ns	

13 Electrical Characteristics and AC Timing (Cont'd)**13.1 Jitter Notes**

- Specific Note a When the device is operated with input clock jitter, this parameter needs to be derated by the actual $t_{ERR}(mper),act$ of the input clock, where $2 \leq m \leq 12$. (output deratings are relative to the SDRAM input clock.)
For example, if the measured jitter into a DDR3-800 SDRAM has $t_{ERR}(mper),act,min} = -172$ ps and $t_{ERR}(mper),act,max} = +193$ ps, then $t_{DQSCK,min}(derated) = t_{DQSCK,min} - t_{ERR}(mper),act,max} = -400$ ps - 193 ps = -593 ps and $t_{DQSCK,max}(derated) = t_{DQSCK,max} - t_{ERR}(mper),act,min} = 400$ ps + 172 ps = +572 ps. Similarly, $t_{LZ}(DQ)$ for DDR3-800 derates to $t_{LZ}(DQ),min(derated) = -800$ ps - 193 ps = -993 ps and $t_{LZ}(DQ),max(derated) = 400$ ps + 172 ps = +572 ps. (Caution on the min/max usage!)
- Note that $t_{ERR}(mper),act,min}$ is the minimum measured value of $t_{ERR}(nper)$ where $2 \leq n \leq 12$, and $t_{ERR}(mper),act,max}$ is the maximum measured value of $t_{ERR}(nper)$ where $2 \leq n \leq 12$.
- Specific Note b When the device is operated with input clock jitter, this parameter needs to be derated by the actual $t_{JIT}(per),act$ 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 $t_{CK}(avg),act} = 2500$ ps, $t_{JIT}(per),act,min} = -72$ ps and $t_{JIT}(per),act,max} = +93$ ps, then $t_{RPRE,min}(derated) = t_{RPRE,min} + t_{JIT}(per),act,min} = 0.9 \times t_{CK}(avg),act} + t_{JIT}(per),act,min} = 0.9 \times 2500$ ps - 72 ps = +2178 ps. Similarly, $t_{QH,min}(derated) = t_{QH,min} + t_{JIT}(per),act,min} = 0.38 \times t_{CK}(avg),act} + t_{JIT}(per),act,min} = 0.38 \times 2500$ ps - 72 ps = +878 ps. (Caution on the min/max usage!)
- Specific Note c These parameters are measured from a data strobe signal ($DQS(L/U)$, $DQS(L/U)\#$) crossing to its respective clock signal (CK , $CK\#$) crossing. The spec values are not affected by the amount of clock jitter applied (i.e. $t_{JIT}(per)$, $t_{JIT}(cc)$, etc.), as these are relative to the clock signal crossing. That is, these parameters should be met whether clock jitter is present 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 ($DQS(L/U)$, $DQS(L/U)\#$) 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 $tRP = 15$ ns, the device will support $tnRP = RU\{tRP / tCK(avg)\} = 6$, as long as the input clock jitter specifications are met, i.e. Pre-charge command at Tm and Active command at $Tm+6$ is valid even if $(Tm+6 - Tm)$ is less than 15 ns due to input clock jitter.

13 Electrical Characteristics and AC Timing (Cont'd)

13.2 Timing Parameter Notes

- Notes:
1. Actual value dependant upon measurement level definitions which are TBD.
 2. Commands requiring a locked DLL are: READ (and RAP) and synchronous ODT commands.
 3. The max values are system dependent.
 4. WR as programmed in mode register
 5. Value must be rounded-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 turn-on time tAON See 5.2.2 "Timing Parameters" on page 81.
 8. For definition of RTT turn-off time tAOF See 5.2.2 "Timing Parameters" on page 81.
 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 as programmed in MR0.
 11. The maximum postamble is bound 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 t.b.d.
 13. Value is only valid for RON34
 14. Single ended signal parameter. Refer to chapter <t.b.d.> for definition and measurement method.
 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, CK# differential slew rate. Note for DQ and DM signals, VREF(DC) = VRefDQ(DC). For input only pins except RESET#, VRef(DC) = VRefCA(DC). See 13.3 "Address / Command Setup, Hold and Derating" on page 159
 17. tDS(base) and tDH(base) values are for 1V/ns DQ single-ended slew rate and 2V/ns DQS, DQS# differential slew rate. Note for DQ and DM signals, VREF(DC) = VRefDQ(DC). For input only pins except RESET#, VRef(DC) = VRefCA(DC). See 13.4 "Data Setup, Hold and Slew Rate Derating" on page 166.
 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(min)
 20. CKE is allowed to be registered low while operations such as row activation, pre-charge, 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 tXP-DLL(min) is also required. See 4.16.3 "Power-Down clarifications - Case 2" on page 78
 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

13 Electrical Characteristics and AC Timing (Cont'd)

13.2 Timing Parameter Notes (Cont'd)

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 ($T_{driftrate}$) and voltage ($V_{driftrate}$) drift rates that the SDRAM is subject to in the application, is illustrated. The interval could be defined by the following formula:

$$\frac{ZQCorrection}{(TSens \times Tdriftrate) + (VSens \times Vdriftrate)}$$

where $TSens = \max(dRTTdT, dRONdTM)$ and $VSens = \max(dRTTdV, dRONdVM)$ define the SDRAM temperature and voltage sensitivities.

For example, if $TSens = 1.5\% / ^\circ C$, $VSens = 0.15\% / mV$, $Tdriftrate = 1 ^\circ C / sec$ and $Vdriftrate = 15 mV / sec$, then the interval between ZQCS commands is calculated as:

$$\frac{0.5}{(1.5 \times 1) + (0.15 \times 15)} = 0.133 \approx 128ms$$

24. n = from 13 cycles to 50 cycles. This row defines 38 parameters.
25. $t_{CH}(abs)$ is the absolute instantaneous clock high pulse width, as measured from one rising edge to the following falling edge.
26. $t_{CL}(abs)$ 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 100 ps of derating to accommodate for the lower alternate threshold of 150 mV and another 25 ps to account for the earlier reference point $[(175 mV - 150 mV) / 1 V/ns]$.

13 Electrical Characteristics and AC Timing (Cont'd)

13.3 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) value (see Table 68) to the ΔtIS and ΔtIH derating value (see Table 69) respectively. Example: tIS (total setup time) = tIS(base) + ΔtIS

Setup (tIS) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of $V_{REF(dc)}$ and the first crossing of $V_{IH(ac)}min$. Setup (tIS) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of $V_{REF(dc)}$ and the first crossing of $V_{IL(ac)}max$. If the actual signal is always earlier than the nominal slew rate line between shaded ' $V_{REF(dc)}$ to ac region', use nominal slew rate for derating value (see Figure Figure 101). If the actual signal is later than the nominal slew rate line anywhere between shaded ' $V_{REF(dc)}$ to ac region', the slew rate of a tangent line to the actual signal from the ac level to dc level is used for derating value (see Figure 103).

Hold (tIH) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of $V_{IL(dc)}max$ and the first crossing of $V_{REF(dc)}$. Hold (tIH) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of $V_{IH(dc)}min$ and the first crossing of $V_{REF(dc)}$. If the actual signal is always later than the nominal slew rate line between shaded 'dc to $V_{REF(dc)}$ region', use nominal slew rate for derating value (see Figure 102). If the actual signal is earlier than the nominal slew rate line anywhere between shaded 'dc to $V_{REF(dc)}$ region', the slew rate of a tangent line to the actual signal from the dc level to $V_{REF(dc)}$ level is used for derating value (see Figure 104).

For a valid transition the input signal has to remain above/below $V_{IH/IL(ac)}$ for some time t_{VAC} (see Table 71).

Although for slow slew rates the total setup time might be negative (i.e. a valid input signal will not have reached $V_{IH/IL(ac)}$ at the time of the rising clock transition, a valid input signal is still required to complete the transition and reach $V_{IH/IL(ac)}$.

For slew rates in between the values listed in Table 69, 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.

Table 68 — ADD/CMD Setup and Hold Base-Values for 1V/ns

Unit [ps]	DDR3-800	DDR3-1066	DDR3-1333	DDR3-1600	Reference
tIS(base)	200	125	65	TBD	$V_{IH/L(ac)}$
tIH(base)	275	200	140	TBD	$V_{IH/L(dc)}$
tIH(base) AC150	-	-	65 + 125	TBD + 125	$V_{IH/L(dc)}$

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

13 Electrical Characteristics and AC Timing (Cont'd)**13.3 Address / Command Setup, Hold and Derating (Cont'd)****Table 69 — Derating values DDR3-800/1066/1333/1600 tIS/tIH - ac/dc based**

		$\Delta t_{IS}, \Delta t_{IH}$ derating in [ps] AC/DC based AC175 Threshold -> $V_{IH}(ac)=V_{REF}(dc)+175mV$, $V_{IL}(ac)=V_{REF}(dc)-175mV$															
		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	
		Δt_{IS}	Δt_{IH}	Δt_{IS}	Δt_{IH}	Δt_{IS}	Δt_{IH}	Δt_{IS}	Δt_{IH}	Δt_{IS}	Δt_{IH}	Δt_{IS}	Δt_{IH}	Δt_{IS}	Δt_{IH}	Δt_{IS}	Δt_{IH}
CMD/ ADD Slew rate V/ns	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

Table 70 — Derating values DDR3-1333/1600 tIS/tIH - ac/dc based - Alternate AC150 Threshold

		$\Delta t_{IS}, \Delta t_{IH}$ derating in [ps] AC/DC based Alternate AC150 Threshold -> $V_{IH}(ac)=V_{REF}(dc)+150mV$, $V_{IL}(ac)=V_{REF}(dc)-150mV$															
		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	
		Δt_{IS}	Δt_{IH}	Δt_{IS}	Δt_{IH}	Δt_{IS}	Δt_{IH}	Δt_{IS}	Δt_{IH}	Δt_{IS}	Δt_{IH}	Δt_{IS}	Δt_{IH}	Δt_{IS}	Δt_{IH}	Δt_{IS}	Δt_{IH}
CMD/ ADD Slew rate V/ns	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

13 Electrical Characteristics and AC Timing (Cont'd)
13.3 Address / Command Setup, Hold and Derating (Cont'd)

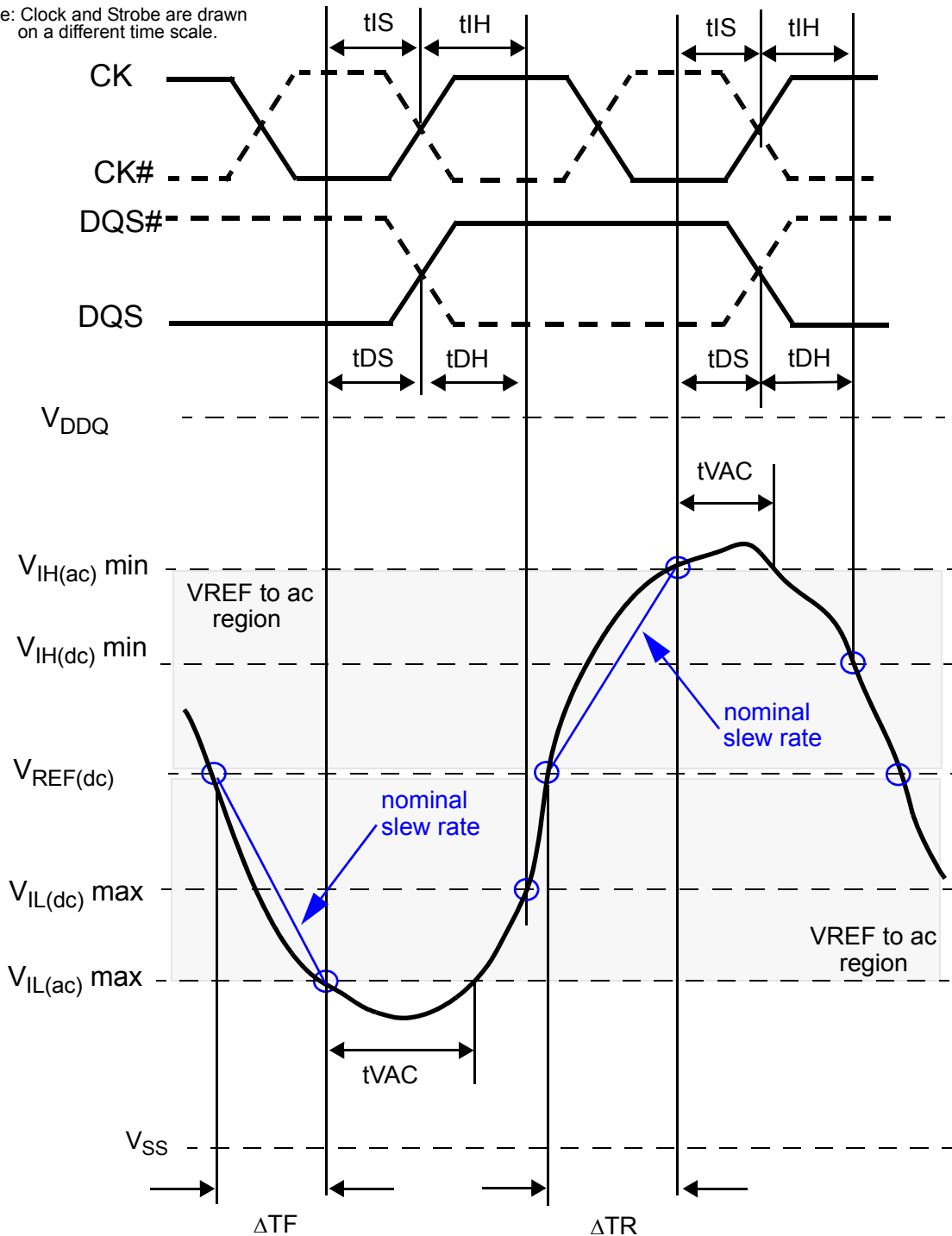
Table 71 — Required time t_{VAC} above $V_{IH}(ac)$ {below $V_{IL}(ac)$ } for valid transition

Slew Rate [V/ns]	t_{VAC} @ 175mV [ps]		t_{VAC} @ 150mV [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	-

13 Electrical Characteristics and AC Timing (Cont'd)

13.3 Address / Command Setup, Hold and Derating (Cont'd)

Note: Clock and Strobe are drawn on a different time scale.



$$\text{Setup Slew Rate Falling Signal} = \frac{V_{REF(dc)} - V_{IL(ac) \max}}{\Delta TF}$$

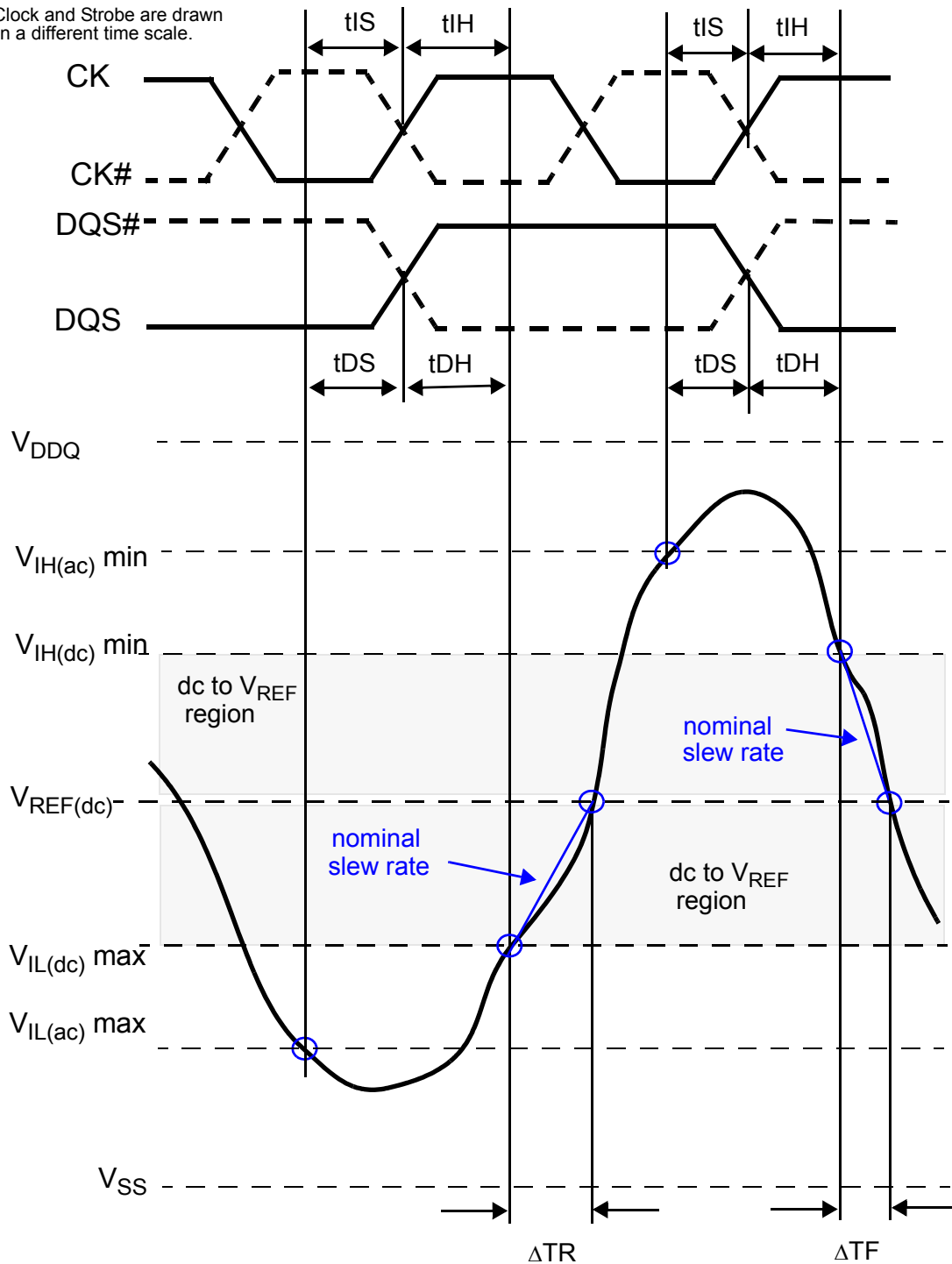
$$\text{Setup Slew Rate Rising Signal} = \frac{V_{IH(ac) \min} - V_{REF(dc)}}{\Delta TR}$$

Figure 101 — Illustration of nominal slew rate and t_{VAC} for setup time t_{DS} (for DQ with respect to strobe) and t_{IS} (for ADD/CMD with respect to clock).

13 Electrical Characteristics and AC Timing (Cont'd)

13.3 Address / Command Setup, Hold and Derating (Cont'd)

Note: Clock and Strobe are drawn on a different time scale.



$$\text{Hold Slew Rate Rising Signal} = \frac{V_{\text{REF}(dc)} - V_{\text{IL}(dc)\text{max}}}{\Delta TR}$$

$$\text{Hold Slew Rate Falling Signal} = \frac{V_{\text{IH}(dc)\text{min}} - V_{\text{REF}(dc)}}{\Delta TF}$$

Figure 102 — Illustration of nominal slew rate for hold time t_{DH} (for DQ with respect to strobe) and t_{IH} (for ADD/CMD with respect to clock).

13 Electrical Characteristics and AC Timing (Cont'd)

13.3 Address / Command Setup, Hold and Derating (Cont'd)

Note: Clock and Strobe are drawn on a different time scale.

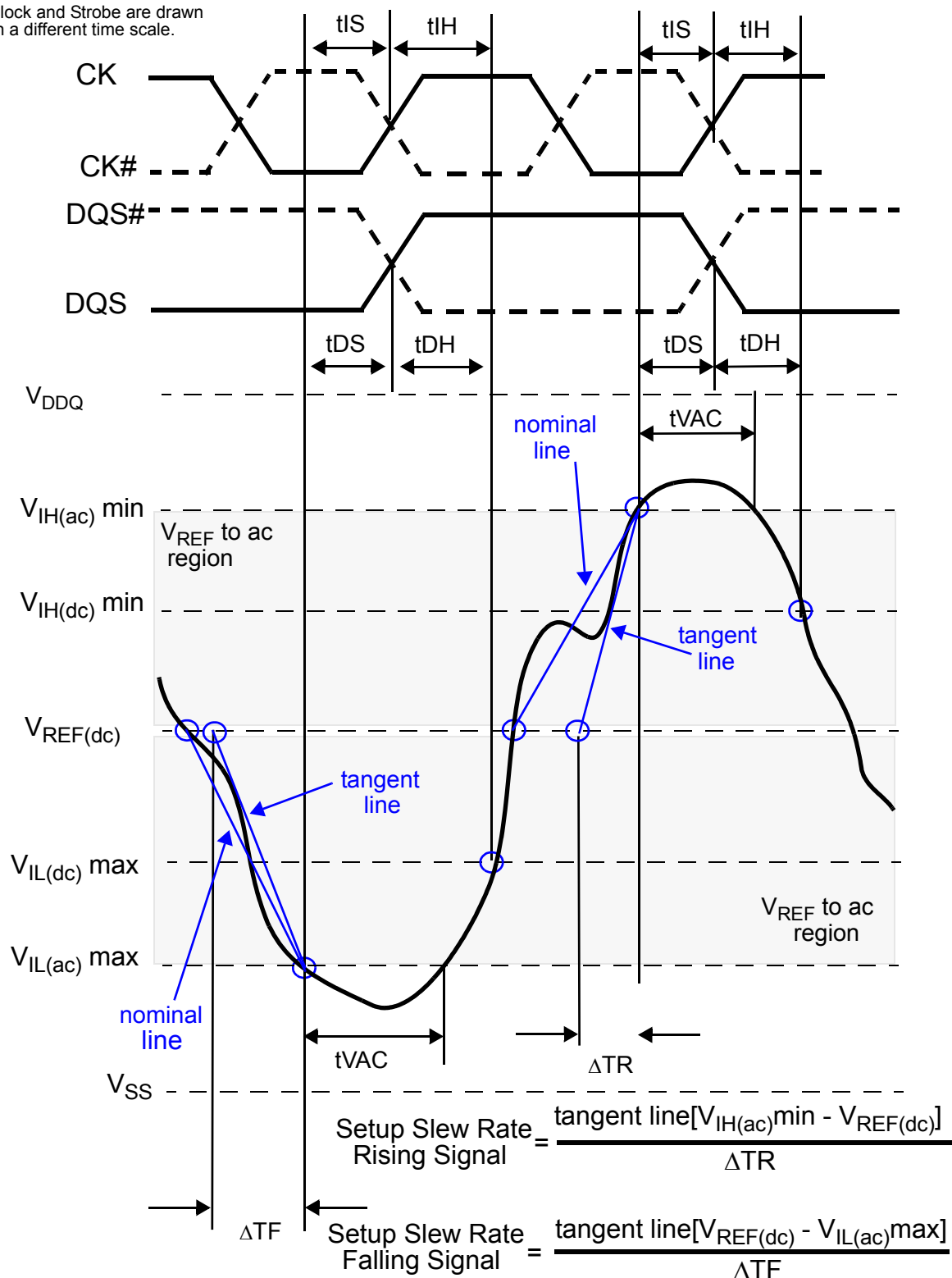


Figure 103 — Illustration of tangent line for setup time t_{DS} (for DQ with respect to strobe) and t_{IS} (for ADD/CMD with respect to clock)

13 Electrical Characteristics and AC Timing (Cont'd)

13.3 Address / Command Setup, Hold and Derating (Cont'd)

Note: Clock and Strobe are drawn on a different time scale.

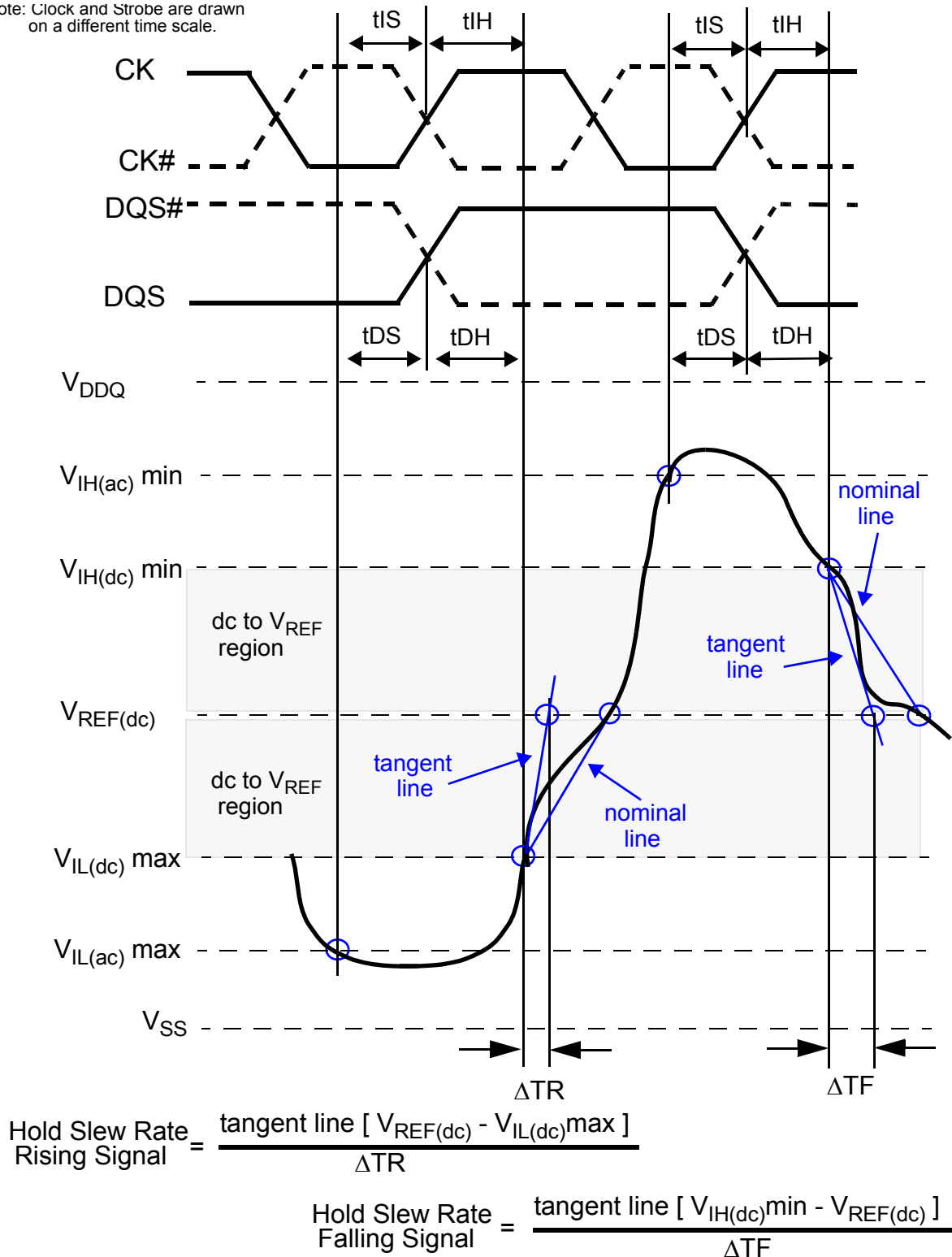


Figure 104 — Illustration of tangent line for for hold time t_{DH} (for DQ with respect to strobe) and t_{IH} (for ADD/CMD with respect to clock)

13 Electrical Characteristics and AC Timing (Cont'd)

13.4 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 tDS(base) and tDH(base) value (see Table 72) to the ΔtDS and ΔtDH (see Table 73) derating value respectively. Example: tDS (total setup time) = tDS(base) + ΔtDS .

Setup (tDS) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of $V_{REF(dc)}$ and the first crossing of $V_{IH(ac)min}$. Setup (tDS) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of $V_{REF(dc)}$ and the first crossing of $V_{IL(ac)max}$ (see Figure 105). If the actual signal is always earlier than the nominal slew rate line between shaded ' $V_{REF(dc)}$ 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 ' $V_{REF(dc)}$ to ac region', the slew rate of a tangent line to the actual signal from the ac level to dc level is used for derating value (see Figure 107).

Hold (tDH) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of $V_{IL(dc)max}$ and the first crossing of $V_{REF(dc)}$. Hold (tDH) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of $V_{IH(dc)min}$ and the first crossing of $V_{REF(dc)}$ (see Figure 106). If the actual signal is always later than the nominal slew rate line between shaded 'dc level to $V_{REF(dc)}$ region', use nominal slew rate for derating value. If the actual signal is earlier than the nominal slew rate line anywhere between shaded 'dc to $V_{REF(dc)}$ region', the slew rate of a tangent line to the actual signal from the dc level to $V_{REF(dc)}$ level is used for derating value (see Figure 108).

For a valid transition the input signal has to remain above/below $V_{IH/IL(ac)}$ for some time t_{VAC} (see Table 74).

Although for slow slew rates the total setup time might be negative (i.e. a valid input signal will not have reached $V_{IH/IL(ac)}$ at the time of the rising clock transition) a valid input signal is still required to complete the transition and reach $V_{IH/IL(ac)}$.

For slew rates in between the values listed in the tables the derating values may obtained by linear interpolation.

These values are typically not subject to production test. They are verified by design and characterization.

Table 72 — Data Setup and Hold Base-Values

Units [ps]	DDR3-800	DDR3-1066	DDR3-1333	DDR3-1600	Reference
tDS(base)	75	25	-10	TBD	$V_{IH/L(ac)}$
tDH(base)	150	100	65	TBD	$V_{IH/L(dc)}$

Note: (ac/dc referenced for 1V/ns DQ-slew rate and 2 V/ns DQS slew rate)

13 Electrical Characteristics and AC Timing (Cont'd)
13.4 Data Setup, Hold and Slew Rate Derating (Cont'd)

Table 73 — Derating values DDR3-800/1066 tDS/tDH - ac/dc based

$\Delta t_{DS}, \Delta t_{DH}$ derating in [ps] AC/DC based ¹																	
		DQS, 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	
		Δt_{DS}	Δt_{DH}	Δt_{DS}	Δt_{DH}	Δt_{DS}	Δt_{DH}	Δt_{DS}	Δt_{DH}	Δt_{DS}	Δt_{DH}	Δt_{DS}	Δt_{DH}	Δt_{DS}	Δt_{DH}	Δt_{DS}	Δt_{DH}
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

NOTE:

1. Cell contents shaded in red are defined as 'not supported'.

Table 74 — Required time t_{VAC} above $V_{IH}(ac)$ {below $V_{IL}(ac)$ } for valid transition

Slew Rate [V/ns]	t_{VAC} [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	-

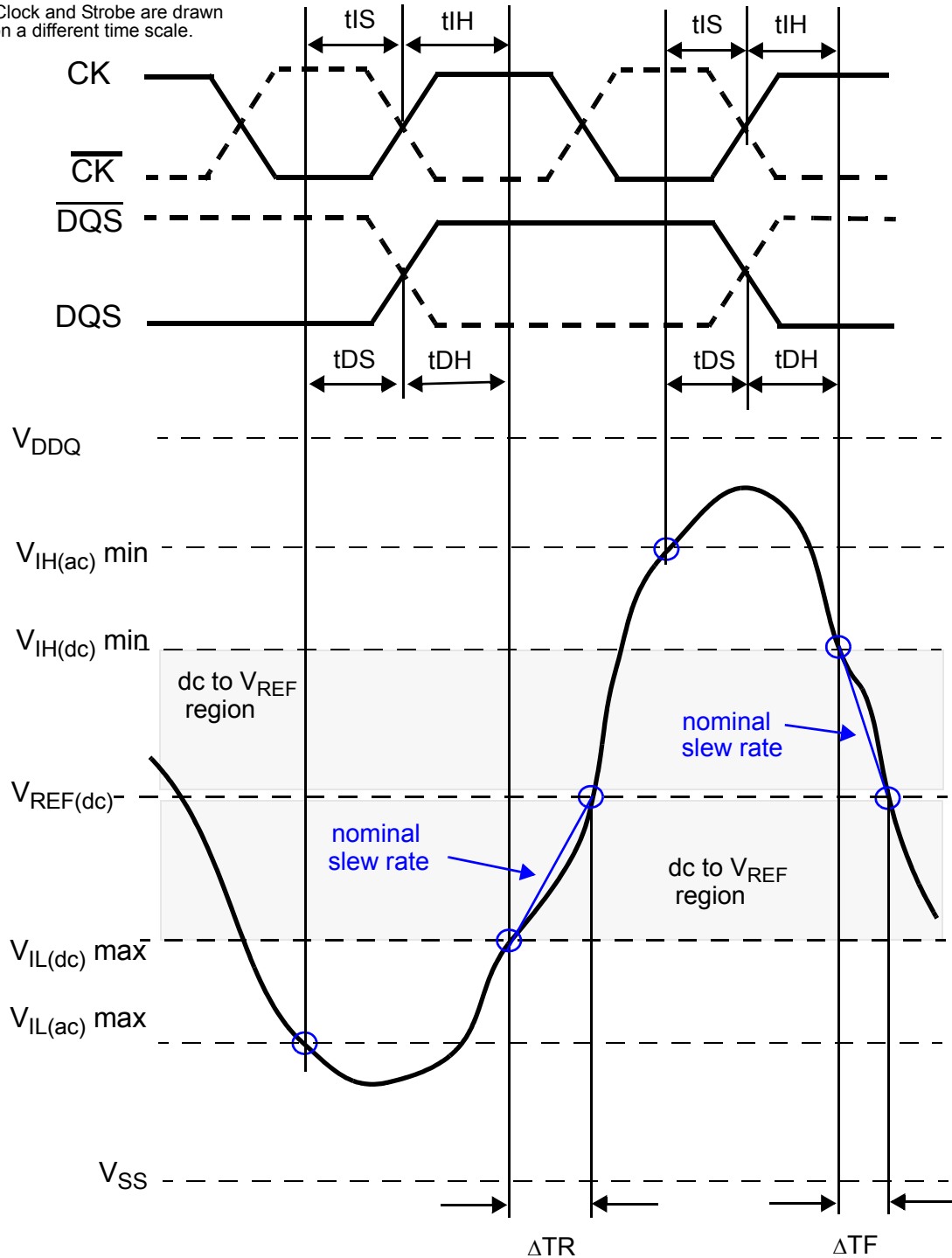
$$\text{Setup Slew Rate Rising Signal} = \frac{V_{IH(ac)}^{min} - V_{REF(dc)}}{\Delta TR}$$

Figure 105 — Illustration of nominal slew rate and t_{VAC} for setup time t_{DS} (for DQ with respect to strobe) and t_{IS} (for ADD/CMD with respect to clock).

13 Electrical Characteristics and AC Timing (Cont'd)

13.4 Data Setup, Hold and Slew Rate Derating (Cont'd)

Note: Clock and Strobe are drawn on a different time scale.



$$\text{Hold Slew Rate Rising Signal} = \frac{V_{REF(dc)} - V_{IL(dc)} \max}{\Delta TR}$$

$$\text{Hold Slew Rate Falling Signal} = \frac{V_{IH(dc)} \min - V_{REF(dc)}}{\Delta TF}$$

Figure 106 — Illustration of nominal slew rate for hold time t_{DH} (for DQ with respect to strobe) and t_{IH} (for ADD/CMD with respect to clock).

13 Electrical Characteristics and AC Timing (Cont'd)

13.4 Data Setup, Hold and Slew Rate Derating (Cont'd)

Note: Clock and Strobe are drawn on a different time scale.

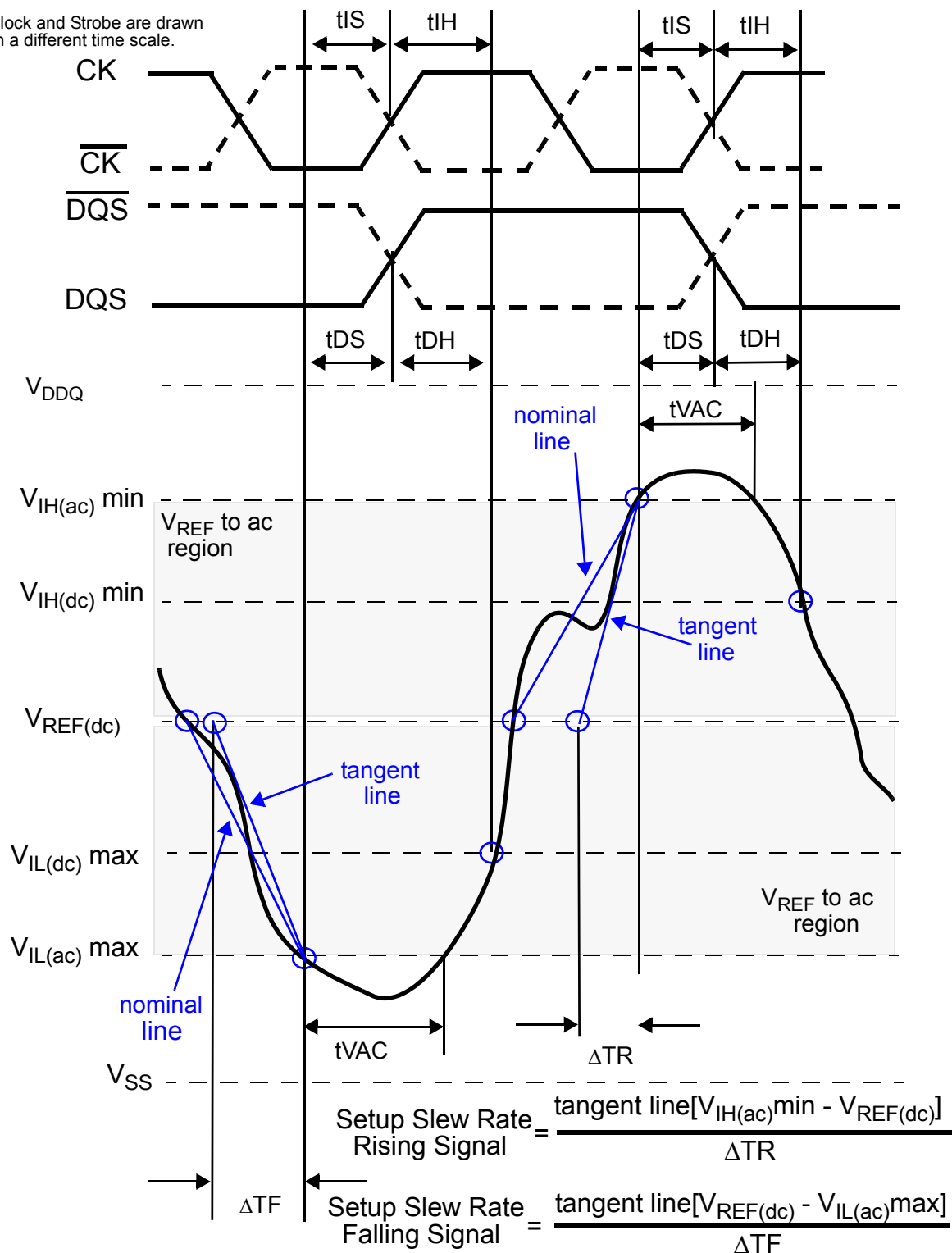


Figure 107 — Illustration of tangent line for setup time t_{DS} (for DQ with respect to strobe) and t_{IS} (for ADD/CMD with respect to clock)

13 Electrical Characteristics and AC Timing (Cont'd)

13.4 Data Setup, Hold and Slew Rate Derating (Cont'd)

Note: Clock and Strobe are drawn on a different time scale.

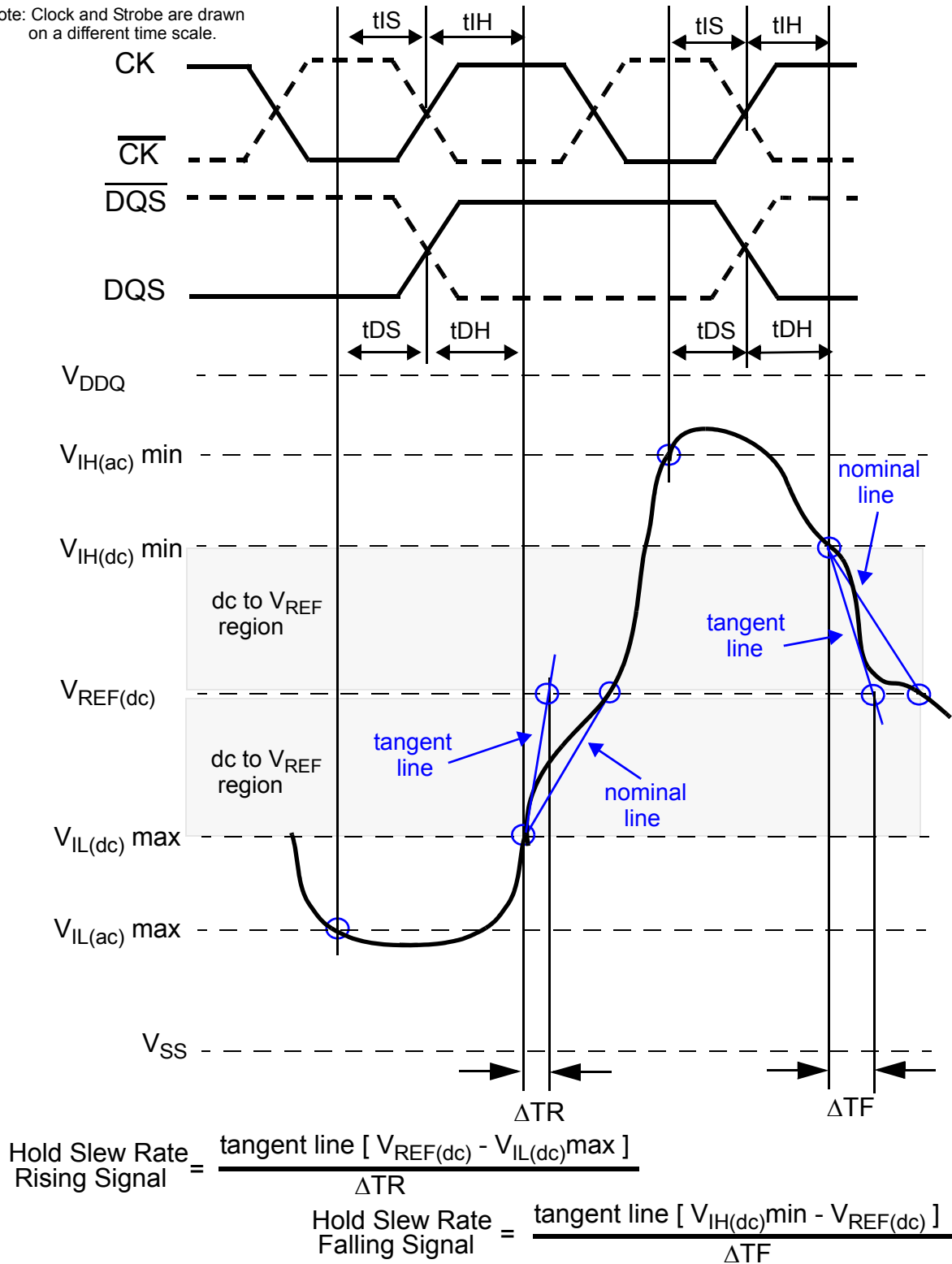


Figure 108 — Illustration of tangent line for for hold time t_{DH} (for DQ with respect to strobe) and t_{IH} (for ADD/CMD with respect to clock)

Annex A (informative) Differences between JESD79-3A, and JESD79-3.

This table briefly describes most of the changes made to this standard, JESD79-3A, compared to its predecessor, JESD79-3. Some editorial changes and format-updates of figures are not included.

Page	Description of Change
13	Per JCB-07-070, DDR3 Specification Updated Figure 1 – Simplified State Diagram Updated Table 2 – State Diagram Command Definitions
54	Per JCB-07-070, DDR3 Specification Updated Section 4.13.2.1 – READ Timing; Clock to Data Strobe relationship
55	Per JCB-07-070, DDR3 Specification Updated Section 4.13.2.2 – READ Timing; Data Strobe to Data Strobe relationship
57	Per JCB-07-070, DDR3 Specification Added Figure 28 – Method for calculating tRPRE transitions and endpoints
63	Per JCB-07-070, DDR3 Specification Removed Figure 40 – Write Timing Parameters Moved Figure 45, renamed as Write Timing Definition and Parameters, to page 63, as Figure 38
64	Per JCB-07-034, tWPRE, tWPST Added Section 4.14.3 – tWPRE Calculation Added Section 4.14.4 – tWPST Calculation
72-79	Per JCB-07-070, DDR3 Specification Reorganized subsections 4.16.1 and 4.16.2, moving Figures 52-61 into 4.16.1 and making one subsection each (4.16.2, 3, and 4) for the power-down entry/exit clarification cases (1-3).
75	Per JCB-07-070, DDR3 Specification Removed Figure 57 – Active Power-Down Entry and Exit Timing Diagram
79	Per JCB-07-070, DDR3 Specification Removed Table 15 – Timing Values tXXPDEN Parameters
84	Per JCB-07-036, ODT Read Timing Updated Figure 68 – OCT must be disabled...during Reads...
86	Per JCB-07-036, ODT Read Timing Updated Section 5.2.3 – ODT During READs
96, 97	Per JCB-07-067, ZQ Input Capacitance Updated Section 5.5.1 – ZQ Calibration Description Replaced Section 5.5.3. Is now: ZQ External Resistor Value, Tolerance, and Capacitance Loading
97	Per JCB-07-070, DDR3 Specification Removed Table 22 – ZQ Calibration Command Truth Table
101	Per JCB-07-065, Vih(dc)max, Vil(dc)min Updated Table 24 – Single Ended AC and DC Input Levels
103-106	Per JCB-07-068, Differentiation Signal Input Specification Added Section 8.2 – AC and CD Logic Input Levels for Differential Signals
128	Per JCB-07-070, DDR3 Specification Updated Table 50 – For IDD testing the followign parameters are utilized

Annex A (informative) Differences between JESD79-3A, and JESD79-3.

This table briefly describes most of the changes made to this standard, JESD79-3A, compared to its predecessor, JESD79-3. Some editorial changes and format-updates of figures are not included.

Page	Description of Change
141	Per JCB-07-038, Capacitance Updated Table 61 – Input/Output Capacitance
141	Per JCB-07-067, ZQ Input Capacitance Updated Table 61 – Input/Output Capacitance
142, 143	Per JCB-07-070, DDR3 Specification Removed unnumbered tables from subsection 12.1. Moved subsection 12.2 material into 12.1. Renumbered subsequent subsections.
149	Per JCB-07-041, tJIT (duty) note modification Updated Table 67 – Timing Parameters by Speed Bin
149, 150	Per JCB-07-032, Cumulative Jitter Updated Table 67 – Timing Parameters by Speed Bin
150	Per JCB-07-034, tWPRE, tWPST Updated Table 67 – Timing Parameters by Speed Bin
150	Per JCB-07-040, Jitter Values for DDR3-1600 Updated Table 67 – Timing Parameters by Speed Bin
150	Per JCB-07-029, Jitter Output Derating Updated Table 67 – Timing Parameters by Speed Bin
150	Per JCB-07-031, tDQSCK tQH Updated Table 67 – Timing Parameters by Speed Bin
150	Per JCB-07-066, tQSH, tQSL values Updated Table 67 – Timing Parameters by Speed Bin
152	Per JCB-07-042, tIS, tIH, DDR3-1333 Updated Table 67 – Timing Parameters by Speed Bin
154	Per JCB-07-035, tWLS, tWLH Updated Table 67 – Timing Parameters by Speed Bin
156-158	Per JCB-07-033, tCH (abs) and tCL (abs) Removed Specific Note F from Table 67 – Timing Parameters by Speed Bin. This action included removing the Table – Min and Max SPEC values. Removed Note 22 from Table 67 – Timing Parameters by Speed Bin Added Notes 25 and 26 to Table 67 – Timing Parameters by Speed Bin
157	Per JCB-07-039, tZQCS Added Note 23
157, 158	Per JCB-07-039, tZQCS Updated Note 23 of Table 67 – Timing Parameters by Speed Bin
158	Per JCB-07-042, tIS, tIH, DDR3-1333 Added Note 27
159	Per JCB-07-027 Updated Table 68 – ADD/CMD Setup and Hold Base-Values for 1V/ns

Annex A (informative) Differences between JESD79-3A, and JESD79-3.

This table briefly describes most of the changes made to this standard, JESD79-3A, compared to its predecessor, JESD79-3. Some editorial changes and format-updates of figures are not included.

Page	Description of Change
160	Per JCB-07-027 Updated Table 69 – Derating values DDR3-800/1066/1333/1600 tIS/tIH - ac/dc based Added Table 70 – Derating values DDR3-1333/1600 tIS/tIH - ac/dc based - Alternate AC150 Threshold
161	Per JCB-07-027 Updated Table 71 – Required time T_{VAC} above VIH(ac) [below VIL(ac)] for valid transition
166	Per JCB-07-037, tDS, tDH 1333 Updated Table 72 – Data Setup and Hold Base-Values
A-1	Added Annex A (Informative) Differences between JESD79-3A and JESD79-3.

