SMARTsemi

Memory IC Datasheet

DDR3-1866 4Gb x16

January 31, 2024

Rev 1.1

Part Number Decoder

K	T	D	M	4	G	3	C	6	1	8	B	G	x	E	A	T
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

1-2	**IC Supplier** **KT:** SMARTsemi
3-4	**Product Family** **DM:** DRAM
5-6	**Density** **4G:** 4Gb
7	**Technology** **3:** DDR3
8	**Voltage** **C:** 1.35V/1.5V
9	**Width** **6:** x16
10-11	**Speed** **18:** DDR3-1866
12-13	**Package** **BG:** Mono BGA
14	**Temperature** **A:** Automotive **C:** Commercial **I:** Industrial
15-16	**Internal Code** **EA**: For Internal Use
17	**Packaging** **T:** Tray

Revision History

Date	Rev	Description
July 1, 2022	1.0	Initial release.
January 31, 2024	1.1	Added Automotive part numbers and information to the datasheet.

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DDR3(L) SDRAM

32M x 16 Bit x 8 Banks DDR3(L) SDRAM

Features

- **Interface and Power Supply**
  - SSTL_135: VDD/VDDQ = 1.35V(-0.067V/+0.1V)
  - SSTL_15: VDD/VDDQ = 1.5V(±0.075V)
- **JEDEC DDR3(L) Compliant**
  - 8n Prefetch Architecture
  - Differential Clock (CK/CK) and Data Strobe (DQS/DQS)
  - Double-data rate on DQs, DQS and DM
- **Data Integrity**
  - Auto Refresh and Self Refresh Modes
- **Power Saving Mode**
  - Partial Array Self Refresh (PASR)
  - Power Down Mode
- **Signal Integrity**
  - Configurable DS for system compatibility
  - Configurable On-Die Termination
  - ZQ Calibration for DS/ODT impedance accuracy via external ZQ pad (240 ohm ± 1%)
- **Signal Synchronization**
  - Write Leveling via MR settings
  - Read Leveling via MPR
- **Programmable Functions**
  - CAS Latency (5/6/7/8/9/10/11/12/13/14)
  - CAS Write Latency (5/6/7/8/9/10)
  - Additive Latency (0/CL-1/CL-2)
  - Write Recovery Time (5/6/7/8/10/12/14/16)
  - Burst Type (Sequential/Interleaved)
  - Burst Length (BL8/BC4/BC4 or 8 on the fly)
  - Self Refresh Temperature Range (Normal/Extended)
  - Output Driver Impedance (34/40)
  - On-Die Termination of RTT_Nom (20/30/40/60/120)
  - On-Die Termination of RTT_WR (60/120)
  - Precharge Power Down (slow/fast)
- **Automotive temp part is AEC-Q100 Compliant**

Ordering Information

Product ID	Max Freq.	V_{DD}	Data Rate (CL-tRCD-tRP)	Package	Temperature	Packing	Comments
KTDM4G3C618BGAEAT	933MHz	1.35V/1.5V	DDR3(L)-1866 (13-13-13)	96 ball BGA	Automotive	Tray	Pb-free
KTDM4G3C618BGCEAT	933MHz	1.35V/1.5V	DDR3(L)-1866 (13-13-13)	96 ball BGA	Commercial	Tray	Pb-free
KTDM4G3C618BGIEAT	933MHz	1.35V/1.5V	DDR3(L)-1866 (13-13-13)	96 ball BGA	Industrial	Tray	Pb-free

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Description

The 4Gb Double-Data-Rate-3 (DDR3(L)) DRAM is double data rate architecture to achieve high-speed operation. It is internally configured as an eight-bank DRAM.

The 4Gb chip is organized as 32Mbit x 16 I/Os x 8 bank devices. These synchronous devices achieve high speed double-data-rate transfer rates of up to 1866 Mb/sec/pin for general applications.

The chip is designed to comply with all key DDR3(L) DRAM key features and all of the control and address inputs are synchronized with a pair of externally supplied differential clocks. Inputs are latched at the cross point of differential clocks (CK rising and $\overline{CK}$ falling). All I/Os are synchronized with a differential DQS pair in a source synchronous fashion.

These devices operate with a single 1.35V -0.067V/+0.1V or 1.5V ± 0.075V power supply and are available in BGA packages.

DDR3(L) SDRAM Addressing

Configuration	256Mb x 16
# of Bank	8
Bank Address	BA0 – BA2
Auto precharge	A10/ P
BL switch on the fly	A12/BC
Row Address	A0 – A14
Column Address	A0 – A9
Page size	2KB

Note:

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

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

where

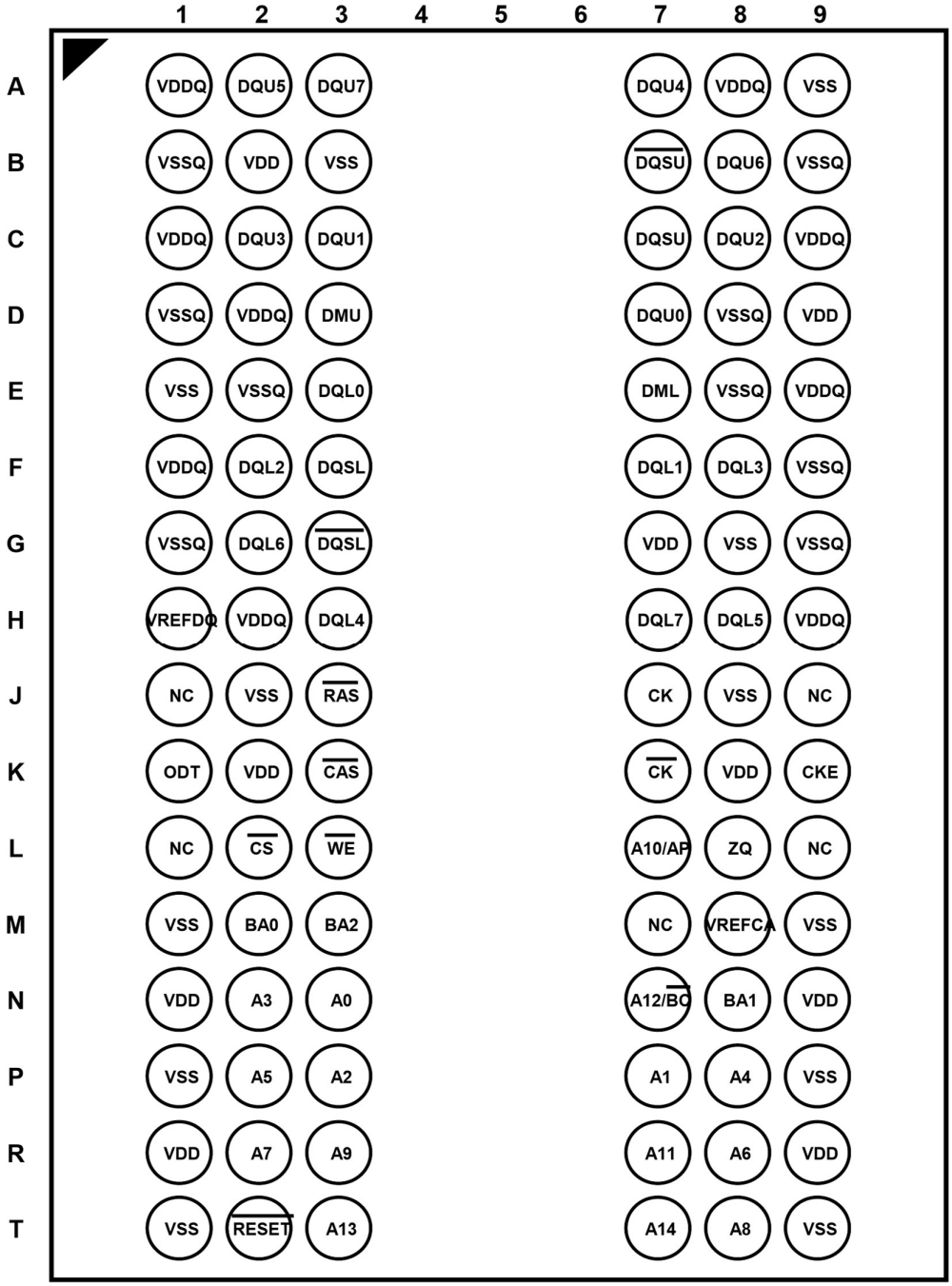
COLBITS = the number of column address bits

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

Pin Configuration – 96 balls BGA Package

< TOP View>

See the balls through the package



Input / Output Functional Description

Symbol	Type	Function
CK, $\overline{CK}$	Input	**Clock:** CK and $\overline{CK}$ are differential clock inputs. All address and control input signals are sampled on the crossing of the positive edge of CK and negative edge of $\overline{CK}$.
CKE	Input	**Clock Enable:** CKE high activates, and CKE low deactivates, internal clock signals 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, $\overline{CK}$, ODT and CKE are disabled during power-down. Input buffers, excluding CKE, are disabled during Self-Refresh.
$\overline{CS}$	Input	**Chip Select:** All commands are masked when $\overline{CS}$ is registered HIGH. $\overline{CS}$ provides for external rank selection on systems with multiple ranks. $\overline{CS}$ is considered part of the command code.
$\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$	Input	**Command Inputs:** $\overline{RAS}$,$\overline{CAS}$ and $\overline{WE}$ (along with $\overline{CS}$) define the command being entered.
DM, (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.
BA0 - BA2	Input	**Bank Address Inputs:** BA0, BA1, and 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.
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.
A0 – A14	Input	**Address Inputs:** Provide the row address for Activate commands and the column address for Read/Write commands to select one location out of the memory array in therespective bank. (A10/AP and A12/$\overline{BC}$ have additional function; as below.) The address inputs also provide the op-code during Mode Register Set commands.
A12/$\overline{BC}$	Input	**Burst Chop:** A12/$\overline{BC}$ is sampled during Read and Write commands to determine if burst chop (on-the-fly) will be performed. (HIGH: no burst chop; LOW: burst chopped).
ODT	Input	**On Die Termination:** ODT (registered HIGH) enables termination resistance internal to the DDR3(L) SDRAM. When enabled, ODT is applied to each DQ, DQS, DQS and DM. The ODT pin will be ignored if MR1and MR2 are programmed to disable RTT.
$\overline{RESET}$	Input	**Active Low Asynchronous Reset:** Reset is active when $\overline{RESET}$ is LOW, and inactive when $\overline{RESET}$ is HIGH. $\overline{RESET}$ must be HIGH during normal operation. $\overline{RESET}$ is a CMOS rail-to-rail signal with DC high and low at 80% and 20% of VDD, i.e. 1.20V for DC high and 0.30V for DC low.
DQ (DQL, DQU)	Input/output	**Data Inputs/Output:** Bi-directional data bus.
DQS, $\overline{DQS}$ (DQSL, $\overline{DQSL}$, DQSU, $\overline{DQSU}$)	Input/output	**Data Strobe:** output with read data, input with write data. Edge aligned with read data, centered in write data. DQSL corresponds to the data on DQL0-DQL7; DQSU corresponds to the data on DQU0-DQU7. The data strobes DQS (DQSL, DQSU) are paired with differential signals $\overline{DQS}$ ($\overline{DQSL}$, $\overline{DQSU}$), respectively, to provide differential pair signaling to the system during both reads and writes. DDR3(L) SDRAM supports differential data strobe only and does not support single-ended.
NC	-	**No Connect:** No internal electrical connection is present.
VDDQ	Supply	**DQ Power Supply:** 1.35V -0.067V/+0.1V or 1.5V ± 0.075V

Symbol	Type	Function
VDD	Supply	**Power Supply:** 1.35V -0.067V/+0.1V or 1.5V ± 0.075V
VSSQ	Supply	**DQ Ground**
VSS	Supply	**Ground**
VREFCA	Supply	**Reference voltage for CA**
VREFDQ	Supply	**Reference voltage for DQ**
ZQ	Supply	**Reference pin for ZQ calibration.**

Note: Input only pins (BA0-BA2, A0-A14, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$, $\overline{CS}$, CKE, ODT, and $\overline{RESET}$) do not supply termination.

Absolute Maximum Ratings

Absolute Maximum DC Ratings

Symbol	Parameter	Rating	Unit	Note
VDD	Voltage on VDD pin relative to VSS	-0.4 ~ 1.80	V	1,3
VDDQ	Voltage on VDDQ pin relative to VSS	-0.4 ~ 1.80	V	1,3
V_{IN}, V_{OUT}	Voltage on any pin relative to VSS	-0.4 ~ 1.80	V	1
T_{STG}	Storage Temperature	-55 ~ 150	°C	1,2

Note:

1. Stresses greater than those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the 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.
3. VDD and VDDQ must be within 300mV of each other at all times; and VREF must be not greater than 0.6 x DDQ, when VDD and VDDQ are less than 500mV; VREF may be equal to or less than 300mV.

DRAM Component Operating Temperature Range

Temperature Range

Symbol	Parameter	Value	Unit	Note
T_{OPER}	Normal Operating Temperature Range - Commercial	0 to 85	°C	1,2
	Normal Operating Temperature Range - Industrial	-40 to 85	°C	1,2
	Normal Operating Temperature Range - Automotive	-40 to 85	°C	1,2
	Extended Temperature Range – Commercial/Industrial	85 to 95	°C	1,3
	Extended Temperature Range – Automotive	85 to 105	°C	1,3,4

Note:

1. Operating Temperature T_{OPER} is the case surface temperature on the center/top side of the DRAM.
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 for Commercial temperature or -40 to 85°C for Industrial temperature under all operating conditions.
3. Some applications require operation of the DRAM in the Extended Temperature Range.
   a) Refresh commands must be doubled in frequency, therefore, reducing the Refresh interval tREFI to 3.9us.
   b) If Self-Refresh operation is required in the Extended Temperature Range, then it is mandatory to either use the Manual Self-Refresh mode with Extended Temperature Range capability (MR2 A6=0 and MR2 A7=1) or enable the optional Auto Self-Refresh mode (MR2 A6=1 and MR2 A7=0).
4. Some applications require operation of the DRAM in the Extended Temperature Range between 95°C and 105°C case temperature. Full specifications are guaranteed in this range, but the following additional apply:
   a) Refresh commands must be quadrupled in frequency, therefore, reducing the Refresh interval tREFI to 1.95 us.

AC & DC Operating Conditions

Recommended DC Operating Conditions

Symbol	Parameter	Operation Voltage	Rating			Unit	Note
			Min.	Typ.	Max.		
VDD	Supply Voltage	1.5V	1.425	1.5	1.575	V	1,2
		1.35V	1.283	1.35	1.45	V	3,4,5
VDDQ	Supply Voltage for Output	1.5V	1.425	1.5	1.575	V	1,2
		1.35V	1.283	1.35	1.45	V	3,4,5

Note:

1. Under all conditions VDDQ must be less than or equal to VDD.
2. VDDQ tracks with VDD. AC parameters are measured with VDD and VDDQ tied together.
3. Maximum DC value may not be greater than 1.425V. The DC value is the linear average of VDD/VDDQ(t) over a very long period of time.
4. If maximum limit is exceeded, input levels shall be governed by DDR3 specifications.
5. Under these supply voltages, the device operates to this DDR3L specification.

AC & DC Input Measurement Levels

AC and DC Logic Input Levels for Single-Ended Signals

AC and DC Input Levels for Single-Ended Command and Address Signals

Single-Ended AC and DC Input Levels for Command and Address

Symbol	Parameter	DDR3-1866		Unit	Note
		Min.	Max.		
VIH.CA(DC100)	DC input logic high	VREF + 0.1	VDD	V	1,5
VIL.CA(DC100)	DC input logic low	VSS	VREF - 0.1	V	1,6
VIH.CA(AC175)	AC input logic high	-	-	V	1,2,7
VIL.CA(AC175)	AC input logic low	-	-	V	1,2,8
VIH.CA(AC150)	AC input logic high	-	-	V	1,2,7
VIL.CA(AC150)	AC input logic low	-	-	V	1,2,8
VIH.CA(AC135)	AC input logic high	VREF + 0.135	Note2	V	1,2,7
VIL.CA(AC135)	AC input logic low	Note2	VREF - 0.135	V	1,2,8
VIH.CA(AC125)	AC input logic high	VREF + 0.125	Note2	V	1,2,7
VIL.CA(AC125)	AC input logic low	Note2	VREF - 0.125	V	1,2,8
VREFCA(DC)	Reference Voltage for ADD, CMD inputs	0.49 * VDD	0.51 * VDD	V	3,4,9

Note:

1. For input only pins except $\overline{\text{RESET}}$ .VREF=VREFCA(DC).
2. See "Overshoot and Undershoot Specifications".
3. The ac peak noise on VREF may not allow VREF to deviate from VREFCA(DC) by more than +/-1% VDD (for reference: approx. +/- 15 mV).
4. For reference: approx. VDD/2 +/- 15 mV.
5. VIH(DC) is used as a simplified symbol for VIH.CA(DC100).
6. VIL(DC) is used as a simplified symbol for VIL.CA(DC100).
7. VIH(AC) is used as a simplified symbol for VIH.CA(AC175), VIH.CA(AC150), VIH.CA(AC135), and VIH.CA(AC125); VIH.CA(AC175) value is used when VREF + 0.175V is referenced, VIH.CA(AC150) value is used when VREF + 0.150V is referenced, VIH.CA(AC135) value is used when VREF + 0.135V is referenced, and VIH.CA(AC125) value is used when VREF + 0.125V is referenced.
8. VIL(AC) is used as a simplified symbol for VIL.CA(AC175), VIL.CA(AC150), VIL.CA(AC135) and VIL.CA(AC125); VIL.CA(AC175) value is used when VREF - 0.175V is referenced, VIL.CA(AC150) value is used when VREF - 0.150V is referenced, VIL.CA(AC135) value is used when VREF - 0.135V is referenced, and VIL.CA(AC125) value is used when VREF - 0.125V is referenced.
9. VREFCA(DC) is measured relative to VDD at the same point in time on the same device.

Single-Ended AC and DC Input Levels for Command and Address - Continued

Symbol	Parameter	DDR3L-1866		Unit	Note
		Min.	Max.		
VIH.CA(DC90)	DC input logic high	VREF + 0.09	VDD	V	1
VIL.CA(DC90)	DC input logic low	VSS	VREF - 0.09	V	1
VIH.CA(AC160)	AC input logic high	-	-	V	1,2
VIL.CA(AC160)	AC input logic low	-	-	V	1,2
VIH.CA(AC135)	AC input logic high	VREF + 0.135	Note2	V	1,2
VIL.CA(AC135)	AC input logic low	Note2	VREF -0.135	V	1,2
VIH.CA(AC125)	AC input logic high	VREF + 0.125	Note2	V	1,2
VIL.CA(AC125)	AC input logic low	Note2	VREF - 0.125	V	1,2
VREFCA(DC)	Reference Voltage for ADD, CMD inputs	0.49 * VDD	0.51 * VDD	V	3,4

Note:
1. For input only pins except $\overline{\text{RESET}}$ .VREF=VREFCA(DC).
2. See "Overshoot and Undershoot Specifications".
3. The ac peak noise on VREF may not allow VREF to deviate from VREFCA(DC) by more than +/-1% VDD (for reference: approx. +/- 13.5 mV).
4. For reference: approx. VDD/2 +/- 13.5mV.

AC and DC Input Levels for Single-Ended Data Signals

Single-Ended AC and DC Input Levels for DQ and DM

Symbol	Parameter	DDR3-1866		Unit	Note
		Min.	Max.		
VIH.DQ(DC100)	DC input logic high	VREF + 0.1	VDD	V	1,5
VIL.DQ(DC100)	DC input logic low	VSS	VREF- 0.1	V	1,6
VIH.DQ(AC175)	AC input logic high	-	-	V	1,2,7
VIL.DQ(AC175)	AC input logic low	-	-	V	1,2,8
VIH.DQ(AC150)	AC input logic high	-	-	V	1,2,7
VIL.DQ(AC150)	AC input logic low	-	-	V	1,2,8
VIH.DQ(AC135)	AC input logic high	VREF + 0.135	Note2	V	1,2,7
VIL.DQ(AC135)	AC input logic low	Note2	VREF - 0.135	V	1,2,8
VREFDQ(DC)	Reference Voltage for DQ, DM inputs	0.49 * VDD	0.51 * VDD	V	3,4,9

Note:

1. VREF = VREFDQ(DC).
2. See "Overshoot and Undershoot Specifications".
3. The ac peak noise on VREF may not allow VREF to deviate from VREFDQ(DC) by more than +/-1% VDD (for reference: approx. +/- 15 mV).
4. For reference: approx. VDD/2 +/- 15 mV.
5. VIH(DC) is used as a simplified symbol for VIH.DQ(DC100).
6. VIL(DC) is used as a simplified symbol for VIL.DQ(DC100).
7. VIH(AC) is used as a simplified symbol for VIH.DQ(AC175), VIH.DQ(AC150), and VIH.DQ(AC135);VIH.DQ(AC175) value is used when VREF + 0.175V is referenced, VIH.DQ(AC150) value is used when VREF + 0.150V is referenced, and VIH.DQ(AC135) value is used when VREF + 0.135V is referenced.
8. VIL(AC) is used as a simplified symbol for VIL.DQ(AC175), VIL.DQ(AC150), and VIL.DQ(AC135);VIL.DQ(AC175) value is used when VREF - 0.175V is referenced, VIL.DQ(AC150) value is used when VREF -0.150V is referenced, and VIL.DQ(AC135) value is used when VREF - 0.135V is referenced.
9. VREFDQ(DC) is measured relative to VDD at the same point in time on the same device.

Single-Ended AC and DC Input Levels for DQ and DM - Continued

Symbol	Parameter	DDR3L-1866		Unit	Note
		Min.	Max.		
VIH.DQ(DC90)	DC input logic high	VREF + 0.09	VDD	V	1
VIL.DQ(DC90)	DC input logic low	VSS	VREF - 0.09	V	1
VIH.DQ(AC135)	AC input logic high	-	-	V	1,2
VIL.DQ(AC135)	AC input logic low	-	-	V	1,2
VIH.DQ(AC130)	AC input logic high	VREF + 0.130	Note2	V	1,2
VIL.DQ(AC130)	AC input logic low	Note2	VREF - 0.130	V	1,2
VREFDQ(DC)	Reference Voltage for DQ, DM inputs	0.49 * VDD	0.51 * VDD	V	3,4

Note:

1. VREF = VREFDQ(DC).
2. See "Overshoot and Undershoot Specifications".
3. The ac peak noise on VREF may not allow VREF to deviate from VREFDQ(DC) by more than +/-1% VDD (for reference: approx. +/- 13.5 mV).
4. For reference: approx. VDD/2 +/- 13.5 mV.

VREF Tolerances

The dc-tolerance limits and ac-noise limits for the reference voltages VREFCA and VREFDQ are illustrated in the following figure. It shows a valid reference voltage VREF (t) as a function of time. (VREF stands for VREFCA and VREFDQ likewise).

VREF(DC) is the linear average of VREF(t) over a very long period of time (e.g.,1 sec). This average has to meet the min/max requirement in previous page. Furthermore VREF(t) may temporarily deviate from VREF(DC) by no more than ±1% VDD.

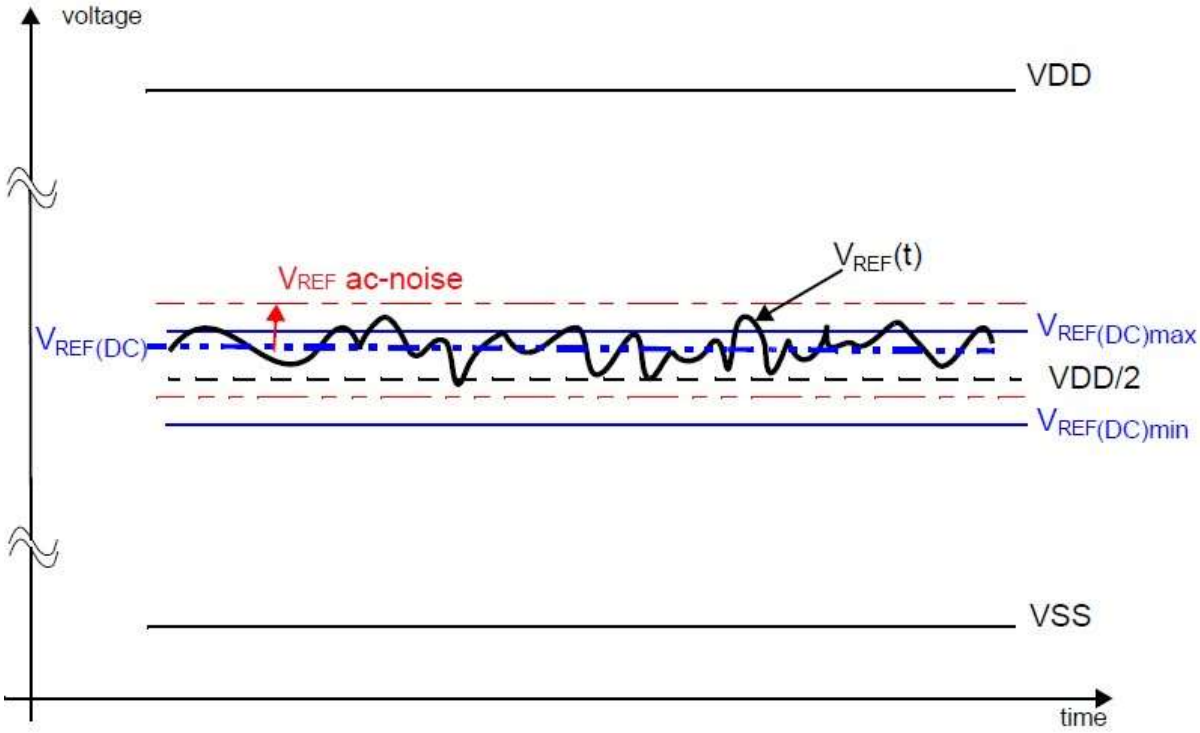
The voltage levels for setup and hold time measurements VIH(AC), VIH(DC), VIL(AC), and VIL(DC) are dependent on VREF.

"VREF" shall be understood as VREF(DC).

The clarifies that dc-variations of VREF 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 VREF(DC) deviations from the optimum position within the data-eye of the input signals.

This also clarifies that the DRAM setup/hold specification and de-rating values need to include time and voltage associated with VREF ac-noise. Timing and voltage effects due to ac-noise on VREF up to the specified limit (±1% of VDD) are included in DRAM timing and their associated de-ratings.

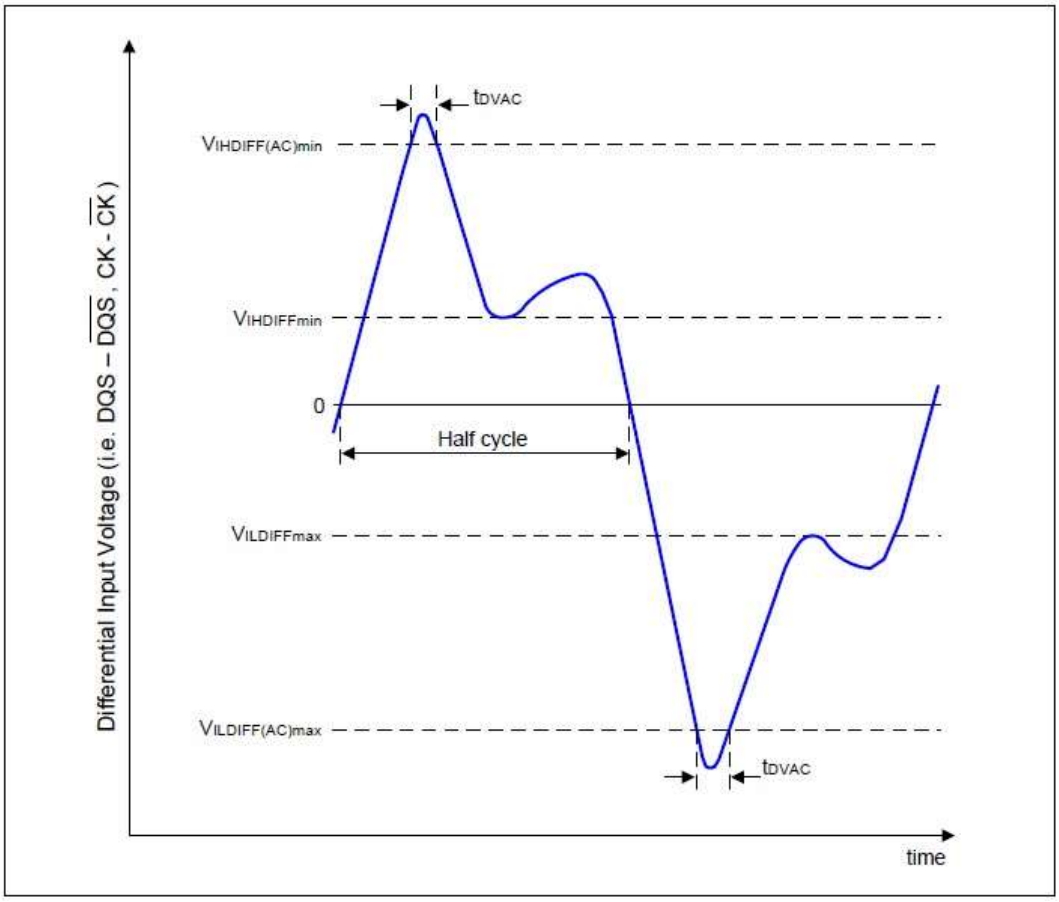
Illustration of VREF(DC) tolerance and VREF ac-noise limits



AC and DC Logic Input Levels for Differential Signals

Differential signal definition

Definition of differential ac-swing and "time above ac-level" tDVAC



Differential swing requirements for clock (CK - $\overline{CK}$) and strobe (DQS - $\overline{DQS}$)

Differential AC and DC Input Levels

Symbol	Parameter	DDR3-1866		Unit	Note
		Min.	Max.		
VIHdiff	Differential input logic high	+0.200	Note3	V	1
VILdiff	Differential input logic low	Note3	-0.200	V	1
VIHdiff(AC)	Differential input high ac	2 x (VIH(AC) – VREF)	Note3	V	2
VILdiff(AC)	Differential input low ac	Note3	2 x (VIL(AC)- VREF)	V	2

Note:

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

Symbol	Parameter	DDR3L-1866		Unit	Note
		Min.	Max.		
VIHdiff	Differential input logic high	+0.180	Note3	V	1
VILdiff	Differential input logic low	Note3	-0.180	V	1
VIHdiff(AC)	Differential input high ac	2 x (VIH(AC) – VREF)	Note3	V	2
VILdiff(AC)	Differential input low ac	Note3	2 x (VIL(AC) - VREF)	V	2

Note:

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

Allowed time before ringback (tDVAC) for CK – CK and DQS - DQS

Slew Rate [V/ns]	DDR3-1866			
	tDVAC [ps] @ IVIH/Ldiff(AC)I = 300mV		tDVAC [ps] @ IVIH/Ldiff(AC)I = (CK-CK)only	
	Min.	Max.	Min.	Max.
> 4.0	134	-	139	-
4.0	134	-	139	-
3.0	112	-	118	-
2.0	67	-	77	-
1.8	52	-	63	-
1.6	33	-	45	-
1.4	9	-	23	-
1.2	note	-	note	-
1.0	note	-	note	-
< 1.0	note	-	note	-

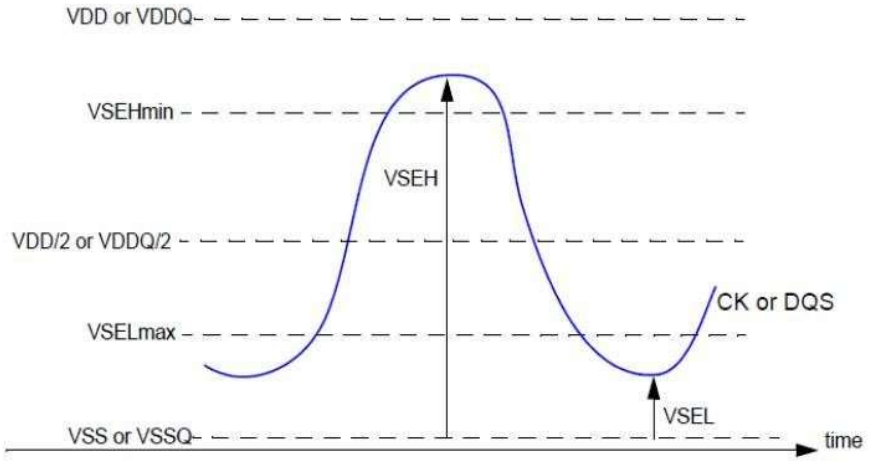
Slew Rate [V/ns]	DDR3L-1866					
	tDVAC [ps] @ IVIH/Ldiff(AC)I = 270mV		tDVAC [ps] @ IVIH/Ldiff(AC)I = 250mV		tDVAC [ps] @ IVIH/Ldiff(AC)I =260mV	
	Min.	Max.	Min.	Max.	Min.	Max.
> 4.0	163	-	168	-	176	-
4.0	163	-	168	-	176	-
3.0	140	-	147	-	154	-
2.0	95	-	105	-	111	-
1.8	80	-	91	-	97	-
1.6	62	-	74	-	78	-
1.4	37	-	52	-	56	-
1.2	5	-	22	-	24	-
1.0	note	-	note	-	note	-
< 1.0	note	-	note	-	note	-

Single-ended requirements for differential signals

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

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

Note that the applicable ac-levels for ADD/CMD and DQ's might be different per speed-bin etc. E.g., if VIH.CA (AC150) / VIL.CA (AC150) is used for ADD/CMD signals, then these ac-levels apply also for the single-ended signals CK and $\overline{CK}$.



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.

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

Symbol	Parameter	DDR3(L)-1866		Unit	Note
		Min.	Max.		
VSEH	Single-ended high level for strobes	(VDD/2) + 0.175	note3	V	1, 2
	Single-ended high level for CK, $\overline{CK}$	(VDD/2) + 0.175	note3	V	1, 2
VSEL	Single-ended low level for strobes	note3	(VDD/2) - 0.175	V	1, 2
	Single-ended low level for CK, $\overline{CK}$	note3	(VDD/2) - 0.175	V	1, 2

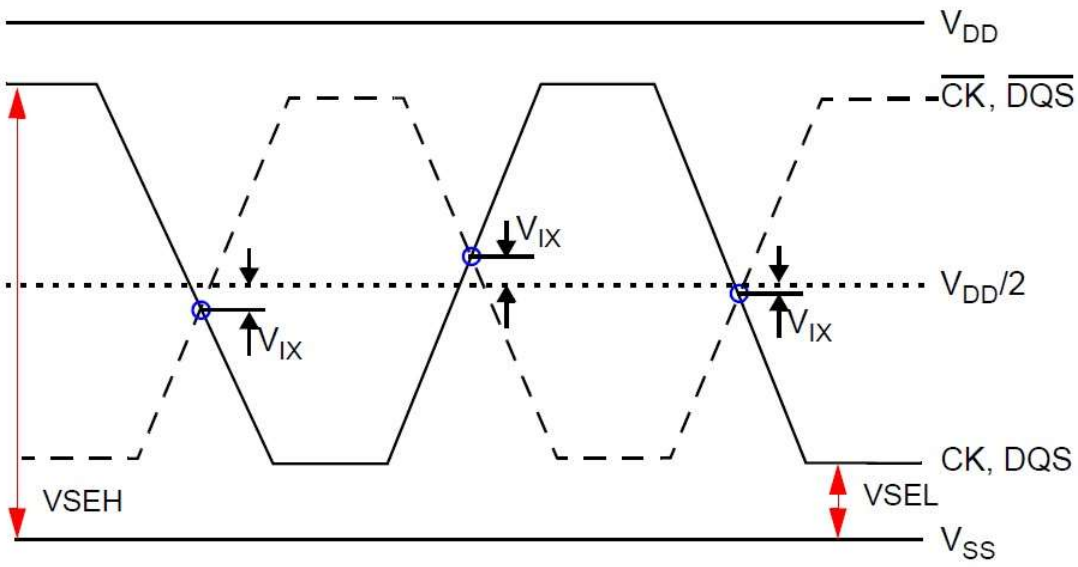
Note:

1. For CK, $\overline{CK}$ use VIH.CA (AC) /VIL.CA (AC) of ADD/CMD; for strobes (DQS, DQSL, DQSU, $\overline{DQS}$, $\overline{DQSL}$, $\overline{DQSU}$) use VIH.DQ (AC)/VIL.CA (AC) of DQs.
2. VIH.DQ (AC)/VIL.CA (AC) for DQs is based on VREFDQ; VIH.CA (AC) /VIL.CA (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 there.
3. These values are not defined, however the single-ended signals CK, $\overline{CK}$, DQS, $\overline{DQS}$, DQSL, $\overline{DQSL}$, DQSU, $\overline{DQSU}$ need to be within the respective limits (VIH(DC)max, VIL(DC)min) for single-ended signals as well as limitations for overshoot and undershoot. Refer to "Overshoot and Undershoot Specifications".

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 the following table. The differential input cross point voltage V_{IX} is measured from the actual cross point of true and complete signal to the midlevel between of VDD and VSS.

V_{IX} Definition



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

Symbol	Parameter	DDR3-1866		DDR3L-1866		Unit	Note
		Min.	Max.	Min.	Max.		
V_{IX}(CK)	Differential Input Cross Point Voltage relative to VDD/2 for CK, $\overline{CK}$	-150	150	-150	+150	mV	1
		-175	175	-	-	mV	2
V_{IX}(DQS)	Differential Input Cross Point Voltage relative to VDD/2 for DQS, $\overline{DQS}$	-150	150	-150	+150	mV	1

Note:

1. The relation between V_{IX} Min/Max and VSEL/VSEH should satisfy following.
   (VDD/2)+V_{IX} (Min.) – VSEL ≥ 25mV
   VSEH – ((VDD/2) +V_{IX} (Max.)) ≥ 25mV
2. Extended range for V_{IX} is only allowed for clock and if single-ended clock input signals CK and $\overline{CK}$ are monotonic with a single-ended swing VSEL / VSEH of at least VDD/2 ± 250mV, and when the differential slew rate of CK-$\overline{CK}$ is larger than 3V/ns.

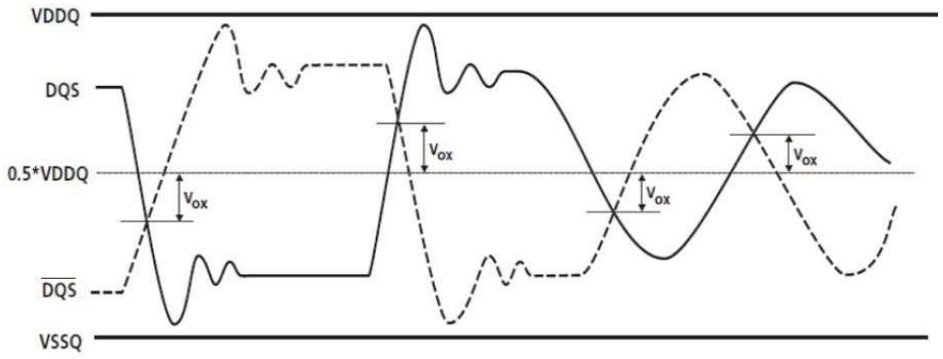
DQS Output Cross point voltage – DDR3L-1866 V_{OX}

Symbol	Parameter		DQS/$\overline{DQS}$ Differential Slew Rate									Unit
			3.5V/ns	4V/ns	5V/ns	6V/ns	7V/ns	8V/ns	9V/ns	10V/ns	12V/ns	
V_{OX}	Deviation of DQS/$\overline{DQS}$ output cross point voltage from 0.5 x VDDQ	Max	+90	+105	+130	+155	+180	+205	+205	+205	+205	mV
		Min	-90	-105	-130	-155	-180	-205	-205	-205	-205	

Note:

1. Measured using an effective test load of 25 Ω to 0.5*VDDQ at each of the differential outputs.
2. For a differential slew rate in between the listed values, the V_{OX} value may be obtained by linear interpolation.
3. Refer to the following figure for reference drawing, DQS/$\overline{DQS}$ shown single-ended for measurement point.
4. The DQS/$\overline{DQS}$ pins under test are not required to be able to drive each of the slew rates listed in the table; the pins under test will provide one V_{OX} value when tested with specified test condition. The DQS and $\overline{DQS}$ differential slew rate when measuring V_{OX} determines which V_{OX} limits to use.

Definition of Output cross point voltage for DQS and $\overline{DQS}$



Slew Rate Definitions for Single-Ended Input Signals

See “Address / Command Setup, Hold and Derating” for single-ended slew rate definitions for address and command signals. See “Data Setup, Hold and Slew Rate Derating” for single-ended slew rate definitions for data signals.

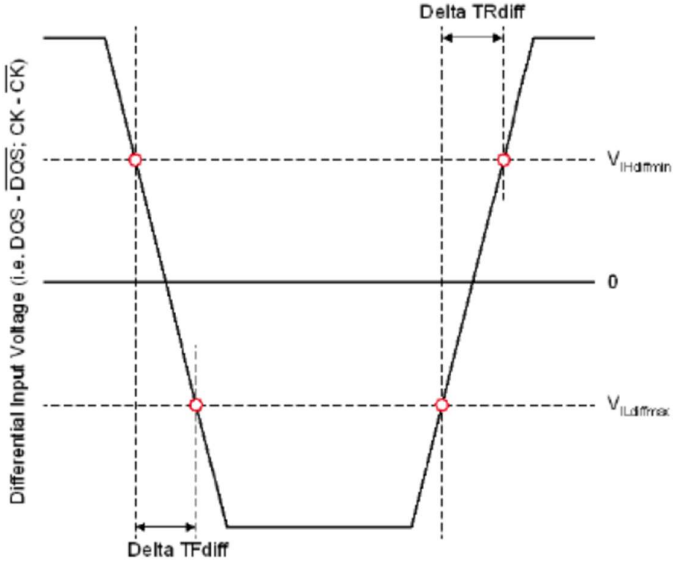
Slew Rate Definition for Differential Input Signals

Input slew rate for differential signals (CK, CK and DQS, DQS) are defined and measured as shown below.

Differential Input Slew Rate Definition

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

Differential Input Slew Rate Definition for DQS, $\overline{DQS}$ and CK, $\overline{CK}$



AC and DC Output Measurement Levels

Single Ended AC and DC Output Levels

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

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

Differential AC and DC Output Levels

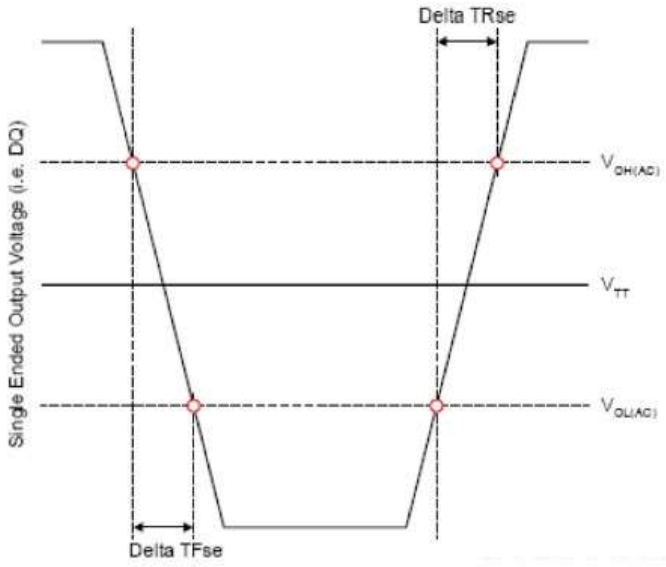
Symbol	Parameter	Value	Unit	Note
VOHdiff(AC)	AC differential output high measurement level (for output SR)	+0.2 x VDDQ	V	1
VOLdiff(AC)	AC differential output low measurement level (for output SR)	-0.2 x VDDQ	V	1

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

Single Ended Output Slew Rate

Single Ended Output Slew Rate Definition

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



Output Slew Rate (single-ended)

Parameter	Symbol	DDR3L-1866		DDR3-1866		Unit
		Min.	Max.	Min.	Max.	
Single-ended Output Slew Rate	SRQse	1.75	5[1]	2.5	5[1]	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 = R_{ZQ}/7 setting.

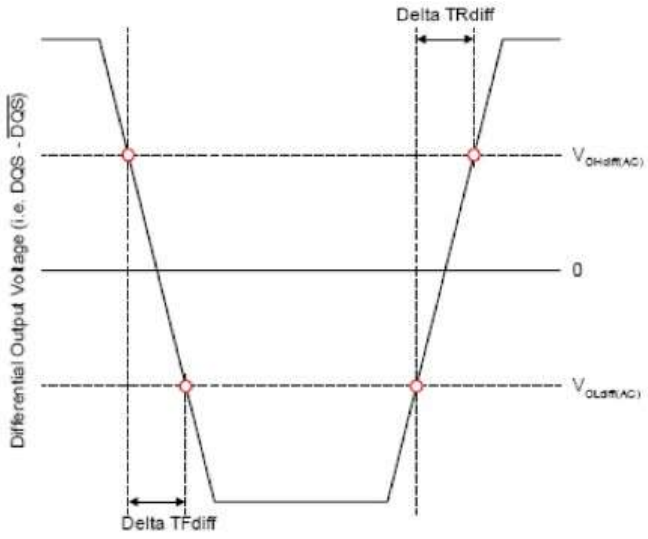
Note:

1. In two cases, a maximum slew rate of 6V/ns applis for a single DQ signal within a byte lane.
   Case 1 is defined for a single DQ signal within a byte lane which is switching into a certain direction (either form high to low or low to high) while all remaining DQ signals in the same byte lane are static (i.e. they stay at either high or low). Case 2 is defined for a single DQ signal within a byte lane which is switching into a certain direction (either from high to low or low to high) while all remaining DQ signals in the same byte lane are switching into the opposite direction (i.e. from low to high or high to low respectively). For the remaining DQ signal switching into the opposite direction, the regular maximum limit of 5 V/ns applies.

Differential Output Slew Rate

Differential Output Slew Rate Definition

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



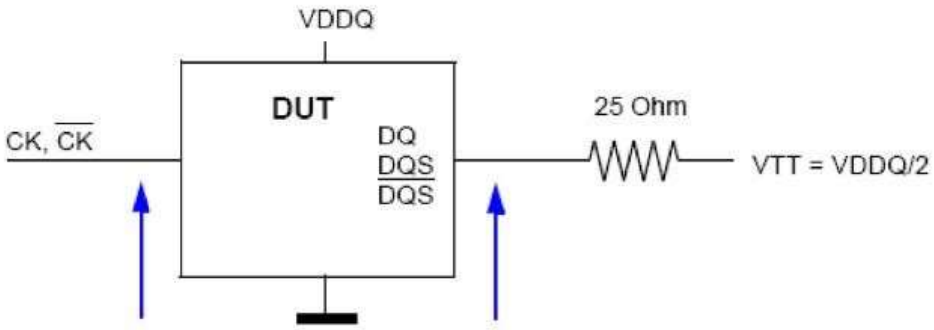
Differential Output Slew Rate

Parameter	Symbol	DDR3L-1866		DDR3-1866		Unit
		Min.	Max.	Min.	Max.	
Differential Output Slew Rate	SRQdiff	3.5	12	5	12	V/ns
Description: SR: Slew Rate. Q: Query Output (like in DQ, which stands for Data-in, Query -Output). diff: Differential signals. For Ron = R_{ZQ}/7 setting						

Reference Load for AC Timing and Output Slew Rate

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

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

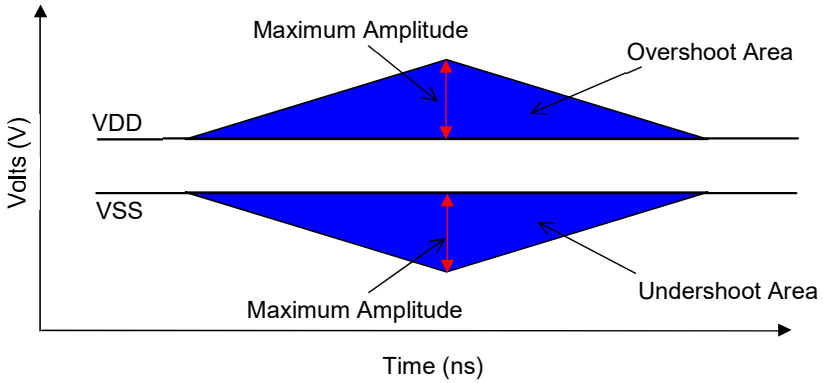


Overshoot and Undershoot Specifications

AC Overshoot/Undershoot Specification for Address and Control Pins

Item	DDR3(L)-1866	Unit
Maximum peak amplitude allowed for overshoot area[1]	0.4	V
Maximum peak amplitude allowed for undershoot area[2]	0.4	V
Maximum overshoot area above VDD	0.28	V-ns
Maximum undershoot area below VSS	0.28	V-ns

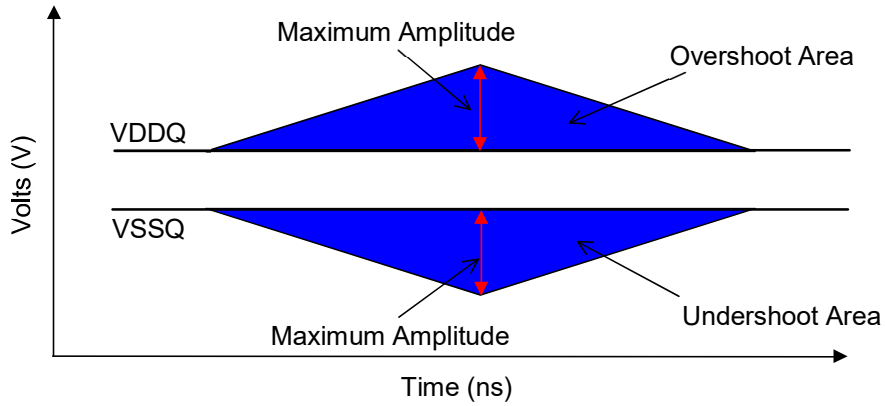
Note:
1. The sum of the applied voltage (VDD) and peak amplitude overshoot voltage is not to exceed absolute maximum DC ratings.
2. The sum of applied voltage (VDD) and the peak amplitude undershoot voltage is not to exceed absolute maximum DC ratings.



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

Item	DDR3(L)-1866	Unit
Maximum peak amplitude allowed for overshoot area[1]	0.4	V
Maximum peak amplitude allowed for undershoot area[2]	0.4	V
Maximum overshoot area above VDDQ	0.11	V-ns
Maximum undershoot area below VSSQ	0.11	V-ns

Note:
1. The sum of the applied voltage (VDD) and peak amplitude overshoot voltage is not to exceed absolute maximum DC ratings.
2. The sum of applied voltage (VDD) and the peak amplitude undershoot voltage is not to exceed absolute maximum DC ratings.



34 Ohm Output Driver DC Electrical Characteristics

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

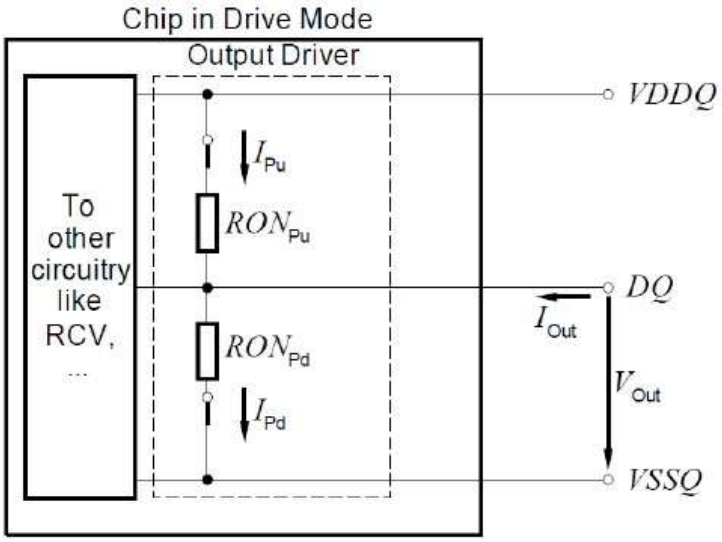
$RON_{34} = R_{ZQ} / 7$ (nominal 34.4ohms +/-10% with nominal R_{ZQ}=240ohms)

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

$RON_{Pu} = [VDDQ-V_{OUT}] / I I_{OUT} I$ ---------- under the condition that RON_{Pd} is turned off (1)

$RON_{Pd} = V_{OUT} / I I_{OUT} I$ ----------under the condition that RON_{Pu} is turned off (2)

Output Driver: Definition of Voltages and Currents



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

RON_{Nom}	Resistor	V_{OUT}	Min.	Nom.	Max.	Unit	Note
DDR3L							
34 ohms	RON_{34Pd}	VOLdc = 0.2 x VDDQ	0.6	1.0	1.15	R_{ZQ} / 7	1,2,3
		VOMdc = 0.5 x VDDQ	0.9	1.0	1.15	R_{ZQ} / 7	1,2,3
		VOHdc = 0.8 x VDDQ	0.9	1.0	1.45	R_{ZQ} / 7	1,2,3
	RON_{34Pu}	VOLdc = 0.2 x VDDQ	0.9	1.0	1.45	R_{ZQ} / 7	1,2,3
		VOMdc = 0.5 x VDDQ	0.9	1.0	1.15	R_{ZQ} / 7	1,2,3
		VOHdc = 0.8 x VDDQ	0.6	1.0	1.15	R_{ZQ} / 7	1,2,3
40 ohms	RON_{40pd}	VOLdc = 0.2 × VDDQ	0.6	1.0	1.15	R_{ZQ} / 6	1,2,3
		VOMdc = 0.5 × VDDQ	0.9	1.0	1.15	R_{ZQ} / 6	1,2,3
		VOHdc = 0.8 × VDDQ	0.9	1.0	1.45	R_{ZQ} / 6	1,2,3
	RON_{40pu}	VOLdc = 0.2 × VDDQ	0.9	1.0	1.45	R_{ZQ} / 6	1,2,3
		VOMdc = 0.5 × VDDQ	0.9	1.0	1.15	R_{ZQ} / 6	1,2,3
		VOHdc = 0.8 × VDDQ	0.6	1.0	1.15	R_{ZQ} / 6	1,2,3
Mismatch between pull-up and pull-down, MM_{PuPd}		VOMdc = 0.5 x VDDQ	-10		+10	%	1,2,4
DDR3							
34 ohms	RON_{34Pd}	VOLdc = 0.2 x VDDQ	0.6	1.0	1.1	R_{ZQ} / 7	1,2,3
		VOMdc = 0.5 x VDDQ	0.9	1.0	1.1	R_{ZQ} / 7	1,2,3
		VOHdc = 0.8 x VDDQ	0.9	1.0	1.4	R_{ZQ} / 7	1,2,3
	RON_{34Pu}	VOLdc = 0.2 x VDDQ	0.9	1.0	1.4	R_{ZQ} / 7	1,2,3
		VOMdc = 0.5 x VDDQ	0.9	1.0	1.1	R_{ZQ} / 7	1,2,3
		VOHdc = 0.8 x VDDQ	0.6	1.0	1.1	R_{ZQ} / 7	1,2,3
40 ohms	RON_{40pd}	VOLdc = 0.2 × VDDQ	0.6	1.0	1.1	R_{ZQ} / 6	1,2,3
		VOMdc = 0.5 × VDDQ	0.9	1.0	1.1	R_{ZQ} / 6	1,2,3
		VOHdc = 0.8 × VDDQ	0.9	1.0	1.4	R_{ZQ} / 6	1,2,3
	RON_{40pu}	VOLdc = 0.2 × VDDQ	0.9	1.0	1.4	R_{ZQ} / 6	1,2,3
		VOMdc = 0.5 × VDDQ	0.9	1.0	1.1	R_{ZQ} / 6	1,2,3
		VOHdc = 0.8 × VDDQ	0.6	1.0	1.1	R_{ZQ} / 6	1,2,3
Mismatch between pull-up and pull-down, MM_{PuPd}		VOMdc = 0.5 x VDDQ	-10		+10	%	1,2,4

Note:

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

   Measure RON_{Pu} and RON_{Pd}, both at 0.5 x VDDQ:

   $MM_{PuPd} = [RON_{Pu} - RON_{Pd}] / RON_{Nom}$ x 100

Output Driver Temperature and Voltage sensitivity

If temperature and/or voltage after calibration, the tolerance limits widen according to the following table.

Delta T = T - T(@calibration); Delta V = VDDQ - VDDQ(@calibration); VDD = VDDQ

Note: dRONdT and dRONdV are not subject to production test but are verified by design and characterization.

Output Driver Sensitivity Definition

Items	Min.	Max.	Unit
RON_{PU}@VOHdc	0.6 - dRONdTH*lDelta TI - dRONdVH*lDelta VI	1.1 + dRONdTH*lDelta TI - dRONdVH*lDelta VI	$R_{ZQ}/7$
RON@VOMdc	0.9 - dRONdTM*lDelta TI - dRONdVM*lDelta VI	1.1 + dRONdTM*lDelta TI - dRONdVM*lDelta VI	$R_{ZQ}/7$
RON_{PD}@VOLdc	0.6 - dRONdTL*lDelta TI - dRONdVL*lDelta VI	1.1 + dRONdTL*lDelta TI - dRONdVL*lDelta VI	$R_{ZQ}/7$

Output Driver Voltage and Temperature Sensitivity

Speed Bin	DDR3(L)-1866		Unit
Items	Min.	Max.	
dRONdTM	0	1.5	%/°C
dRONdVM	0	0.13	%/mV
dRONdTL	0	1.5	%/°C
dRONdVL	0	0.13	%/mV
dRONdTH	0	1.5	%/°C
dRONdVH	0	0.13	%/mV
Note: These parameters may not be subject to production test. They are verified by design and characterization.			

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

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

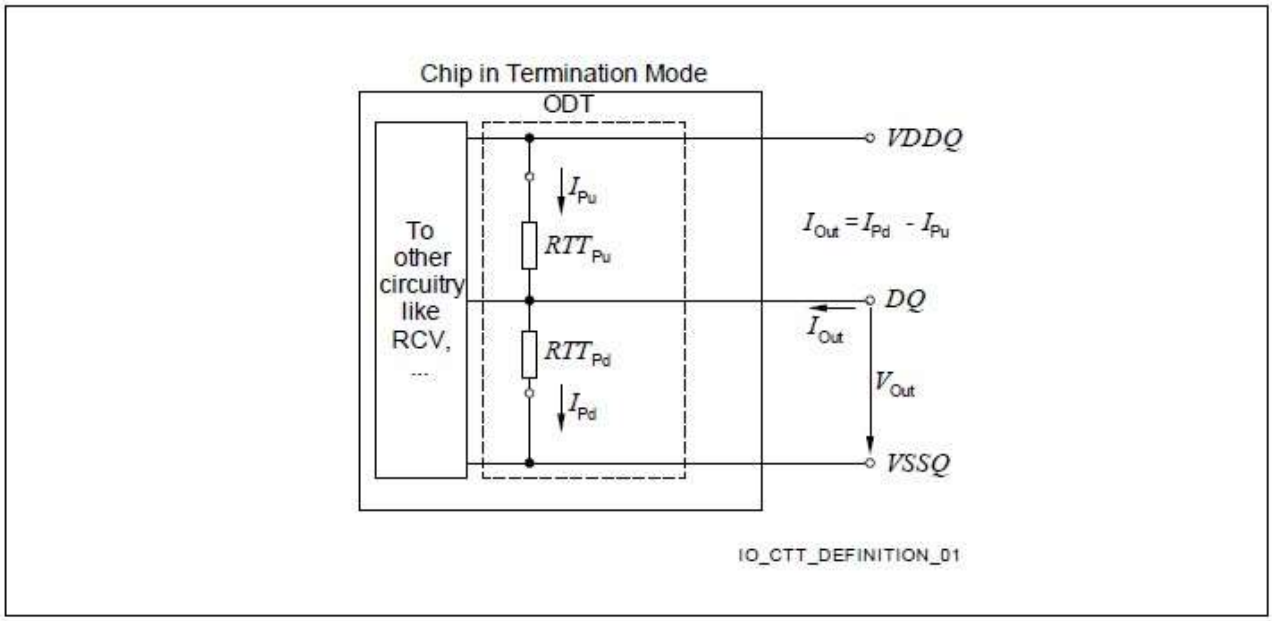
ODT is applied to the DQ, DM, DQS/$\overline{DQS}$ pins.

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

$RTT_{Pu} = [VDDQ - V_{OUT}] / I\ I_{OUT}\ I$ ---------- under the condition that RTT_{Pd} is turned off (3)

$RTT_{Pd} = V_{OUT} / I\ I_{OUT}\ I$ ---------- under the condition that RTT_{Pu} is turned off (4)

On-Die Termination: Definition of Voltages and Currents



ODT DC Electrical Characteristics

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

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

DDR3L								
MR1 A9,A6,A2	RTT	Resistor	VOUT	Min.	Nom.	Max.	Unit	Note
0,1,0	120Ω	$RTT_{120Pd240}$	VOLdc = 0.2 x VDDQ	0.6	1	1.15	R_{ZQ}	1,2,3,4
			0.5 x VDDQ	0.9	1	1.15	R_{ZQ}	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.9	1	1.45	R_{ZQ}	1,2,3,4
		$RTT_{120Pu240}$	VOLdc = 0.2 x VDDQ	0.9	1	1.45	R_{ZQ}	1,2,3,4
			0.5 x VDDQ	0.9	1	1.15	R_{ZQ}	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.6	1	1.15	R_{ZQ}	1,2,3,4
		RTT_{120}	VIL(AC) to VIH(AC)	0.9	1	1.65	R_{ZQ} /2	1,2,5
0, 0, 1	60Ω	$RTT_{60Pd120}$	VOLdc = 0.2 x VDDQ	0.6	1	1.15	$R_{ZQ}/2$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.15	$R_{ZQ}/2$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.9	1	1.45	$R_{ZQ}/2$	1,2,3,4
		$RTT_{60Pu120}$	VOLdc = 0.2 x VDDQ	0.9	1	1.45	$R_{ZQ}/2$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.15	$R_{ZQ}/2$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.6	1	1.15	$R_{ZQ}/2$	1,2,3,4
		RTT_{60}	VIL(AC) to VIH(AC)	0.9	1	1.65	$R_{ZQ}/4$	1,2,5
0, 1, 1	40Ω	RTT_{40Pd80}	VOLdc = 0.2 x VDDQ	0.6	1	1.15	$R_{ZQ}/3$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.15	$R_{ZQ}/3$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.9	1	1.45	$R_{ZQ}/3$	1,2,3,4
		RTT_{40Pu80}	VOLdc = 0.2 x VDDQ	0.9	1	1.45	$R_{ZQ}/3$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.15	$R_{ZQ}/3$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.6	1	1.15	$R_{ZQ}/3$	1,2,3,4
		RTT_{40}	VIL(AC) to VIH(AC)	0.9	1	1.65	$R_{ZQ}/6$	1,2,5
1, 0, 1	30Ω	RTT_{30Pd60}	VOLdc = 0.2 x VDDQ	0.6	1	1.15	$R_{ZQ}/4$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.15	$R_{ZQ}/4$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.9	1	1.45	$R_{ZQ}/4$	1,2,3,4
		RTT_{30Pu60}	VOLdc = 0.2 x VDDQ	0.9	1	1.45	$R_{ZQ}/4$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.15	$R_{ZQ}/4$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.6	1	1.15	$R_{ZQ}/4$	1,2,3,4
		RTT_{30}	VIL(AC) to VIH(AC)	0.9	1	1.65	$R_{ZQ}/8$	1,2,5
1, 0, 0	20Ω	RTT_{20Pd40}	VOLdc = 0.2 x VDDQ	0.6	1	1.15	$R_{ZQ}/6$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.15	$R_{ZQ}/6$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.9	1	1.45	$R_{ZQ}/6$	1,2,3,4
		RTT_{20Pu40}	VOLdc = 0.2 x VDDQ	0.9	1	1.45	$R_{ZQ}/6$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.15	$R_{ZQ}/6$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.6	1	1.15	$R_{ZQ}/6$	1,2,3,4
		RTT_{20}	VIL(AC) to VIH(AC)	0.9	1	1.65	$R_{ZQ}/12$	1,2,5
Deviation of V_M w.r.t. VDDQ/2, Delta V_M				-5		+5	%	1,2,5,6

DDR3								
MR1 A9,A6,A2	RTT	Resistor	VOUT	Min.	Nom.	Max.	Unit	Note
0,1,0	120Ω	$RTT_{120Pd240}$	VOLdc = 0.2 x VDDQ	0.6	1	1.1	R_{ZQ}	1,2,3,4
			0.5 x VDDQ	0.9	1	1.1	R_{ZQ}	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.9	1	1.4	R_{ZQ}	1,2,3,4
		$RTT_{120Pu240}$	VOLdc = 0.2 x VDDQ	0.9	1	1.4	R_{ZQ}	1,2,3,4
			0.5 x VDDQ	0.9	1	1.1	R_{ZQ}	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.6	1	1.1	R_{ZQ}	1,2,3,4
		RTT_{120}	VIL(AC) to VIH(AC)	0.9	1	1.6	$R_{ZQ}/2$	1,2,5
0, 0, 1	60Ω	$RTT_{60Pd120}$	VOLdc = 0.2 x VDDQ	0.6	1	1.1	$R_{ZQ}/2$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.1	$R_{ZQ}/2$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.9	1	1.4	$R_{ZQ}/2$	1,2,3,4
		$RTT_{60Pu120}$	VOLdc = 0.2 x VDDQ	0.9	1	1.4	$R_{ZQ}/2$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.1	$R_{ZQ}/2$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.6	1	1.1	$R_{ZQ}/2$	1,2,3,4
		RTT_{60}	VIL(AC) to VIH(AC)	0.9	1	1.6	$R_{ZQ}/4$	1,2,5
0, 1, 1	40Ω	RTT_{40Pd80}	VOLdc = 0.2 x VDDQ	0.6	1	1.1	$R_{ZQ}/3$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.1	$R_{ZQ}/3$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.9	1	1.4	$R_{ZQ}/3$	1,2,3,4
		RTT_{40Pu80}	VOLdc = 0.2 x VDDQ	0.9	1	1.4	$R_{ZQ}/3$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.1	$R_{ZQ}/3$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.6	1	1.1	$R_{ZQ}/3$	1,2,3,4
		RTT_{40}	VIL(AC) to VIH(AC)	0.9	1	1.6	$R_{ZQ}/6$	1,2,5
1, 0, 1	30Ω	RTT_{30Pd60}	VOLdc = 0.2 x VDDQ	0.6	1	1.1	$R_{ZQ}/4$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.1	$R_{ZQ}/4$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.9	1	1.4	$R_{ZQ}/4$	1,2,3,4
		RTT_{30Pu60}	VOLdc = 0.2 x VDDQ	0.9	1	1.4	$R_{ZQ}/4$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.1	$R_{ZQ}/4$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.6	1	1.1	$R_{ZQ}/4$	1,2,3,4
		RTT_{30}	VIL(AC) to VIH(AC)	0.9	1	1.6	$R_{ZQ}/8$	1,2,5
1, 0, 0	20Ω	RTT_{20Pd40}	VOLdc = 0.2 x VDDQ	0.6	1	1.1	$R_{ZQ}/6$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.1	$R_{ZQ}/6$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.9	1	1.4	$R_{ZQ}/6$	1,2,3,4
		RTT_{20Pu40}	VOLdc = 0.2 x VDDQ	0.9	1	1.4	$R_{ZQ}/6$	1,2,3,4
			0.5 x VDDQ	0.9	1	1.1	$R_{ZQ}/6$	1,2,3,4
			VOHdc = 0.8 x VDDQ	0.6	1	1.1	$R_{ZQ}/6$	1,2,3,4
		RTT_{20}	VIL(AC) to VIH(AC)	0.9	1	1.6	$R_{ZQ}/12$	1,2,5
Deviation of V_M w.r.t. VDDQ/2, Delta V_M				-5		+5	%	1,2,5,6

Note:

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

ODT Temperature and Voltage sensitivity

If temperature and/or voltage change after calibration, the tolerance limits widen according to the following table.

Delta T = T - T(@calibration); Delta V = VDDQ - VDDQ(@calibration); VDD = VDDQ

ODT Sensitivity Definition

Symbol	Min.	Max.	Unit
RTT	0.9 - dRTTdT*|Delta TI - dRTTdV*|Delta VI	1.6 + dRTTdT*|Delta TI + dRTTdV*|Delta VI	RZQ/2,4,6,8,12

ODT Voltage and Temperature Sensitivity

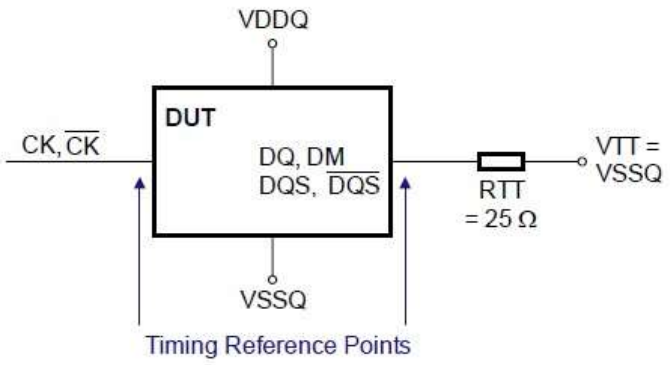
Symbol	Min.	Max.	Unit
dRTTdT	0	1.5	%/°C
dRTTdV	0	0.15	%/mV
Note: These parameters may not be subject to production test. They are verified by design and characterization.			

ODT Timing Definitions

Test Load for ODT Timings

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

ODT Timing Reference Load



ODT Timing Definitions

Definitions for tAON, tAONPD, tAOF, tAOFPD, and tADC are provided in the following table and subsequent figures.

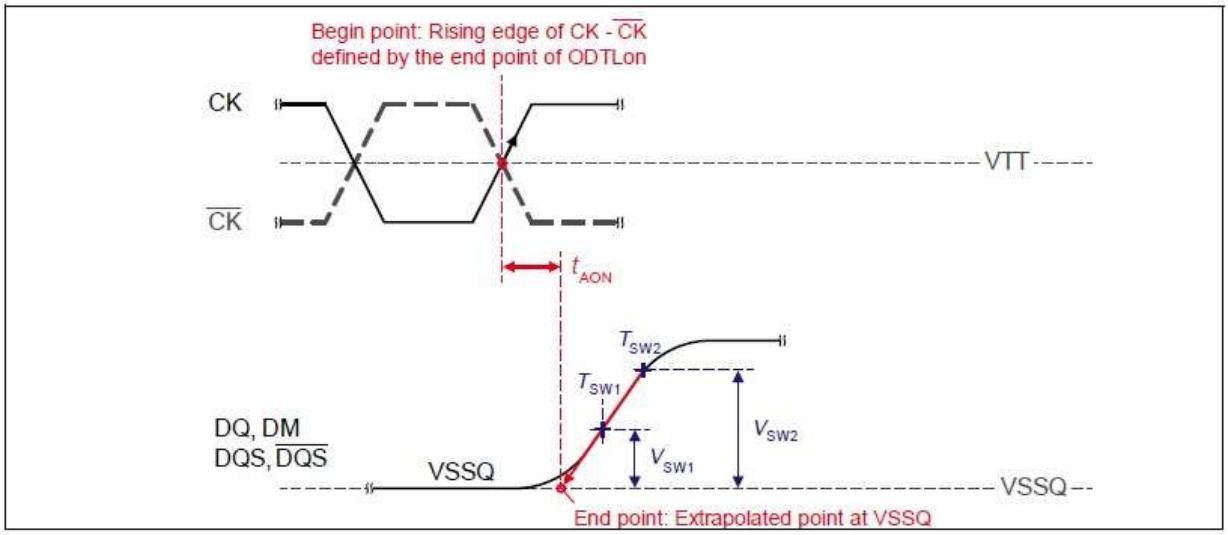
Symbol	Begin Point Definition	End Point Definition
tAON	Rising edge of CK - $\overline{CK}$ defined by the end point of ODTLon	Extrapolated point at VSSQ
tAONPD	Rising edge of CK - $\overline{CK}$ with ODT being first registered high	Extrapolated point at VSSQ
tAOF	Rising edge of CK - $\overline{CK}$ defined by the end point of ODTLoff	End point: Extrapolated point at VRTT_Nom
tAOFPD	Rising edge of CK - $\overline{CK}$ with ODT being first registered low	End point: Extrapolated point at VRTT_Nom
tADC	Rising edge of CK - $\overline{CK}$ defined by the end point of ODTLcnw, ODTLcwn4, or ODTLcwn8	End point: Extrapolated point at VRTT_Wr and VRTT_Nom respectively

Reference Settings for ODT Timing Measurements

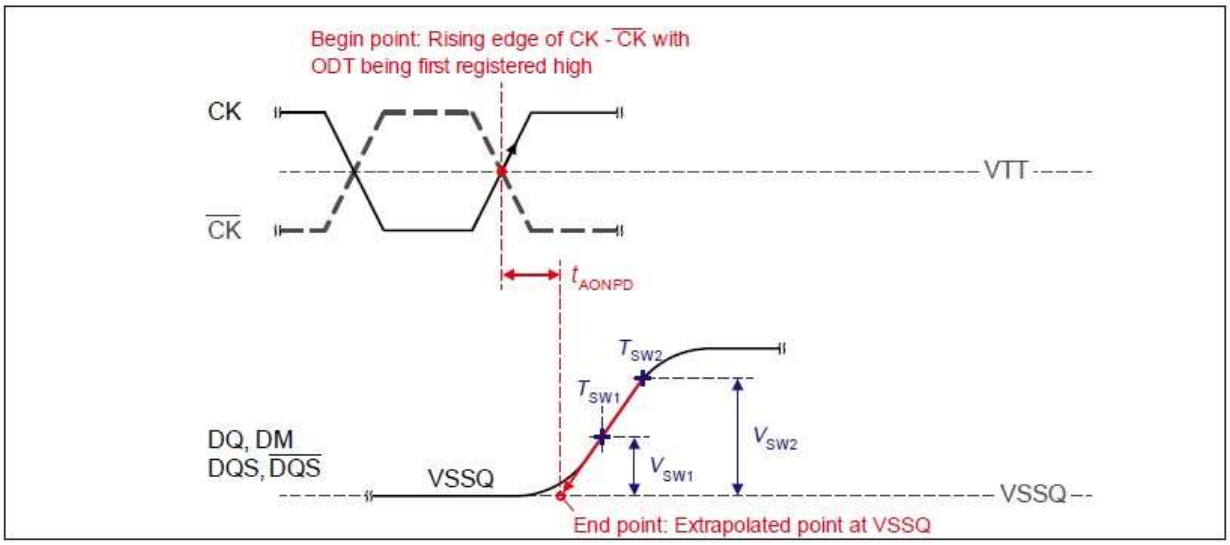
DDR3					
Measured Parameter	RTT_Nom Setting	RTT_Wr Setting	V_{SW1}[V]	V_{SW2}[V]	Note
tAON	RZQ/4	NA	0.05	0.10	
	RZQ/12	NA	0.10	0.20	
tAONPD	RZQ/4	NA	0.05	0.10	
	RZQ/12	NA	0.10	0.20	
tAOF	RZQ/4	NA	0.05	0.10	
	RZQ/12	NA	0.10	0.20	
tAOFPD	RZQ/4	NA	0.05	0.10	
	RZQ/12	NA	0.10	0.20	
tADC	RZQ/12	RZQ/2	0.20	0.30	

DDR3L					
Measured Parameter	RTT_Nom Setting	RTT_Wr Setting	V_{SW1}[V]	V_{SW2}[V]	Note
tAON	RZQ/4	NA	0.05	0.10	
	RZQ/12	NA	0.10	0.20	
tAONPD	RZQ/4	NA	0.05	0.10	
	RZQ/12	NA	0.10	0.20	
tAOF	RZQ/4	NA	0.05	0.10	
	RZQ/12	NA	0.10	0.20	
tAOFPD	RZQ/4	NA	0.05	0.10	
	RZQ/12	NA	0.10	0.20	
tADC	RZQ/12	RZQ/2	0.20	0.25	

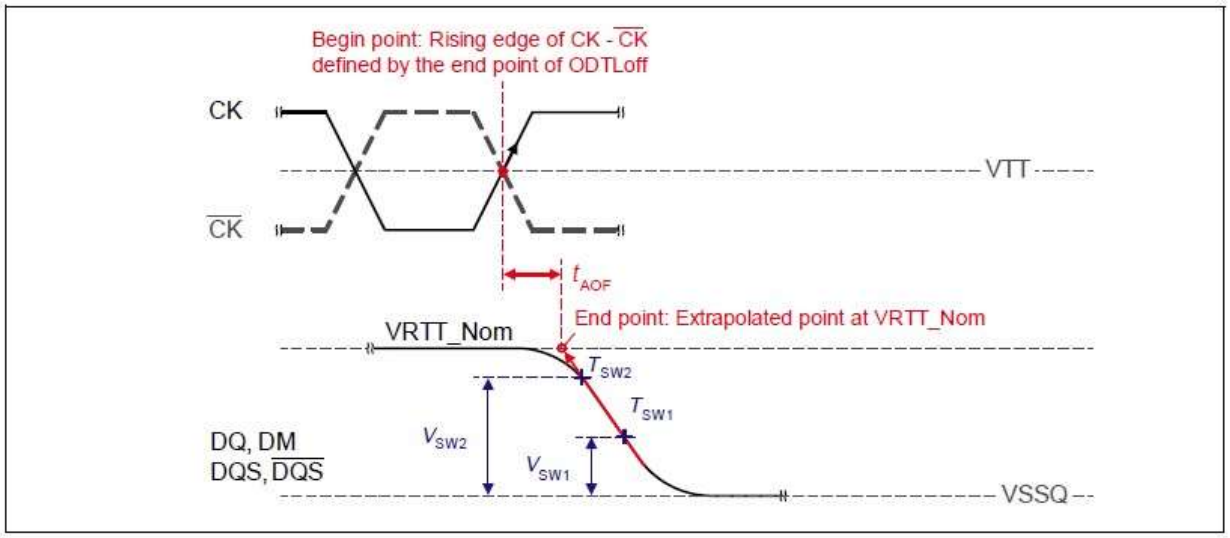
Definition of tAON



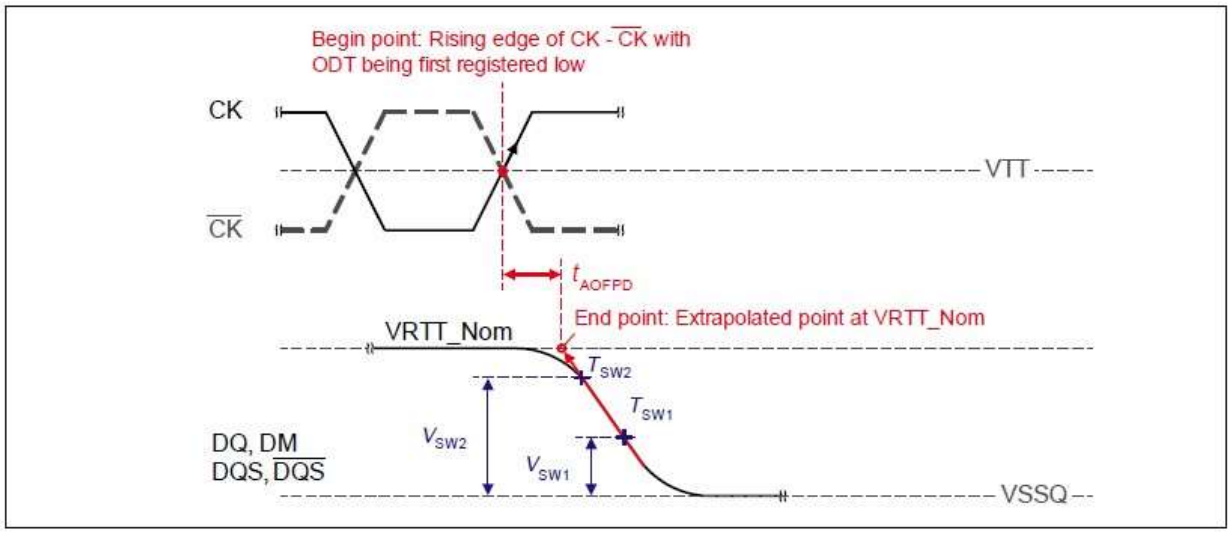
Definition of tAONPD



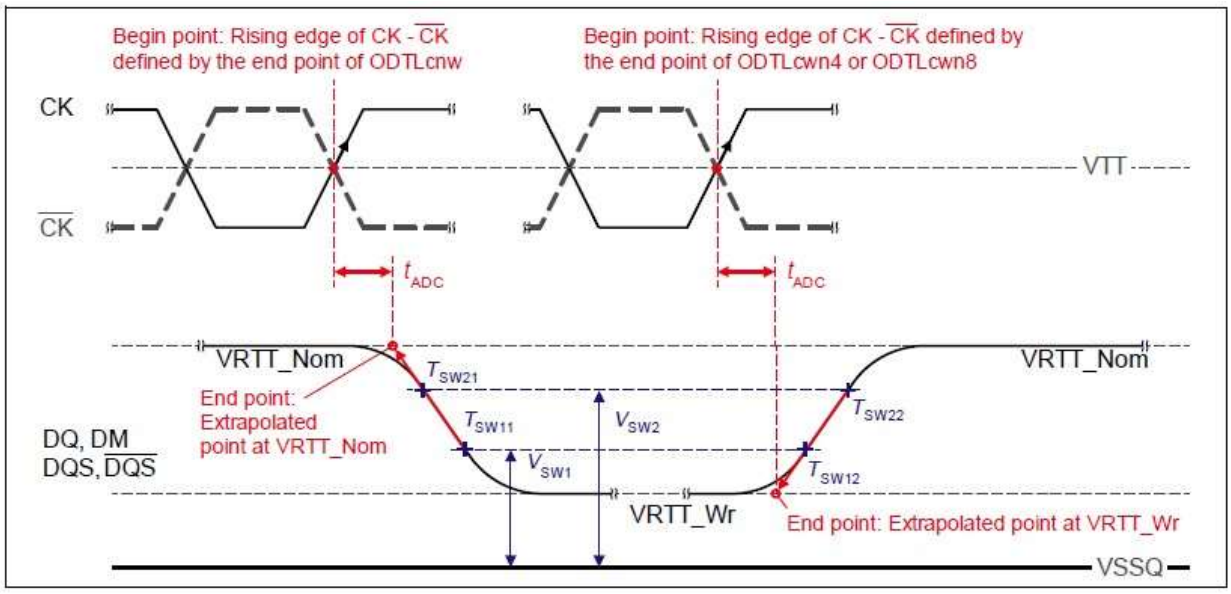
Definition of tAOF



Definition of tAOFPD



Definition of tADC



Input / Output Capacitance

Symbol	Parameter	1866		Unit	Note
		Min.	Max		
C_{IO} (DDR3)	Input/output capacitance (DQ, DM, DQS, $\overline{DQS}$)	1.4	2.2	pF	1,2,3
C_{IO} (DDR3L)		1.4	2.1		
C_{CK}	Input capacitance, CK and $\overline{CK}$	0.8	1.3	pF	2,3
C_{DCK}	Input capacitance delta, CK and $\overline{CK}$	0	0.15	pF	2,3,4
C_{DDQS}	Input/output capacitance delta, DQS and $\overline{DQS}$	0	0.15	pF	2,3,5
C_I (DDR3)	Input capacitance, CTRL, ADD, CMD input-only pins	0.75	1.2	pF	2,3,6
C_I (DDR3L)		0.75	1.2		
C_{DI_CTRL}	Input capacitance delta, all CTRL input-only pins	-0.4	0.2	pF	2,3,7,8
$C_{DI_ADD_CMD}$	Input capacitance delta, all ADD/CMD input-only pins	-0.4	0.4	pF	2,3,9,10
C_{DIO}	Input/output capacitance delta, DQ, DM, DQS, $\overline{DQS}$	-0.5	0.3	pF	2,3,11
C_{ZQ}	Input/output capacitance of ZQ pin	-	3	pF	2,3,12

Note:

1. Although the DM pin has 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, $\overline{RESET}$ and ODT as necessary). VDD=VDDQ=1.5V for DDR3 / 1.35V for DDR3L, 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}-$C_{\overline{CK}}$.
5. Absolute value of C_{IO}(DQS)-C_{IO}($\overline{DQS}$).
6. C_I applies to ODT, CS, CKE, A0-A14, BA0-BA2,$\overline{RAS}$,$\overline{CAS}$,$\overline{WE}$.
7. C_{DI_CTRL} applies to ODT, $\overline{CS}$ and CKE.
8. C_{DI_CTRL}=C_I(CTRL)-0.5*(C_I(CLK)+C_I($\overline{CLK}$)).
9. $C_{DI_ADD_CMD}$ applies to A0-A14, BA0-BA2, $\overline{RAS}$,$\overline{CAS}$ and $\overline{WE}$.
10. $C_{DI_ADD_CMD}$=C_I(ADD_CMD) - 0.5*(C_I(CLK)+C_I($\overline{CLK}$)).
11. C_{DIO}=C_{IO}(DQ,DM) - 0.5*(C_{IO}(DQS)+C_{IO}($\overline{DQS}$)).
12. Maximum external load capacitance on ZQ pin: 5 pF.

IDD and IDDQ Specification Parameters and Test Conditions

IDD and IDDQ Measurement Conditions

In this chapter, IDD and IDDQ measurement conditions such as test load and patterns are defined.
The following figure shows the setup and test load for IDD and IDDQ measurements.

- **IDD currents** (such as IDD0, IDD1, IDD2N, IDD2NT, IDD2P0, IDD2P1, IDD2Q, IDD3N, IDD3P, IDD4R, IDD4W, IDD5B, IDD6, IDD6ET, IDD6TC and IDD7) are measured as time-averaged currents with all VDD balls of the DDR3(L) SDRAM under test tied together. Any IDDQ current is not included in IDD currents.

- **IDDQ currents** (such as IDDQ2NT and IDDQ4R) are measured as time-averaged currents with all VDDQ balls of the DDR3(L) SDRAM under test tied together. Any IDD current is not included in IDDQ currents.

  Attention: IDDQ values cannot be directly used to calculate IO power of the DDR3(L) SDRAM. They can be used to support correlation of simulated IO power to actual IO power as outlined in following figure. In DRAM module application, IDDQ cannot be measured separately since VDD and VDDQ are using one merged-power layer in Module PCB.

For IDD and IDDQ measurements, the following definitions apply:

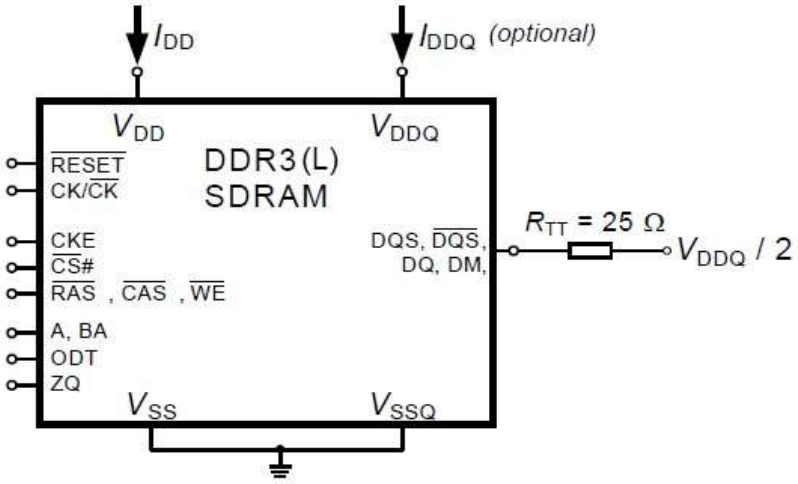
- "0" and "LOW" is defined as VIN <= VILAC(max).
- "1" and "HIGH" is defined as VIN >= VIHAC(min). ● "MID-LEVEL" is defined as inputs are VREF = VDD / 2.
- Timings used for IDD and IDDQ Measurement-Loop Patterns are provided in "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table.
- Basic IDD and IDDQ Measurement Conditions are described in "Basic IDD and IDDQ Measurement Conditions" Table.
- Detailed IDD and IDDQ Measurement-Loop Patterns are described in "IDDx Measurement-Loop Pattern" Tables.
- IDD Measurements are done after properly initializing the DDR3(L) SDRAM. This includes but is not limited to setting
  RON = R_{ZQ}/7 (34 Ohm in MR1);
  Qoff = 0B (Output Buffer enabled in MR1);
  RTT_Nom = R_{ZQ}/6 (40 Ohm in MR1);
  RTT_Wr = R_{ZQ}/2 (120 Ohm in MR2);

Attention: The IDD and IDDQ Measurement-Loop Patterns need to be executed at least one time before actual IDD or IDDQ measurement is started.

Define D = {$\overline{CS}$,$\overline{RAS}$,$\overline{CAS}$, $\overline{WE}$ } := {HIGH, LOW, LOW, LOW}

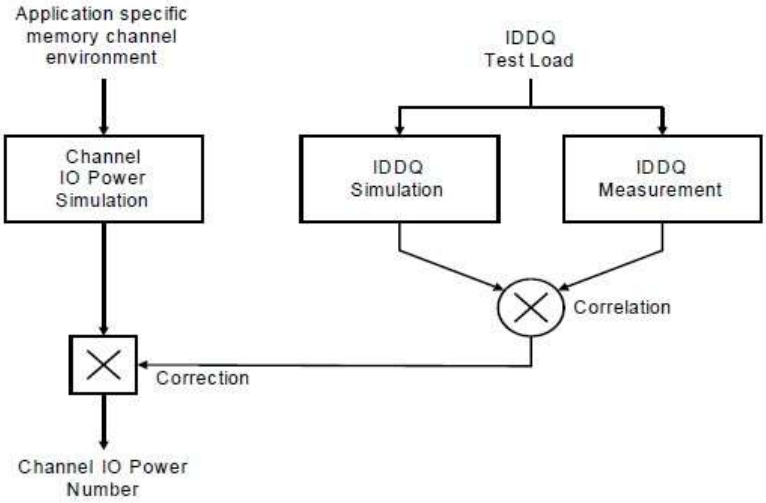
Define D# = {$\overline{CS}$,$\overline{RAS}$,$\overline{CAS}$, $\overline{WE}$ } := {HIGH, HIGH, HIGH, HIGH}

Measurement Setup and Test Load for IDD and IDDQ Measurements



Note: DIMM level Output test load condition may be different from above.

Correlation from simulated Channel IO Power to actual Channel IO Power supported by IDDQ Measurement.



Timings used for IDD and IDDQ Measurement-Loop Patterns

Symbol	DDR3(L)-1866 (13-13-13)	Unit
tCK	1.071	ns
CL	13	nCK
nRCD	13	nCK
nRC	45	nCK
nRAS	32	nCK
nRP	13	nCK
nFAW	33	nCK
nRRD	6	nCK
nRFC	243	nCK

Basic IDD and IDDQ Measurement Conditions

Symbol	Description
IDD0	**Operating One Bank Active-Precharge Current** **CKE:** High; **External clock:** On; **tCK, nRC, nRAS, CL:** see "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table; **BL:** 8(1); **AL:** 0; **$\overline{CS}$:** High between ACT and PRE; **Command, Address, Bank Address Inputs:** partially toggling according to "IDD0 Measurement-Loop Pattern" Table; **Data IO:** MID-LEVEL; **DM:** stable at 0; **Bank Activity:** Cycling with one bank active at a time: 0, 0, 1,1,2,2... **Output Buffer and RTT:** Enabled in Mode Registers(2); **ODT Signal:** stable at 0; **Pattern Details:** see "IDD0 Measurement-Loop Pattern" Table
IDD1	**Operating One Bank Active-Read-Precharge Current** **CKE:** High; **External clock:** On; **tCK, nRC, nRAS, nRCD, CL:** see "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table; **BL:** 8(1, 6); **AL:** 0; **$\overline{CS}$:** High between ACT, RD and PRE; **Command, Address, Bank Address Inputs, Data IO:** partially toggling according to "IDD1 Measurement-Loop Pattern" Table; **DM:** stable at 0; **Bank Activity:** Cycling with one bank active at a time: 0, 0, 1,1,2,2... **Output Buffer and RTT:** Enabled in Mode Registers (2); **ODT Signal:** stable at 0; **Pattern Details:** see "IDD1 Measurement-Loop Pattern" Table
IDD2N	**Precharge Standby Current** **CKE:** High; **External clock:** On; **tCK, CL:** see "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table; **BL:** 8(1); **AL:** 0; **$\overline{CS}$**: stable at 1; **Command, Address, Bank Address Inputs:** partially toggling according to "IDD2N Measurement-Loop Pattern" Table; **Data IO:** MID-LEVEL; **DM:** stable at 0; **Bank Activity:** all banks closed; **Output Buffer and RTT:** Enabled in Mode Registers (2); **ODT Signal:** stable at 0. **Pattern Details:** see "IDD2N Measurement-Loop Pattern" Table
IDD2NT	**Precharge Standby ODT Current** **CKE:** High; **External clock:** On; **tCK, CL:** see "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table; **BL:** 8(1); **AL:** 0; **$\overline{CS}$:** stable at 1; **Command, Address, Bank Address Inputs:** partially toggling according to "IDD2NT Measurement-Loop Pattern" Table; **Data IO:** MID-LEVEL; **DM:** stable at 0; **Bank Activity:** all banks closed; **Output Buffer and RTT:** Enabled in Mode Registers (2); **ODT Signal:** toggling according to "IDD2NT Measurement-Loop Pattern" Table; **Pattern Details:** see "IDD2NT Measurement-Loop Pattern" Table
IDD2P0	**Precharge Power-Down Current Slow Exit** **CKE:** Low; **External clock:** On; **tCK, CL:** see "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table; **BL:** 8(1); **AL:** 0; **$\overline{CS}$:** stable at 1; **Command, Address, Bank Address Inputs:** stable at 0; **Data IO:** MID-LEVEL; **DM:** stable at 0; **Bank Activity:** all banks closed; **Output Buffer and RTT:** Enabled in Mode Registers (2); **ODT Signal:** stable at 0; **Precharge Power Down Mode:** Slow Exit (3)

Symbol	Description
IDD2P1	**Precharge Power-Down Current Fast Exit** **CKE:** Low; **External clock:** On; **tCK, CL:** see "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table; **BL:** 8(1); **AL:** 0; **$\overline{CS}$:** stable at 1; **Command, Address, Bank Address Inputs:** stable at 0; **Data IO:** MID-LEVEL; **DM:** stable at 0; **Bank Activity:** all banks closed; **Output Buffer and RTT:** Enabled in Mode Registers (2); **ODT Signal:** stable at 0; **Precharge Power Down Mode:** Fast Exit (3)
IDD2Q	**Precharge Quiet Standby Current** **CKE:** High; **External clock:** On; **tCK, CL:** see "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table; **BL:** 8(1); **AL:** 0; **$\overline{CS}$:** stable at 1; **Command, Address, Bank Address Inputs:** stable at 0; **Data IO:** MID-LEVEL; **DM:** stable at 0; **Bank Activity:** all banks closed; **Output Buffer and RTT:** Enabled in Mode Registers (2); **ODT Signal:** stable at 0.
IDD3N	**Active Standby Current** **CKE:** High; **External clock:** On; **tCK, CL:** see "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table; **BL:** 8(1); **AL:** 0; **$\overline{CS}$:** stable at 1; **Command, Address, Bank Address Inputs:** partially toggling according to "IDD3N Measurement-Loop Pattern" Table; **Data IO:** MID-LEVEL; **DM:** stable at 0; **Bank Activity:** all banks open; **Output Buffer and RTT:** Enabled in Mode Registers (2); **ODT Signal:** stable at 0; **Pattern Details:** see "IDD3N Measurement-Loop Pattern" Table
IDD3P	**Active Power-Down Current** **CKE:** Low; **External clock:** On; **tCK, CL:** see "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table; **BL:** 8(1); **AL:** 0; **$\overline{CS}$:** stable at 1; **Command, Address, Bank Address Inputs:** stable at 0; **Data IO:** MID-LEVEL; **DM:** stable at 0; **Bank Activity:** all banks open; **Output Buffer and RTT:** Enabled in Mode Registers (2); **ODT Signal:** stable at 0.
IDD4R	**Operating Burst Read Current** **CKE:** High; **External clock:** On; **tCK, CL:** see "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table; **BL:** 8(1, 6); **AL:** 0; **$\overline{CS}$:** High between RD; **Command, Address, Bank Address Inputs:** partially toggling according to "IDD4R and IDD4W Measurement-Loop Pattern" Table; **Data IO:** seamless read data burst with different data between one burst and the next one according to "IDD4R and IDD4W Measurement-Loop Pattern" Table; **DM:** stable at 0; **Bank Activity:** all banks open, RD commands cycling through banks: 0,0,1,1,2,2,...; **Output Buffer and RTT:** Enabled in Mode Registers (2); **ODT Signal:** stable at 0; **Pattern Details:** see "IDD4R and IDD4W Measurement-Loop Pattern" Table
IDD4W	**Operating Burst Write Current** **CKE:** High; **External clock:** On; **tCK, CL:** see "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table; **BL:** 8(1); **AL:** 0; **$\overline{CS}$:** High between WR; **Command, Address, Bank Address Inputs:** partially toggling according to "IDD4R and IDD4W Measurement-Loop Pattern" Table; **Data IO:** seamless write data burst with different data between one burst and the next one according to "IDD4R and IDD4W Measurement-Loop Pattern" Table; **DM:** stable at 0; **Bank Activity:** all banks open, WR commands cycling through banks: 0, 0, 1,1,2,2...; **Output Buffer and RTT:** Enabled in Mode Registers (2); **ODT Signal:** stable at HIGH **Pattern Details:** see "IDD4R and IDD4W Measurement-Loop Pattern" Table

Symbol	Description
IDD5B	**Burst Refresh Current** **CKE:** High; **External clock:** On; **tCK, CL, nRFC:** see "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table; **BL:** 8(1); **AL:** 0; **CS:** High between REF; **Command, Address, Bank Address Inputs:** partially toggling according to "IDD5B Measurement-Loop Pattern" Table; **Data IO:** MID-LEVEL; **DM:** stable at 0; **Bank Activity:** REF command every nRFC; **Output Buffer and RTT:** Enabled in Mode Registers (2); **ODT Signal:** stable at 0; **Pattern Details:** see "IDD5B Measurement-Loop Pattern" Table
IDD6	**Self Refresh Current: Normal Temperature Range** **T_{OPER}:** 0 - 85°C or -40 - 85°C; **Auto Self-Refresh (ASR):** Disabled(4); **Self-Refresh Temperature Range (SRT):** Normal(5); **CKE:** Low; **External clock:** Off; **CK** and **CK:** LOW; **CL**: see "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table; **BL:** 8(1); **AL:** 0; **CS, Command, Address, Bank Address, Data IO:** MID-LEVEL; **DM:** stable at 0; **Bank Activity:** Self-Refresh operation; **Output Buffer and RTT:** Enabled in Mode Registers (2); **ODT Signal:** MID-LEVEL
IDD6ET	**Self-Refresh Current: Extended Temperature Range** (6) **T_{OPER}:** 0 – 95°C or -40 – 95°C or -40 – 105°C; **Auto Self-Refresh (ASR):** Disabled(4); **Self-Refresh Temperature Range (SRT):** Extended(5); **CKE:** Low; **External clock:** Off; **CK** and **CK:** LOW; **CL:** see "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table; **BL:** 8(1); **AL:** 0; **CS, Command, Address, Bank Address, Data IO:** MID-LEVEL; **DM:** stable at 0; **Bank Activity:** Extended Temperature Self-Refresh operation; **Output Buffer and RTT:** Enabled in Mode Registers (2); **ODT Signal:** MID-LEVEL
IDD7	**Operating Bank Interleave Read Current** **CKE:** High; **External clock:** On; **tCK, nRC, nRAS, nRCD, nRRD, nFAW, CL:** see "Timings used for IDD and IDDQ Measurement-Loop Patterns" Table; **BL:** 8(1, 6); **AL:** CL-1; **CS:** High between ACT and RDA; **Command, Address, Bank Address inputs:** partially toggling according to "IDD7 Measurement-Loop Pattern" Table; **Data IO:** read data bursts with different data between one burst and the next one according to "IDD7 Measurement-Loop Pattern" Table; **DM:** stable at 0; **Bank Activity:** two times interleaved cycling through banks (0, 1, ...7) with different addressing; **Output Buffer and RTT:** Enabled in Mode Registers (2); **ODT Signal:** stable at 0; **Pattern Details:** see "IDD7 Measurement-Loop Pattern" Table
IDD8	**RESET Low Current** **RESET :** LOW; **External clock:** Off; **CK and CK:** LOW; **CKE:** FLOATING; **CS**, **Command, Address, Bank Address, Data IO:** FLOATING; **ODT Signal:** FLOATING; RESET Low current reading is valid once power is stable and **RESET** has been LOW for at least 1ms.

Note:

1. Burst Length: BL8 fixed by MRS: set MR0 A[1,0] = 00B.
2. Output Buffer Enable: set MR1 A[12] = 0B; set MR1 A[5,1] = 01B; RTT_Nom enable: set MR1 A[9,6,2] = 011B; RTT_Wr enable: set MR2 A[10,9] = 10B.
3. Precharge Power Down Mode: set MR0 A12 = 0B for Slow Exit or MR0 A12 = 1B for Fast Exit.
4. Auto Self-Refresh (ASR): set MR2 A6 = 0B to disable or 1B to enable feature.
5. Self-Refresh Temperature Range (SRT): set MR2 A7 = 0B for normal or 1B for extended temperature range.
6. Read Burst Type: Nibble Sequential, set MR0 A[3] = 0B.

IDD0 Measurement-Loop Pattern[1]

CK, /CK	CKE	Sub-Loop	Cycle Number	Command	/CS	/RAS	/CAS	/WE	ODT	BA[2:0]	A[13:11]	A[10]	A[9:7]	A[6:3]	A[2:0]	Data[2]
toggling	Static High	0	0	ACT	0	0	1	1	0	0	00	0	0	0	0	-
			1, 2	D, D	1	0	0	0	0	0	00	0	0	0	0	-
			3, 4	D#, D#	1	1	1	1	0	0	00	0	0	0	0	-
			…	repeat pattern 1...4 until nRAS - 1, truncate if necessary												
			nRAS	PRE	0	0	1	0	0	0	00	0	0	0	0	-
			…	repeat pattern 1...4 until nRC - 1, truncate if necessary												
			1*nRC + 0	ACT	0	0	1	1	0	0	00	0	0	F	0	-
			1*nRC + 1, 2	D, D	1	0	0	0	0	0	00	0	0	F	0	-
			1*nRC + 3, 4	D#, D#	1	1	1	1	0	0	00	0	0	F	0	-
			…	repeat pattern nRC + 1,...,4 until 1*nRC + nRAS - 1, truncate if necessary												
			1*nRC + nRAS	PRE	0	0	1	0	0	0	00	0	0	F	0	-
			…	repeat nRC + 1,...,4 until 2*nRC - 1, truncate if necessary												
		1	2*nRC	repeat Sub-Loop 0, use **BA[2:0] = 1** instead												
		2	4*nRC	repeat Sub-Loop 0, use **BA[2:0] = 2** instead												
		3	6*nRC	repeat Sub-Loop 0, use **BA[2:0] = 3** instead												
		4	8*nRC	repeat Sub-Loop 0, use **BA[2:0] = 4** instead												
		5	10*nRC	repeat Sub-Loop 0, use **BA[2:0] = 5** instead												
		6	12*nRC	repeat Sub-Loop 0, use **BA[2:0] = 6** instead												
		7	14*nRC	repeat Sub-Loop 0, use **BA[2:0] = 7** instead												

Note:
1. DM must be driven LOW all the time. DQS, $\overline{DQS}$ are MID-LEVEL.
2. DQ signals are MID-LEVEL.

IDD1 Measurement-Loop Pattern[1]

CK, /CK	CKE	Sub-Loop	Cycle Number	Command	/CS	/RAS	/CAS	/WE	ODT	BA[2:0]	A[13:11]	A[10]	A[9:7]	A[6:3]	A[2:0]	Data[2]
toggling	Static High	0	0	ACT	0	0	1	1	0	0	00	0	0	0	0	-
			1, 2	D, D	1	0	0	0	0	0	00	0	0	0	0	-
			3, 4	D#, D#	1	1	1	1	0	0	00	0	0	0	0	-
			…	repeat pattern 1...4 until nRCD - 1, truncate if necessary												
			nRCD	RD	0	1	0	1	0	0	00	0	0	0	0	00000000
			…	repeat pattern 1...4 until nRAS - 1, truncate if necessary												
			nRAS	PRE	0	0	1	0	0	0	00	0	0	0	0	-
			…	repeat pattern 1...4 until nRC - 1, truncate if necessary												
			1*nRC + 0	ACT	0	0	1	1	0	0	00	0	0	F	0	-
			1*nRC + 1, 2	D, D	1	0	0	0	0	0	00	0	0	F	0	-
			1*nRC + 3, 4	D#, D#	1	1	1	1	0	0	00	0	0	F	0	-
			…	repeat pattern nRC + 1,..., 4 until nRC + nRCD - 1, truncate if necessary												
			1*nRC + nRCD	RD	0	1	0	1	0	0	00	0	0	F	0	00110011
			…	repeat pattern nRC + 1,..., 4 until nRC + nRAS - 1, truncate if necessary												
			1*nRC + nRAS	PRE	0	0	1	0	0	0	00	0	0	F	0	-
			…	repeat pattern nRC + 1,..., 4 until 2 * nRC - 1, truncate if necessary												
		1	2*nRC	repeat Sub-Loop 0, use **BA[2:0] = 1** instead												
		2	4*nRC	repeat Sub-Loop 0, use **BA[2:0] = 2** instead												
		3	6*nRC	repeat Sub-Loop 0, use **BA[2:0] = 3** instead												
		4	8*nRC	repeat Sub-Loop 0, use **BA[2:0] = 4** instead												
		5	10*nRC	repeat Sub-Loop 0, use **BA[2:0] = 5** instead												
		6	12*nRC	repeat Sub-Loop 0, use **BA[2:0] = 6** instead												
		7	14*nRC	repeat Sub-Loop 0, use **BA[2:0] = 7** instead												

Note:

1. DM must be driven LOW all the time. DQS, DQS are used according to RD Commands, otherwise MID-LEVEL.
2. Burst Sequence driven on each DQ signal by Read Command. Outside burst operation, DQ signals are MID-LEVEL.

IDD2N and IDD3N Measurement-Loop Pattern[1]

CK, /CK	CKE	Sub-Loop	Cycle Number	Command	/CS	/RAS	/CAS	/WE	ODT	BA[2:0]	A[13:11]	A[10]	A[9:7]	A[6:3]	A[2:0]	Data[2]
toggling	Static High	0	0	D	1	0	0	0	0	0	0	0	0	0	0	-
			1	D	1	0	0	0	0	0	0	0	0	0	0	-
			2	D#	1	1	1	1	0	0	0	0	0	F	0	-
			3	D#	1	1	1	1	0	0	0	0	0	F	0	-
		1	4-7	repeat Sub-Loop 0, use **BA[2:0] = 1** instead												
		2	8-11	repeat Sub-Loop 0, use **BA[2:0] = 2** instead												
		3	12-15	repeat Sub-Loop 0, use **BA[2:0] = 3** instead												
		4	16-19	repeat Sub-Loop 0, use **BA[2:0] = 4** instead												
		5	20-23	repeat Sub-Loop 0, use **BA[2:0] = 5** instead												
		6	24-27	repeat Sub-Loop 0, use **BA[2:0] = 6** instead												
		7	28-31	repeat Sub-Loop 0, use **BA[2:0] = 7** instead												

Note:
1. DM must be driven LOW all the time. DQS, $\overline{DQS}$ are MID-LEVEL.
2. DQ signals are MID-LEVEL.

IDD2NT Measurement-Loop Pattern[1]

CK, /CK	CKE	Sub-Loop	Cycle Number	Command	/CS	/RAS	/CAS	/WE	ODT	BA[2:0]	A[13:11]	A[10]	A[9:7]	A[6:3]	A[2:0]	Data[2]
toggling	Static High	0	0	D	1	0	0	0	0	0	0	0	0	0	0	-
			1	D	1	0	0	0	0	0	0	0	0	0	0	-
			2	D#	1	1	1	1	0	0	0	0	0	F	0	-
			3	D#	1	1	1	1	0	0	0	0	0	F	0	-
		1	4-7	repeat Sub-Loop 0, but **ODT = 0** and **BA[2:0] = 1**												
		2	8-11	repeat Sub-Loop 0, but **ODT = 0** and **BA[2:0] = 2**												
		3	12-15	repeat Sub-Loop 0, but **ODT = 1** and **BA[2:0] = 3**												
		4	16-19	repeat Sub-Loop 0, but **ODT = 1** and **BA[2:0] = 4**												
		5	20-23	repeat Sub-Loop 0, but **ODT = 0** and **BA[2:0] = 5**												
		6	24-27	repeat Sub-Loop 0, but **ODT = 1** and **BA[2:0] = 6**												
		7	28-31	repeat Sub-Loop 0, but **ODT = 1** and **BA[2:0] = 7**												

Note:
1. DM must be driven LOW all the time. DQS, $\overline{DQS}$ are MID-LEVEL.
2. DQ signals are MID-LEVEL.

IDD4R and IDDQ4R Measurement-Loop Pattern[1]

CK, /CK	CKE	Sub-Loop	Cycle Number	Command	/CS	/RAS	/CAS	/WE	ODT	BA[2:0]	A[13:11]	A[10]	A[9:7]	A[6:3]	A[2:0]	Data[2]
toggling	Static High	0	0	RD	0	1	0	1	0	0	00	0	0	0	0	00000000
			1	D	1	0	0	0	0	0	00	0	0	0	0	-
			2, 3	D#, D#	1	1	1	1	0	0	00	0	0	0	0	-
			4	RD	0	1	0	1	0	0	00	0	0	F	0	00110011
			5	D	1	0	0	0	0	0	00	0	0	F	0	-
			6, 7	D#, D#	1	1	1	1	0	0	00	0	0	F	0	-
		1	8-15	repeat Sub-Loop 0, but **BA[2:0] = 1**												
		2	16-23	repeat Sub-Loop 0, but **BA[2:0] = 2**												
		3	24-31	repeat Sub-Loop 0, but **BA[2:0] = 3**												
		4	32-39	repeat Sub-Loop 0, but **BA[2:0] = 4**												
		5	40-47	repeat Sub-Loop 0, but **BA[2:0] = 5**												
		6	48-55	repeat Sub-Loop 0, but **BA[2:0] = 6**												
		7	56-63	repeat Sub-Loop 0, but **BA[2:0] = 7**												

Note:

1. DM must be driven LOW all the time. DQS, $\overline{DQS}$ are used according to RD Commands, otherwise MID-LEVEL.
2. Burst Sequence driven on each DQ signal by Read Command. Outside burst operation, DQ signals are MID-LEVEL.

IDD4W Measurement-Loop Pattern[1]

CK, /CK	CKE	Sub-Loop	Cycle Number	Command	/CS	/RAS	/CAS	/WE	ODT	BA[2:0]	A[13:11]	A[10]	A[9:7]	A[6:3]	A[2:0]	Data[2]
toggling	Static High	0	0	WR	0	1	0	0	1	0	00	0	0	0	0	00000000
			1	D	1	0	0	0	1	0	00	0	0	0	0	-
			2, 3	D#, D#	1	1	1	1	1	0	00	0	0	0	0	-
			4	WR	0	1	0	0	1	0	00	0	0	F	0	00110011
			5	D	1	0	0	0	1	0	00	0	0	F	0	-
			6, 7	D#, D#	1	1	1	1	1	0	00	0	0	F	0	-
		1	8-15	repeat Sub-Loop 0, but **BA[2:0] = 1**												
		2	16-23	repeat Sub-Loop 0, but **BA[2:0] = 2**												
		3	24-31	repeat Sub-Loop 0, but **BA[2:0] = 3**												
		4	32-39	repeat Sub-Loop 0, but **BA[2:0] = 4**												
		5	40-47	repeat Sub-Loop 0, but **BA[2:0] = 5**												
		6	48-55	repeat Sub-Loop 0, but **BA[2:0] = 6**												
		7	56-63	repeat Sub-Loop 0, but **BA[2:0] = 7**												

Note:
1. DM must be driven LOW all the time. DQS, $\overline{\text{DQS}}$ are used according to WR Commands, otherwise MID-LEVEL.
2. Burst Sequence driven on each DQ signal by Write Command. Outside burst operation, DQ signals are MID-LEVEL.

IDD5B Measurement-Loop Pattern[1]

CK, /CK	CKE	Sub-Loop	Cycle Number	Command	/CS	/RAS	/CAS	/WE	ODT	BA[2:0]	A[13:11]	A[10]	A[9:7]	A[6:3]	A[2:0]	Data[2]
toggling	Static High	0	0	REF	0	0	0	1	0	0	0	0	0	0	0	-
		1	1, 2	D, D	1	0	0	0	0	0	00	0	0	0	0	-
			3, 4	D#, D#	1	1	1	1	0	0	00	0	0	F	0	-
			5…8	repeat cycles 1...4, but **BA[2:0] = 1**												
			9…12	repeat cycles 1...4, but **BA[2:0] = 2**												
			13…16	repeat cycles 1...4, but **BA[2:0] = 3**												
			17…20	repeat cycles 1...4, but **BA[2:0] = 4**												
			21…24	repeat cycles 1...4, but **BA[2:0] = 5**												
			25…28	repeat cycles 1...4, but **BA[2:0] = 6**												
			29…32	repeat cycles 1...4, but **BA[2:0] = 7**												
		2	33…nRFC-1	**repeat Sub-Loop 1, until nRFC - 1**. Truncate, if necessary												

Note:
1. DM must be driven LOW all the time. DQS, $\overline{DQS}$ are MID-LEVEL.
2. DQ signals are MID-LEVEL.

IDD7 Measurement-Loop Pattern[1]

ATTENTION: Sub-Loops 10-19 have inverse A[6:3] Pattern and Data Pattern than Sub-Loops 0-9

CK, /CK	CKE	Sub-Loop	Cycle Number	Command	/CS	/RAS	/CAS	/WE	ODT	BA[2:0]	A[13:11]	A[10]	A[9:7]	A[6:3]	A[2:0]	Data[2]
toggling	Static High	0	0	ACT	0	0	1	1	0	0	00	0	0	0	0	-
			1	RDA	0	1	0	1	0	0	00	1	0	0	0	00000000
			2	D	1	0	0	0	0	0	00	0	0	0	0	-
			…	repeat above D Command until nRRD - 1												
		1	nRRD	ACT	0	0	1	1	0	1	00	0	0	F	0	-
			nRRD + 1	RDA	0	1	0	1	0	1	00	1	0	F	0	00110011
			nRRD + 2	D	1	0	0	0	0	1	00	0	0	F	0	-
			…	repeat above D Command until 2 * nRRD - 1												
		2	2*nRRD	repeat Sub-Loop 0, but **BA[2:0] = 2**												
		3	3*nRRD	repeat Sub-Loop 1, but **BA[2:0] = 3**												
		4	4*nRRD	D	1	0	0	0	0	3	00	0	0	F	0	-
				Assert and repeat above D Command until nFAW - 1, if necessary												
		5	nFAW	repeat Sub-Loop 0, but **BA[2:0] = 4**												

CK, /CK	CKE	Sub-Loop	Cycle Number	Command	/CS	/RAS	/CAS	/WE	ODT	BA[2:0]	A[13:11]	A[10]	A[9:7]	A[6:3]	A[2:0]	Data[2]
		6	nFAW + nRRD	repeat Sub-Loop 1, but **BA[2:0] = 5**												
		7	nFAW + 2*nRRD	repeat Sub-Loop 0, but **BA[2:0] = 6**												
		8	nFAW + 3*nRRD	repeat Sub-Loop 1, but **BA[2:0] = 7**												
		9	nFAW + 4*nRRD	D	1	0	0	0	0	7	00	0	0	F	0	-
				Assert and repeat above D Command until 2 * nFAW - 1, if necessary												
		10	2*nFAW + 0	ACT	0	0	1	1	0	0	00	0	0	F	0	-
			2*nFAW + 1	RDA		1	0	1	0	0	00	1	0	F	0	00110011
			2*nFAW + 2	D	1	0	0	0	0	0	00	0	0	F	0	-
				repeat above D Command until 2 * nFAW + nRRD - 1												
		11	2*nFAW + nRRD	ACT	0	0	1	1	0	1	00	0	0	0	0	-
			2*nFAW + nRRD + 1	RDA	0	1	0	1	0	1	00	1	0	0	0	00000000
			2*nFAW + nRRD + 2	D	1	0	0	0	0	1	00	0	0	0	0	-
				repeat above D Command until 2 * nFAW + 2 * nRRD -1												
		12	2*nFAW +2*nRRD	repeat Sub-Loop 10, but **BA[2:0] = 2**												
		13	2*nFAW + 3*nRRD	repeat Sub-Loop 11, but **BA[2:0] = 3**												
		14	2*nFAW + 4*nRRD	D	1	0	0	0	0	3	00	0	0	0	0	-
				Assert and repeat above D Command until 3 * nFAW - 1, if necessary												
		15	3*nFAW	repeat Sub-Loop 10, but **BA[2:0] = 4**												
		16	3*nFAW + nRRD	repeat Sub-Loop 11, but **BA[2:0] = 5**												
		17	3*nFAW + 2*nRRD	repeat Sub-Loop 10, but **BA[2:0] = 6**												
		18	3*nFAW + 3*nRRD	repeat Sub-Loop 11, but **BA[2:0] = 7**												
		19	3*nFAW + 4*nRRD	D	1	0	0	0	0	7	00	0	0	0	0	-
				Assert and repeat above D Command until 4 * nFAW - 1, if necessary												

Note:

1. DM must be driven LOW all the time. DQS, $\overline{DQS}$ are used according to RD Commands, otherwise MID-LEVEL.
2. Burst Sequence driven on each DQ signal by Read Command. Outside burst operation, DQ signals are MID-LEVEL.

IDD Specifications[3]

Symbol	Parameter/ Condition	DDR3L-1866	Unit
IDD0	**Operating Current 0** One Bank Activate -> Precharge	110	mA
IDD1	**Operating Current 1** One Bank Activate -> Read -> Precharge	160	mA
IDD2P0 (SLOW)	**Precharge Power-Down Current** Slow Exit - MR0 bit A12 = 0	20	mA
IDD2P1 (FAST)	**Precharge Power-Down Current** Fast Exit - MR0 bit A12 = 1	50	mA
IDD2Q	**Precharge Quiet Standby Current**	70	mA
IDD2N	**Precharge Standby Current**	70	mA
IDD2NT	**Precharge Standby ODT IDDQ Current**	80	mA
IDD3N	**Active Standby Current**	90	mA
IDD3P	**Active Power-Down Current** Always Fast Exit	60	mA
IDD4R	**Operating Current Burst Read**	240	mA
IDD4W	**Operating Current Burst Write**	220	mA
IDD5B	**Burst Refresh Current**	242	mA
IDD6[1]	**Self-Refresh Current:** Normal Temperature Range (0-85°C or -40-85°C)	15	mA
IDD6ET[2]	**Self-Refresh Current:** Extended Temperature Range (0-95°C or -40-95°C or -40-105°C)	20	mA
IDD7	**All Bank Interleave Read Current**	230	mA
IDD8	**Reset Low Current**	12	mA

Note:

1. IDD6: SRT is 'Normal', ASR is disabled. Value is maximum.
2. IDD6ET: SRT is 'Extended', ASR is disabled. Value is maximum.
3. IDD will be derated (increased) when above 95°C.

IDD Specifications- Continued[3]

Symbol	Parameter/ Condition	DDR3-1866	Unit
IDD0	**Operating Current 0** One Bank Activate -> Precharge	110	mA
IDD1	**Operating Current 1** One Bank Activate -> Read -> Precharge	160	mA
IDD2P0 (SLOW)	**Precharge Power-Down Current** Slow Exit - MR0 bit A12 = 0	20	mA
IDD2P1 (FAST)	**Precharge Power-Down Current** Fast Exit - MR0 bit A12 = 1	50	mA
IDD2Q	**Precharge Quiet Standby Current**	70	mA
IDD2N	**Precharge Standby Current**	70	mA
IDD2NT	**Precharge Standby ODT IDDQ Current**	80	mA
IDD3N	**Active Standby Current**	90	mA
IDD3P	**Active Power-Down Current** Always Fast Exit	60	mA
IDD4R	**Operating Current Burst Read**	240	mA
IDD4W	**Operating Current Burst Write**	220	mA
IDD5B	**Burst Refresh Current**	242	mA
IDD6[1]	**Self-Refresh Current:** Normal Temperature Range (0-85°C or -40-85°C)	15	mA
IDD6ET[2]	**Self-Refresh Current:** Extended Temperature Range (0-95°C or -40-95°C or -40-105°C)	20	mA
IDD7	**All Bank Interleave Read Current**	230	mA
IDD8	**Reset Low Current**	12	mA

Note:

1. IDD6: SRT is 'Normal', ASR is disabled. Value is maximum.
2. IDD6ET: SRT is 'Extended', ASR is disabled. Value is maximum.
3. IDD will be derated (increased) when above 95°C

Electrical Characteristics & AC Timing

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 (L) SDRAM device.

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 $N = 200$

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.

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 $N = 200$

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 {tCKi - 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.

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) = Max of |{tCKi +1 - tCKi}|.
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.

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.

Refresh parameters

Parameter	Symbol		Value	Unit
REF command to ACT or REF command time	tRFC		260	ns
Average periodic refresh interval	tREFI	$0°C \le T_{OPER} \le +85°C$	7.8	us
		$-40°C \le T_{OPER} \le +85°C$		
		$85°C < T_{OPER} \le +95°C$	3.9	us
		$95°C < T_{OPER} \le +105°C$	1.95	us

Standard Speed Bins

Speed Bins and Operating Conditions

Speed Bins			DDR3(L)-1866 (13-13-13)		Unit	Note
Symbol	Parameter		Min	Max		
tAA	Internal read command to first data		13.91	20	ns	
tRCD	ACT to internal read or write delay time		13.91	-	ns	
tRP	PRE command period		13.91	-	ns	
tRC	ACT to ACT or REF command period		47.91	-	ns	
tRAS	ACT to PRE command period		34	9*tREFI	ns	
tCK (avg)	CL6	CWL5	2.5	3.3	ns	1,2,3,5
		CWL6/7/8/9	Reserved		ns	4
	CL7	CWL5	Reserved		ns	4
		CWL6	1.875	< 2.5	ns	1,2,3,5
		CWL7/8/9	Reserved		ns	4
	CL8	CWL5	Reserved		ns	4
		CWL6	1.875	< 2.5	ns	1,2,3,5
		CWL7/8/9	Reserved		ns	4
	CL9	CWL5/6	Reserved		ns	4
		CWL7	1.5	< 1.875	ns	1,2,3,5
		CWL8/9	Reserved		ns	4
	CL10	CWL5/6	Reserved		ns	4
		CWL7	1.5	< 1.875	ns	1,2,3,5
		CWL8	Reserved		ns	4
	CL11	CWL5/6/7	Reserved		ns	4
		CWL8	1.25	< 1.5	ns	1,2,3,5
		CWL9	Reserved		ns	4
	CL12	CWL5/6/7/8	Reserved		ns	4
		CWL9	Reserved		ns	4
	CL13	CWL5/6/7/8	Reserved		ns	4
		CWL9	1.07	< 1.25	ns	1,2,3
Supported CL			6,7,8,9,10,11,13		nCK	
Supported CWL			5,6,7,8,9		nCK	

Note:

Absolute Specification (T_{OPER}; VDDQ = VDD = 1.5V +/- 0.075 V for DDR3; VDDQ = VDD = 1.35V -0.067V/+0.1V for DDR3(L))

1. The CL setting and CWL setting result in tCK(avg).MIN and tCK(avg).MAX requirements. When making a selection of tCK(avg), both need to be fulfilled: Requirements from CL setting as well as requirements from CWL setting.
2. tCK(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 tCK(avg) value (3.0, 2.5, 1.875, 1.5, 1.25, 1.07 ns) when calculating CL [nCK] = tAA [ns] / tCK(Avg) [ns], rounding up to the next 'Supported CL', where tCK(avg) = 3.0 ns should only be used for CL = 5 calculation.
3. tCK(avg).MAX limits: Calculate tCK(avg) = tAA.MAX / CL SELECTED and round the resulting tCK(avg) down to the next valid speed bin (i.e. 3.3ns or 2.5ns or 1.875 ns or 1.5 ns or 1.25 ns or 1.07 ns). This result is tCK(avg).MAX corresponding to CL SELECTED.
4. 'Reserved' settings are not allowed. User must program a different value.
5. Any DDR3(L)-1866 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.

Timing Parameters by Speed Bin

VDDQ = VDD = 1.5V +/- 0.075 V for DDR3; VDDQ = VDD = 1.35V -0.067V/+0.1V for DDR3(L)

Parameter	Symbol	DDR3(L)-1866		Unit	Note
		Min.	Max.		
Clock Timing					
Minimum Clock Cycle Time (DLL off mode)	tCK (DLL_off)	8	-	ns	6
Average Clock Period	tCK(avg)	Refer to “Standard Speed Bins”			
Average high pulse width	tCH(avg)	0.47	0.53	tCK(avg)	
Average low pulse width	tCL(avg)	0.47	0.53	tCK(avg)	
Absolute Clock Period	tCK(abs)	tCK(avg)min + tJIT(per)min	tCK(avg)max + tJIT(per)max	ps	
Absolute clock HIGH pulse width	tCH(abs)	0.43	-	tCK(avg)	25
Absolute clock LOW pulse width	tCL(abs)	0.43	-	tCK(avg)	26
Clock Period Jitter	JIT(per)	-60	60	ps	
Clock Period Jitter during DLL locking period	JIT(per, lck)	-50	50	ps	
Cycle to Cycle Period Jitter	tJIT(cc)	120		ps	
Cycle to Cycle Period Jitter during DLL locking period	JIT(cc, lck)	100		ps	
Duty Cycle Jitter	tJIT(duty)	-	-	-	
Cumulative error across 2 cycles	tERR(2per)	-88	88	ps	
Cumulative error across 3 cycles	tERR(3per)	-105	105	ps	
Cumulative error across 4 cycles	tERR(4per)	-117	117	ps	
Cumulative error across 5 cycles	tERR(5per)	-126	126	ps	
Cumulative error across 6 cycles	tERR(6per)	-133	133	ps	
Cumulative error across 7 cycles	tERR(7per)	-139	139	ps	
Cumulative error across 8 cycles	tERR(8per)	-145	145	ps	
Cumulative error across 9 cycles	tERR(9per)	-150	150	ps	
Cumulative error across 10 cycles	tERR(10per)	-154	154	ps	
Cumulative error across 11 cycles	tERR(11per)	-158	158	ps	
Cumulative error across 12 cycles	tERR(12per)	-161	161	ps	
Cumulative error across n = 13,14…49,50 cycles	tERR(nper)	(1 + 0.68ln(n)) * tJIT(per)min	(1 + 0.68ln(n)) * tJIT(per)max	ps	24
Data Timing					
DQS, $\overline{DQS}$ to DQ skew, per group, per access	tDQSQ	-	85	ps	13
DQ output hold time from DQS, $\overline{DQS}$	tQH	0.38	-	tCK(avg)	13,g
DQ low-impedance time from CK, $\overline{CK}$	tLZ(DQ)	-390	195	ps	13,14,f
DQ high-impedance time from CK, $\overline{CK}$	tHZ(DQ)	-	195	ps	13,14,f

Parameter	Symbol	DDR3(L)-1866		Unit	Note
		Min.	Max.		
Data setup time to DQS, $\overline{DQS}$ referenced to VIH (AC) / VIL(AC) levels	tDS(base) AC150 DDR3	-	-	ps	d,17
	tDS(base) AC135 DDR3	68	-	ps	d,17
	tDS(base) AC135 SR = 1V/ns DDR3L	-	-	ps	d,17
	tDS(base) AC130 SR=2V/ns DDR3L	70	-	ps	d
Data hold time from DQS, $\overline{DQS}$ referenced to VIH(DC) / VIL(DC) levels	tDH(base) DC100 DDR3	-	-	ps	d,17
	tDH(base) DC90 SR = 1V/ns DDR3L	-	-	ps	d,17
	tDH(base) DC90 SR=2V/ns DDR3L	75	-	ps	d
DQ and DM Input pulse width for each input	tDIPW	320	-	ps	28
DQS, $\overline{DQS}$ differential READ Preamble	tRPRE	0.9	Note 19	tCK(avg)	13,19,g
DQS, $\overline{DQS}$ differential READ Postamble	tRPST	0.3	Note 11	tCK(avg)	11,13,g
DQS, $\overline{DQS}$ differential output high time	tQSH	0.4	-	tCK(avg)	13,g
DQS, $\overline{DQS}$ differential output low time	tQSL	0.4	-	tCK(avg)	13,g
DQS, $\overline{DQS}$ differential WRITE Preamble	tWPRE	0.9	-	tCK(avg)	1
DQS, $\overline{DQS}$ differential WRITE Postamble	tWPST	0.3	-	tCK(avg)	1
DQS, $\overline{DQS}$ rising edge output access time from rising CK,$\overline{CK}$	tDQSCK	-195	195	ps	13,f
DQS and $\overline{DQS}$ low-impedance time (Referenced from RL-1)	tLZ(DQS)	-390	195	ps	13,14,f
DQS and $\overline{DQS}$ high-impedance time (Referenced from RL+BL/2)	tHZ(DQS)	-	195	ps	13,14,f
DQS, $\overline{DQS}$ differential input low pulse width	tDQSL	0.45	0.55	tCK(avg)	29,31
DQS, $\overline{DQS}$ differential input high pulse width	tDQSH	0.45	0.55	tCK(avg)	30,31

Parameter	Symbol	DDR3(L)-1866		Unit	Note
		Min.	Max.		
DQS, $\overline{DQS}$ rising edge to CK, $\overline{CK}$ rising edge	tDQSS	-0.27	0.27	tCK(avg)	c
DQS, $\overline{DQS}$ falling edge setup time to CK, $\overline{CK}$ rising edge	tDSS	0.18	-	tCK(avg)	c,32
DQS, $\overline{DQS}$ falling edge hold time from CK, $\overline{CK}$ rising edge	tDSH	0.18	-	tCK(avg)	c,32
Command and Address Timing					
DLL locking time	tDLLK	512	-	nCK	
Internal READ Command to PRECHARGE Command delay	tRTP	max(4tCK, 7.5ns)	-		e
Delay from start of internal write transaction to internal read command	tWTR	max(4tCK, 7.5ns)	-		e,18
WRITE recovery time	tWR	15	-	ns	e,18
Mode Register Set command cycle time	tMRD	4	-	nCK	
Mode Register Set command update delay	tMOD	max(12tCK, 15ns)	-		
ACT to internal read or write delay time	tRCD	Refer to “Standard Speed Bins”			e
PRE command period	tRP	Refer to “Standard Speed Bins”			e
ACT to ACT or REF command period	tRC	Refer to “Standard Speed Bins”			e
ACTIVE to PRECHARGE command period	tRAS	Refer to “Standard Speed Bins”			e
$\overline{CAS}$ to $\overline{CAS}$ command delay	tCCD	4	-	nCK	
Auto precharge write recovery + precharge time	tDAL(min)	WR + round up(tRP / tCK(avg))		nCK	
Multi-Purpose Register Recovery Time	tMPRR	1	-	nCK	22
ACTIVE to ACTIVE command period for 2KB page size	tRRD	Max(4tCK, 6ns)	-		e
Four activate window for 2KB page size	tFAW	35	-	ns	e
Command and Address setup time to CK, $\overline{CK}$ referenced to VIH(AC) / VIL(AC) levels	tIS(base) AC175 DDR3	-	-	ps	b,16
	tIS(base) AC150 DDR3	-	-	ps	b,16,27
	tIS(base) AC125 DDR3	150	-	ps	b,16,27
	tIS(base) AC160 SR = 1V/ns DDR3L	-	-	ps	b,16
	tIS(base) AC135 SR = 1V/ns DDR3L	65	-	ps	b,16
	tIS(base) AC125 SR = 1V/ns DDR3L	150	-	ps	b,16

Parameter	Symbol	DDR3(L)-1866		Unit	Note
		Min.	Max.		
Command and Address hold time from CK, $\overline{CK}$ referenced to VIH(DC) / VIL(DC) levels	tIH(base) DC100 DDR3	100	-	ps	b,16
	tIH(base) DC90 SR = 1V/ns DDR3L	110	-	ps	b,16
Control and Address Input pulse width for each input	tIPW	535	-	ps	28
Calibration Timing					
Power-up and $\overline{RESET}$ calibration time	tZQinit	max(512 tCK, 640ns)	-	-	
Normal operation Full calibration time	tZQoper	max(256 tCK, 320ns)	-	-	
Normal operation Short calibration time	tZQCS	max(64 tCK, 80ns)	-	-	23
Reset Timing					
Exit Reset from CKE HIGH to a valid command	tXPR	max(5 tCK, tRFC(min) + 10ns)	-	-	
Self Refresh Timing					
Exit Self Refresh to commands not requiring a locked DLL	tXS	max(5 tCK, tRFC(min) + 10ns)	-	-	
Exit Self Refresh to commands requiring a locked DLL	tXSDLL	tDLLK(min)	-	nCK	
Minimum CKE low width for Self Refresh entry to exit timing	tCKESR	tCKE(min) + 1 tCK	-	-	
Valid Clock Requirement after Self Refresh Entry (SRE) or Power-Down Entry (PDE)	tCKSRE	max(5 tCK, 10 ns)	-	-	
Valid Clock Requirement before Self Refresh Exit (SRX) or Power-Down Exit (PDX) or Reset Exit	tCKSRX	max(5 tCK, 10 ns)	-	-	
Power Down Timing					
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(3tCK, 6ns)	-		
CKE minimum pulse width	tCKE	max(3tCK, 5ns)	-		
Exit Precharge Power Down with DLL frozen to commands requiring a locked DLL	tXPDLL	max(10 tCK, 24ns)	-		2
Command pass disable delay	tCPDED	2	-	nCK	
Power Down Entry to Exit Timing	tPD	tCKE(min)	9*tREFI		15
Timing of ACT command to Power Down entry	tACTPDEN	1	-	nCK	20

Parameter	Symbol	DDR3(L)-1866		Unit	Note
		Min.	Max.		
Timing of PRE or PREA command to Power Down entry	tPRPDEN	1	-	nCK	20
Timing of RD/RDA command to Power Down entry	tRDPDEN	RL+4+1	-	nCK	
Timing of WR command to Power Down entry (BL8OTF, BL8MRS, BC4OTF)	tWRPDEN	WL + 4 + (tWR / tCK(avg))	-	nCK	9
Timing of WRA command to Power Down entry (BL8OTF, BL8MRS, BC4OTF)	tWRAPDEN	WL+4+WR+1	-	nCK	10
Timing of WR command to Power Down entry (BC4MRS)	tWRPDEN	WL + 2 + (tWR / tCK(avg))	-	nCK	9
Timing of WRA command to Power Down entry (BC4MRS)	tWRAPDEN	WL + 2 +WR + 1	-	nCK	10
Timing of REF command to Power Down entry	tREFPDEN	1	-	nCK	20,21
Timing of MRS command to Power Down entry	tMRSPDEN	tMOD(min)	-		
ODT Timing					
ODT turn on Latency	ODTLon	WL-2=CWL+AL-2		nCK	
ODT turn off Latency	ODTLoff	WL-2=CWL+AL-2		nCK	
ODT high time without write command or with write command and BC4	ODTH4	4	-	nCK	
ODT high time with Write command and BL8	ODTH8	6	-	nCK	
Asynchronous RTT turn-on delay (Power-Down with DLL frozen)	tAONPD	2	8.5	ns	
Asynchronous RTT turn-off delay (Power-Down with DLL frozen)	tAOFPD	2	8.5	ns	
RTT turn-on	tAON	-195	195	ps	7,f
RTT_Nom and RTT_WR turn-off time from ODTLoff reference	tAOF	0.3	0.7	tCK(avg)	8,f
RTT dynamic change skew	tADC	0.3	0.7	tCK(avg)	f
Write Leveling Timing					
First DQS/$\overline{DQS}$ rising edge after write leveling mode is programmed	tWLMRD	40	-	nCK	3
DQS/$\overline{DQS}$ delay after write leveling mode is programmed	tWLDQSEN	25	-	nCK	3
Write leveling setup time from rising CK, $\overline{CK}$ crossing to rising DQS, $\overline{DQS}$ crossing	tWLS	140	-	ps	
Write leveling hold time from rising DQS, $\overline{DQS}$ crossing to rising CK, $\overline{CK}$ crossing	tWLH	140	-	ps	
Write leveling output delay	tWLO	0	7.5	ns	
Write leveling output error	tWLOE	0	2	ns	

Jitter Notes

a. Unit "tCK(avg)" represents the actual tCK(avg) of the input clock under operation. Unit "nCK" represents one clock cycle of the input clock, counting the actual clock edges. Ex) tMRD=4 [nCK] means; if one Mode Register Set command is registered at Tm, anther Mode Register Set command may be registered at Tm+4, even if (Tm+4-Tm) is 4 x tCK(avg) + tERR(4per), min.

b. These parameters are measured from a command/address signal (CKE, $\overline{CS}$,$\overline{RAS}$,$\overline{CAS}$, $\overline{WE}$, ODT, BA0, A0, A1, etc) transition edge to its respective clock signal (CK/ $\overline{CK}$) crossing. The spec values are not affected by the amount of clock jitter applied (i.e. tJIT(per), tJIT(cc), etc.), as the setup and hold are relative to the clock signal crossing that latches the command/address. That is, these parameters should be met whether clock jitter is present or not.

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

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

e. For these parameters, the DDR3(L) SDRAM device supports tnPARAM [nCK] = RU{tPARAM[ns] / tCK(avg)[ns]}, which is in clock cycles, assuming all input clock jitter specifications are satisfied.

f. When the device is operated with input clock jitter, this parameter needs to be derated by the actual tERR(mper), act of the input clock, where 2 <= m <=12. (Output derating is relative to the SDRAM input clock.)

g. When the device is operated with input clock jitter, this parameter needs to be derated by the actual tJIT(per),act of the input clock. (Output deratings are relative to the SDRAM input clock.)

Timing Parameter Notes

1. Actual value dependent upon measurement level definitions see Figure - "Method for calculating tWPRE transitions and endpoints" and "Method for calculating tWPST transitions and endpoints".
2. Commands requiring a locked DLL are: READ (and RAP) are synchronous ODT commands.
3. The max values are system dependent.
4. WR as programmed in mode register.
5. Value must be rouned-up to next higher integer value.
6. There is no maximum cycle time limit besides the need to satisfy the refresh interval, tREFI.
7. For definition of RTT-on time tAON, see "Timing Parameters".
8. For definition of RTT-off time tAOF, see "Timing Parameters".
9. tWR is defined in ns, for calculation of tWRPDEN it is necessary to round up tWR/tCK to the next integer.
10. WR in clock cycles are programmed in MR0.
11. The maximum read postamble is bounded by tDQSCK(min) plus tQSH(min) on the left side and tHZ(DQS)max on the right side. See Figure - "Clock to Data Strobe Relationship".
12. Output timing deratings are relative to the SDRAM input clock. When the device is operated with input clock jitter, this parameter needs to be derated by TBD.
13. Value is only valid for RON34.
14. Single ended signal parameter.
15. tREFI depends on T_{OPER}.
16. tIS(base) and tIH(base) values are for 1V/ns CMD/ADD single-ended slew rate and 2V/ns CK, $\overline{CK}$ differential slew rate.

    Note for DQ and DM signals, VREF(DC)=VREFDQ(DC). For input only pins except $\overline{RESET}$, VREF(DC)=VREFCA(DC). See "Address / Command Setup, Hold and Derating"
17. tDS(base) and tDH(base) values are for 1V/ns DQ single-ended slew rate and 2V/ns DQS, $\overline{DQS}$ differential slew rate.

    Note for DQ and DM signals, VREF(DC)=VREFDQ(DC). For input only pins except $\overline{RESET}$, VREF(DC)=VREFCA(DC). See "Data Setup, Hold and Slew Rate Derating".
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 read preamble is bound by tLZ (DQS)min on the left side and tDQSCK(max) on the right side. See Figure - "Clock to Data Strobe Relationship".
20. CKE is allowed to be registered low while operations such as row activation, precharge, autoprecharge or refresh are in progress, but power-down IDD spec will not be applied until finishing those operations.
21. Although CKE is allowed to be registered LOW after a REFRESH command once tREFPDEN(min) is satisfied, there are cases where additional time such as tXPDLL(min) is also required. See "Power-Down clarifications - Case 2".
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% (ZQ Correction) of RON and RTT impedance error within 64 nCK for all speed bins assuming the maximum sensitivities specified in the “Output Driver Voltage and Temperature Sensitivity” and “ODT Voltage and Temperature Sensitivity” tables. The appropriate interval between ZQCS commands can be determined from these tables and other application-specific parameters.

    One method for calculating the interval between ZQCS commands, given the temperature (Tdriftrate) and voltage (Vdriftrate) drift rates that the SDRAM is subject to in the application, is illustrated. The interval could be defined by the following formula:

$$\frac{\text{ZQ Correction}}{(\text{TSens} \times \text{Tdriftrate}) + (\text{VSens} \times \text{Vdriftrate})}$$

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

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

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

24. n = from 13 cycles to 50 cycles. This row defines 38 parameters.
25. tCH(abs) is the absolute instantaneous clock high pulse width, as measured from one rising edge to the following falling edge.
26. tCL(abs) is the absolute instantaneous clock low pulse width, as measured from one falling edge to the following rising edge.
27. The tIS(base) AC150 specifications are adjusted from the tIS(base) specification by adding an additional 100ps of derating to accommodate for the lower altemate threshold of 150mV and another 25ps to account for the earlier reference point [(175mV – 150mV) / 1V/ns].
28. Pulse width of a input signal is defined as the width between the first crossing of VREF(DC) and the consecutive crossing of VREF(DC).
29. tDQSL describes the instantaneous differential input low pulse width on DQS - $\overline{\text{DQS}}$, as measured from one falling edge to the next consecutive rising edge.
30. tDQSH describes the instantaneous differential input high pulse width on DQS - $\overline{\text{DQS}}$, as measured from one rising edge to the next consecutive falling edge.
31. tDQSH,act + tDQSL,act = 1 tCK,act ; with tXYZ,act being the actual measured value of the respective timing parameter in the application.
32. tDSH,act + tDSS,act = 1 tCK,act ; with tXYZ,act being the actual measured value of the respective timing parameter in the application.

Address / Command Setup, Hold and Derating

For all input signals the total tIS (setup time) and tIH (hold time) required is calculated by adding the data sheet tIS(base) and tIH(base) and tIH(base) value to the delta tIS and delta tIH derating value respectively.

Example: tIS (total setup time) = tIS(base) + delta tIS

Setup (tIS) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of VREF(DC) and the first crossing of VIH(AC)min. Setup (tIS) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of VREF(DC) and the first crossing of VIL(AC)max. If the actual signal is always earlier than the nominal slew rate line between shaded 'VREF (DC) to ac region', use nominal slew rate for derating value. If the actual signal is later than the nominal slew rate line anywhere between shaded 'VREF(DC) to ac region', the slew rate of the tangent line to the actual signal from the ac level to dc level is used for derating value.

Hold (tIH) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of VIL(DC)max and the first crossing of VREF(DC). Hold (tIH) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of VIH(DC)min and the first crossing of VREF(DC). If the actual signal is always later than the nominal slew rate line between shaded 'dc to VREF(DC) region', use nominal slew rate for derating value. If the actual signal is earlier than the nominal slew rate line anywhere between shaded 'dc to VREF(DC) region', the slew rate of a tangent line to the actual signal from the dc level to VREF(DC) level is used for derating value. For a valid transition the input signal has to remain above/below VIH/IL(AC) for some time tVAC. Although for slow slew rates the total setup time might be negative (i.e. a valid input signal will not have reached VIH/IL(AC) at the time of the rising clock transition) a valid input signal is still required to complete the transition and reach VIH/IL(AC).

For slew rates in between the values listed in following 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.

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

Grade	Symbol	Reference	1866	Unit	Note
DDR3	tIS(base) AC175	VIH/L(AC)	-	ps	1
	tIS(base) AC150	VIH/L(AC)	-	ps	1,2
	tIS(base) AC135	VIH/L(AC)	60	ps	1
	tIS(base) AC125	VIH/L(AC)	150	ps	1,3
	tIH(base) DC100	VIH/L(DC)	100	ps	1
DDR3L	tIS(base) AC160	VIH/L(AC): SR =1V/ns	-	ps	1
	tIS(base) AC135	VIH/L(AC): SR =1V/ns	65	ps	1,4
	tIS(base) AC125	VIH/L(AC): SR =1V/ns	150	ps	1,5
	tIH(base) DC90	VIH/L(DC): SR =1V/ns	110	ps	1

Derating values DDR3-1866 tIS/tIH – AC/DC based AC135 Threshold

		ΔtIS, ΔtIH derating in [ps] AC/DC based															
		AC 135 Threshold -> VIH (AC) = VREF (DC) + 135mV, VIL (AC) = VREF(DC) - 135mV															
		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	
		ΔtIS	ΔtIH	ΔtIS	ΔtIH	ΔtIS	ΔtIH	ΔtIS	ΔtIH	ΔtIS	ΔtIH	ΔtIS	ΔtIH	ΔtIS	ΔtIH	ΔtIS	ΔtIH
CMD/ADD Slew Rate (V/ns)	2	68	50	68	50	68	50	76	58	84	66	92	74	100	84	108	100
	1.5	45	34	45	34	45	34	53	42	61	50	69	58	77	68	85	84
	1	0	0	0	0	0	0	8	8	16	16	24	24	32	34	40	50
	0.9	2	-4	2	-4	2	-4	10	4	18	12	26	20	34	30	42	46
	0.8	3	-10	3	-10	3	-10	11	-2	19	6	27	14	35	24	43	40
	0.7	6	-16	6	-16	6	-16	14	-8	22	0	30	8	38	18	46	34
	0.6	9	-26	9	-26	9	-26	17	-18	25	-10	33	-2	41	8	49	24
	0.5	5	-40	5	-40	5	-40	13	-32	21	-24	29	-16	37	-6	45	10
	0.4	-3	-60	-3	-60	-3	-60	6	-52	14	-44	22	-36	30	-26	38	-10

Derating values DDR3-1866 tIS/tIH – AC/DC based AC125 Threshold

		ΔtIS, ΔtIH derating in [ps] AC/DC based															
		AC 125 Threshold -> VIH (AC) = VREF (DC) + 125mV, VIL (AC) = VREF(DC) - 125mV															
		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	
		ΔtIS	ΔtIH	ΔtIS	ΔtIH	ΔtIS	ΔtIH	ΔtIS	ΔtIH	ΔtIS	ΔtIH	ΔtIS	ΔtIH	ΔtIS	ΔtIH	ΔtIS	ΔtIH
CMD/ADD Slew Rate (V/ns)	2	63	50	63	50	63	50	71	58	79	66	87	74	95	84	103	100
	1.5	42	34	42	34	42	34	50	42	58	50	66	58	74	68	82	84
	1	0	0	0	0	0	0	8	8	16	16	24	24	32	34	40	50
	0.9	4	-4	4	-4	4	-4	12	4	20	12	28	20	36	30	44	46
	0.8	6	-10	6	-10	6	-10	14	-2	22	6	30	14	38	24	46	40
	0.7	11	-16	11	-16	11	-16	19	-8	27	0	35	8	43	18	51	34
	0.6	16	-26	16	-26	16	-26	24	-18	32	-10	40	-2	48	8	56	24
	0.5	15	-40	15	-40	15	-40	23	-32	31	-24	39	-16	47	-6	55	10
	0.4	13	-60	13	-60	13	-60	21	-52	29	-44	37	-36	45	-26	53	-10

Derating values DDR3L-1866 tIS/tIH – AC/DC based AC125 Threshold

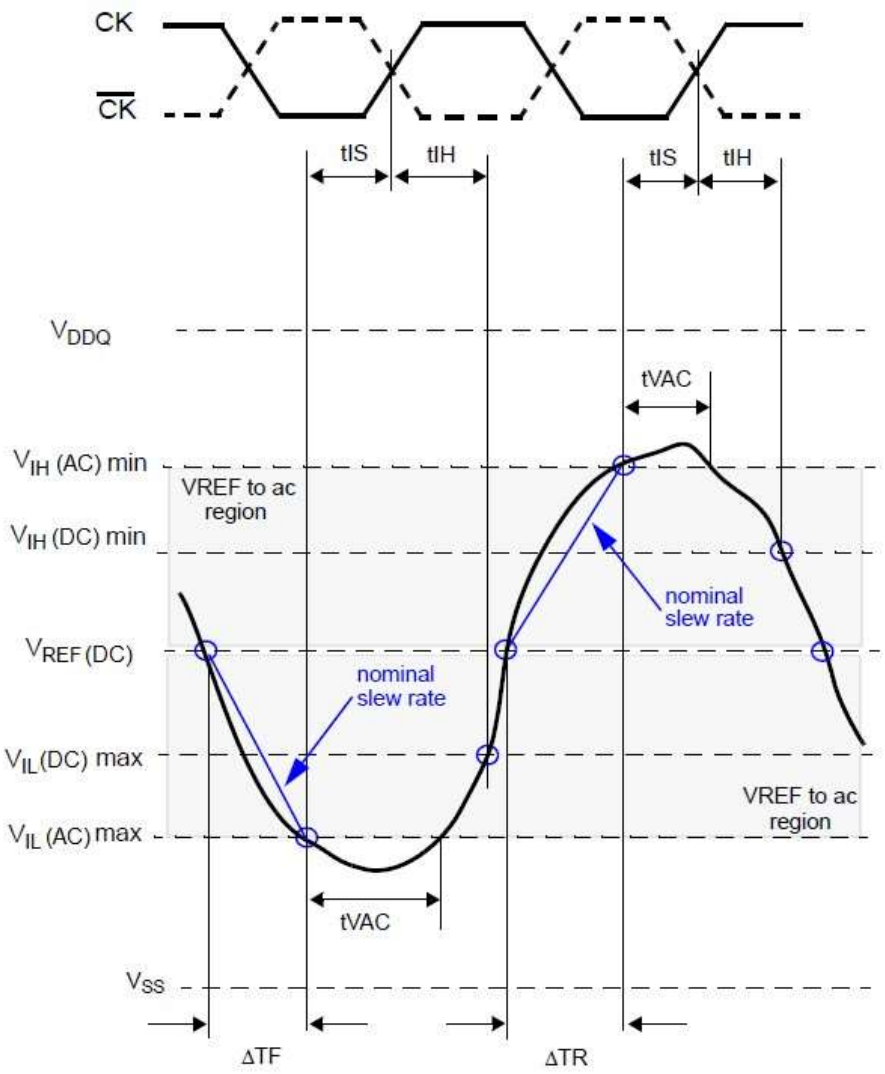
		△tIS, △tIH derating in [ps] AC/DC based															
		AC 125 Threshold -> VIH (AC) = VREF (DC) + 125mV, VIL (AC) = VREF(DC) - 125mV															
		CK,/CK Differential Slew Rate															
		4.0 V/ns		3.0 V/ns		2.0 V/ns		1.8 V/ns		1.6 V/ns		1.4 V/ns		1.2 V/ns		1.0 V/ns	
		△tIS	△tIH	△tIS	△tIH	△tIS	△tIH	△tIS	△tIH	△tIS	△tIH	△tIS	△tIH	△tIS	△tIH	△tIS	△tIH
CMD/ADD Slew Rate (V/ns)	2	63	45	63	45	63	45	71	53	79	61	87	69	95	79	103	95
	1.5	42	30	42	30	42	30	50	38	58	46	66	54	74	64	82	80
	1	0	0	0	0	0	0	8	8	16	16	24	24	32	34	40	50
	0.9	3	-3	3	-3	3	-3	11	5	19	13	27	21	35	31	43	47
	0.8	6	-8	6	-8	6	-8	14	1	22	9	30	17	38	27	46	43
	0.7	10	-13	10	-13	10	-13	18	-5	26	3	34	11	42	21	50	37
	0.6	16	-20	16	-20	16	-20	24	-12	32	4	40	-4	48	14	56	30
	0.5	15	-30	15	0	15	-30	23	-22	31	-14	39	-6	47	4	55	20
	0.4	13	-45	13	-45	13	-45	21	-37	29	-29	37	-21	45	-11	53	5

Required time tVAC above VIH(AC) {below VIL(AC)} for ADD/CMD transition

Slew Rate [V/ns]	DDR3		DDR3L	
	1866		1866	
	tVAC @ 135mV [ps]	tVAC @ 125mV [ps]	tVAC @ 135mV [ps]	tVAC @ 125mV [ps]
	min	min	min	min
>2.0	168	173	200	205
2	168	173	200	205
1.5	145	152	178	184
1	100	110	133	143
0.9	85	96	118	129
0.8	66	79	99	111
0.7	42	56	75	89
0.6	10	27	43	59
0.5	Note	Note	Note	18
<0.5	Note	Note	Note	18

Note: Rising input signal shall become equal to or greater than VIH(AC) level and falling input signal shall become equal to or less than VIL(AC) level.

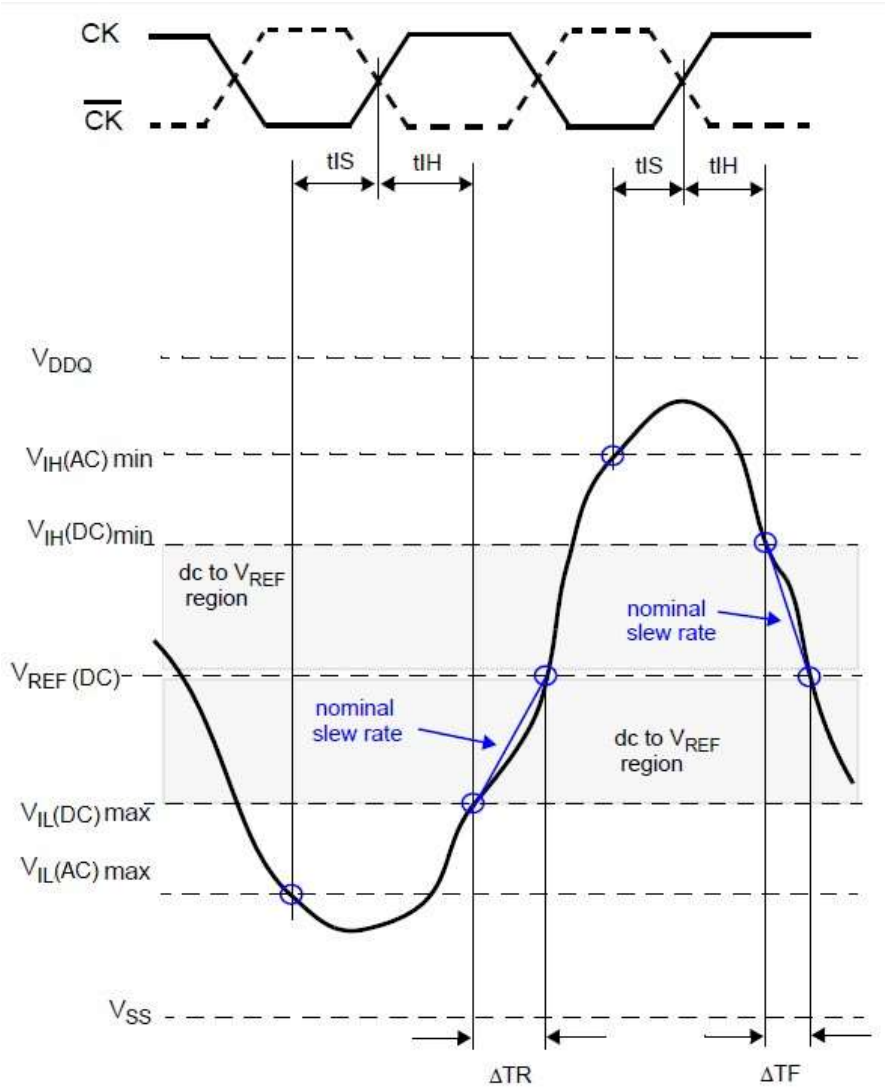
Illustration of nominal slew rate and tVAC for setup time tIS (for ADD/CMD with respect to clock)



$$\text{Setup Slew Rate}_{\text{Falling Signal}} = \frac{\text{VREF(DC) - VIL(AC)max}}{\Delta \text{ TF}}$$

$$\text{Setup Slew Rate}_{\text{Rising Signal}} = \frac{\text{VIH(AC)min - VREF(DC)}}{\Delta \text{ TR}}$$

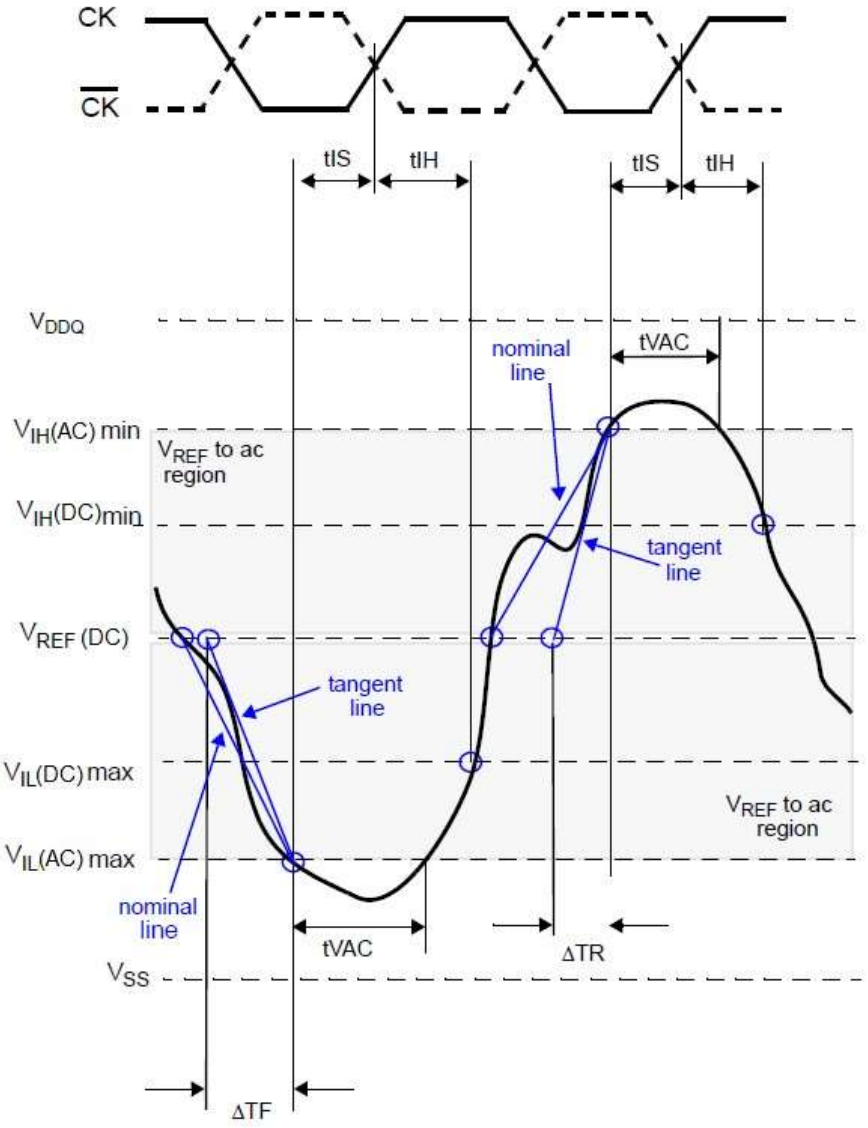
Illustration of nominal slew rate for hold time tIH (for ADD/CMD with respect to clock)



$$\text{Hold Slew Rate Rising Signal} = \frac{\text{VREF(DC) - VIL(DC)max}}{\Delta \text{ TR}}$$

$$\text{Hold Slew Rate Falling Signal} = \frac{\text{VIH(DC)min - VREF(DC)}}{\Delta \text{ TF}}$$

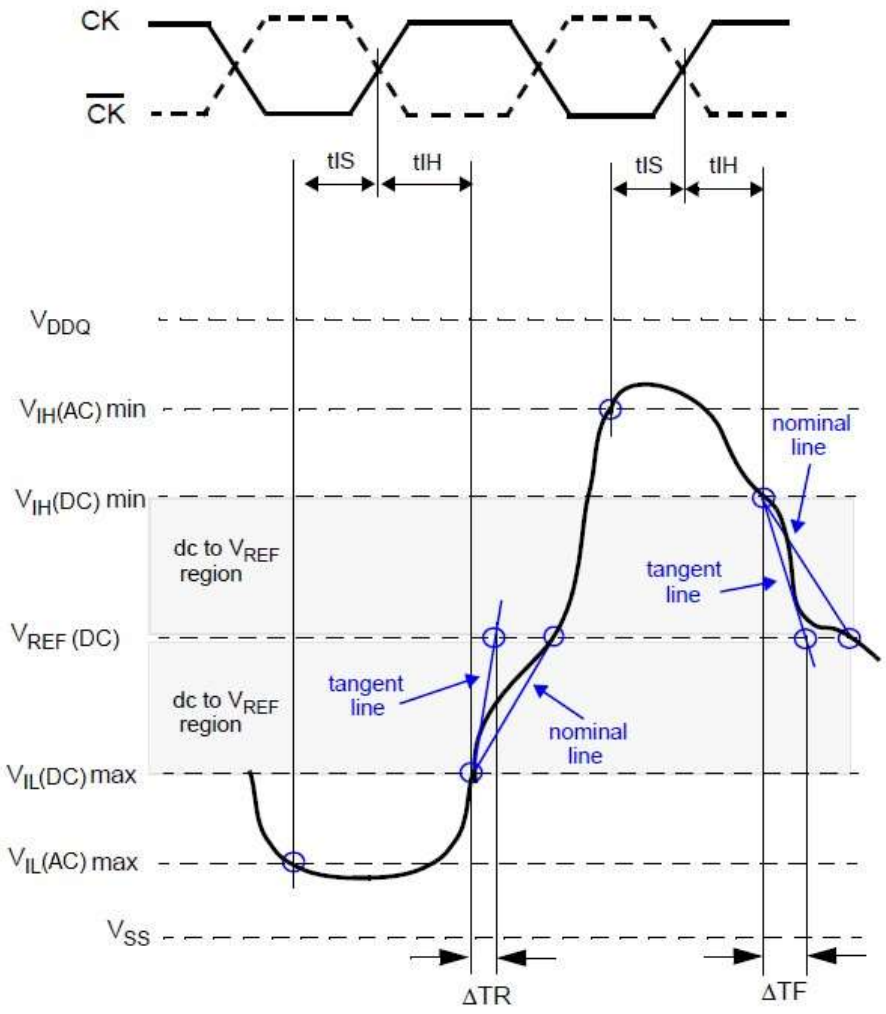
Illustration of tangent line for setup time tIS (for ADD/CMD with respect to clock)



$$\text{Setup Slew Rate Falling Signal} = \frac{\text{tangent line[VREF(DC) - VIL(AC)max]}}{\Delta \text{ TF}}$$

$$\text{Setup Slew Rate Rising Signal} = \frac{\text{tangent line[VIH(AC)min - VREF(DC)]}}{\Delta \text{ TR}}$$

Illustration of tangent line for for hold time tIH (for ADD/CMD with respect to clock)



$$\text{Hold Slew Rate Rising Signal} = \frac{\text{tangent line [VREF(DC) - VIL(DC)max]}}{\Delta \text{ TR}}$$

$$\text{Hold Slew Rate Falling Signal} = \frac{\text{tangent line [VIH(DC)min - VREF(DC)]}}{\Delta \text{ TF}}$$

Data Setup, Hold and Slew Rate Derating

For all input signals the total tDS (setup time) and tDH (hold time) required is calculated by adding the data sheet tDH(base) and tDH(base) value to the delta tDS and delta tDH derating value respectively.

Example: tDS (total setup time) = tDS(base) + delta tDS

Setup (tDS) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of VREF(DC) and the first crossing of VIH(AC)min. Setup (tDS) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of VREF(DC) and the first crossing of VIL(AC)max. If the actual signal is always earlier than the nominal slew rate line between shaded 'VREF(DC) to ac region', use nominal slew rate for derating value. If the actual signal is later than the nominal slew rate line anywhere between shaded 'VREF(DC) to ac region', the slew rate of the tangent line to the actual signal from the ac level to dc level is used for derating value.

Hold (tDH) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of VIL(DC)max and the first crossing of VREF(DC). Hold (tDH) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of VIH(DC)min and the first crossing of VREF(DC). If the actual signal is always later than the nominal slew rate line between shaded 'dc level to VREF(DC) region', use nominal slew rate for derating value. If the actual signal is earlier than the nominal slew rate line anywhere between shaded 'dc to VREF(DC) region', the slew rate of a tangent line to the actual signal from the dc level to VREF(DC) level is used for derating value.

For a valid transition the input signal has to remain above/below VIH/IL(AC) for some time tVAC.
Although for slow slew rates the total setup time might be negative (i.e. a valid input signal will not have reached VIH/IL(AC) at the time of the rising clock transition) a valid input signal is still required to complete the transition and reach VIH/IL(AC).

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

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

Data Setup and Hold Base-Values

Grade	Symbol	Reference	1866	Unit	Note
DDR3	tDS(base) AC150	VIH/L(AC) : SR =1V/ns	-	ps	2
	tDS(base) AC135	VIH/L(AC) : SR =1V/ns	-	ps	2
	tDS(base) AC135	VIH/L(AC) : SR =2V/ns	68	ps	1
	tDH(base) DC100	VIH/L(DC) : SR =1V/ns	-	ps	2
	tDH(base) DC100	VIH/L(DC) : SR =2V/ns	70	ps	1
DDR3L	tDS(base) AC135	VIH/L(AC) : SR =1V/ns	-	ps	2
	tDS(base) AC130	VIH/L(AC) : SR =2V/ns	70	ps	1
	tDH(base) DC90	VIH/L(DC) : SR =2V/ns	75	ps	1
	tDH(base) DC90	VIH/L(DC) : SR =1V/ns	-	ps	2

Note:
1. AC/DC referenced for 2V/ns DQ-slew rate and 4V/ns DQS slew rate.
2. AC/DC referenced for 1V/ns DQ-slew rate and 2V/ns DQS slew rate.

Derating values DDR3-1866 tDS/tDH – AC/DC based AC135 Threshold

		△tDS, △tDH derating in [ps] AC/DC based																							
		AC 135 Threshold -> VIH (AC) = VREF (DC) + 135mV, VIL (AC) = VREF(DC) - 135mV																							
		DC 100 Threshold -> VIH (DC) = VREF (DC) + 100mV, VIL (DC) = VREF(DC) - 100mV																							
		8.0 V/ns		7.0 V/ns		6.0 V/ns		5.0 V/ns		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	
		△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH
DQ Slew Rate (V/ns)	4	34	25	34	25	34	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3.5	29	21	29	21	29	21	29	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	23	17	23	17	23	17	23	17	23	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2.5	-	-	14	10	14	10	14	10	14	10	14	10	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-
	1.5	-	-	-	-	-	-	-23	-17	-23	-17	-23	-17	-23	-17	-15	-9	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-68	-50	-68	-50	-68	-50	-60	-42	-52	-34	-	-	-	-	-	-
	0.9	-	-	-	-	-	-	-	-	-	-	-66	-54	-66	-54	-58	-46	-50	-38	-42	-30	-	-	-	-
	0.8	-	-	-	-	-	-	-	-	-	-	-	-	-64	-60	-56	-52	-48	-44	-40	-36	-32	-26	-	-
	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-53	-59	-45	-51	-37	-43	-29	-33	-21	-17
	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-43	-61	-35	-53	-27	-43	-19	-27
	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-39	-66	-31	-56	-23	-40
	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-38	-76	-30	-60

Note: Cell contents shaded in gray are defined as 'not supported'.

Derating values DDR3L-1866 tDS/tDH – AC/DC based AC130 Threshold

		△tDS, △tDH derating in [ps] AC/DC based																							
		AC 130 Threshold -> VIH (AC) = VREF (DC) + 130mV, VIL (AC) = VREF(DC) - 130mV																							
		DQS, /DQS Differential Slew Rate																							
		8.0 V/ns		7.0 V/ns		6.0 V/ns		5.0 V/ns		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	
		△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH	△tDS	△tDH
DQ Slew Rate (V/ns)	4	33	23	33	23	33	23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3.5	28	19	28	19	28	19	28	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	22	15	22	15	22	15	22	15	22	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2.5	-	-	13	9	13	9	13	9	13	9	13	9	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-
	1.5	-	-	-	-	-	-	-22	-15	-22	-15	-22	-15	-22	-15	-14	-7	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-65	-45	-65	-45	-65	-45	-57	-37	-49	-29	-	-	-	-	-	-
	0.9	-	-	-	-	-	-	-	-	-	-	-62	-48	-62	-48	-54	-40	-46	-32	-38	-24	-	-	-	-
	0.8	-	-	-	-	-	-	-	-	-	-	-	-	-61	-53	-53	-45	-45	-37	-37	-29	-29	-19	-	-
	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-49	-50	-41	-42	-33	-34	-25	-24	-17	-8
	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-37	-49	-29	-41	-21	-31	-13	-15
	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-31	-51	-23	-41	-15	-25
	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-28	-56	-20	-40

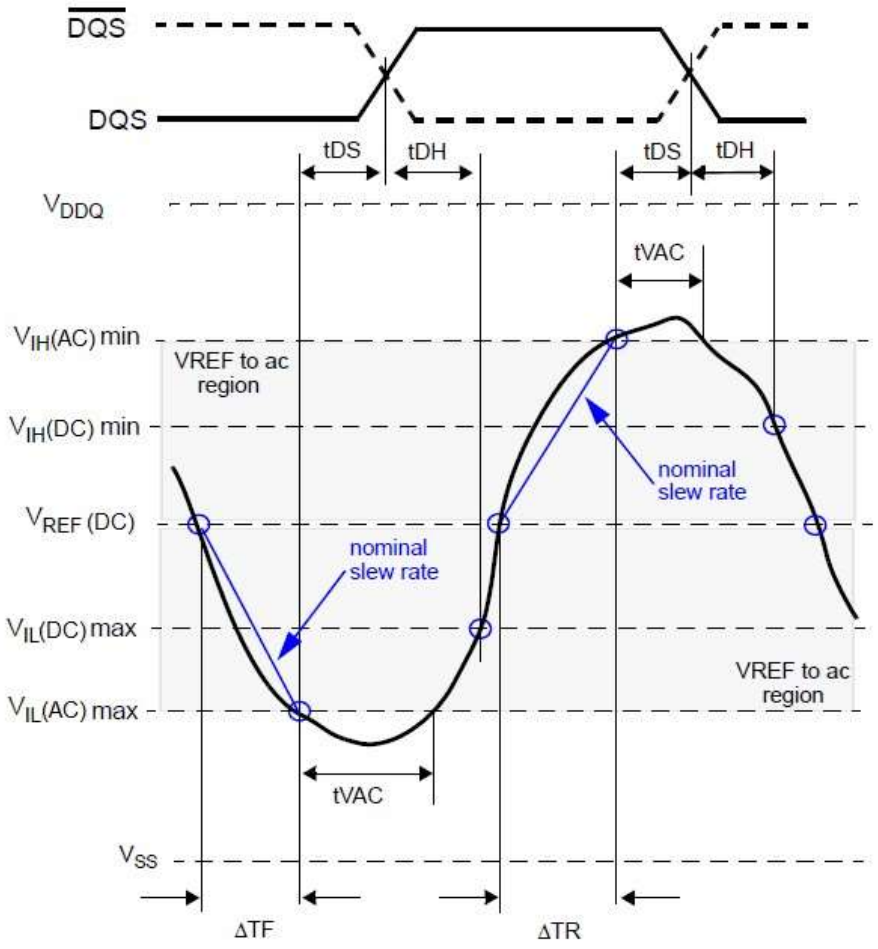
Note: Cell contents shaded in gray are defined as 'not supported'.

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

Slew Rate [V/ns]	DDR3	DDR3L
	1866	1866
	tVAC @ 135mV [ps]	tVAC @ 130mV [ps]
	min	min
>2.0	93	95
2	93	95
1.5	70	73
1	25	30
0.9	Note	16
0.8	Note	Note
0.7	-	-
0.6	-	-
0.5	-	-
<0.5	-	-

Note: Rising input signal shall become equal to or greater than VIH(AC) level and falling input signal shall become equal to or less than VIL(AC) level.

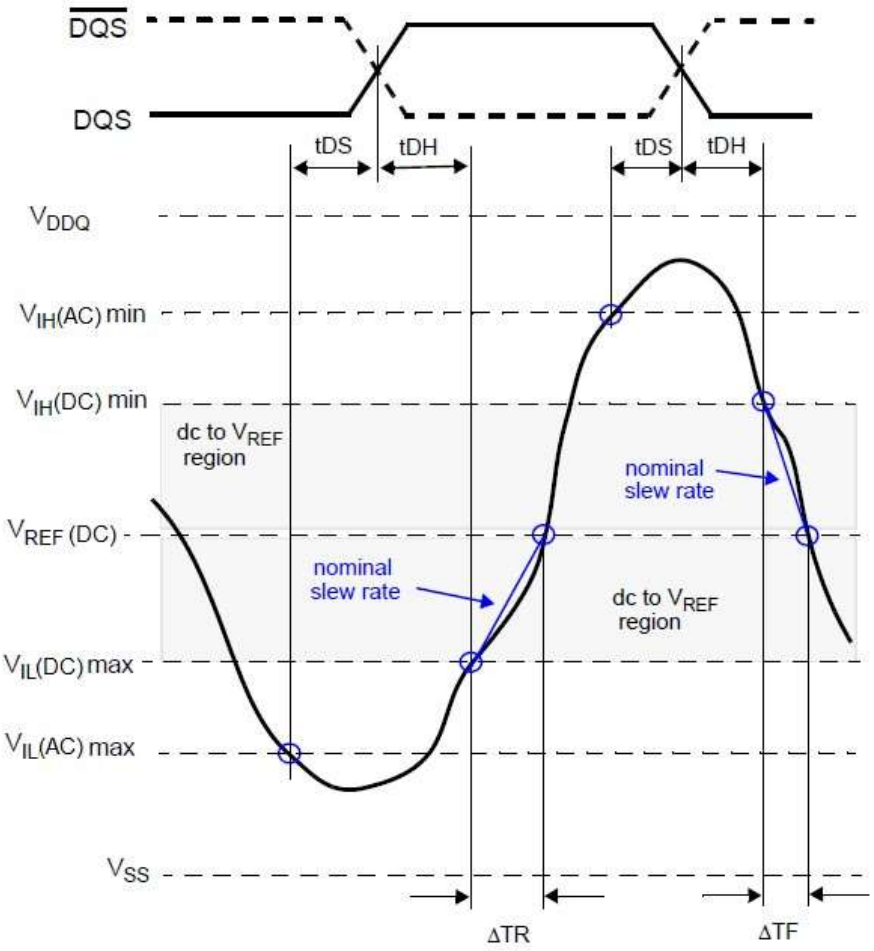
Illustration of nominal slew rate and tVAC for setup time tDS (for DQ with respect to strobe)



$$\text{Setup Slew Rate Falling Signal} = \frac{\text{VREF(DC) - VIL(AC)max}}{\Delta \text{ TF}}$$

$$\text{Setup Slew Rate Rising Signal} = \frac{\text{VIH(AC)min - VREF(DC)}}{\Delta \text{ TR}}$$

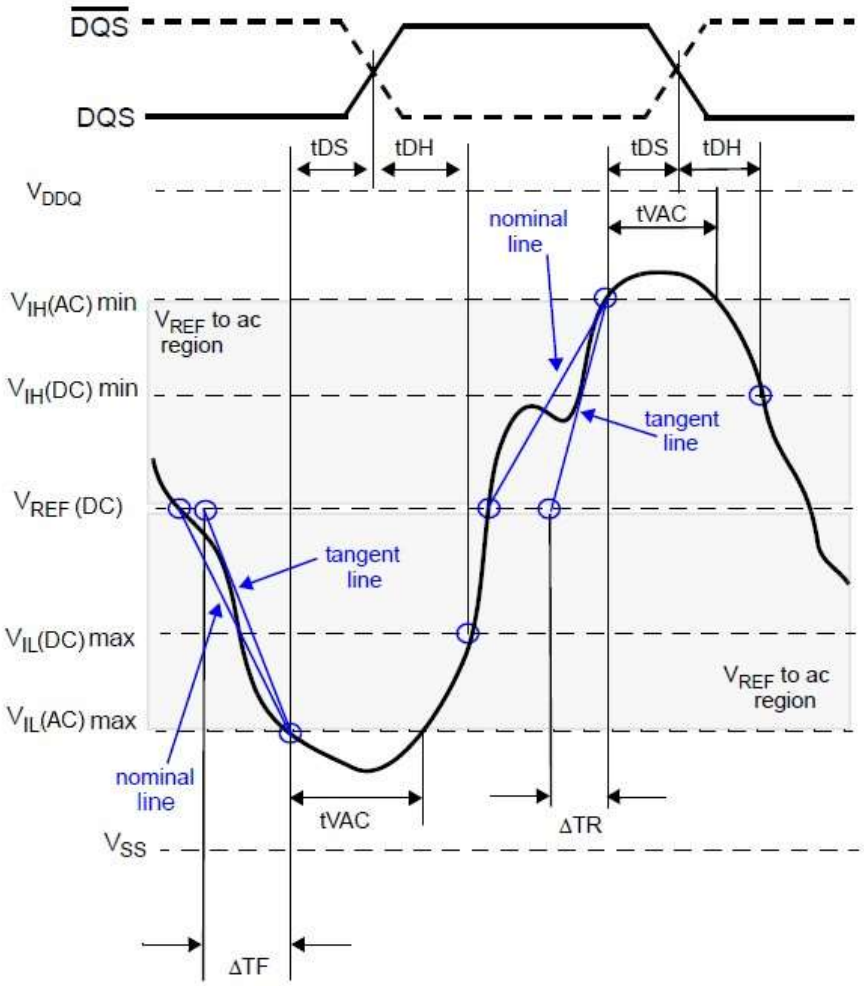
Illustration of nominal slew rate for hold time tDH (for DQ with respect to strobe)



$$\text{Hold Slew Rate}_{\text{Rising Signal}} = \frac{\text{VREF(DC) - VIL(DC)max}}{\Delta \text{ TR}}$$

$$\text{Hold Slew Rate}_{\text{Falling Signal}} = \frac{\text{VIH(DC)min - VREF(DC)}}{\Delta \text{ TF}}$$

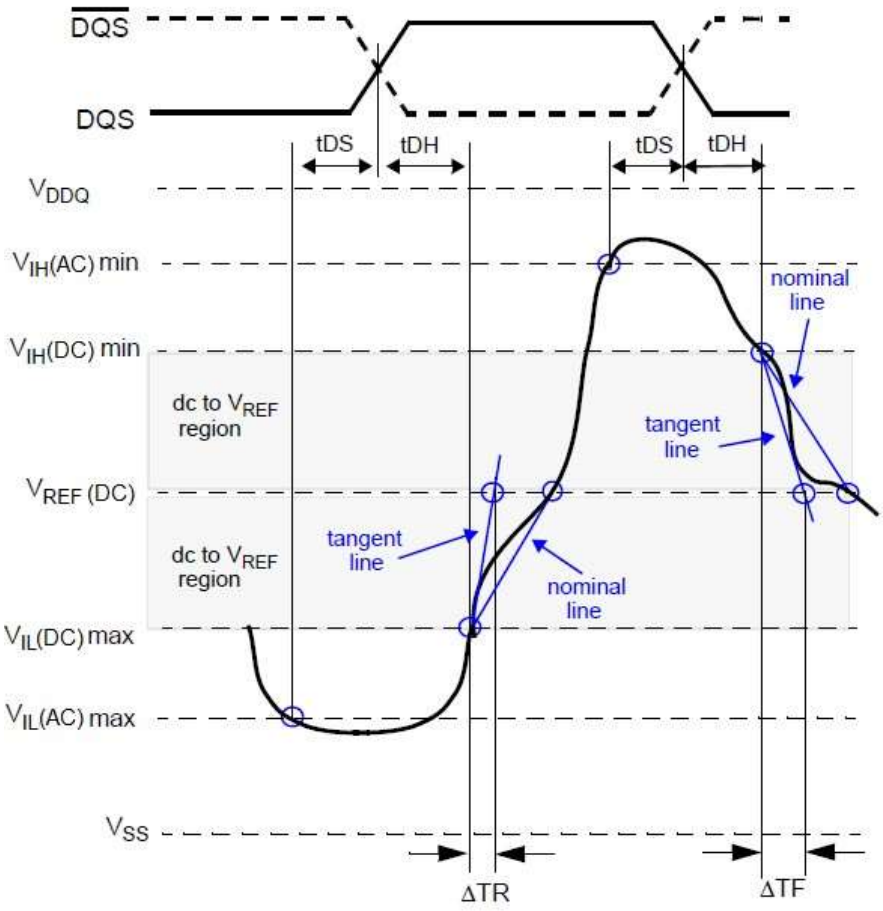
Illustration of tangent line for setup time tDS (for DQ with respect to strobe)



$$\text{Setup Slew Rate Falling Signal} = \frac{\text{tangent line[VREF(DC) - VIL(AC)max]}}{\Delta \text{ TF}}$$

$$\text{Setup Slew Rate Rising Signal} = \frac{\text{tangent line[VIH(AC)min - VREF(DC)]}}{\Delta \text{ TR}}$$

Illustration of tangent line for hold time tDH (for DQ with respect to strobe)

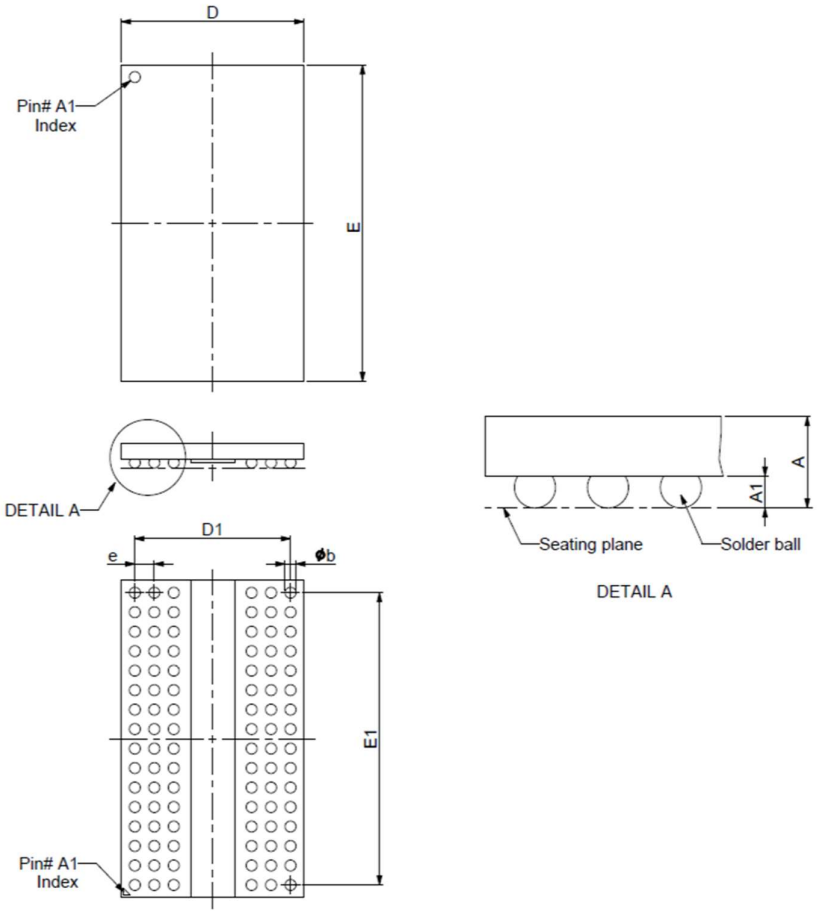


$$\text{Hold Slew Rate Rising Signal} = \frac{\text{tangent line [VREF(DC) - VIL(DC)max]}}{\Delta \text{ TR}}$$

$$\text{Hold Slew Rate Falling Signal} = \frac{\text{tangent line [VIH(DC)min - VREF(DC)]}}{\Delta \text{ TF}}$$

PACKING DIMENSIONS

96-BALL DDR SDRAM (7.5x13 mm)



Symbol	Dimension in mm			Dimension in inch		
	Min	Norm	Max	Min	Norm	Max
A	---	---	1.00	---	---	0.039
A_1	0.30	0.35	0.40	0.012	0.014	0.016
Φ_b	0.40	0.45	0.50	0.016	0.018	0.020
D	7.40	7.50	7.60	0.291	0.295	0.299
E	12.90	13.00	13.10	0.508	0.512	0.516
D_1	6.40 BSC			0.252 BSC		
E_1	12.00 BSC			0.472 BSC		
e	0.80 BSC			0.031 BSC		

Controlling dimension : Millimeter.

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