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**SCB13H8G162EF**

**8Gbit DDR3 SDRAM**

**EU RoHS Compliant Products**

**Data Sheet**

**Rev. A**

| Revision History |          |                                              |
|------------------|----------|----------------------------------------------|
| Date             | Revision | Subjects (major changes since last revision) |
| 2024-05          | A        | Initial Release                              |
|                  |          |                                              |
|                  |          |                                              |

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# 1 Features

- Power supply:  $V_{DD} = V_{DDQ} = 1.35V$  (1.283V - 1.45V)
- Backward compatible to  $V_{DD} = V_{DDQ} = 1.5V \pm 0.075V$ 
  - Supports DDR3L devices to be backward compatible in 1.5V application
- Package: 96-Ball FBGA(x16)
- Array configuration: 8 Banks
- 8n-Bit prefetch architecture
- Differential clock inputs (CK, CK#)
- Nominal and dynamic on-die termination (ODT) for data, strobe, and mask signals
- Programmable CAS (READ) latency (CL)
- Programmable posted CAS additive latency (AL)
- Programmable CAS (WRITE) latency (CWL)
- Fixed burst length (BL) of 8 and burst chop (BC) of 4 (via the mode register set [MRS])
- Selectable BC4 or BL8 on-the-fly (OTF)
- Self refresh mode
- Operating case temperature:  $-40^{\circ}C \leq T_{CASE} \leq 95^{\circ}C$
- Average refresh period:
  - $-7.8\mu s$  at  $0^{\circ}C \leq T_{CASE} \leq 85^{\circ}C$
  - $-3.9\mu s$  at  $85^{\circ}C < T_{CASE} \leq 95^{\circ}C$
- JEDEC JESD79-3F compliant
- RoHS compliant

## Note:

1. The functionality described and the timing specifications included in this data sheet are for the DLL enabled mode of operation.

## 1.1 Address Table

| Parameter                | 512Mb x 16 |
|--------------------------|------------|
| Number of Banks          | 8          |
| Bank Address             | BA0 - BA2  |
| Auto Precharge           | A10/AP     |
| BC Switch on the fly     | A12/BC#    |
| Row Address              | A0 - A15   |
| Column Address           | A0 - A9    |
| Page Size <sup>(1)</sup> | 2KB        |

Note:

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

$$\text{Page size} = 2^{\text{COLBITS}} \times \text{ORG} / 8$$

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

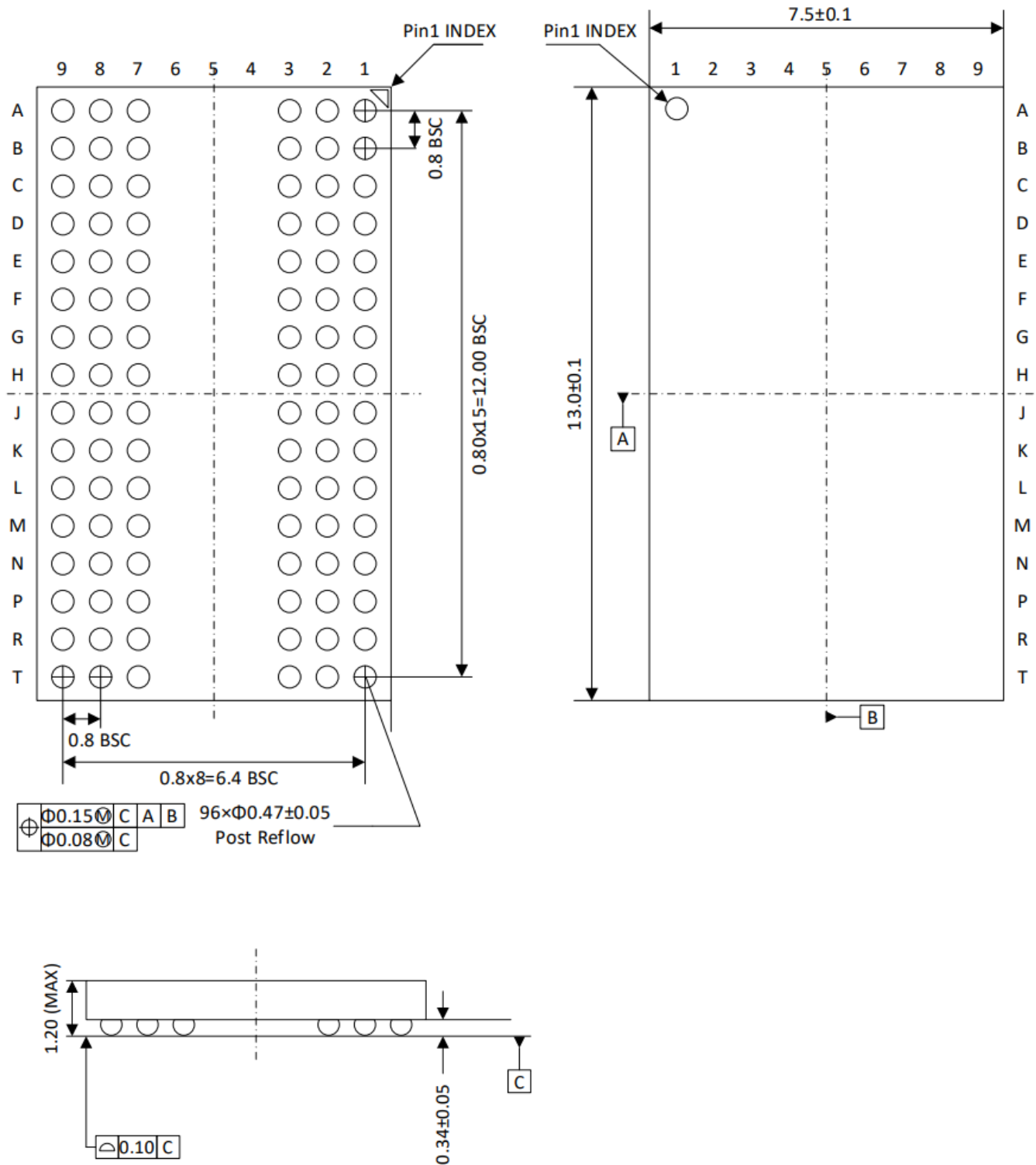
## 2 Ordering information

### 2.1 Valid Part Numbers

| UnilC Part Number                                            | Max. Clock frequency | CAS-RCD-RP latencies | Speed Sort Name | Package    |
|--------------------------------------------------------------|----------------------|----------------------|-----------------|------------|
| 8Gbit DDR3 SDRAM Components in × 16 Organization (512M × 16) |                      |                      |                 |            |
| Industrial Temperature Range (-40°C- 95°C )                  |                      |                      |                 |            |
| SCB13H8G162EF-11MI                                           | 933 MHz              | 13-13-13             | DDR3L-1866M     | PG-FBGA-96 |

## 3 Package information

### 3.1 Package 96-Ball FBGA (x16)



## 4 Ball Assignments

### 4.1 96-Ball FBGA (x16) Ball Assignments

|   | 1                                                                                                      | 2                                                                                                    | 3                                                                                                 | 4 | 5 | 6 | 7                                                                                                  | 8                                                                                                        | 9                                                                                                      |   |
|---|--------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|---|---|---|----------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|---|
| A |  V <sub>DDQ</sub>     |  DQU5               |  DQU7            |   |   |   |  DQU4             |  V <sub>DDQ</sub>     |  V <sub>SS</sub>    | A |
| B |  V <sub>SSQ</sub>     |  V <sub>DD</sub>    |  V <sub>SS</sub> |   |   |   |  DQSU#            |  DQU6                 |  V <sub>SSQ</sub>   | B |
| C |  V <sub>DDQ</sub>     |  DQU3               |  DQU1            |   |   |   |  DQSU             |  DQU2                 |  V <sub>DDQ</sub>   | C |
| D |  V <sub>SSQ</sub>     |  V <sub>DDQ</sub>   |  DMU             |   |   |   |  DQU0             |  V <sub>SSQ</sub>     |  V <sub>DD</sub>    | D |
| E |  V <sub>SS</sub>      |  V <sub>SSQ</sub>   |  DQL0            |   |   |   |  DML              |  V <sub>SSQ</sub>     |  V <sub>DDQ</sub>   | E |
| F |  V <sub>DDQ</sub>     |  DQL2               |  DQSL            |   |   |   |  DQL1             |  DQL3                 |  V <sub>SSQ</sub>   | F |
| G |  V <sub>SSQ</sub>    |  DQL6              |  DQSL#          |   |   |   |  V <sub>DD</sub> |  V <sub>SS</sub>     |  V <sub>SSQ</sub>  | G |
| H |  V <sub>REFDQ</sub> |  V <sub>DDQ</sub> |  DQL4          |   |   |   |  DQL7           |  DQL5               |  V <sub>DDQ</sub> | H |
| J |  NC                 |  V <sub>SS</sub>  |  RAS#          |   |   |   |  CK             |  V <sub>SS</sub>    |  NC               | J |
| K |  ODT                |  V <sub>DD</sub>  |  CAS#          |   |   |   |  CK#            |  V <sub>DD</sub>    |  CKE              | K |
| L |  NC                 |  CS#              |  WE#           |   |   |   |  A10/AP         |  ZQ                 |  NC               | L |
| M |  V <sub>SS</sub>    |  BA0              |  BA2           |   |   |   |  A15            |  V <sub>REFCA</sub> |  V <sub>SS</sub>  | M |
| N |  V <sub>DD</sub>    |  A3               |  A0            |   |   |   |  A12/BC#        |  BA1                |  V <sub>DD</sub>  | N |
| P |  V <sub>SS</sub>    |  A5               |  A2            |   |   |   |  A1             |  A4                 |  V <sub>SS</sub>  | P |
| R |  V <sub>DD</sub>    |  A7               |  A9            |   |   |   |  A11            |  A6                 |  V <sub>DD</sub>  | R |
| T |  V <sub>SS</sub>    |  RESET#           |  A13           |   |   |   |  A14            |  A8                 |  V <sub>SS</sub>  | T |
|   | 1                                                                                                      | 2                                                                                                    | 3                                                                                                 | 4 | 5 | 6 | 7                                                                                                  | 8                                                                                                        | 9                                                                                                      |   |

## 4.2 Ball Description

| Symbol            | Type  | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CK, CK#           | Input | <b>Clock:</b> CK and CK# are differential clock inputs. All address and control input signals are sampled on the crossing of positive edge of CK and negative edge of CK#. Output (read) data is referenced to the crossings of CK and CK#.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| CKE               | Input | <b>Clock Enable:</b> 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, however, timing parameters such as tXS are still calculated from the first rising clock edge where CKE HIGH satisfies tIS. After V <sub>REFCA</sub> and V <sub>REFDQ</sub> have become stable during the power on and initialization sequence, they must be maintained during all operations (including SELF REFRESH). CKE must be maintained HIGH throughout read and write accesses. Input buffers, excluding CK, CK#, ODT and CKE, are disabled during power-down. Input buffers, excluding CKE, are disabled during SELF REFRESH. |
| CS#               | Input | <b>Chip Select:</b> All commands are masked when CS# is registered HIGH. CS# provides for external rank selection on systems with multiple ranks. CS# is considered part of the command code.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| ODT               | Input | <b>On Die Termination:</b> ODT (registered HIGH) enables termination resistance internal to the DDR3 SDRAM. When enabled, ODT is only applied to each DQ, DQS, DQS# and DM. For x16 configuration, ODT is applied to each DQ, DQSU, DQSU#, DQSL, DQSL#, DMU, and DML signal. The ODT pin will be ignored if MR1 and MR2 are programmed to disable R <sub>TT</sub> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| RAS#, CAS#<br>WE# | Input | <b>Command Input:</b> RAS#, CAS#, and WE# (along with CS#) defines the command being entered.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| DML, DMU          | Input | <b>Input Data Mask:</b> 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 | <b>Bank Address Inputs:</b> BA0 - BA2 define the bank to which an ACTIVE, READ, WRITE or PRECHARGE command is being applied. Bank address also determines which mode register is to be accessed during MRS cycle.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| A0 – A15          | Input | <b>Address Inputs:</b> Provide the row address for ACTIVATE commands and the column address for READ/WRITE commands to select one location out of the memory array in the respective bank. (A10/AP and A12/BC# have additional functions, see below). The address inputs also provide the op-code during MODE REGISTER SET commands.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| A10/AP            | Input | <b>Auto Precharge:</b> A10 is sampled during READ/WRITE commands to determine whether auto precharge should be performed to the accessed bank after the READ/WRITE operation. (HIGH: auto precharge; LOW: No auto precharge) A10 is sampled during a PRECHARGE command to determine whether the precharge applies to one bank (A10 LOW) or all banks (A10 HIGH). If only one bank is to be precharged, the bank is selected by bank addresses.                                                                                                                                                                                                                                                                                                                                                                                                                  |
| A12/BC#           | Input | <b>Burst Chop:</b> A12/BC# is sampled during READ/WRITE commands to determine if burst chop (on-the-fly) will be performed. (HIGH: no burst chop; LOW: burst chopped).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

| Symbol                           | Type   | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|----------------------------------|--------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| RESET#                           | Input  | <b>Active LOW Asynchronous Reset:</b> Reset is active when RESET# is LOW, and inactive when RESET# is HIGH. RESET# must be HIGH during normal operation. RESET# is a CMOS rail-to-rail signal with DC HIGH and LOW at 80% and 20% of $V_{DD}$ .                                                                                                                                                                                                                                                            |
| DQ<br>DQL, DQU                   | I/O    | <b>Data Input/Output:</b> Bi-directional data bus.                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| DQSL,<br>DQSL#<br>DQSU,<br>DQSU# | I/O    | <b>Data Strobe:</b> Output with read data, input with write data. Edge-aligned with read data, centered in write data. For the x16, DQSL corresponds to the data on DQL0-DQL7, DQSU corresponds to the data on DQU0-DQU7. The data strobe DQS, DQSL and DQSU are paired with differential signals DQS#, DQSL#, and DQSU#, respectively, to provide differential pair signaling to the system during reads and writes. DDR3 SDRAM supports differential data strobe only and does not support single-ended. |
| NC                               | -      | <b>No Connect:</b> No internal electrical connection is present.                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| $V_{DDQ}$                        | Supply | <b>DQ Power Supply:</b> DDR3L operation = 1.283 to 1.450V; DDR3 operation = 1.425 to 1.575V.                                                                                                                                                                                                                                                                                                                                                                                                               |
| $V_{SSQ}$                        | Supply | <b>DQ Ground</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| $V_{DD}$                         | Supply | <b>Power Supply:</b> DDR3L operation = 1.283 to 1.450V; DDR3 operation = 1.425 to 1.575V.                                                                                                                                                                                                                                                                                                                                                                                                                  |
| $V_{SS}$                         | Supply | <b>Ground</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| $V_{REFDQ}$                      | Supply | <b>Reference Voltage for DQ</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| $V_{REFCA}$                      | Supply | <b>Reference Voltage for CA</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| ZQ                               | Supply | <b>Reference Pin for ZQ Calibration</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

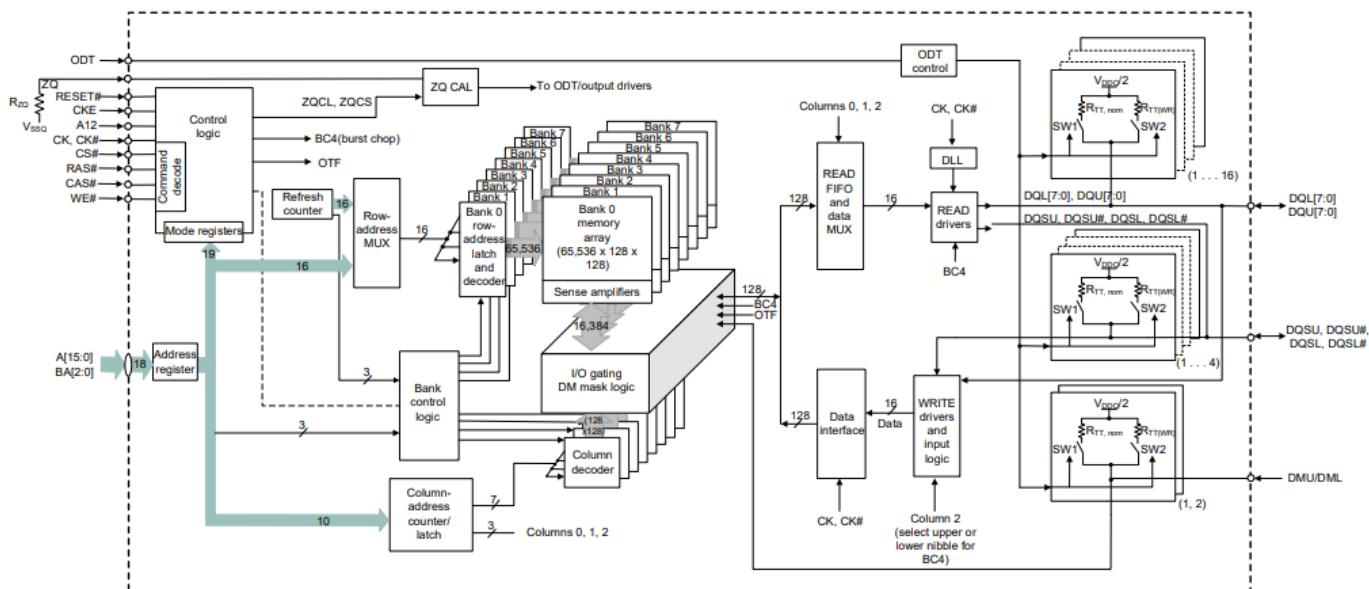
Note:

- Input only pins (BA0 - BA2, A0 – A15, RAS#, CAS#, WE#, CS#, CKE, ODT and RESET#) do not supply termination.

## 5 Functional block diagrams

DDR3 SDRAM is a high-speed, CMOS dynamic random access memory. It is internally configured as an 8-bank DRAM.

Figure- 1 512 Meg x 16 Functional Block Diagram



## 6 Absolute maximum ratings

### 6.1 Absolute Maximum DC Ratings

Table- 1 Absolute Maximum DC Ratings

| Symbol                             | Parameter                                                   | Rating     | Unit | Note |
|------------------------------------|-------------------------------------------------------------|------------|------|------|
| V <sub>DD</sub>                    | Voltage on V <sub>DD</sub> pin relative to V <sub>SS</sub>  | -0.4 ~ 1.8 | V    | 1,3  |
| V <sub>DDQ</sub>                   | Voltage on V <sub>DDQ</sub> pin relative to V <sub>SS</sub> | -0.4 ~ 1.8 | V    | 1,3  |
| V <sub>IN</sub> , V <sub>OUT</sub> | Voltage on any pin relative to V <sub>SS</sub>              | -0.4 ~ 1.8 | V    | 1    |
| T <sub>STG</sub>                   | Storage Temperature                                         | -55 ~ 150  | °C   | 1,2  |

Note:

- 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 condition 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.
- Storage Temperature is the case surface temperature on the center/top side of the DRAM. For the measurement conditions, please refer to JESD51-2 standard.
- V<sub>DD</sub> and V<sub>DDQ</sub> must be within 300mV of each other at all times, and V<sub>REF</sub> must not be greater than 0.6 x V<sub>DDQ</sub>, when V<sub>DD</sub> and V<sub>DDQ</sub> are less than 500mV, V<sub>REF</sub> may be equal to or less than 300mV.

### 6.2 Recommended DC Operating Conditions

Table- 2 Recommended DC Operating Conditions

| Symbol           | Parameter                 |       | Rating |      |       | Unit | Note        |
|------------------|---------------------------|-------|--------|------|-------|------|-------------|
|                  |                           |       | Min    | Typ. | Max   |      |             |
| V <sub>DD</sub>  | Supply voltage            | DDR3L | 1.283  | 1.35 | 1.45  | V    | 1,2,3,4,5,6 |
|                  |                           | DDR3  | 1.425  | 1.5  | 1.575 | V    | 1,2         |
| V <sub>DDQ</sub> | Supply voltage for output | DDR3L | 1.283  | 1.35 | 1.45  | V    | 1,2,3,4,5,6 |
|                  |                           | DDR3  | 1.425  | 1.5  | 1.575 | V    | 1,2         |

Note:

- Under all conditions V<sub>DDQ</sub> must be less than or equal to V<sub>DD</sub>.
- V<sub>DDQ</sub> tracks with V<sub>DD</sub>, AC parameters are measured with V<sub>DD</sub> and V<sub>DDQ</sub> tied together.
- Maximum DC value may not be greater than 1.425V. The DC value is the linear average of V<sub>DD</sub>/V<sub>DD</sub>(t) over a long period of time (e.g., 1 sec).
- If maximum limit is exceeded, input levels shall be governed by DDR3 specifications.
- Under these supply voltages, the device operates to this DDR3L specification.
- Under 1.5V operation, this DDR3L device operates in accordance with the DDR3 specifications under the same speed timings as defined for this device.

## 6.3 DRAM Component Operating Temperature Range

Table- 3 Temperature Range

| Symbol            | Parameter                          | Rating   | Unit | Note |
|-------------------|------------------------------------|----------|------|------|
| T <sub>OPER</sub> | Normal Operating Temperature Range | 0 ~ 85   | °C   | 1,2  |
|                   | Wide temperature                   | -40 ~ 85 | °C   | 1,2  |
|                   | Extended Temperature Range         | 85 ~ 95  | °C   | 1,3  |

Note:

- Operating Temperature T<sub>OPER</sub> is the case surface temperature on the center/top side of the DRAM. As for measurement conditions, please refer to the JEDEC document JESD51-2.
- 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 ~ 85°C under all operating conditions.
- Some applications require DRAM to operate in the Extended Temperature Range between 85°C and 95°C case temperature. Full specifications are supported in this range, but the following additional conditions apply:
  - REFRESH commands must be doubled in frequency, therefore reducing the Refresh interval t<sub>REFI</sub> to 3.9μs. It is also possible to specify a component with 1X refresh (t<sub>REFI</sub> to 7.8μs) in the Extended Temperature Range.
  - 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 = 0b and MR2 A7 = 1b) or enable the optional Auto Self Refresh mode (MR2 A6 = 1b and MR2 A7 = 0b).

## 7 AC AND DC INPUT MEASUREMENT LEVELS

### 7.1 AC and DC Logic Input Levels for Single-ended Signals

#### 7.1.1 AC and DC Input Levels for Single-ended Command and Address Signals

Table- 4 Single-ended AC and DC Input Levels for Command and Address

| Symbol             | Parameter                             | DDR3L-800/1066       |                      | DDR3L-1333/1600      |                      | DDR3L-1866/2133      |                      | Unit | Note |
|--------------------|---------------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|------|------|
|                    |                                       | Min                  | Max                  | Min                  | Max                  | Min                  | Max                  |      |      |
| $V_{IH.CA}(DC90)$  | DC input logic high                   | $V_{REF} + 0.09$     | $V_{DD}$             | $V_{REF} + 0.09$     | $V_{DD}$             | $V_{REF} + 0.09$     | $V_{DD}$             | V    | 1    |
| $V_{IL.CA}(DC90)$  | DC input logic low                    | $V_{SS}$             | $V_{REF} - 0.09$     | $V_{SS}$             | $V_{REF} - 0.09$     | $V_{SS}$             | $V_{REF} - 0.09$     | V    | 1    |
| $V_{IH.CA}(AC160)$ | AC input logic high                   | $V_{REF} + 0.16$     | Note 2               | $V_{REF} + 0.16$     | Note 2               | -                    | -                    | V    | 1,2  |
| $V_{IL.CA}(AC160)$ | AC input logic low                    | Note 2               | $V_{REF} - 0.16$     | Note 2               | $V_{REF} - 0.16$     | -                    | -                    | V    | 1,2  |
| $V_{IH.CA}(AC135)$ | AC input logic high                   | $V_{REF} + 0.135$    | Note 2               | $V_{REF} + 0.135$    | Note 2               | $V_{REF} + 0.135$    | Note 2               | V    | 1,2  |
| $V_{IL.CA}(AC135)$ | AC input logic low                    | Note 2               | $V_{REF} - 0.135$    | Note 2               | $V_{REF} - 0.135$    | Note 2               | $V_{REF} - 0.135$    | V    | 1,2  |
| $V_{IH.CA}(AC125)$ | AC input logic high                   | -                    | -                    | -                    | -                    | $V_{REF} + 0.125$    | Note 2               | V    | 1,2  |
| $V_{IL.CA}(AC125)$ | AC input logic low                    | -                    | -                    | -                    | -                    | Note 2               | $V_{REF} - 0.125$    | V    | 1,2  |
| $V_{REFCA}(DC)$    | Reference voltage for ADD, CMD inputs | $0.49 \times V_{DD}$ | $0.51 \times V_{DD}$ | $0.49 \times V_{DD}$ | $0.51 \times V_{DD}$ | $0.49 \times V_{DD}$ | $0.51 \times V_{DD}$ | V    | 3,4  |

| Symbol             | Parameter                             | DDR3-800/1066        |                      | DDR3-1333/1600       |                      | DDR3-1866/2133       |                      | Unit | Note  |
|--------------------|---------------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|------|-------|
|                    |                                       | Min                  | Max                  | Min                  | Max                  | Min                  | Max                  |      |       |
| $V_{IH.CA}(DC100)$ | DC input logic high                   | $V_{REF} + 0.10$     | $V_{DD}$             | $V_{REF} + 0.10$     | $V_{DD}$             | $V_{REF} + 0.10$     | $V_{DD}$             | V    | 1,5   |
| $V_{IL.CA}(DC100)$ | DC input logic low                    | $V_{SS}$             | $V_{REF} - 0.10$     | $V_{SS}$             | $V_{REF} - 0.10$     | $V_{SS}$             | $V_{REF} - 0.10$     | V    | 1,6   |
| $V_{IH.CA}(AC175)$ | AC input logic high                   | $V_{REF} + 0.175$    | Note 2               | $V_{REF} + 0.175$    | Note 2               | -                    | -                    | V    | 1,2,7 |
| $V_{IL.CA}(AC175)$ | AC input logic low                    | Note 2               | $V_{REF} - 0.175$    | Note 2               | $V_{REF} - 0.175$    | -                    | -                    | V    | 1,2,8 |
| $V_{IH.CA}(AC150)$ | AC input logic high                   | $V_{REF} + 0.15$     | Note 2               | $V_{REF} + 0.15$     | Note 2               | -                    | -                    | V    | 1,2,7 |
| $V_{IL.CA}(AC150)$ | AC input logic low                    | Note 2               | $V_{REF} - 0.15$     | Note 2               | $V_{REF} - 0.15$     | -                    | -                    | V    | 1,2,8 |
| $V_{IH.CA}(AC135)$ | AC input logic high                   | -                    | -                    | -                    | -                    | $V_{REF} + 0.135$    | Note 2               | V    | 1,2,7 |
| $V_{IL.CA}(AC135)$ | AC input logic low                    | -                    | -                    | -                    | -                    | Note 2               | $V_{REF} - 0.135$    | V    | 1,2,8 |
| $V_{IH.CA}(AC125)$ | AC input logic high                   | -                    | -                    | -                    | -                    | $V_{REF} + 0.125$    | Note 2               | V    | 1,2,7 |
| $V_{IL.CA}(AC125)$ | AC input logic low                    | -                    | -                    | -                    | -                    | Note 2               | $V_{REF} - 0.125$    | V    | 1,2,8 |
| $V_{REFCA}(DC)$    | Reference voltage for ADD, CMD inputs | $0.49 \times V_{DD}$ | $0.51 \times V_{DD}$ | $0.49 \times V_{DD}$ | $0.51 \times V_{DD}$ | $0.49 \times V_{DD}$ | $0.51 \times V_{DD}$ | V    | 3,4,9 |

Note:

- For input only pins except RESET#.  $V_{REF} = V_{REFCA(DC)}$ .
- See "Overshoot and Undershoot Specifications" in Section 8.6.
- The AC peak noise on  $V_{REF}$  may not allow  $V_{REF}$  to deviate from  $V_{REF(DC)}$  by more than  $\pm 1\% V_{DD}$  (for reference: DDR3L: approx.  $\pm 13.5mV$ ; DDR3: approx.  $\pm 15mV$ ).
- For reference: DDR3 has approx.  $V_{DD}/2 \pm 15mV$ , DDR3L has approx.  $V_{DD}/2 \pm 13.5mV$ .
- $V_{IH(DC)}$  is used as a simplified symbol for  $V_{IH.CA(DC100)}$ .
- $V_{IL(DC)}$  is used as a simplified symbol for  $V_{IL.CA(DC100)}$ .
- $V_{IH(AC)}$  is used as a simplified symbol for  $V_{IH.CA(AC175)}$ ,  $V_{IH.CA(AC150)}$ ,  $V_{IH.CA(AC135)}$ , and  $V_{IH.CA(AC125)}$ ;  $V_{IH.CA(AC175)}$  value is used when  $V_{REF} + 0.175V$  is referenced,  $V_{IH.CA(AC150)}$  value is used when  $V_{REF} + 0.15V$  is referenced,  $V_{IH.CA(AC135)}$  value is used when  $V_{REF} + 0.135V$  is referenced, and  $V_{IH.CA(AC125)}$  value is used when  $V_{REF} + 0.125V$  is referenced.
- $V_{IL(AC)}$  is used as a simplified symbol for  $V_{IL.CA(AC175)}$ ,  $V_{IL.CA(AC150)}$ ,  $V_{IL.CA(AC135)}$  and  $V_{IL.CA(AC125)}$ ;  $V_{IL.CA(AC175)}$  value is used when  $V_{REF} - 0.175V$  is referenced,  $V_{IL.CA(AC150)}$  value is used when  $V_{REF} - 0.15V$  is referenced,  $V_{IL.CA(AC135)}$  value is used when  $V_{REF} - 0.135V$  is referenced, and  $V_{IL.CA(AC125)}$  value is used when  $V_{REF} - 0.125V$  is referenced.
- $V_{REFCA(DC)}$  is measured relative to  $V_{DD}$  at the same point in time on the same device.

## 7.1.2 AC and DC Input Levels for Single-ended Data Signals

Table- 5 Single-ended AC and DC Input Levels for DQ and DM

| Symbol             | Parameter                           | DDR3L-800/1066       |                      | DDR3L-1333/1600      |                      | DDR3L-1866/2133      |                      | Unit | Note |
|--------------------|-------------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|------|------|
|                    |                                     | Min                  | Max                  | Min                  | Max                  | Min                  | Max                  |      |      |
| $V_{IH.DQ(DC90)}$  | DC input logic high                 | $V_{REF} + 0.09$     | $V_{DD}$             | $V_{REF} + 0.09$     | $V_{DD}$             | $V_{REF} + 0.09$     | $V_{DD}$             | V    | 1    |
| $V_{IL.DQ(DC90)}$  | DC input logic low                  | $V_{SS}$             | $V_{REF} - 0.09$     | $V_{SS}$             | $V_{REF} - 0.09$     | $V_{SS}$             | $V_{REF} - 0.09$     | V    | 1    |
| $V_{IH.DQ(AC160)}$ | AC input logic high                 | $V_{REF} + 0.16$     | Note 2               | -                    | -                    | -                    | -                    | V    | 1,2  |
| $V_{IL.DQ(AC160)}$ | AC input logic low                  | Note 2               | $V_{REF} - 0.16$     | -                    | -                    | -                    | -                    | V    | 1,2  |
| $V_{IH.DQ(AC135)}$ | AC input logic high                 | $V_{REF} + 0.135$    | Note 2               | $V_{REF} + 0.135$    | Note 2               | -                    | -                    | V    | 1,2  |
| $V_{IL.DQ(AC135)}$ | AC input logic low                  | Note 2               | $V_{REF} - 0.135$    | Note 2               | $V_{REF} - 0.135$    | -                    | -                    | V    | 1,2  |
| $V_{IH.DQ(AC130)}$ | AC input logic high                 | -                    | -                    | -                    | -                    | $V_{REF} + 0.13$     | Note 2               | V    | 1,2  |
| $V_{IL.DQ(AC130)}$ | AC input logic low                  | -                    | -                    | -                    | -                    | Note 2               | $V_{REF} - 0.13$     | V    | 1,2  |
| $V_{REFDQ(DC)}$    | Reference voltage for DQ, DM inputs | $0.49 \times V_{DD}$ | $0.51 \times V_{DD}$ | $0.49 \times V_{DD}$ | $0.51 \times V_{DD}$ | $0.49 \times V_{DD}$ | $0.51 \times V_{DD}$ | V    | 3,4  |

| Symbol             | Parameter                           | DDR3-800/1066        |                      | DDR3-1333/1600       |                      | DDR3-1866/2133       |                      | Unit | Note  |
|--------------------|-------------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|------|-------|
|                    |                                     | Min                  | Max                  | Min                  | Max                  | Min                  | Max                  |      |       |
| $V_{IH.DQ(DC100)}$ | DC input logic high                 | $V_{REF} + 0.10$     | $V_{DD}$             | $V_{REF} + 0.10$     | $V_{DD}$             | $V_{REF} + 0.10$     | $V_{DD}$             | V    | 1,5   |
| $V_{IL.DQ(DC100)}$ | DC input logic low                  | $V_{SS}$             | $V_{REF} - 0.10$     | $V_{SS}$             | $V_{REF} - 0.10$     | $V_{SS}$             | $V_{REF} - 0.10$     | V    | 1,6   |
| $V_{IH.DQ(AC175)}$ | AC input logic high                 | $V_{REF} + 0.175$    | Note 2               | -                    | -                    | -                    | -                    | V    | 1,2,7 |
| $V_{IL.DQ(AC175)}$ | AC input logic low                  | Note 2               | $V_{REF} - 0.175$    | -                    | -                    | -                    | -                    | V    | 1,2,8 |
| $V_{IH.DQ(AC150)}$ | AC input logic high                 | $V_{REF} + 0.15$     | Note 2               | $V_{REF} + 0.15$     | Note 2               | -                    | -                    | V    | 1,2,7 |
| $V_{IL.DQ(AC150)}$ | AC input logic low                  | Note 2               | $V_{REF} - 0.15$     | Note 2               | $V_{REF} - 0.15$     | -                    | -                    | V    | 1,2,8 |
| $V_{IH.DQ(AC135)}$ | AC input logic high                 | $V_{REF} + 0.135$    | Note 2               | $V_{REF} + 0.135$    | Note 2               | $V_{REF} + 0.135$    | Note 2               | V    | 1,2,7 |
| $V_{IL.DQ(AC135)}$ | AC input logic low                  | Note 2               | $V_{REF} - 0.135$    | Note 2               | $V_{REF} - 0.135$    | Note 2               | $V_{REF} - 0.135$    | V    | 1,2,8 |
| $V_{REFDQ(DC)}$    | Reference voltage for DQ, DM inputs | $0.49 \times V_{DD}$ | $0.51 \times V_{DD}$ | $0.49 \times V_{DD}$ | $0.51 \times V_{DD}$ | $0.49 \times V_{DD}$ | $0.51 \times V_{DD}$ | V    | 3,4,9 |

## Note:

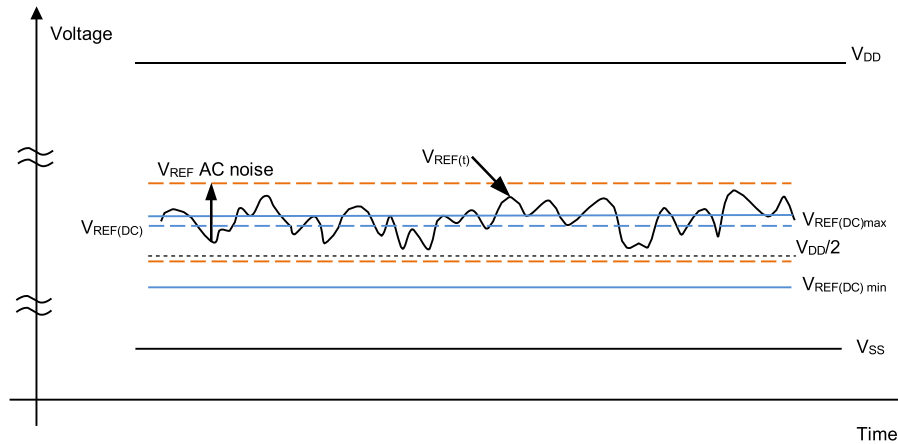
1.  $V_{REF} = V_{REFDQ(DC)}$ .
2. See “Overshoot and Undershoot Specifications” in Section 8.6.
3. The AC peak noise on  $V_{REF}$  may not allow  $V_{REF}$  to deviate from  $V_{REFDQ(DC)}$  by more than  $\pm 1\% V_{DD}$  (for reference: DDR3L: approx.  $\pm 13.5\text{mV}$ ; DDR3: approx.  $\pm 15\text{mV}$ ).
4. For reference: DDR3 has approx.  $V_{DD}/2 \pm 15\text{mV}$ , and DDR3L has approx.  $V_{DD}/2 \pm 13.5\text{mV}$ .
5.  $V_{IH(DC)}$  is used as a simplified symbol for  $V_{IH.DQ(DC100)}$ .
6.  $V_{IL(DC)}$  is used as a simplified symbol for  $V_{IL.DQ(DC100)}$ .
7.  $V_{IH(AC)}$  is used as a simplified symbol for  $V_{IH.DQ(AC175)}$ ,  $V_{IH.DQ(AC150)}$ , and  $V_{IH.DQ(AC135)}$ ;  $V_{IH.DQ(AC175)}$  value is used when  $V_{REF} + 0.175\text{V}$  is referenced,  $V_{IH.DQ(AC150)}$  value is used when  $V_{REF} + 0.15\text{V}$  is referenced, and  $V_{IH.DQ(AC135)}$  value is used when  $V_{REF} + 0.135\text{V}$  is referenced.
8.  $V_{IL(AC)}$  is used as a simplified symbol for  $V_{IL.DQ(AC175)}$ ,  $V_{IL.DQ(AC150)}$ , and  $V_{IL.DQ(AC135)}$ ;  $V_{IL.DQ(AC175)}$  value is used when  $V_{REF} - 0.175\text{V}$  is referenced,  $V_{IL.DQ(AC150)}$  value is used when  $V_{REF} - 0.15\text{V}$  is referenced, and  $V_{IL.DQ(AC135)}$  value is used when  $V_{REF} - 0.135\text{V}$  is referenced.
9.  $V_{REFDQ(DC)}$  is measured relative to  $V_{DD}$  at the same point in time on the same device.

## 7.2 VREF Tolerances

The DC-Tolerance limits and AC-Noise limits for the reference voltages  $V_{REFCA}$  and  $V_{REFDQ}$  are illustrated in Figure- 2. It shows a valid reference voltage  $V_{REF(t)}$  as a function of time. ( $V_{REF}$  stands for  $V_{REFCA}$  and  $V_{REFDQ}$  likewise).

$V_{REF(DC)}$  is the linear average of  $V_{REF(t)}$  over a very long period of time (e.g., 1 sec). This average has to meet the min/max requirement in Table-4. Furthermore  $V_{REF(t)}$  may temporarily deviate from  $V_{REF(DC)}$  by no more than  $\pm 1\% V_{DD}$ .

**Figure- 2 Illustration of VREF(DC) Tolerance and VREF AC-Noise limits**



The voltage levels for setup and hold time measurements  $V_{IH(AC)}$ ,  $V_{IH(DC)}$ ,  $V_{IL(AC)}$  and  $V_{IL(DC)}$  are dependent on  $V_{REF}$ . “ $V_{REF}$ ” should be understood as  $V_{REF(DC)}$ .

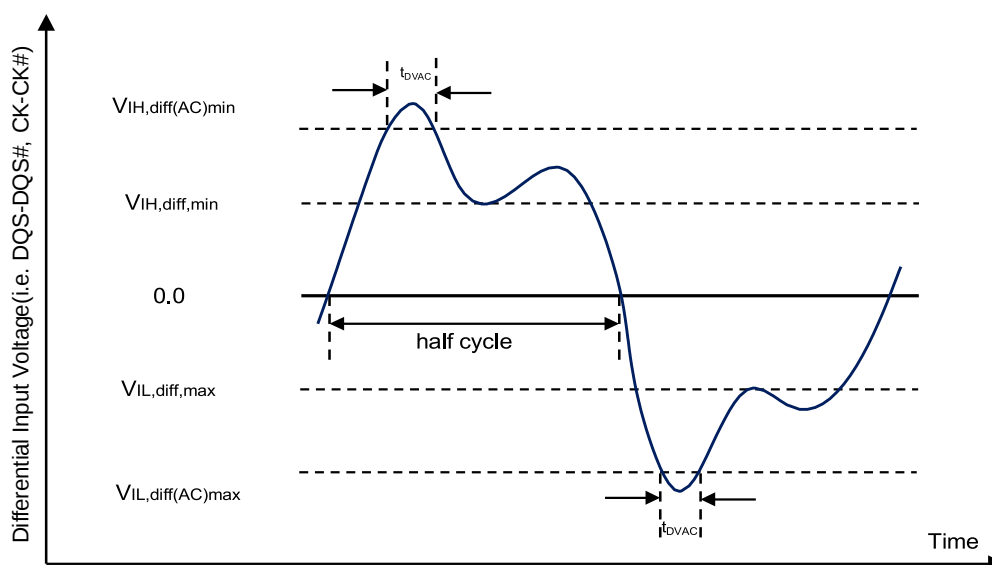
This clarifies that DC-Variations of  $V_{REF}$  affect the absolute voltage a signal has to reach to achieve a valid high or low level, and therefore the time to which setup and hold is measured. System timing and voltage budgets need to account for  $V_{REF(DC)}$  deviations from the optimum position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

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

## 7.3 AC and DC Logic Input Levels for Differential Signals

### 7.3.1 Differential Signals Definition

Figure- 3 Definition of Differential AC-Swing and “Time above AC-Level” tDVAC



### 7.3.2 Differential Swing Requirements for Clock (CK - CK#) and strobe (DQS - DQS#)

Table- 6 Differential AC and DC Input Levels

| Symbol                   | Parameter                  | DDR3L/DDR3-800/1066/1333/1600/1866/2133       |                                               |                                               |                                               | Unit | Note |
|--------------------------|----------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|------|------|
|                          |                            | 1.35V                                         |                                               | 1.5V                                          |                                               |      |      |
|                          |                            | Min                                           | Max                                           | Min                                           | Max                                           |      |      |
| V <sub>IH,diff</sub>     | Differential input high    | + 0.18                                        | Note 3                                        | + 0.20                                        | Note 3                                        | V    | 1    |
| V <sub>IL,diff</sub>     | Differential input low     | Note 3                                        | - 0.18                                        | Note 3                                        | - 0.20                                        | V    | 1    |
| V <sub>IH,diff(AC)</sub> | Differential input high AC | 2 x (V <sub>IH(AC)</sub> - V <sub>REF</sub> ) | Note 3                                        | 2 x (V <sub>IH(AC)</sub> - V <sub>REF</sub> ) | Note 3                                        | V    | 2    |
| V <sub>IL,diff(AC)</sub> | Differential input low AC  | Note 3                                        | 2 x (V <sub>IL(AC)</sub> - V <sub>REF</sub> ) | Note 3                                        | 2 x (V <sub>IL(AC)</sub> - V <sub>REF</sub> ) | V    | 2    |

Note:

- Used to define a differential signal slew-rate.
- For CK - CK# use  $V_{IH}/V_{IL(AC)}$  of ADD/CMD and  $V_{REFCA}$ ; for DQS - DQS#, DQSL - DQSL#, DQSU - DQSU# use  $V_{IH}/V_{IL(AC)}$  of DQS and  $V_{REFDQ}$ ; if a reduced AC-high or AC-low level is used for a signal group, then the reduced level applies also here.
- These values are not defined, however, the single-ended signals CK, CK#, DQS, DQS#, DQSL, DQSL#, DQSU, DQSU# need to be within the respective limits ( $V_{IH(DC)max}$ ,  $V_{IL(DC)min}$ ) for single-ended signals as well as the limitations for overshoot and undershoot.

Table- 7 Allowed Time before Ringback (tDVAC) for CK - CK# and DQS - DQS# (1.35V)

|                     | DDR3L-800/1066/1333/1600                              |     |                                                       |     |                                                       |     | DDR3L-1866/2133                                       |     |                                                       |     |
|---------------------|-------------------------------------------------------|-----|-------------------------------------------------------|-----|-------------------------------------------------------|-----|-------------------------------------------------------|-----|-------------------------------------------------------|-----|
| Slew Rate<br>[V/ns] | tDVAC [ps]<br>@ V <sub>IH/L,diff(AC)</sub> =<br>320mV |     | tDVAC [ps]<br>@ V <sub>IH/L,diff(AC)</sub> =<br>270mV |     | tDVAC [ps]<br>@ V <sub>IH/L,diff(AC)</sub> =<br>270mV |     | tDVAC [ps]<br>@ V <sub>IH/L,diff(AC)</sub> =<br>250mV |     | tDVAC [ps]<br>@ V <sub>IH/L,diff(AC)</sub> =<br>260mV |     |
|                     | Min                                                   | Max | Min                                                   | Max | Min                                                   | Max | Min                                                   | Max | Min                                                   | Max |
| >4.0                | 189                                                   | -   | 201                                                   | -   | 163                                                   | -   | 168                                                   | -   | 176                                                   | -   |
| 4.0                 | 189                                                   | -   | 201                                                   | -   | 163                                                   | -   | 168                                                   | -   | 176                                                   | -   |
| 3.0                 | 162                                                   | -   | 179                                                   | -   | 140                                                   | -   | 147                                                   | -   | 154                                                   | -   |
| 2.0                 | 109                                                   | -   | 134                                                   | -   | 95                                                    | -   | 105                                                   | -   | 111                                                   | -   |
| 1.8                 | 91                                                    | -   | 119                                                   | -   | 80                                                    | -   | 91                                                    | -   | 97                                                    | -   |
| 1.6                 | 69                                                    | -   | 100                                                   | -   | 62                                                    | -   | 74                                                    | -   | 78                                                    | -   |
| 1.4                 | 40                                                    | -   | 76                                                    | -   | 37                                                    | -   | 52                                                    | -   | 56                                                    | -   |
| 1.2                 | Note                                                  | -   | 44                                                    | -   | 5                                                     | -   | 22                                                    | -   | 24                                                    | -   |
| 1.0                 | Note                                                  | -   | Note                                                  | -   | Note                                                  | -   | Note                                                  | -   | Note                                                  | -   |
| <1.0                | Note                                                  | -   | Note                                                  | -   | Note                                                  | -   | Note                                                  | -   | Note                                                  | -   |

Note:

1. Rising input differential signal shall become equal to or greater than V<sub>IH,diff(AC)</sub> level and falling input signal shall become equal to or less than V<sub>IL,diff(AC)</sub> level.

Table- 8 Allowed Time before Ringback (tDVAC) for CK - CK# and DQS - DQS# (1.5 V)

|                     | DDR3-800/1066/1333/1600                               |     |                                                       |     |                                                                      |     | DDR3-1866/2133                                        |     |                                                                 |     |
|---------------------|-------------------------------------------------------|-----|-------------------------------------------------------|-----|----------------------------------------------------------------------|-----|-------------------------------------------------------|-----|-----------------------------------------------------------------|-----|
| Slew Rate<br>[V/ns] | tDVAC [ps]<br>@ V <sub>IH/L,diff(AC)</sub> =<br>350mV |     | tDVAC [ps]<br>@ V <sub>IH/L,diff(AC)</sub> =<br>300mV |     | tDVAC [ps]<br>@ V <sub>IH/L,diff(AC)</sub> =<br>(DQS - DQS#)<br>only |     | tDVAC [ps]<br>@ V <sub>IH/L,diff(AC)</sub> =<br>300mV |     | tDVAC [ps]<br>@ V <sub>IH/L,diff(AC)</sub> =<br>(CK - CK#) only |     |
|                     | Min                                                   | Max | Min                                                   | Max | Min                                                                  | Max | Min                                                   | Max | Min                                                             | Max |
| >4.0                | 75                                                    | -   | 175                                                   | -   | 214                                                                  | -   | 134                                                   | -   | 139                                                             | -   |
| 4.0                 | 57                                                    | -   | 170                                                   | -   | 214                                                                  | -   | 134                                                   | -   | 139                                                             | -   |
| 3.0                 | 50                                                    | -   | 167                                                   | -   | 191                                                                  | -   | 112                                                   | -   | 118                                                             | -   |
| 2.0                 | 38                                                    | -   | 119                                                   | -   | 146                                                                  | -   | 67                                                    | -   | 77                                                              | -   |
| 1.8                 | 34                                                    | -   | 102                                                   | -   | 131                                                                  | -   | 52                                                    | -   | 63                                                              | -   |
| 1.6                 | 29                                                    | -   | 81                                                    | -   | 113                                                                  | -   | 33                                                    | -   | 45                                                              | -   |
| 1.4                 | 22                                                    | -   | 54                                                    | -   | 88                                                                   | -   | 9                                                     | -   | 23                                                              | -   |
| 1.2                 | Note                                                  | -   | 19                                                    | -   | 56                                                                   | -   | Note                                                  | -   | Note                                                            | -   |
| 1.0                 | Note                                                  | -   | Note                                                  | -   | 11                                                                   | -   | Note                                                  | -   | Note                                                            | -   |
| <1.0                | Note                                                  | -   | Note                                                  | -   | Note                                                                 | -   | Note                                                  | -   | Note                                                            | -   |

Note:

1. Rising input differential signal shall become equal to or greater than V<sub>IH,diff(AC)</sub> level and falling input differential signal shall become equal to or less than V<sub>IL,diff(AC)</sub> level.

### 7.3.3 Single-ended Requirements for Differential Signals

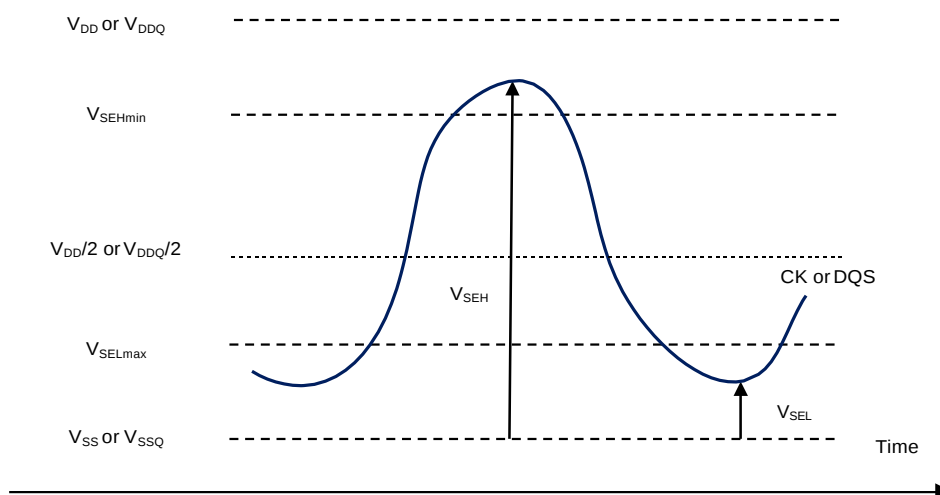
Each individual component of a differential signal (CK, DQS, DQSL, DQSU, CK#, DQS#, DQSL#, or DQSU#) has also to comply with certain requirements for single-ended signals.

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

DQS, DQSL, DQSU, DQS#, DQSL# have to reach  $V_{SEHmin}/V_{SELmax}$  (approximately the AC-Levels ( $V_{IH(AC)}/V_{IL(AC)}$ ) for DQ signal) 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  $V_{IH.CA(AC150)}/V_{IL.CA(AC150)}$  is used for ADD/CMD signals, then these AC-levels apply also for the single-ended signals CK and CK#.

**Figure- 4 Single-ended Requirement for Differential Signals**



Note that, while ADD/CMD and DQ signal requirements are with respect to  $V_{REF}$ , the single-ended components of differential signals have a requirement with respect to  $V_{DD}/2$ , 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  $V_{SELmax}$ ,  $V_{SEHmin}$  has no bearing on timing, but adds a restriction on the common mode characteristics of these signals.

**Table- 9 Single-ended Levels for CK, DQS, DQSL, DQSU, CK#, DQS#, DQSL#, or DQSU#**

| Symbol    | Parameter                           | DDR3L/DDR3-<br>800/1066/1333/1600/1866/2133 |                      | Unit | Note |
|-----------|-------------------------------------|---------------------------------------------|----------------------|------|------|
|           |                                     | Min                                         | Max                  |      |      |
| $V_{SEH}$ | Single-ended high-level for strobes | $(V_{DD}/2) + 0.175$                        | Note 3               | V    | 1,2  |
|           | Single-ended high-level for CK, CK# | $(V_{DD}/2) + 0.175$                        | Note 3               | V    | 1,2  |
| $V_{SEL}$ | Single-ended low-level for strobes  | Note 3                                      | $(V_{DD}/2) - 0.175$ | V    | 1,2  |
|           | Single-ended low-level for CK, CK#  | Note 3                                      | $(V_{DD}/2) - 0.175$ | V    | 1,2  |

Note:

- For CK, CK# use  $V_{IH}/V_{IL(AC)}$  of ADD/CMD; for strobes (DQS, DQS#, DQSL, DQSL#, DQSU, DQSU#) use  $V_{IH}/V_{IL(AC)}$  of DQS.
- $V_{IH(AC)}/V_{IL(AC)}$  for DQ is based on  $V_{REFDQ}$ ;  $V_{IH(AC)}/V_{IL(AC)}$  for ADD/CMD is based on  $V_{REFCA}$ ; if a reduced AC-high or AC-low level

is used for a signal group, then the reduced level applies also here.

3. These values are not defined, however the single-ended signals CK, CK#, DQS, DQS#, DQSL, DQSL#, DQSU, DQSU# need to be within the respective limits ( $V_{IH(DC)max}$ ,  $V_{IL(DC)min}$ ) for single-ended signals as well as the limitations for overshoot and undershoot.

## 7.4 Differential Input Cross Point Voltage

To guarantee tight setup and hold times as well as output skew parameters with respect to clock and strobe, each cross point voltage of differential input signals (CK, CK# and DQS, DQS#) must meet the requirements in Table-10 and Table-11. The differential input cross point voltage  $V_{IX}$  is measured from the actual cross point of true and complement signals to the MID-LEVEL between of  $V_{DD}$  and  $V_{SS}$ .

Figure- 5  $V_{IX}$  Definition

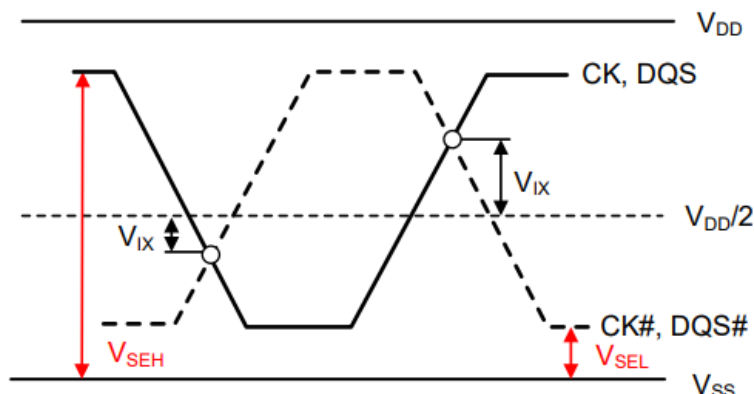


Table- 10 Cross Point Voltage for Differential Input Signals (CK, DQS):1.35V

| Symbol        | Parameter                                                                   | DDR3L-800/1066/1333/1600/1866/2133 |     | Unit | Note |
|---------------|-----------------------------------------------------------------------------|------------------------------------|-----|------|------|
|               |                                                                             | Min                                | Max |      |      |
| $V_{IX(CK)}$  | Differential Input Cross Point Voltage relative to $V_{DD}/2$ for CK, CK#   | -150                               | 150 | mV   | 1    |
| $V_{IX(DQS)}$ | Differential Input Cross Point Voltage relative to $V_{DD}/2$ for DQS, DQS# | -150                               | 150 | mV   | -    |

Note:

- The relation between  $V_{IX(min/max)}$  and  $V_{SEL}/V_{SEH}$  should satisfy following.  
 $(V_{DD}/2) + V_{IX(min)} - V_{SEL} \geq 25mV$   
 $V_{SEH} - ((V_{DD}/2) + V_{IX(max)}) \geq 25mV$

Table- 11 Cross Point Voltage for Differential Input Signals (CK, DQS):1.5V

| Symbol        | Parameter                                                                   | DDR3-800/1066/1333/1600/1866/2133 |     | Unit | Note |
|---------------|-----------------------------------------------------------------------------|-----------------------------------|-----|------|------|
|               |                                                                             | Min                               | Max |      |      |
| $V_{IX(CK)}$  | Differential Input Cross Point Voltage relative to $V_{DD}/2$ for CK, CK#   | -150                              | 150 | mV   | 2    |
|               |                                                                             | -175                              | 175 | mV   | 1    |
| $V_{IX(DQS)}$ | Differential Input Cross Point Voltage relative to $V_{DD}/2$ for DQS, DQS# | -150                              | 150 | mV   | 2    |

Note:

- Extended range for  $V_{IX}$  is only allowed for clock and if single-ended clock input signals CK and CK# are monotonic with a

- single-ended swing  $V_{SEL}/V_{SEH}$  of at least  $V_{DD}/2 \pm 250\text{mV}$ , and when the differential slew rate of  $CK - CK\#$  is larger than  $3\text{V/ns}$ .
- The relation between  $V_{IX(\min/\max)}$  and  $V_{SEL}/V_{SEH}$  should satisfy following.  
 $(V_{DD}/2) + V_{IX(\min)} - V_{SEL} \geq 25\text{mV}$ ;  $V_{SEH} - ((V_{DD}/2) + V_{IX(\max)}) \geq 25\text{mV}$

## 7.5 Slew Rate Definitions for Single-ended Input Signals

See section 12.5 “Address/Command Setup, Hold and Derating” single-ended slew rate definitions for address and command signals.

See section 12.6 “Data Setup, Hold and Slew Rate Derating” single-ended slew rate definitions for datasignals.

## 7.6 Slew Rate Definitions for Differential Input Signals

Input slew rate for differential signals ( $CK$ ,  $CK\#$ , and  $DQS$ ,  $DQS\#$ ) are defined and measured as shown in Table-12 and Figure-6.

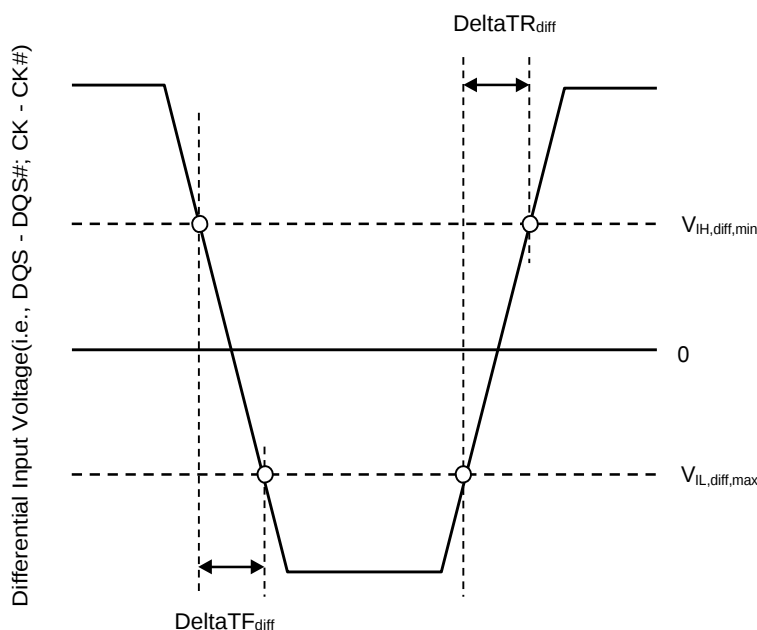
**Table- 12 Differential Input Slew Rate Definition**

| Description                                                                     | Measured          |                   | Defined by                                             |
|---------------------------------------------------------------------------------|-------------------|-------------------|--------------------------------------------------------|
|                                                                                 | From              | To                |                                                        |
| Differential input slew rate for rising edge ( $CK - CK\#$ and $DQS - DQS\#$ )  | $V_{IL,diff,max}$ | $V_{IH,diff,min}$ | $[V_{IH,diff,min} - V_{IL,diff,max}]/\Delta TR_{diff}$ |
| Differential input slew rate for falling edge ( $CK - CK\#$ and $DQS - DQS\#$ ) | $V_{IH,diff,min}$ | $V_{IL,diff,max}$ | $[V_{IH,diff,min} - V_{IL,diff,max}]/\Delta TF_{diff}$ |

Note:

- The differential signal (i.e.,  $CK - CK\#$  and  $DQS - DQS\#$ ) must be linear between these thresholds.

**Figure- 6 Differential Input Slew Rate Definition for  $DQS$ ,  $DQS\#$  and  $CK$ ,  $CK\#$**



## 8 AC&DC OUTPUT MEASUREMENT LEVELS

### 8.1 Single-ended AC and DC Output Levels

Table-13 shows the output levels used for measurements of single-ended signals.

**Table- 13 Single-ended AC&DC Output Levels**

| Symbol       | Parameter                                                 | Value                         | Unit | Note |
|--------------|-----------------------------------------------------------|-------------------------------|------|------|
| $V_{OH(DC)}$ | DC output high measurement level (for IV curve linearity) | $0.8 \times V_{DDQ}$          | V    | -    |
| $V_{OM(DC)}$ | DC output mid measurement level (for IV curve linearity)  | $0.5 \times V_{DDQ}$          | V    | -    |
| $V_{OL(DC)}$ | DC output low measurement level (for IV curve linearity)  | $0.2 \times V_{DDQ}$          | V    | -    |
| $V_{OH(AC)}$ | AC output high measurement level (for output SR)          | $V_{TT} + 0.1 \times V_{DDQ}$ | V    | 1    |
| $V_{OL(AC)}$ | AC output low measurement level (for output SR)           | $V_{TT} - 0.1 \times V_{DDQ}$ | V    | 1    |

Note:

- The swing of  $\pm 0.1 \times V_{DDQ}$  is based on approximately 50% of the static single-ended output high or low swing with a driver impedance of  $40\Omega$  and an effective test load of  $25\Omega$  to  $V_{TT} = V_{DDQ}/2$ .

### 8.2 Differential AC and DC Output Levels

Table-14 Differential AC&DC Output Levels shows the output levels used for measurements of differential signals.

**Table- 14 Differential AC&DC Output Levels**

| Symbol            | Parameter                                                     | Value                  | Unit | Note |
|-------------------|---------------------------------------------------------------|------------------------|------|------|
| $V_{OH,diff(AC)}$ | AC differential output high measurement level (for output SR) | $+ 0.2 \times V_{DDQ}$ | V    | 1    |
| $V_{OL,diff(AC)}$ | AC differential output low measurement level (for output SR)  | $- 0.2 \times V_{DDQ}$ | V    | 1    |

Note:

- The swing of  $\pm 0.2 \times V_{DDQ}$  is based on approximately 50% of the static single-ended output high or low swing with a driver impedance of  $40\Omega$  and an effective test load of  $25\Omega$  to  $V_{TT} = V_{DDQ}/2$  at each of the differential outputs.

### 8.3 Single-ended Output Slew Rate

With the reference load for timing measurements, output slew rate for falling and rising edges is defined and measured between  $V_{OL(AC)}$  and  $V_{OH(AC)}$  for single-ended signals as shown in Table-15 and Figure- 7.

**Table- 15 Single-ended Output Slew Rate Definition**

| Description                                    | Measured     |              | Defined by                                 |
|------------------------------------------------|--------------|--------------|--------------------------------------------|
|                                                | From         | To           |                                            |
| Single-ended output slew rate for rising edge  | $V_{OL(AC)}$ | $V_{OH(AC)}$ | $[V_{OH(AC)} - V_{OL(AC)}]/\Delta t_{Rse}$ |
| Single-ended output slew rate for falling edge | $V_{OH(AC)}$ | $V_{OL(AC)}$ | $[V_{OH(AC)} - V_{OL(AC)}]/\Delta t_{Fse}$ |

Note:

- Output slew rate is verified by design and characterization, and may not be subject to production test.

Figure- 7 Single-ended Output Slew Rate Definition

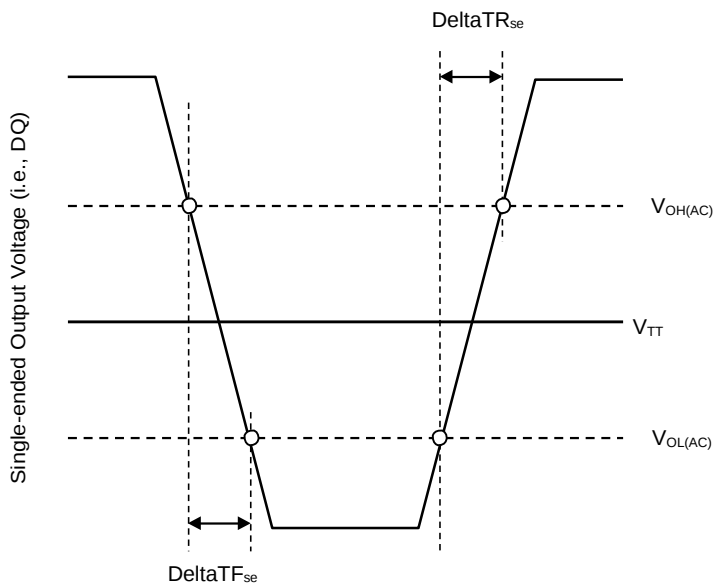


Table- 16 Single-ended Output Slew Rate

| Parameter                     | Symbol     | Operation Voltage | 800  |                  | 1066 |                  | 1333 |                  | 1600 |                  | 1866 |                  | 2133 |                  | Unit |
|-------------------------------|------------|-------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|------------------|------|
|                               |            |                   | Min  | Max              | Min  | Max              | Min  | Max              | Min  | Max              | Min  | Max              | Min  | Max              |      |
| single-ended output slew rate | $SRQ_{se}$ | 1.35V             | 1.75 | 5 <sup>(1)</sup> | 1.75 | 5 <sup>(1)</sup> | 1.75 | 5 <sup>(1)</sup> | 1.75 | 5 <sup>(1)</sup> | 1.75 | 5 <sup>(1)</sup> | 1.75 | 5 <sup>(1)</sup> | V/ns |
|                               |            | 1.5V              | 2.5  | 5                | 2.5  | 5                | 2.5  | 5                | 2.5  | 5                | 2.5  | 5 <sup>(1)</sup> | 2.5  | 5 <sup>(1)</sup> | V/ns |

Description:

SR: Slew Rate

Q: Query Output (like in DQ, which stands for Data-in, Query-Output)

se: Single-ended Signals

For  $R_{ON} = R_{ZQ}/7$  Setting

Note:

- In two cases, a maximum slew rate of 6V/ns applies 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 from 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 5V/ns applies).

## 8.4 Differential Output Slew Rate

With the reference load for timing measurements, output slew rate for falling and rising edges is defined and measured between  $V_{OL,diff(AC)}$  and  $V_{OH,diff(AC)}$  for differential signals as shown in Table-17 and Figure-8.

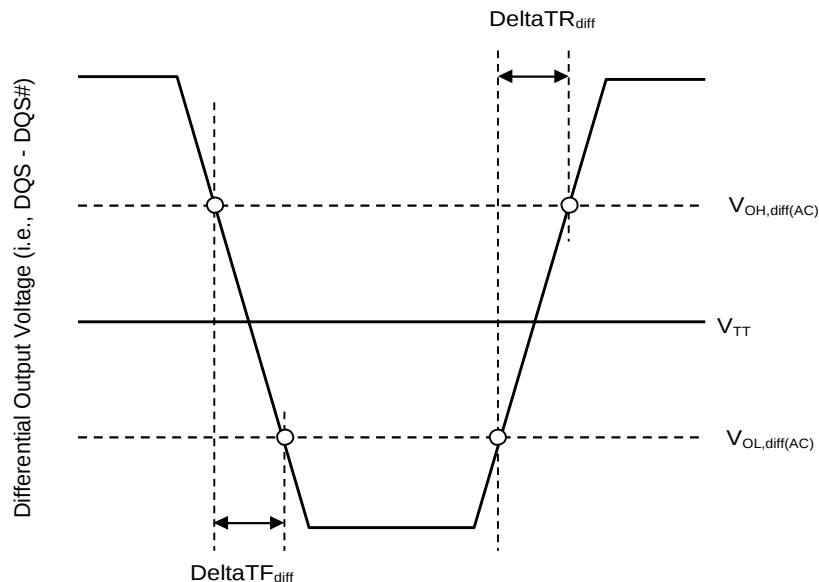
**Table- 17 Differential Output Slew Rate Definition**

| Description                                    | Measured          |                   | Defined by                                             |
|------------------------------------------------|-------------------|-------------------|--------------------------------------------------------|
|                                                | From              | To                |                                                        |
| Differential output slew rate for rising edge  | $V_{OL,diff(AC)}$ | $V_{OH,diff(AC)}$ | $[V_{OH,diff(AC)} - V_{OL,diff(AC)}]/\Delta TR_{diff}$ |
| Differential output slew rate for falling edge | $V_{OH,diff(AC)}$ | $V_{OL,diff(AC)}$ | $[V_{OH,diff(AC)} - V_{OL,diff(AC)}]/\Delta TF_{diff}$ |

Note:

- Output slew rate is verified by design and characterization, and may not be subject to production test.

**Figure- 8 Differential Output Slew Rate Definition**



**Table- 18 Differential Output Slew Rate**

| Parameter                     | Symbol  | Operation Voltage | 800 |     | 1066 |     | 1333 |     | 1600 |     | 1866 |     | 2133 |     | Unit |
|-------------------------------|---------|-------------------|-----|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|
|                               |         |                   | Min | Max | Min  | Max | Min  | Max | Min  | Max | Min  | Max | Min  | Max |      |
| single-ended output slew rate | SRQdiff | 1.35V             | 3.5 | 12  | 3.5  | 12  | 3.5  | 12  | 3.5  | 12  | 3.5  | 12  | 3.5  | 12  | V/ns |
|                               |         | 1.5V              | 5   | 10  | 5    | 10  | 5    | 10  | 5    | 10  | 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

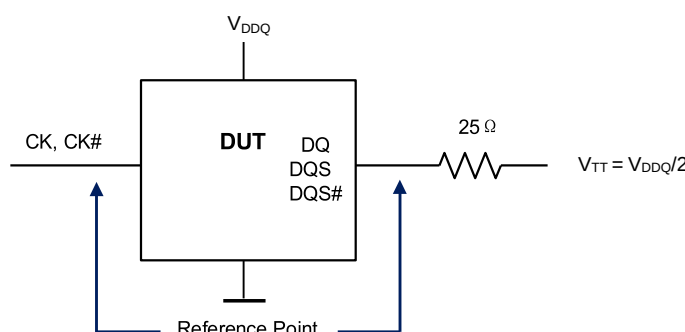
For  $R_{ON} = R_{ZQ}/7$  Setting

## 8.5 Reference Load for AC Timing and Output Slew Rate

Figure-9 represents the effective reference load of  $25\Omega$  used in defining the relevant AC timing parameters of the device as well as output slew rate measurements.

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

**Figure- 9 Reference Load for AC Timing and Output Slew Rate**



## 8.6 Overshoot and Undershoot Specifications

### 8.6.1 Address and Control Overshoot and Undershoot Specifications

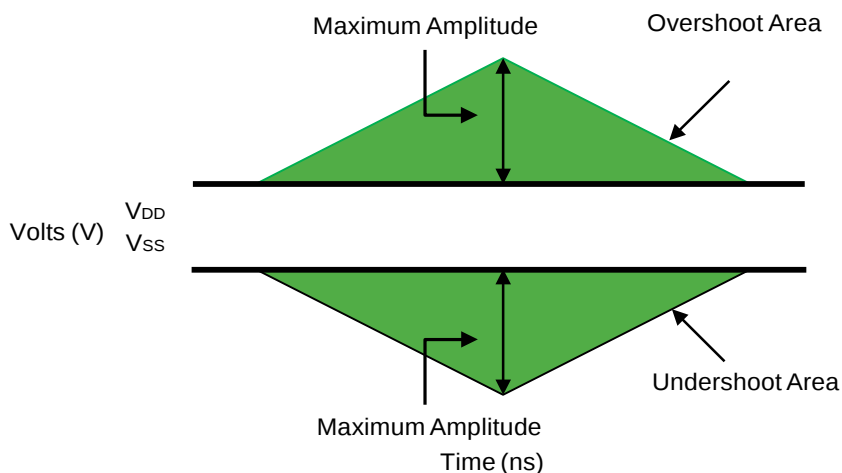
**Table- 19 AC Overshoot/Undershoot Specification for Address and Control Pins**

| Parameter                                                         | 800  | 1066 | 1333 | 1600 | 1866 | 2133 | Unit |
|-------------------------------------------------------------------|------|------|------|------|------|------|------|
| Maximum peak amplitude allowed for overshoot area <sup>(1)</sup>  | 0.4  | 0.4  | 0.4  | 0.4  | 0.4  | 0.4  | V    |
| Maximum peak amplitude allowed for undershoot area <sup>(2)</sup> | 0.4  | 0.4  | 0.4  | 0.4  | 0.4  | 0.4  | V    |
| Maximum overshoot area above $V_{DD}$                             | 0.67 | 0.5  | 0.4  | 0.33 | 0.28 | 0.25 | V-ns |
| Maximum undershoot area below $V_{SS}$                            | 0.67 | 0.5  | 0.4  | 0.33 | 0.28 | 0.25 | V-ns |
| (A0 – A15, BA0 - BA2, CS#, RAS#, CAS#, WE#, CKE, ODT)             |      |      |      |      |      |      |      |

Note:

1. The sum of the applied voltage ( $V_{DD}$ ) and peak amplitude overshoot voltage is not to exceed absolute maximum DC ratings.
2. The sum of the applied voltage ( $V_{DD}$ ) and the peak amplitude undershoot voltage is not to exceed absolute maximum DC ratings.

Figure- 10 Address and Control Overshoot and Undershoot Definition



## 8.6.2 Clock, Data, Strobe and Mask Overshoot and Undershoot Specifications

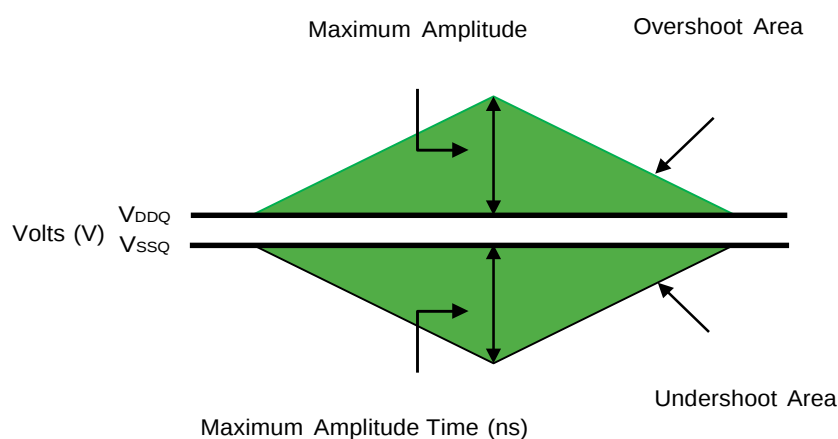
Table- 20 AC Overshoot/Undershoot Specification for Clock, Data, Strobe and Mask

| Parameter                                                         | 800  | 1066 | 1333 | 1600 | 1866 | 2133 | Unit |
|-------------------------------------------------------------------|------|------|------|------|------|------|------|
| Maximum peak amplitude allowed for overshoot area <sup>(1)</sup>  | 0.4  | 0.4  | 0.4  | 0.4  | 0.4  | 0.4  | V    |
| Maximum peak amplitude allowed for undershoot area <sup>(2)</sup> | 0.4  | 0.4  | 0.4  | 0.4  | 0.4  | 0.4  | V    |
| Maximum overshoot area above V <sub>DDQ</sub>                     | 0.25 | 0.19 | 0.15 | 0.13 | 0.11 | 0.10 | V-ns |
| Maximum undershoot area below V <sub>SSQ</sub>                    | 0.25 | 0.19 | 0.15 | 0.13 | 0.11 | 0.10 | V-ns |
| (CK, CK#, DQ, DQS, DQS#, DM)                                      |      |      |      |      |      |      |      |

Note:

1. The sum of the applied voltage (V<sub>DD</sub>) and peak amplitude overshoot voltage is not to exceed absolute maximum DC ratings.
2. The sum of the applied voltage (V<sub>DD</sub>) and the peak amplitude undershoot voltage is not to exceed absolute maximum DC ratings.

Figure- 11 Clock, Data, Strobe and Mask Overshoot and Undershoot Definition



## 8.7 34Ω Output Driver DC Electronic Characteristics

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

$$R_{ON34} = R_{ZQ}/7 \text{ (Nominal } 34.3\Omega \pm 10\% \text{ with nominal } R_{ZQ} = 240\Omega).$$

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

$$R_{ONPu} = \frac{V_{DDQ} - V_{OUT}}{|I_{OUT}|} \text{ under the condition that } R_{ON(Pd)} \text{ is turned off.}$$

$$R_{ONPd} = \frac{V_{OUT}}{|I_{OUT}|} \text{ under the condition that } R_{ON(Pu)} \text{ is turned off.}$$

Figure- 12 Output Driver: Definition of Voltages and Currents

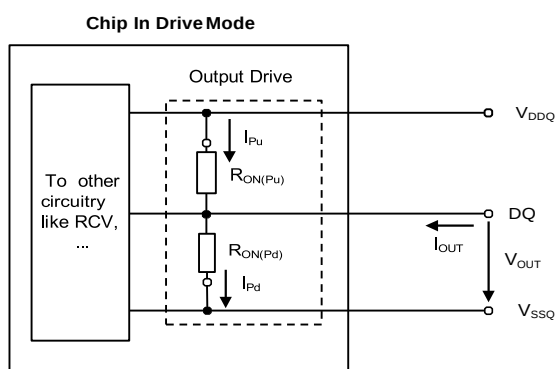


Table- 21 Output Driver DC Electrical Characteristics, assuming  $R_{ZQ} = 240\Omega$ ; entire operating temperature range; after proper ZQ calibration

| $R_{ON,Nom}$                                        | Resistor      | $V_{OUT}$                         | Min | Nom | Max<br>(DDR3L) | Max<br>(DDR3) | Unit       | Note  |
|-----------------------------------------------------|---------------|-----------------------------------|-----|-----|----------------|---------------|------------|-------|
| 34Ω                                                 | $R_{ON,34Pd}$ | $V_{OL(DC)} = 0.2 \times V_{DDQ}$ | 0.6 | 1.0 | 1.15           | 1.1           | $R_{ZQ}/7$ | 1,2,3 |
|                                                     |               | $V_{OM(DC)} = 0.5 \times V_{DDQ}$ | 0.9 | 1.0 | 1.15           | 1.1           | $R_{ZQ}/7$ | 1,2,3 |
|                                                     |               | $V_{OH(DC)} = 0.8 \times V_{DDQ}$ | 0.9 | 1.0 | 1.45           | 1.4           | $R_{ZQ}/7$ | 1,2,3 |
|                                                     | $R_{ON,34Pu}$ | $V_{OL(DC)} = 0.2 \times V_{DDQ}$ | 0.9 | 1.0 | 1.45           | 1.4           | $R_{ZQ}/7$ | 1,2,3 |
|                                                     |               | $V_{OM(DC)} = 0.5 \times V_{DDQ}$ | 0.9 | 1.0 | 1.15           | 1.1           | $R_{ZQ}/7$ | 1,2,3 |
|                                                     |               | $V_{OH(DC)} = 0.8 \times V_{DDQ}$ | 0.6 | 1.0 | 1.15           | 1.1           | $R_{ZQ}/7$ | 1,2,3 |
| 40Ω                                                 | $R_{ON,40Pd}$ | $V_{OL(DC)} = 0.2 \times V_{DDQ}$ | 0.6 | 1.0 | 1.15           | 1.1           | $R_{ZQ}/6$ | 1,2,3 |
|                                                     |               | $V_{OM(DC)} = 0.5 \times V_{DDQ}$ | 0.9 | 1.0 | 1.15           | 1.1           | $R_{ZQ}/6$ | 1,2,3 |
|                                                     |               | $V_{OH(DC)} = 0.8 \times V_{DDQ}$ | 0.9 | 1.0 | 1.45           | 1.4           | $R_{ZQ}/6$ | 1,2,3 |
|                                                     | $R_{ON,40Pu}$ | $V_{OL(DC)} = 0.2 \times V_{DDQ}$ | 0.9 | 1.0 | 1.45           | 1.4           | $R_{ZQ}/6$ | 1,2,3 |
|                                                     |               | $V_{OM(DC)} = 0.5 \times V_{DDQ}$ | 0.9 | 1.0 | 1.15           | 1.1           | $R_{ZQ}/6$ | 1,2,3 |
|                                                     |               | $V_{OH(DC)} = 0.8 \times V_{DDQ}$ | 0.6 | 1.0 | 1.15           | 1.1           | $R_{ZQ}/6$ | 1,2,3 |
| Mismatch between pull-up and pull-down, $MM_{PuPd}$ |               | $V_{OM(DC)} = 0.5 \times V_{DDQ}$ | -10 | -   | +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  $V_{DDQ} = V_{DD}$  and that  $V_{SSQ} = V_{SS}$ .
3. Pull-down and pull-up output driver impedances are recommended to be calibrated at  $0.5 \times V_{DDQ}$ . Other calibration schemes may be used to achieve the linearity spec shown above, e.g. calibration at  $0.2 \times V_{DDQ}$  and  $0.8 \times V_{DDQ}$ .
4. Measurement definition for mismatch between pull-up and pull-down,  $MM_{PuPd}$ :  
Measure  $R_{ON(Pu)}$  and  $R_{ON(Pd)}$ , both at  $0.5 \times V_{DDQ}$ :

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

## 8.7.1 Output Driver Temperature and Voltage Sensitivity

If temperature and/or voltage change after calibration, the tolerance limits widen according to Table 8-10 and Table 8-11.

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

Note:

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

**Table- 22 Output Driver Sensitivity Denfinition**

| Item                    | Min                                                                 | Max                                                                 | Unit  |
|-------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------|-------|
| $R_{ON(Pu)}@V_{OH(DC)}$ | $0.6 - dR_{ONdTH} \times  \Delta T  - dR_{ONdVH} \times  \Delta V $ | $1.1 + dR_{ONdTH} \times  \Delta T  + dR_{ONdVH} \times  \Delta V $ | Rzq/7 |
| $R_{ON}@V_{OM(DC)}$     | $0.9 - dR_{ONdTM} \times  \Delta T  - dR_{ONdVM} \times  \Delta V $ | $1.1 + dR_{ONdTM} \times  \Delta T  + dR_{ONdVM} \times  \Delta V $ | Rzq/7 |
| $R_{ON(Pd)}@V_{OL(DC)}$ | $0.6 - dR_{ONdTL} \times  \Delta T  - dR_{ONdVL} \times  \Delta V $ | $1.1 + dR_{ONdTL} \times  \Delta T  + dR_{ONdVL} \times  \Delta V $ | Rzq/7 |

**Table- 23 Output Driver Voltage and Temperature Sensitivity**

| Speed Bin    | 800/1066/1333 |      | 1600/1866/2133 |      | Unit |
|--------------|---------------|------|----------------|------|------|
| Item         | Min           | Max  | Min            | Max  |      |
| $dR_{ONdTM}$ | 0             | 1.5  | 0              | 1.5  | %/°C |
| $dR_{ONdVM}$ | 0             | 0.15 | 0              | 0.13 | %/mV |
| $dR_{ONdTL}$ | 0             | 1.5  | 0              | 1.5  | %/°C |
| $dR_{ONdVL}$ | 0             | 0.15 | 0              | 0.13 | %/mV |
| $dR_{ONdTH}$ | 0             | 1.5  | 0              | 1.5  | %/°C |
| $dR_{ONdVH}$ | 0             | 0.15 | 0              | 0.13 | %/mV |

Note:

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

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

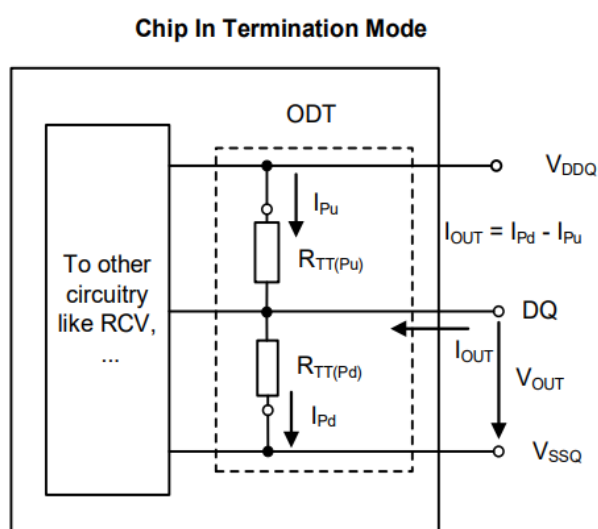
On-Die Termination effective resistance  $R_{TT}$  is defined by bits A9, A6 and A2 of MR1 register. ODT is applied to the DQ, DM, DQS /DQS# pins.

A functional representation of the on-die termination is shown below. The individual pull-up and pull-down resistors ( $R_{TT(Pu)}$  and  $R_{TT(Pd)}$ ) are defined as follows:

$$R_{TTPu} = \frac{V_{DDQ} - V_{out}}{|I_{out}|} \text{ under the condition that } R_{TT(Pd)} \text{ is turned off.}$$

$$R_{TTPd} = \frac{V_{out}}{|I_{out}|} \text{ under the condition that } R_{TT(Pu)} \text{ is turned off.}$$

**Figure- 13 On-Die Termination: Definition of Voltages and Currents**



### 8.8.1 ODT DC Electrical Characteristic

Table-24 provides an overview of the ODT DC electrical characteristics. Their values for  $R_{TT60(Pd120)}$ ,  $R_{TT60(Pu120)}$ ,  $R_{TT120(Pd240)}$ ,  $R_{TT120(Pu240)}$ ,  $R_{TT40(Pd80)}$ ,  $R_{TT40(Pu80)}$ ,  $R_{TT30(Pd60)}$ ,  $R_{TT30(Pu60)}$ ,  $R_{TT20(Pd40)}$ ,  $R_{TT20(Pu40)}$  are not specification requirements, but can be used as design guide lines.

Table- 24 ODT DC Electrics, assuming  $R_{ZQ} = 240\Omega \pm 1\%$  entire operating temperature range; after proper ZQ calibration

| MR1<br>(A9, A6,<br>A2)                                                 | R <sub>TT</sub> | Resistor                   | V <sub>OUT</sub>                             | Min | Nom | Max<br>(DDR3L) | Max<br>(DDR3) | Unit                | Note    |
|------------------------------------------------------------------------|-----------------|----------------------------|----------------------------------------------|-----|-----|----------------|---------------|---------------------|---------|
| (0,1,0)                                                                | 120Ω            | R <sub>TT120</sub> (Pd240) | V <sub>OL(DC)</sub> = 0.2 x V <sub>DDQ</sub> | 0.6 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub>     | 1,2,3,4 |
|                                                                        |                 |                            | 0.5 x V <sub>DDQ</sub>                       | 0.9 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub>     | 1,2,3,4 |
|                                                                        |                 |                            | V <sub>OH(DC)</sub> = 0.8 x V <sub>DDQ</sub> | 0.9 | 1.0 | 1.45           | 1.4           | R <sub>ZQ</sub>     | 1,2,3,4 |
|                                                                        |                 | R <sub>TT120</sub> (Pu240) | V <sub>OL(DC)</sub> = 0.2 x V <sub>DDQ</sub> | 0.9 | 1.0 | 1.45           | 1.4           | R <sub>ZQ</sub>     | 1,2,3,4 |
|                                                                        |                 |                            | 0.5 x V <sub>DDQ</sub>                       | 0.9 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub>     | 1,2,3,4 |
|                                                                        |                 |                            | V <sub>OH(DC)</sub> = 0.8 x V <sub>DDQ</sub> | 0.6 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub>     | 1,2,3,4 |
|                                                                        |                 | R <sub>TT120</sub>         | V <sub>IL(AC)</sub> to V <sub>IH(AC)</sub>   | 0.9 | 1.0 | 1.65           | 1.6           | R <sub>ZQ</sub> /2  | 1,2,5   |
| (0,0,1)                                                                | 60Ω             | R <sub>TT60</sub> (Pd120)  | V <sub>OL(DC)</sub> = 0.2 x V <sub>DDQ</sub> | 0.6 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /2  | 1,2,3,4 |
|                                                                        |                 |                            | 0.5 x V <sub>DDQ</sub>                       | 0.9 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /2  | 1,2,3,4 |
|                                                                        |                 |                            | V <sub>OH(DC)</sub> = 0.8 x V <sub>DDQ</sub> | 0.9 | 1.0 | 1.45           | 1.4           | R <sub>ZQ</sub> /2  | 1,2,3,4 |
|                                                                        |                 | R <sub>TT60</sub> (Pu120)  | V <sub>OL(DC)</sub> = 0.2 x V <sub>DDQ</sub> | 0.9 | 1.0 | 1.45           | 1.4           | R <sub>ZQ</sub> /2  | 1,2,3,4 |
|                                                                        |                 |                            | 0.5 x V <sub>DDQ</sub>                       | 0.9 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /2  | 1,2,3,4 |
|                                                                        |                 |                            | V <sub>OH(DC)</sub> = 0.8 x V <sub>DDQ</sub> | 0.6 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /2  | 1,2,3,4 |
|                                                                        |                 | R <sub>TT60</sub>          | V <sub>IL(AC)</sub> to V <sub>IH(AC)</sub>   | 0.9 | 1.0 | 1.65           | 1.6           | R <sub>ZQ</sub> /4  | 1,2,5   |
| (0,1,1)                                                                | 40Ω             | R <sub>TT40</sub> (Pd80)   | V <sub>OL(DC)</sub> = 0.2 x V <sub>DDQ</sub> | 0.6 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /3  | 1,2,3,4 |
|                                                                        |                 |                            | 0.5 x V <sub>DDQ</sub>                       | 0.9 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /3  | 1,2,3,4 |
|                                                                        |                 |                            | V <sub>OH(DC)</sub> = 0.8 x V <sub>DDQ</sub> | 0.9 | 1.0 | 1.45           | 1.4           | R <sub>ZQ</sub> /3  | 1,2,3,4 |
|                                                                        |                 | R <sub>TT40</sub> (Pu80)   | V <sub>OL(DC)</sub> = 0.2 x V <sub>DDQ</sub> | 0.9 | 1.0 | 1.45           | 1.4           | R <sub>ZQ</sub> /3  | 1,2,3,4 |
|                                                                        |                 |                            | 0.5 x V <sub>DDQ</sub>                       | 0.9 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /3  | 1,2,3,4 |
|                                                                        |                 |                            | V <sub>OH(DC)</sub> = 0.8 x V <sub>DDQ</sub> | 0.6 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /3  | 1,2,3,4 |
|                                                                        |                 | R <sub>TT40</sub>          | V <sub>IL(AC)</sub> to V <sub>IH(AC)</sub>   | 0.9 | 1.0 | 1.65           | 1.6           | R <sub>ZQ</sub> /6  | 1,2,5   |
| (1,0,1)                                                                | 30Ω             | R <sub>TT30</sub> (Pd60)   | V <sub>OL(DC)</sub> = 0.2 x V <sub>DDQ</sub> | 0.6 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /4  | 1,2,3,4 |
|                                                                        |                 |                            | 0.5 x V <sub>DDQ</sub>                       | 0.9 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /4  | 1,2,3,4 |
|                                                                        |                 |                            | V <sub>OH(DC)</sub> = 0.8 x V <sub>DDQ</sub> | 0.9 | 1.0 | 1.45           | 1.4           | R <sub>ZQ</sub> /4  | 1,2,3,4 |
|                                                                        |                 | R <sub>TT30</sub> (Pu60)   | V <sub>OL(DC)</sub> = 0.2 x V <sub>DDQ</sub> | 0.9 | 1.0 | 1.45           | 1.4           | R <sub>ZQ</sub> /4  | 1,2,3,4 |
|                                                                        |                 |                            | 0.5 x V <sub>DDQ</sub>                       | 0.9 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /4  | 1,2,3,4 |
|                                                                        |                 |                            | V <sub>OH(DC)</sub> = 0.8 x V <sub>DDQ</sub> | 0.6 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /4  | 1,2,3,4 |
|                                                                        |                 | R <sub>TT30</sub>          | V <sub>IL(AC)</sub> to V <sub>IH(AC)</sub>   | 0.9 | 1.0 | 1.65           | 1.6           | R <sub>ZQ</sub> /8  | 1,2,5   |
| (1,0,0)                                                                | 20Ω             | R <sub>TT20</sub> (Pd40)   | V <sub>OL(DC)</sub> = 0.2 x V <sub>DDQ</sub> | 0.6 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /6  | 1,2,3,4 |
|                                                                        |                 |                            | 0.5 x V <sub>DDQ</sub>                       | 0.9 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /6  | 1,2,3,4 |
|                                                                        |                 |                            | V <sub>OH(DC)</sub> = 0.8 x V <sub>DDQ</sub> | 0.9 | 1.0 | 1.45           | 1.4           | R <sub>ZQ</sub> /6  | 1,2,3,4 |
|                                                                        |                 | R <sub>TT20</sub> (Pu40)   | V <sub>OL(DC)</sub> = 0.2 x V <sub>DDQ</sub> | 0.9 | 1.0 | 1.45           | 1.4           | R <sub>ZQ</sub> /6  | 1,2,3,4 |
|                                                                        |                 |                            | 0.5 x V <sub>DDQ</sub>                       | 0.9 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /6  | 1,2,3,4 |
|                                                                        |                 |                            | V <sub>OH(DC)</sub> = 0.8 x V <sub>DDQ</sub> | 0.6 | 1.0 | 1.15           | 1.1           | R <sub>ZQ</sub> /6  | 1,2,3,4 |
|                                                                        |                 | R <sub>TT20</sub>          | V <sub>IL(AC)</sub> to V <sub>IH(AC)</sub>   | 0.9 | 1.0 | 1.65           | 1.6           | R <sub>ZQ</sub> /12 | 1,2,5   |
| Deviation of V <sub>M</sub> w.r.t V <sub>DDQ</sub> /2, ΔV <sub>M</sub> |                 |                            |                                              | -5  | -   | +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  $V_{DDQ} = V_{DD}$  and that  $V_{SSQ} = V_{SS}$ .
3. Pull-down and pull-up ODT resistors are recommended to be calibrated at  $0.5 \times V_{DDQ}$ . Other calibration schemes may be used to achieve the linearity spec shown above, e.g. calibration at  $0.2 \times V_{DDQ}$  and  $0.8 \times V_{DDQ}$ .
4. Not a specification requirement, but a design guide line.
5. Measurement definition for  $R_{TT}$ :

Apply  $V_{IH(AC)}$  to pin under test and measure current  $I(V_{IH(AC)})$ , then apply  $V_{IL(AC)}$  to pin under test and measure current  $I(V_{IL(AC)})$  respectively.

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

6. Measurement definition for VM and  $\Delta VM$ :  $\Delta$ Measure voltage (VM) at test pin (midpoint) with no load:

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

## 8.8.2 ODT DC Temperature and Voltage Sensitivity

If temperature and/or voltage change after calibration, the tolerance limits widen according to Table-25 and Table-26.

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

**Table- 25 ODT Sensitivity Definition**

|          | Min                                                               | Max                                                               | Unit                    |
|----------|-------------------------------------------------------------------|-------------------------------------------------------------------|-------------------------|
| $R_{TT}$ | $0.9 - dR_{TTdT} \times  \Delta T  - dR_{TTdV} \times  \Delta V $ | $1.6 + dR_{TTdT} \times  \Delta T  + dR_{TTdV} \times  \Delta V $ | $R_{ZQ}/2, 4, 6, 8, 12$ |

**Table- 26 ODT Voltage and Temperature Sensitivity**

|             | Min | Max  | Unit |
|-------------|-----|------|------|
| $dR_{TTdT}$ | 0   | 1.5  | %/°C |
| $dR_{TTdV}$ | 0   | 0.15 | %/mV |

Note:

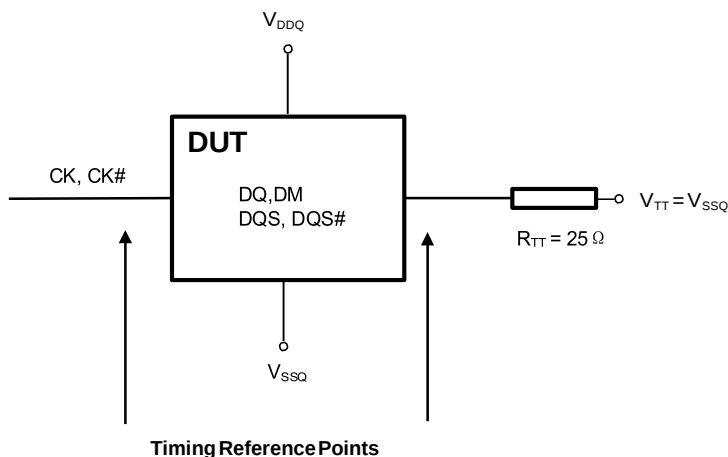
- These parameters may not be subject to production test. They are verified by design and characterization.

## 8.9 ODT Timing Definitions

### 8.9.1 Test Load for ODT Timings

Different than for timing measurements, the reference load for ODT timings is defined in Figure- 14.

**Figure- 14 ODT Timing Reference Load**



### 8.9.2 ODT Timing Definitions

Definitions for  $t_{AON}$ ,  $t_{AONPD}$ ,  $t_{AOF}$ ,  $t_{AOFPD}$  and  $t_{ADC}$  are provided in Table- 27 and subsequent figures. Measurement reference settings are provided in Table- 28.

**Table- 27 ODT Timing Definitions**

| Symbol      | Begin Point Definition                                                            | End Point Definition                                                           | Figure      |
|-------------|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------|-------------|
| $t_{AON}$   | Rising edge of CK - CK# defined by the end point of ODTLon                        | Extrapolated point at $V_{SSQ}$                                                | Figure 8-9  |
| $t_{AONPD}$ | Rising edge of CK - CK# with ODT being first registered HIGH                      | Extrapolated point at $V_{SSQ}$                                                | Figure 8-10 |
| $t_{AOF}$   | Rising edge of CK - CK# defined by the end point of ODTLoff                       | End point: Extrapolated point at $V_{RTT,Nom}$                                 | Figure 8-11 |
| $t_{AOFPD}$ | Rising edge of CK - CK# with ODT being first registered LOW                       | End point: Extrapolated point at $V_{RTT,Nom}$                                 | Figure 8-12 |
| $t_{ADC}$   | Rising edge of CK - CK# defined by the end point of ODTLcnw, ODTLcwn4 of ODTLcwn8 | End point: Extrapolated points at $V_{RTT(WR)}$ and $V_{RTT,Nom}$ respectively | Figure 8-13 |

Table- 28 Reference Settings for ODT Timing Measurements

| Measured Parameter |              | $R_{TT,Nom}$ Setting | $R_{TT(WR)}$ Setting | $V_{SW1}[V]$ | $V_{SW2}[V]$ |
|--------------------|--------------|----------------------|----------------------|--------------|--------------|
| $t_{AON}$          |              | $R_{ZQ}/4$           | NA                   | 0.05         | 0.10         |
|                    |              | $R_{ZQ}/12$          | NA                   | 0.10         | 0.20         |
| $t_{AONPD}$        |              | $R_{ZQ}/4$           | NA                   | 0.05         | 0.10         |
|                    |              | $R_{ZQ}/12$          | NA                   | 0.10         | 0.20         |
| $t_{AOF}$          |              | $R_{ZQ}/4$           | NA                   | 0.05         | 0.10         |
|                    |              | $R_{ZQ}/12$          | NA                   | 0.10         | 0.20         |
| $t_{AOFPD}$        |              | $R_{ZQ}/4$           | NA                   | 0.05         | 0.10         |
|                    |              | $R_{ZQ}/12$          | NA                   | 0.10         | 0.20         |
| $t_{ADC}$          | DDR3L(1.35V) | $R_{ZQ}/12$          | $R_{ZQ}/2$           | 0.20         | 0.25         |
|                    | DDR3(1.5V)   | $R_{ZQ}/12$          | $R_{ZQ}/2$           | 0.20         | 0.30         |

Figure- 15 Definition of  $t_{AON}$

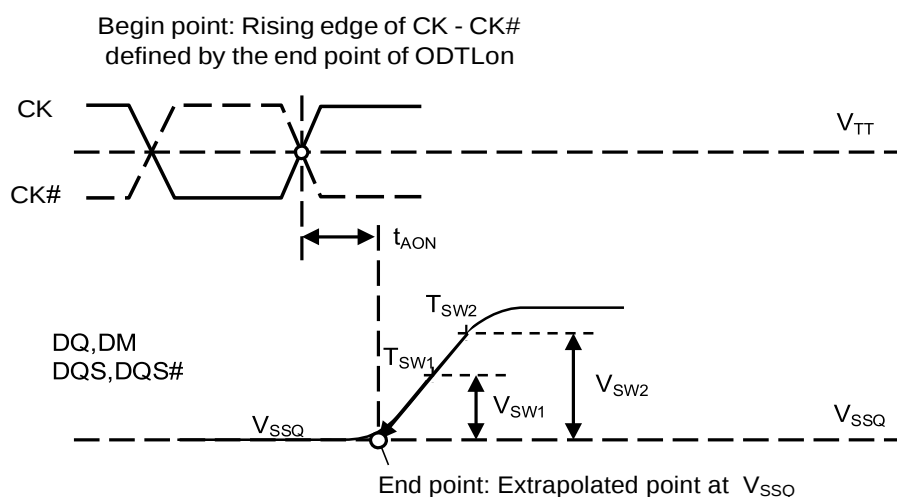


Figure- 16 Definition of  $t_{AONPD}$

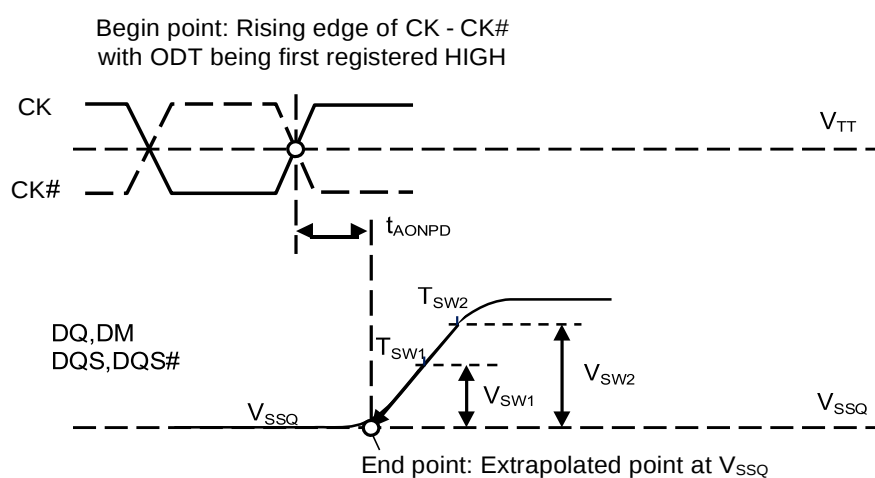


Figure- 17 Definition of  $t_{AOF}$

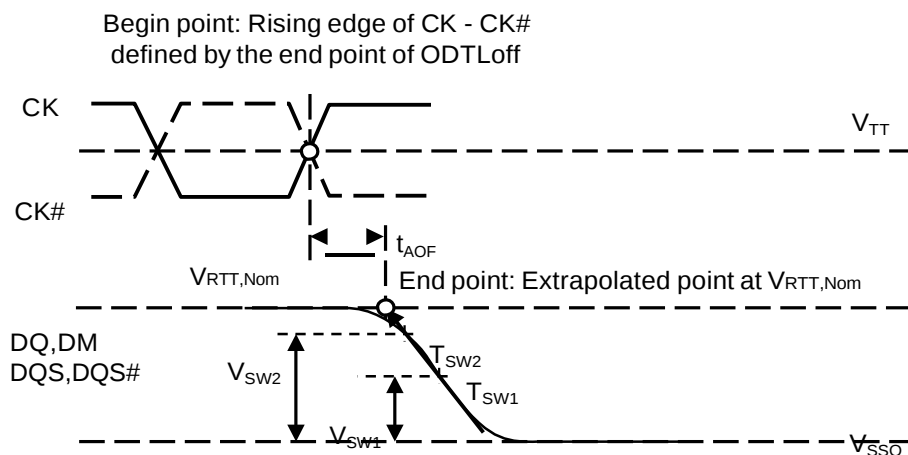


Figure- 18 Definition of  $t_{AOFPD}$

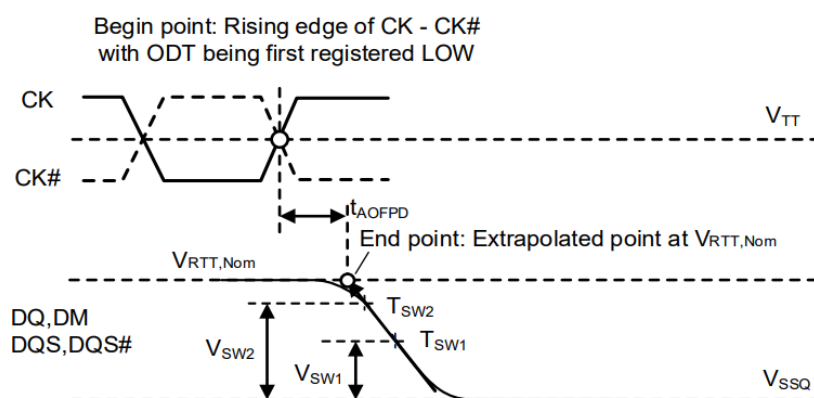
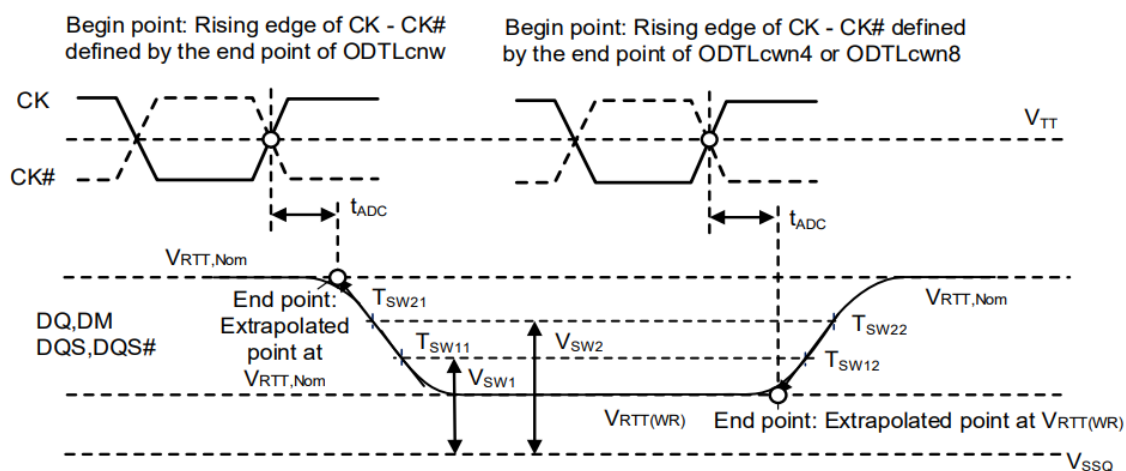


Figure- 19 Definition of  $t_{ADC}$



## 9 I<sub>DD</sub> CURRENT MEASURE METHOD

### 9.1 I<sub>DD</sub> Measurement Conditions

In this chapter, I<sub>DD</sub> and I<sub>DDQ</sub> measurement conditions such as test load and patterns are defined. Figure- 20 shows the setup and test load for I<sub>DD</sub> and I<sub>DDQ</sub> measurements.

- I<sub>DD</sub> currents (such as I<sub>DD0</sub>, I<sub>DD1</sub>, I<sub>DD2N</sub>, I<sub>DD2NT</sub>, I<sub>DD2P0</sub>, I<sub>DD2P1</sub>, I<sub>DD2Q</sub>, I<sub>DD3N</sub>, I<sub>DD3P</sub>, I<sub>DD4R</sub>, I<sub>DD4W</sub>, I<sub>DD5B</sub>, I<sub>DD6</sub>, I<sub>DD6ET</sub>, I<sub>DD6TC</sub> and I<sub>DD7</sub>) are measured as time-averaged currents with all V<sub>DD</sub> balls of the DDR3 SDRAM under test tied together. Any I<sub>DDQ</sub> current is not included in I<sub>DD</sub> currents.
- I<sub>DDQ</sub> currents (such as I<sub>DDQ2NT</sub> and I<sub>DDQ4R</sub>) are measured as time-averaged currents with all V<sub>DDQ</sub> balls of the DDR3 SDRAM under test tied together. Any I<sub>DD</sub> current is not included in I<sub>DDQ</sub> currents.

Attention: I<sub>DDQ</sub> values cannot be directly used to calculate I/O power of the DDR3 SDRAM. They can be used to support correlation of simulated I/O power to actual I/O power as outlined in Figure- 21. In DRAM module application, I<sub>DDQ</sub> cannot be measured separately since V<sub>DD</sub> and V<sub>DDQ</sub> are using one merged-power layer in Module PCB.

**For I<sub>DD</sub> and I<sub>DDQ</sub> measurements, the following definitions apply:**

- "0" and "LOW" is defined as  $V_{IN} \leq V_{IL.AC(max)}$ .
- "1" and "HIGH" is defined as  $V_{IN} \geq V_{IH.AC(min)}$ .
- "MID-LEVEL" is defined as inputs are  $V_{REF} = V_{DD} / 2$ .
- "Timing used for I<sub>DD</sub> and I<sub>DDQ</sub> Measured - Loop Patterns" are provided in Table- 29.
- "Basic IDD and IDDQ Measurement Conditions" are described in Table- 30
- Detailed I<sub>DD</sub> and I<sub>DDQ</sub> Measurement-Loop Patterns are described in Table 9-3 through Table- 38.
- I<sub>DD</sub> Measurements are done after properly initializing the DDR3 SDRAM. This includes but is not limited to setting:  
 $R_{ON} = R_{ZQ} / 7$  (34Ω in MR1)  
 Qoff = 0b (Output Buffer enabled in MR1)  
 $R_{TT,Nom} = R_{ZQ} / 6$  (40Ω in MR1)  
 $R_{TT(WR)} = R_{ZQ} / 2$  (120Ω in MR2)  
 TDQS Feature disabled in MR1

**Attention:** The I<sub>DD</sub> and I<sub>DDQ</sub> Measurement-Loop Patterns need to be executed at least one time before actual I<sub>DD</sub> or I<sub>DDQ</sub> measurement is started.

- Define D = {CS#, RAS#, CAS#, WE#} = {HIGH, LOW, LOW, LOW}
- Define D# = {CS#, RAS#, CAS#, WE#} = {HIGH, HIGH, HIGH, HIGH}

Figure- 20 Measurement Setup and Test Load for IDD and IDDQ Measurements

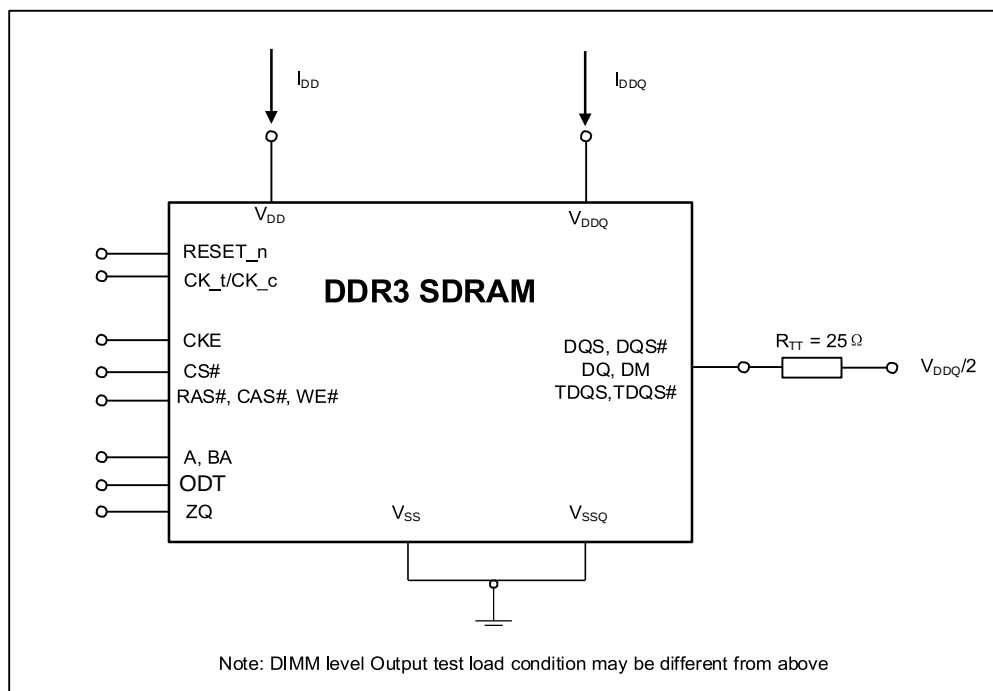


Figure- 21 Correlation from Simulated Channel I/O Power to Actual Channel I/O Power Supported by IDDQ Measurement

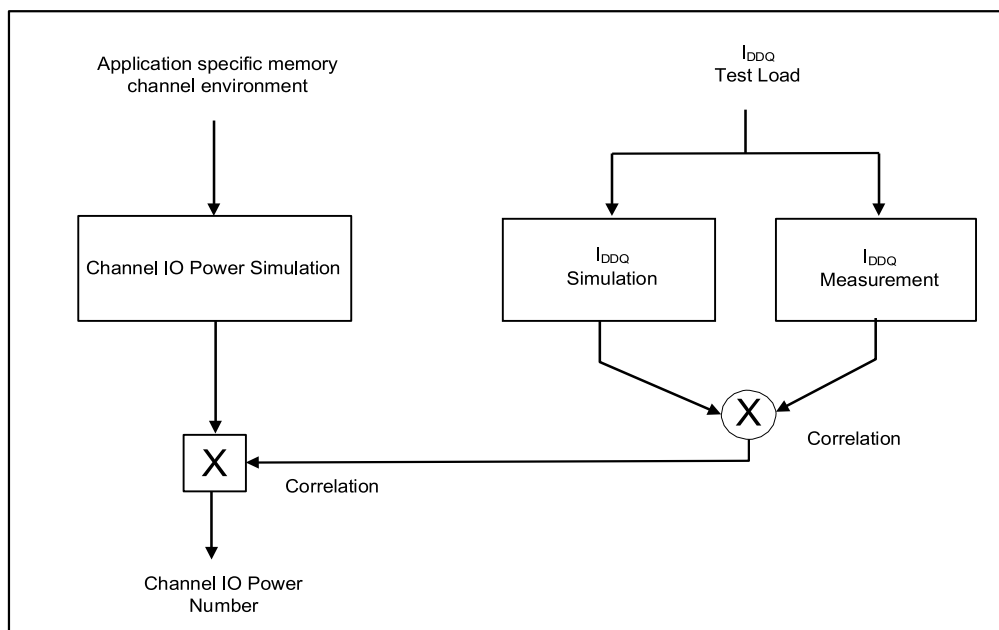


Table- 29 Timing used for I<sub>DD</sub> and I<sub>DDQ</sub> Measured-Loop Patterns for 1866/2133

| Symbol          |               | DDR3/DDR3L<br>1866 | DDR3/DDR3L<br>2133 | Unit |
|-----------------|---------------|--------------------|--------------------|------|
|                 |               | 13-13-13           | 14-14-14           |      |
| t <sub>CK</sub> |               | 1.071              | 0.938              | ns   |
| CL              |               | 13                 | 14                 | nCK  |
| nRCD            |               | 13                 | 14                 | nCK  |
| nRC             |               | 45                 | 50                 | nCK  |
| nRAS            |               | 32                 | 36                 | nCK  |
| nRP             |               | 13                 | 14                 | nCK  |
| nFAW            | 1KB page size | 26                 | 27                 | nCK  |
|                 | 2KB page size | 33                 | 38                 | nCK  |
| nRRD            | 1KB page size | 5                  | 6                  | nCK  |
|                 | 2KB page size | 6                  | 7                  | nCK  |
| nRFC 512Mb      |               | 85                 | 97                 | nCK  |
| nRFC 1Gb        |               | 103                | 118                | nCK  |
| nRFC 2Gb        |               | 150                | 172                | nCK  |
| nRFC 4Gb        |               | 243                | 279                | nCK  |
| nRFC 8Gb        |               | 328                | 375                | nCK  |

Table- 30 Basic IDD and IDDQ Measurement Conditions

| Symbol           | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I <sub>DD0</sub> | <p><b>Operating One Bank Active-Precharge Current</b><br/> <b>CKE:</b> HIGH<br/> <b>External Clock:</b> On<br/> <b>t<sub>CK</sub>, nRC, nRAS, nRCD, CL:</b> See Table- 29<br/> <b>BL:</b> 8<sup>(1)</sup><br/> <b>AL:</b> 0<br/> <b>CS#:</b> HIGH between ACT and PRE<br/> <b>Command, Address, Bank Address Inputs:</b> Partially toggling according to Table- 31<br/> <b>Data I/O:</b> MID-LEVEL<br/> <b>DM:</b> Stable at 0<br/> <b>Bank Activity:</b> Cycling with one bank active at a time: 0,0,1,1,2,2, ... (see Table- 31)<br/> <b>Output Buffer and R<sub>TT</sub>:</b> Enabled in Mode Registers<sup>(2)</sup><br/> <b>ODT Signal:</b> Stable at 0<br/> <b>Pattern Details:</b> See Table- 31</p> |
| I <sub>DD1</sub> | <p><b>Operating One Bank Active-Read-Precharge Current</b><br/> <b>CKE:</b> HIGH<br/> <b>External Clock:</b> On<br/> <b>t<sub>CK</sub>, nRC, nRAS, nRCD, CL:</b> See Table- 29<br/> <b>BL:</b> 8<sup>(1,6)</sup><br/> <b>AL:</b> 0<br/> <b>CS#:</b> HIGH between ACT, RD and PRE<br/> <b>Command, Address, Bank Address Inputs, Data I/O:</b> Partially toggling according to Table- 32<br/> <b>DM:</b> Stable at 0<br/> <b>Bank Activity:</b> Cycling with one bank active at a time: 0,0,1,1,2,2, ... (see Table- 32)<br/> <b>Output Buffer and R<sub>TT</sub>:</b> Enabled in Mode Registers<sup>(2)</sup><br/> <b>ODT Signal:</b> Stable at 0<br/> <b>Pattern Details:</b> See Table- 32</p>            |

| Symbol       | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|--------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $I_{DD2N}$   | <b>Precharge Standby Current</b><br><b>CKE:</b> HIGH<br><b>External Clock:</b> On<br><b>tCK, CL:</b> See Table- 29<br><b>BL:</b> 8 <sup>(1)</sup><br><b>AL:</b> 0<br><b>CS#:</b> Stable at 1<br><b>Command, Address, Bank Address Inputs:</b> Partially toggling according to Table- 33<br><b>Data I/O:</b> MID-LEVEL<br><b>DM:</b> Stable at 0<br><b>Bank Activity:</b> All banks closed<br><b>Output Buffer and RTT:</b> Enabled in Mode Registers <sup>(2)</sup><br><b>ODT Signal:</b> Stable at 0<br><b>Pattern Details:</b> See Table- 33                     |
| $I_{DD2NT}$  | <b>Precharge Standby ODT Current</b><br><b>CKE:</b> HIGH<br><b>External Clock:</b> On<br><b>tCK, CL:</b> See Table- 29<br><b>BL:</b> 8 <sup>(1)</sup><br><b>AL:</b> 0<br><b>CS#:</b> Stable at 1<br><b>Command, Address, Bank Address Inputs:</b> Partially toggling according to Table- 34<br><b>Data I/O:</b> MID-LEVEL<br><b>DM:</b> Stable at 0<br><b>Bank Activity:</b> All banks closed<br><b>Output Buffer and RTT:</b> Enabled in Mode Registers <sup>(2)</sup><br><b>ODT Signal:</b> Toggling according to Table- 34<br><b>Pattern Details:</b> Table- 34 |
| $I_{DDQ2NT}$ | <b>Precharge Standby ODT <math>I_{DDQ}</math> Current</b><br>Same definition like for $I_{DD2NT}$ , however measuring $I_{DDQ}$ current instead of $I_{DD}$ current.                                                                                                                                                                                                                                                                                                                                                                                               |
| $I_{DD2P0}$  | <b>Precharge Power-Down Current Slow Exit</b><br><b>CKE:</b> LOW<br><b>External Clock:</b> On<br><b>tCK, CL:</b> See Table- 29<br><b>BL:</b> 8 <sup>(1)</sup><br><b>AL:</b> 0<br><b>CS#:</b> Stable at 1<br><b>Command, Address, Bank Address Inputs:</b> Stable at 0<br><b>Data I/O:</b> MID-LEVEL<br><b>DM:</b> Stable at 0<br><b>Bank Activity:</b> All banks closed<br><b>Output Buffer and RTT:</b> Enabled in Mode Registers <sup>(2)</sup><br><b>ODT Signal:</b> Stable at 0<br><b>Precharge Power Down Mode:</b> Slow Exit <sup>(3)</sup>                  |
| $I_{PP2P1}$  | <b>Precharge Power-Down Current Fast Exit</b><br><b>CKE:</b> LOW<br><b>External Clock:</b> On<br><b>tCK, CL:</b> See Table- 29<br><b>BL:</b> 8 <sup>(1)</sup><br><b>AL:</b> 0<br><b>CS#:</b> Stable at 1<br><b>Command, Address, Bank Address Inputs:</b> Stable at 0<br><b>Data I/O:</b> MID-LEVEL<br><b>DM:</b> Stable at 0<br><b>Bank Activity:</b> All banks closed<br><b>Output Buffer and RTT:</b> Enabled in Mode Registers <sup>(2)</sup><br><b>ODT Signal:</b> Stable at 0<br><b>Precharge Power Down Mode:</b> Fast Exit <sup>(3)</sup>                  |

| Symbol             | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I <sub>DD2Q</sub>  | <b>Precharge Quiet Standby Current</b><br><b>CKE:</b> HIGH<br><b>External Clock:</b> On<br><b>t<sub>CK</sub>, CL:</b> See Table- 29<br><b>BL:</b> 8 <sup>(1)</sup><br><b>AL:</b> 0<br><b>CS#:</b> Stable at 1<br><b>Command, Address, Bank Address Inputs:</b> Stable at 0<br><b>Data I/O:</b> MID-LEVEL<br><b>DM:</b> Stable at 0<br><b>Bank Activity:</b> All banks closed<br><b>Output Buffer and R<sub>TT</sub>:</b> Enabled in Mode Registers <sup>(2)</sup><br><b>ODT Signal:</b> Stable at 0                                                                                                                                                                                                                                           |
| I <sub>DD3N</sub>  | <b>Active Standby Current</b><br><b>CKE:</b> HIGH<br><b>External Clock:</b> On<br><b>t<sub>CK</sub>, CL:</b> See Table- 29<br><b>BL:</b> 8 <sup>(1)</sup><br><b>AL:</b> 0<br><b>CS#:</b> Stable at 1<br><b>Command, Address, Bank Address Inputs:</b> Partially toggling according to Table- 33<br><b>Data I/O:</b> MID-LEVEL<br><b>DM:</b> Stable at 0<br><b>Bank Activity:</b> All banks open<br><b>Output Buffer and R<sub>TT</sub>:</b> Enabled in Mode Registers <sup>(2)</sup><br><b>ODT Signal:</b> Stable at 0<br><b>Pattern Details:</b> See Table- 33                                                                                                                                                                               |
| I <sub>DD3P</sub>  | <b>Active Power-Down Current</b><br><b>CKE:</b> LOW<br><b>External Clock:</b> On<br><b>t<sub>CK</sub>, CL:</b> See Table- 29<br><b>BL:</b> 8 <sup>(1)</sup><br><b>AL:</b> 0<br><b>CS#:</b> Stable at 1<br><b>Command, Address, Bank Address Inputs:</b> Stable at 0<br><b>Data I/O:</b> MID-LEVEL<br><b>DM:</b> Stable at 0<br><b>Bank Activity:</b> All banks open<br><b>Output Buffer and R<sub>TT</sub>:</b> Enabled in Mode Registers <sup>(2)</sup><br><b>ODT Signal:</b> Stable at 0                                                                                                                                                                                                                                                    |
| I <sub>DD4R</sub>  | <b>Operating Burst Read Current</b><br><b>CKE:</b> HIGH<br><b>External Clock:</b> On<br><b>t<sub>CK</sub>, CL:</b> See Table- 29<br><b>BL:</b> 8 <sup>(1,6)</sup><br><b>AL:</b> 0<br><b>CS#:</b> HIGH between RD<br><b>Command, Address, Bank Address Inputs:</b> Partially toggling according to Table- 35<br><b>Data I/O:</b> Seamless read data burst with different data between one burst and the next one according to Table- 35<br><b>DM:</b> Stable at 0<br><b>Bank Activity:</b> All banks open, RD commands cycling through banks: 0,0,1,1,2,2, ... (see Table- 35)<br><b>Output Buffer and R<sub>TT</sub>:</b> Enabled in Mode Registers <sup>(2)</sup><br><b>ODT Signal:</b> Stable at 0<br><b>Pattern Details:</b> See Table- 35 |
| I <sub>DDQ4R</sub> | <b>Operating Burst Read I<sub>DDQ</sub> Current</b><br>Same definition like for I <sub>DD4R</sub> , however measuring I <sub>DDQ</sub> current instead of I <sub>DD</sub> current.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

| Symbol             | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|--------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I <sub>DD4W</sub>  | <p><b>Operating Burst Write Current</b><br/> <b>CKE:</b> HIGH<br/> <b>External Clock:</b> On<br/> <b>t<sub>CK</sub>, CL:</b> See Table- 29<br/> <b>BL:</b> 8<sup>(1)</sup><br/> <b>AL:</b> 0<br/> <b>CS#:</b> HIGH between WR<br/> <b>Command, Address, Bank Address Inputs:</b> Partially toggling according to Table- 36<br/> <b>Data I/O:</b> Seamless write data burst with different data between one burst and the next one according to Table- 36<br/> <b>DM:</b> Stable at 0<br/> <b>Bank Activity:</b> All banks open, WR commands cycling through banks: 0,0,1,1,2,2, ... (see Table- 36)<br/> <b>Output Buffer and R<sub>TT</sub>:</b> Enabled in Mode Registers<sup>(2)</sup><br/> <b>ODT Signal:</b> Stable at HIGH<br/> <b>Pattern Details:</b> See Table- 36</p> |
| I <sub>DD5B</sub>  | <p><b>Burst Refresh Current</b><br/> <b>CKE:</b> HIGH<br/> <b>External Clock:</b> On<br/> <b>t<sub>CK</sub>, CL:</b> See Table- 29<br/> <b>BL:</b> 8<sup>(1)</sup><br/> <b>AL:</b> 0<br/> <b>CS#:</b> HIGH between REF<br/> <b>Command, Address, Bank Address Inputs:</b> Partially toggling according to Table- 37<br/> <b>Data I/O:</b> MID-LEVEL<br/> <b>DM:</b> Stable at 0<br/> <b>Bank Activity:</b> REF command every nRFC (see Table- 37)<br/> <b>Output Buffer and R<sub>TT</sub>:</b> Enabled in Mode Registers<sup>(2)</sup><br/> <b>ODT Signal:</b> Stable at 0<br/> <b>Pattern Details:</b> See Table- 37</p>                                                                                                                                                      |
| I <sub>DD6</sub>   | <p><b>Self Refresh Current: Normal Temperature Range</b><br/> <b>T<sub>CASE</sub>:</b> 0 - 85°C<br/> <b>Auto Self Refresh (ASR):</b> Disabled<sup>(4)</sup><br/> <b>Self Refresh Temperature Range (SRT):</b> Normal<sup>(5)</sup><br/> <b>CKE:</b> LOW<br/> <b>External Clock:</b> Off<br/> <b>CK and CK#:</b> LOW<br/> <b>CL:</b> See Table- 29<br/> <b>BL:</b> 8<sup>(1)</sup><br/> <b>AL:</b> 0<br/> <b>CS#, Command, Address, Bank Address, Data I/O:</b> MID-LEVEL<br/> <b>DM:</b> Stable at 0<br/> <b>Bank Activity:</b> Self Refresh operation<br/> <b>Output Buffer and R<sub>TT</sub>:</b> Enabled in Mode Registers<sup>(2)</sup><br/> <b>ODT Signal:</b> MID-LEVEL</p>                                                                                              |
| I <sub>DD6ET</sub> | <p><b>Self Refresh Current: Extended Temperature Range</b><br/> <b>T<sub>CASE</sub>:</b> 0 - 95°C<br/> <b>Auto Self Refresh (ASR):</b> Disabled<sup>(4)</sup><br/> <b>Self Refresh Temperature Range (SRT):</b> Extended<sup>(5)</sup><br/> <b>CKE:</b> LOW<br/> <b>External Clock:</b> Off<br/> <b>CK and CK#:</b> LOW<br/> <b>CL:</b> See Table- 29<br/> <b>BL:</b> 8<sup>(1,6)</sup><br/> <b>AL:</b> 0<br/> <b>CS#, Command, Address, Bank Address, Data I/O:</b> MID-LEVEL<br/> <b>DM:</b> Stable at 0<br/> <b>Bank Activity:</b> Extended Temperature Self Refresh operation<br/> <b>Output Buffer and R<sub>TT</sub>:</b> Enabled in Mode Registers<sup>(2)</sup><br/> <b>ODT Signal:</b> MID-LEVEL</p>                                                                   |

| Symbol             | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I <sub>DD6TC</sub> | <b>Auto Self-Refresh Current (optional)</b><br>T <sub>CASE</sub> : 0 - 95°C<br><b>Auto Self-Refresh (ASR):</b> Enabled <sup>(4)</sup><br><b>Self-Refresh Temperature Range (SRT):</b> Normal <sup>(5)</sup><br><b>CKE:</b> Low<br><b>External clock:</b> Off<br><b>CK and CK#:</b> LOW;<br><b>CL:</b> see Table- 29<br><b>BL:</b> 8 <sup>(1)</sup><br><b>AL:</b> 0<br><b>CS#, Command, Address, Bank Address, Data IO:</b> MID-LEVEL<br><b>DM:</b> stable at 0<br><b>Bank Activity:</b> Auto Self-Refresh operation<br><b>Output Buffer and R<sub>TT</sub>:</b> Enabled in Mode Registers <sup>(2)</sup><br><b>ODT Signal:</b> MID-LEVEL                                                                                                                                                               |
| I <sub>DD7</sub>   | <b>Operating Bank Interleave Read Current</b><br><b>CKE:</b> HIGH<br><b>External Clock:</b> On<br><b>t<sub>CK</sub>, nRC, nRAS, nRCD, nRRD, nFAW, CL:</b> See Table- 29<br><b>BL:</b> 8 <sup>(1,6)</sup><br><b>AL:</b> CL-1<br><b>CS#:</b> HIGH between ACT and RDA<br><b>Command, Address, Bank Address Inputs:</b> Partially toggling according to Table- 38<br><b>Data I/O:</b> Read data bursts with different data between one burst and the next one according to Table- 38<br><b>DM:</b> Stable at 0<br><b>Bank Activity:</b> Two times interleaved cycling through banks (0, 1, ...7) with different addressing, see Table- 38<br><b>Output Buffer and R<sub>TT</sub>:</b> Enabled in Mode Registers <sup>(2)</sup><br><b>ODT Signal:</b> Stable at 0<br><b>Pattern Details:</b> See Table- 38 |
| I <sub>DD8</sub>   | <b>RESET Low Current</b><br><b>RESET:</b> LOW<br><b>External Clock:</b> Off<br><b>CK and CK#:</b> LOW<br><b>CKE:</b> FLOATING<br><b>CS#, Command, Address, Bank Address, Data I/O:</b> FLOATING<br><b>ODT Signal:</b> FLOATING<br>RESET Low current reading is valid once power is stable and RESET has been LOW for at least 1ms.                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

Note:

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

Table- 31 I<sub>DD0</sub> Measurement-Loop Pattern<sup>(1)</sup>

| CK, CK#  | CKE         | Sub-Loop | Cycle Number   | Command                                                                    | CS# | RAS# | CAS# | WE# | ODT | BA[2:0] | A[15:14] | A[10] | A[9:7] | A[6:3] | A[2:0] | Data <sup>(2)</sup> |
|----------|-------------|----------|----------------|----------------------------------------------------------------------------|-----|------|------|-----|-----|---------|----------|-------|--------|--------|--------|---------------------|
| 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:

- DM must be driven LOW all the time. DQS, DQS# are MID-LEVEL.  
DQ signals are MID-LEVEL.

Table- 32 I<sub>DD1</sub> Measurement-Loop Pattern<sup>(1)</sup>

| CK, CK#  | CKE         | Sub-Loop | Cycle Number <sup>r</sup> | Command                                                                | CS# | RAS# | CAS# | WE# | ODT | BA[2:0] | A[15:11] | A[10] | A[9:7] | A[6:3] | A[2:0] | Data <sup>(2)</sup> |
|----------|-------------|----------|---------------------------|------------------------------------------------------------------------|-----|------|------|-----|-----|---------|----------|-------|--------|--------|--------|---------------------|
| 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:

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

Table- 33 I<sub>DD2N</sub> and I<sub>DD3N</sub> Measurement-Loop Pattern<sup>(1)</sup>

| CK, CK#  | CKE         | Sub-Loop | Cycle Number | Command                                    | CS# | RAS# | CAS# | WE# | ODT | BA[2:0] | A[15:11] | A[10] | A[9:7] | A[6:3] | A[2:0] | Data <sup>(2)</sup> |
|----------|-------------|----------|--------------|--------------------------------------------|-----|------|------|-----|-----|---------|----------|-------|--------|--------|--------|---------------------|
| 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:

- DM must be driven LOW all the time. DQS, DQS# are MID-LEVEL.
- DQ signals are MID-LEVEL.

Table- 34 I<sub>DD2NT</sub> and I<sub>DDQ2NT</sub> Measurement-Loop Pattern<sup>(1)</sup>

| CK, CK#  | CKE         | Sub-Loop | Cycle Number | Command                                        | CS# | RAS# | CAS# | WE# | ODT | BA[2:0] | A[15:11] | A[10] | A[9:7] | A[6:3] | A[2:0] | Data <sup>(2)</sup> |
|----------|-------------|----------|--------------|------------------------------------------------|-----|------|------|-----|-----|---------|----------|-------|--------|--------|--------|---------------------|
| 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 = 1 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 = 0 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 |     |      |      |     |     |         |          |       |        |        |        |                     |

Table- 35 I<sub>DD4R</sub> and I<sub>DDQ4R</sub> Measurement-Loop Pattern<sup>(1)</sup>

| CK, CK#  | CKE         | Sub-Loop | Cycle Number | Command                            | CS# | RAS# | CAS# | WE# | ODT | BA[2:0] | A[15:11] | A[10] | A[9:7] | A[6:3] | A[2:0] | Data <sup>(2)</sup> |
|----------|-------------|----------|--------------|------------------------------------|-----|------|------|-----|-----|---------|----------|-------|--------|--------|--------|---------------------|
| 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:

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

Table- 36 I<sub>DD4W</sub> Measurement-Loop Pattern<sup>(1)</sup>

| CK, CK#  | CKE         | Sub-Loop | Cycle Number | Command                            | CS# | RAS# | CAS# | WE# | ODT | BA[2:0] | A[15:11] | A[10] | A[9:7] | A[6:3] | A[2:0] | Data <sup>(2)</sup> |
|----------|-------------|----------|--------------|------------------------------------|-----|------|------|-----|-----|---------|----------|-------|--------|--------|--------|---------------------|
| 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:

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

Table- 37  $I_{DD5B}$  Measurement-Loop Pattern<sup>(1)</sup>

| CK, CK#  | CKE         | Sub-Loop | Cycle Number  | Command                                                    | CS# | RAS# | CAS# | WE# | ODT | BA[2:0] | A[15:11] | A[10] | A[9:7] | A[6:3] | A[2:0] | Data <sup>(2)</sup> |
|----------|-------------|----------|---------------|------------------------------------------------------------|-----|------|------|-----|-----|---------|----------|-------|--------|--------|--------|---------------------|
| Toggling | Static HIGH | 0        | 0             | REF                                                        | 0   | 0    | 0    | 1   | 0   | 0       | 00       | 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:

- DM must be driven LOW all the time. DQS, DQS# are MID-LEVEL.
- DQ signals are MID-LEVEL.

Table- 38  $I_{DD7}$  Measurement-Loop Pattern<sup>(1)</sup>

| CK, CK#  | CKE         | Sub-Loop | Cycle Number | Command                                                        | CS# | RAS# | CAS# | WE# | ODT | BA[2:0] | A[15:11] | A[10] | A[9:7] | A[6:3] | A[2:0] | Data <sup>(2)</sup> |
|----------|-------------|----------|--------------|----------------------------------------------------------------|-----|------|------|-----|-----|---------|----------|-------|--------|--------|--------|---------------------|
| 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 x nRRD - 1                      |     |      |      |     |     |         |          |       |        |        |        |                     |
|          |             | 2        | 2 x nRRD     | repeat Sub-Loop 0, but BA[2:0] = 2                             |     |      |      |     |     |         |          |       |        |        |        |                     |
|          |             | 3        | 3 x nRRD     | repeat Sub-Loop 1, but BA[2:0] = 3                             |     |      |      |     |     |         |          |       |        |        |        |                     |
|          |             | 4        | 4 x 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[15:11] | A[10] | A[9:7] | A[6:3] | A[2:0] | Data <sup>(2)</sup> |
|---------|-----|----------|------------------------------------------------------|--------------------------------------------------------------------|-----|------|------|-----|-----|---------|----------|-------|--------|--------|--------|---------------------|
|         |     | 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                                                                | 0   | 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, 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.

## 9.2 ICDD Specifications

Table- 39 ICDD Specifications

| Combined Symbol          | Individual Die Status                 | Unit | Note |
|--------------------------|---------------------------------------|------|------|
| $I_{CDD0}$               | $I_{CDD0} = 2 \times I_{DD0}$         | mA   | x16  |
| $I_{CDD1}$               | $I_{CDD1} = 2 \times I_{DD1}$         | mA   | x16  |
| $I_{CDD2P(0)}$ slow exit | $I_{CDD2P(0)} = 2 \times I_{DD2P(0)}$ | mA   | x16  |
| $I_{CDD2P(1)}$ fast exit | $I_{CDD2P(1)} = 2 \times I_{DD2P(1)}$ | mA   | x16  |
| $I_{CDD2N}$              | $I_{CDD2N} = 2 \times I_{DD2N}$       | mA   | x16  |
| $I_{CDD2NT}$             | $I_{CDD2NT} = 2 \times I_{DD2NT}$     | mA   | x16  |
| $I_{CDD2Q}$              | $I_{CDD2Q} = 2 \times I_{DD2Q}$       | mA   | x16  |
| $I_{CDD3P}$              | $I_{CDD3P} = 2 \times I_{DD3P}$       | mA   | x16  |
| $I_{CDD3N}$              | $I_{CDD3N} = 2 \times I_{DD3N}$       | mA   | x16  |
| $I_{CDD4R}$              | $I_{CDD4R} = 2 \times I_{DD4R}$       | mA   | x16  |
| $I_{CDD4W}$              | $I_{CDD4W} = 2 \times I_{DD4W}$       | mA   | x16  |
| $I_{CDD5B}$              | $I_{CDD5B} = 2 \times I_{DD5B}$       | mA   | x16  |
| $I_{CDD6}$               | $I_{CDD6} = 2 \times I_{DD6}$         | mA   | x16  |
| $I_{CDD6ET}$             | $I_{CDD6ET} = 2 \times I_{DD6ET}$     | mA   | x16  |
| $I_{CDD7}$               | $I_{CDD7} = 2 \times I_{DD7}$         | mA   | x16  |
| $I_{CDD8}$               | $I_{CDD8} = 2 \times I_{DD8}$         | mA   | x16  |

Note:

1.  $I_{CDD}$  values reflect the combined current of both individual die.  $I_{DDx}$  represents individual die values.

## 10 INPUT/OUTPUT CAPACITANCE

### 10.1 Input/Output Capacitance

Table- 40 DDR3L/DDR3-800/1066/1333/1600 Input/Output Capacitance

| Symbol                  | Parameter                                             |               | 800   |      | 1066  |      | 1333  |      | 1600  |      | Unit | Note     |
|-------------------------|-------------------------------------------------------|---------------|-------|------|-------|------|-------|------|-------|------|------|----------|
|                         |                                                       |               | Min   | Max  | Min   | Max  | Min   | Max  | Min   | Max  |      |          |
| C <sub>IO</sub>         | Input/output capacitance (DQ, DM, DQS, DQS#)          | DDR3 (1.5V)   | 2.80  | 5.00 | 2.80  | 5.00 | 2.80  | 4.60 | 2.80  | 4.40 | pF   | 1,2,3    |
|                         |                                                       | DDR3L (1.35V) | 2.80  | 5.00 | 2.80  | 5.00 | 2.80  | 4.60 | 2.80  | 4.40 |      |          |
| C <sub>CK</sub>         | Input capacitance, CK and CK#                         |               | 2.40  | 4.92 | 2.40  | 4.92 | 2.40  | 4.31 | 2.40  | 4.31 | pF   | 2,3      |
| C <sub>DCK</sub>        | Input capacitance delta, CK and CK#                   |               | 0.00  | 0.30 | 0.00  | 0.30 | 0.00  | 0.30 | 0.00  | 0.30 | pF   | 2,3,4    |
| C <sub>DDQS</sub>       | Input/output capacitance delta DQS and DQS#           |               | 0.00  | 0.40 | 0.00  | 0.40 | 0.00  | 0.30 | 0.00  | 0.30 | pF   | 2,3,5    |
| C <sub>I</sub>          | Input capacitance (CTRL, ADD, CMD input-only pins)    | DDR3 (1.5V)   | 2.40  | 4.98 | 2.40  | 4.98 | 2.40  | 4.98 | 2.40  | 4.60 | pF   | 2,3,6    |
|                         |                                                       | DDR3L (1.35V) | 2.40  | 4.98 | 2.40  | 4.98 | 2.40  | 4.98 | 2.40  | 4.60 |      |          |
| C <sub>DI_CTRL</sub>    | Input capacitance delta (All CTRL input-only pins)    |               | -1.00 | 1.20 | -1.00 | 1.20 | -0.80 | 0.80 | -0.80 | 0.80 | pF   | 2,3,7,8  |
| C <sub>DI_ADD_CMD</sub> | Input capacitance delta (All ADD/CMD input-only pins) |               | -1.00 | 1.00 | -1.00 | 1.00 | -0.80 | 0.80 | -0.80 | 0.80 | pF   | 2,3,9,10 |
| C <sub>DIO</sub>        | Input/output capacitance delta, DQ, DM, DQS, DQS#     |               | -1.00 | 0.60 | -1.00 | 0.60 | -1.00 | 0.60 | -1.00 | 0.60 | pF   | 2,3,11   |
| C <sub>ZQ</sub>         | Input/output capacitance of ZQ pin                    |               | -     | 6.10 | -     | 6.10 | -     | 6.10 | -     | 6.10 | pF   | 2,3,12   |

Note:

1. The DM pin load 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 vec-tor network analyzer (VNA)") with V<sub>DD</sub>, V<sub>DDQ</sub>, V<sub>SS</sub>, V<sub>SSQ</sub> applied and all other pins floating (except the pin under test, CKE, RESET# and ODT as necessary). V<sub>DD</sub> = V<sub>DDQ</sub> = 1.35V, V<sub>BIAS</sub> = V<sub>DD</sub>/2 and on-die termination off.
3. This parameter applies to monolithic devices only, stacked/dual-die devices are not covered here.

4. Absolute value of  $C_{CK} - C_{CK\#}$ .
5. Absolute value of  $C_{IO(DQS)} - C_{IO(DQS\#)}$ .
6.  $C_I$  applies to ODT, CS#, CKE, A0 – A15, BA0 - BA2, RAS#, CAS#, WE#.
7.  $C_{DI\_CTRL}$  applies to ODT, CS# and CKE.
8.  $C_{DI\_CTRL} = C_{I(CTRL)} - 0.5 \times (C_{I(CLK)} + C_{I(CLK\#)})$ .
9.  $C_{DI\_ADD\_CMD}$  applies to A0 – A15, BA0 - BA2, RAS#, CAS# and WE#.
10.  $C_{DI\_ADD\_CMD} = C_{I(ADD\_CMD)} - 0.5 \times (C_{I(CLK)} + C_{I(CLK\#)})$ .
11.  $C_{DIO} = C_{IO(DQ, DM)} - 0.5 \times (C_{IO(DQS)} + C_{IO(DQS\#)})$ .
12. Maximum external load capacitance on ZQ pin: 5pF.

**Table- 41 DDR3L/DDR3-1866/2133 Input/Output Capacitance**

| Symbol                  | Parameter                                             |               | 1866/2133 |      | Unit | Note     |
|-------------------------|-------------------------------------------------------|---------------|-----------|------|------|----------|
|                         |                                                       |               | Min       | Max  |      |          |
| C <sub>IO</sub>         | Input/output capacitance (DQ, DM, DQS, DQS#)          | DDR3 (1.5V)   | 2.80      | 4.20 | pF   | 1,2,3    |
|                         |                                                       | DDR3L (1.35V) | 2.80      | 4.20 |      |          |
| C <sub>CK</sub>         | Input capacitance, CK and CK#                         |               | 2.40      | 4.00 | pF   | 2,3      |
| C <sub>DCK</sub>        | Input capacitance delta, CK and CK#                   |               | 0.00      | 0.30 | pF   | 2,3,4    |
| C <sub>DDQS</sub>       | Input/output capacitance delta DQS and DQS#           |               | 0.00      | 0.30 | pF   | 2,3,5    |
| C <sub>I</sub>          | Input capacitance (CTRL, ADD, CMD input-only pins)    | DDR3 (1.5V)   | 2.40      | 4.60 | pF   | 2,3,6    |
|                         |                                                       | DDR3L (1.35V) | 2.40      | 4.60 |      |          |
| C <sub>DI_CTRL</sub>    | Input capacitance delta (All CTRL input-only pins)    |               | -0.80     | 0.80 | pF   | 2,3,7,8  |
| C <sub>DI_ADD_CMD</sub> | Input capacitance delta (All ADD/CMD input-only pins) |               | -0.80     | 0.80 | pF   | 2,3,9,10 |
| C <sub>DIO</sub>        | Input/output capacitance delta, DQ, DM, DQS, DQS#     |               | -1.00     | 0.60 | pF   | 2,3,11   |
| C <sub>ZQ</sub>         | Input/output capacitance of ZQ pin                    |               | -         | 6.10 | pF   | 2,3,12   |

Note:

1. The DM pin load 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 vec-tor network analyzer(VNA)") with V<sub>DD</sub>, V<sub>DDQ</sub>, V<sub>SS</sub>, V<sub>SSQ</sub> applied and all other pins floating (except the pin under test, CKE, RESET# and ODT as necessary).  
V<sub>DD</sub> = V<sub>DDQ</sub> = 1.35V, V<sub>BIAS</sub> = V<sub>DD</sub>/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<sub>CK</sub> – C<sub>CK#</sub>.
5. Absolute value of C<sub>IO(DQS)</sub> – C<sub>IO(DQS#)</sub>.
6. C<sub>I</sub> applies to ODT, CS#, CKE, A0 – A15, BA0 – BA2, RAS#, CAS#, WE#.
7. C<sub>DI\_CTRL</sub> applies to ODT, CS# and CKE.
8. C<sub>DI\_CTRL</sub> = C<sub>I(CTRL)</sub> – 0.5 × (C<sub>I(CLK)</sub> + C<sub>I(CLK#)</sub>).
9. C<sub>DI\_ADD\_CMD</sub> applies to A0 – A15, BA0 – BA2, RAS#, CAS# and WE#.
10. C<sub>DI\_ADD\_CMD</sub> = C<sub>I(ADD\_CMD)</sub> – 0.5 × (C<sub>I(CLK)</sub> + C<sub>I(CLK#)</sub>).
11. C<sub>DIO</sub> = C<sub>IO(DQ, DM)</sub> – 0.5 × (C<sub>IO(DQS)</sub> + C<sub>IO(DQS#)</sub>).
12. Maximum external load capacitance on ZQ pin: 5pF.

## 11 ELECTRICAL CHARACTERISTICS AND TIMING

### 11.1 Clock Specification

The jitter specified is a random jitter meeting a Gaussian distribution. Input clocks violating the min/max values may result in malfunction of the DDR3L SDRAM device.

#### 11.1.1 Definition for $t_{CK(avg)}$

$t_{CK(avg)}$  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.

#### 11.1.2 Definition for $t_{CK(abs)}$

$$T_{CK(avg)} = \left( \sum_{j=1}^N t_{CKj} \right) / N \quad N=200$$

$t_{CK(abs)}$  is defined as the absolute clock period, as measured from one rising edge to the next consecutive rising edge.  $T_{CK(abs)}$  is not subject to production test.

#### 11.1.3 Definition for $t_{CH(avg)}$ and $t_{CL(avg)}$

$t_{CH(avg)}$  is defined as the average high pulse width, as calculated across any consecutive 200 high pulses.

$$T_{CH(avg)} = \left( \sum_{j=1}^N t_{CHj} \right) / (N \times t_{CK(avg)}) \quad N=200$$

$t_{CL(avg)}$  is defined as the average low pulse width, as calculated across any consecutive 200 low pulses.

$$T_{CL(avg)} = \left( \sum_{j=1}^N t_{CLj} \right) / (N \times t_{CK(avg)}) \quad N=200$$

#### 11.1.4 Definition for $t_{JIT(per)}$ and $t_{JIT(per, lck)}$

$t_{JIT(per)}$  is defined as the largest deviation of any signal  $t_{CK}$  from  $t_{CK(avg)}$ .

$t_{JIT(per)} = \min/\max$  of  $\{t_{CKi} - t_{CK(avg)} \text{ where } i = 1 \text{ to } 200\}$ .

$t_{JIT(per)}$  defines the single period jitter when the DLL is already locked.

$t_{JIT(per, lck)}$  uses the same definition for single period jitter, during the DLL locking period only.

$t_{JIT(per)}$  and  $t_{JIT(per, lck)}$  are not subject to production test.

#### 11.1.5 Definition for $t_{JIT(cc)}$ and $t_{JIT(cc, lck)}$

$t_{JIT(cc)}$  is defined as the absolute difference in clock period between two consecutive clock cycles.

$t_{JIT(cc)} = \max$  of  $\{t_{CKi+1} - t_{CKi}\}$ .

$t_{JIT(cc)}$  defines the cycle to cycle jitter when the DLL is already locked.

$t_{JIT(cc, lck)}$  uses the same definition for cycle to cycle jitter, during the DLL locking period only.

$t_{JIT(cc)}$  and  $t_{JIT(cc, lck)}$  are not subject to production test.

### 11.1.6 Definition for $t_{ERR(nper)}$

$t_{ERR}$  is defined as the cumulative error across multiple consecutive cycles from  $t_{CK(avg)}$ .  $t_{ERR}$  is not subject to production test.

## 11.2 Refresh Parameters By Device Density

Table- 42 Refresh Parameters by Device Density

| Parameter                              | Symbol            |                                 | 8Gb | Unit | Note |
|----------------------------------------|-------------------|---------------------------------|-----|------|------|
| REF command to ACT or REF command time | t <sub>RFC</sub>  |                                 | 350 | ns   | -    |
| Average periodic refresh interval      | t <sub>REFI</sub> | 0°C ≤ T <sub>CASE</sub> ≤ 85°C  | 7.8 | μs   | -    |
|                                        |                   | 85°C < T <sub>CASE</sub> ≤ 95°C | 3.9 | μs   | -    |

## 11.3 Standard Speed Bins

DDR3 SDRAM Standard Speed Bins include  $t_{CK}$ ,  $t_{RCD}$ ,  $t_{RP}$ ,  $t_{RAS}$  and  $t_{RC}$  for each corresponding bin.

Table- 43 DDR3L/DDR3-1866 Speed Bins and Operating Conditions

| Speed Bin                                |                  |                       | DDR3L/DDR3-1866       |         | Unit | Note      |
|------------------------------------------|------------------|-----------------------|-----------------------|---------|------|-----------|
| CL-nRCD-nRP                              |                  |                       | 13-13-13              |         |      |           |
| Parameter                                | Symbol           | Min                   | Max                   |         |      |           |
| Internal READ command to first data      | t <sub>AA</sub>  | 13.91(13.125)         | 20                    |         | ns   | -         |
| ACT to internal READ or WRITE delay time | t <sub>RCD</sub> | 13.91(13.125)         | -                     |         | ns   | -         |
| PRE command period                       | t <sub>RP</sub>  | 13.91(13.125)         | -                     |         | ns   | -         |
| ACT to PRE command period                | t <sub>RAS</sub> | 34                    | 9 × t <sub>REFI</sub> |         | ns   | -         |
| ACT to ACT or REF command period         | t <sub>RC</sub>  | 47.91(47.125)         | -                     |         | ns   | -         |
| CL = 6                                   | CWL = 5          | t <sub>CK</sub> (avg) | 2.5                   | 3.3     | ns   | 1,2,3,5   |
|                                          | CWL = 6          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 7,8,9      | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
| CL = 7                                   | CWL = 5          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 6          | t <sub>CK</sub> (avg) | 1.875                 | < 2.5   | ns   | 1,2,3,4,5 |
|                                          | CWL = 7,8,9      | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
| CL = 8                                   | CWL = 5          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 6          | t <sub>CK</sub> (avg) | 1.875                 | < 2.5   | ns   | 1,2,3,5   |
|                                          | CWL = 7          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 8,9        | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
| CL = 9                                   | CWL = 5,6        | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 7          | t <sub>CK</sub> (avg) | 1.5                   | < 1.875 | ns   | 1,2,3,4,5 |
|                                          | CWL = 8          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 9          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
| CL = 10                                  | CWL = 5,6        | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 7          | t <sub>CK</sub> (avg) | 1.5                   | < 1.875 | ns   | 1,2,3,5   |
|                                          | CWL = 8          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
| CL = 11                                  | CWL = 5,6,7      | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 8          | t <sub>CK</sub> (avg) | 1.25                  | < 1.5   | ns   | 1,2,3,4,5 |
|                                          | CWL = 9          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
| CL = 13                                  | CWL = 5,6,7,8    | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 9          | t <sub>CK</sub> (avg) | 1.07                  | < 1.25  | ns   | 1,2,3     |
| Supported CL Settings                    |                  |                       | 6,7,8,9,10,11,13      |         | nCK  | -         |
| Supported CWL Settings                   |                  |                       | 5,6,7,8,9             |         | nCK  | -         |

Table- 44 DDR3L/DDR3-2133 Speed Bins and Operating Conditions

| Speed Bin                                |                  |                       | DDR3L/DDR3-2133       |         | Unit | Note      |
|------------------------------------------|------------------|-----------------------|-----------------------|---------|------|-----------|
| CL-nRCD-nRP                              |                  |                       | 14-14-14              |         |      |           |
| Parameter                                | Symbol           | Min                   | Max                   |         |      |           |
| Internal READ command to first data      | t <sub>AA</sub>  | 13.09                 | 20                    |         | ns   | -         |
| ACT to internal READ or WRITE delay time | t <sub>RCD</sub> | 13.09                 | -                     |         | ns   | -         |
| PRE command period                       | t <sub>RP</sub>  | 13.09                 | -                     |         | ns   | -         |
| ACT to PRE command period                | t <sub>RAS</sub> | 33                    | 9 × t <sub>REFI</sub> |         | ns   | -         |
| ACT to ACT or REF command period         | t <sub>RC</sub>  | 46.09                 | -                     |         | ns   | -         |
| CL = 5                                   | CWL = 5          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 6,7,8,9,10 | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
| CL = 6                                   | CWL = 5          | t <sub>CK</sub> (avg) | 2.5                   | 3.3     | ns   | 1,2,3,6   |
|                                          | CWL = 6          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 7,8,9,10   | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
| CL = 7                                   | CWL = 5          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 6          | t <sub>CK</sub> (avg) | 1.875                 | < 2.5   | ns   | 1,2,3,6   |
|                                          | CWL = 7          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 8,9,10     | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
| CL = 8                                   | CWL = 5          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 6          | t <sub>CK</sub> (avg) | 1.875                 | < 2.5   | ns   | 1,2,3,6   |
|                                          | CWL = 7          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 8,9,10     | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
| CL = 9                                   | CWL = 5,6        | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 7          | t <sub>CK</sub> (avg) | 1.5                   | < 1.875 | ns   | 1,2,3,4,6 |
|                                          | CWL = 8          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 9,10       | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
| CL = 10                                  | CWL = 5,6        | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 7          | t <sub>CK</sub> (avg) | 1.5                   | < 1.875 | ns   | 1,2,3,6   |
|                                          | CWL = 8          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 9          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 10         | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
| CL = 11                                  | CWL = 5,6,7      | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 8          | t <sub>CK</sub> (avg) | 1.25                  | < 1.5   | ns   | 1,2,3,6   |
|                                          | CWL = 9          | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 10         | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
| CL = 13                                  | CWL = 5,6,7,8    | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 9          | t <sub>CK</sub> (avg) | 1.07                  | < 1.25  | ns   | 1,2,3,6   |
|                                          | CWL = 10         | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
| CL = 14                                  | CWL = 5,6,7,8,9  | t <sub>CK</sub> (avg) | Reserved              |         | -    | 4         |
|                                          | CWL = 10         | t <sub>CK</sub> (avg) | 0.938                 | < 1.07  | ns   | 1,2,3     |
| Supported CL Settings                    |                  |                       | 5,6,7,8,9,10,11,13,14 |         | nCK  | -         |
| Supported CWL Settings                   |                  |                       | 5,6,7,8,9,10          |         | nCK  | -         |

### 11.3.1 Speed Bin Table Note

Note:

1. The CL setting and CWL setting result in  $t_{CK(avg)min}$  and  $t_{CK(avg)max}$  requirements. When selecting  $t_{CK(avg)}$ , both need to be fulfilled requirements from CL setting as well as requirements from CWL setting.
2.  $t_{CK(avg)min}$  limits: since CAS Latency is not purely analog-data and strobe output are synchronized by the DLL-all possible intermediate frequencies may not be guaranteed. An application should use the next smaller JEDEC standard  $t_{CK(avg)}$  value (3.0, 2.5, 1.875, 1.5, 1.25, 1.07 or 0.938ns) when calculating CL [nCK] =  $t_{AA} [ns] / t_{CK(avg)} [ns]$ , rounding up to the next "Supported CL", where  $t_{CK(avg)} = 3.0ns$  should only be used for CL = 5 calculation.
3.  $t_{CK(avg)max}$  limits: calculate  $t_{CK(avg)} = t_{aAmax} / CL$  SELECTED and round the resulting  $t_{CK(avg)}$  down to the next valid speed bin (3.3, 2.5, 1.875, 1.5, 1.25, 1.07 or 0.938ns). This result is  $t_{CK(avg)max}$  corresponding to CL SELECTED.
4. 'Reserved' settings are not allowed. User must program a different value.
5. Any DDR3L/DDR3-1866 speed bin also supports functional operation at lower frequencies as shown in the corresponding table which are not subject to Production Tests but verified by Design/Characterization.
6. Any DDR3L/DDR3-2133 speed bin also supports functional operation at lower frequencies as shown in the corresponding table which are not subject to Production Tests but verified by Design/Characterization.
7. DDR3L-800 AC timing apply if DRAM operates at lower than 800MT/s data rate.
8. For devices supporting optional down binning to CL = 11, CL = 9 and CL = 7,  $t_{AA}/t_{RCD}/t_{rPmin}$  must be 13.125ns. SPD setting must be programmed to match.

## 12 ELECTRICAL CHARACTERISTICS AND AC TIMING

### 12.1 Timing Parameters for DDR3L-800, DDR3L-1066, DDR3L-1333, DDR3L-1600 Speed Bins

Table- 45 Timing Parameters by Speed Bin

| Speed                                                  |                            | DDR3L/DDR3-800                                        |                                                       | DDR3L/DDR3-1066                                       |                                                       | DDR3L/DDR3-1333                                       |                                                       | DDR3L/DDR3-1600                                       |                                                       | Unit                 | Note |
|--------------------------------------------------------|----------------------------|-------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------|----------------------|------|
| Parameter                                              | Symbol                     | Min                                                   | Max                                                   | Min                                                   | Max                                                   | Min                                                   | Max                                                   | Min                                                   | Max                                                   |                      |      |
| Clock Timing                                           |                            |                                                       |                                                       |                                                       |                                                       |                                                       |                                                       |                                                       |                                                       |                      |      |
| Minimum clock cycle time (DLL off mode)                | t <sub>CK(DLL_OFF)</sub>   | 8                                                     | -                                                     | 8                                                     | -                                                     | 8                                                     | -                                                     | 8                                                     | -                                                     | ns                   | 6    |
| Average clock period                                   | t <sub>CK(avg)</sub>       | See Standard Speed Bins                               |                                                       |                                                       |                                                       |                                                       |                                                       |                                                       |                                                       | -                    | -    |
| Average high pulse width                               | t <sub>CH(avg)</sub>       | 0.47                                                  | 0.53                                                  | 0.47                                                  | 0.53                                                  | 0.47                                                  | 0.53                                                  | 0.47                                                  | 0.53                                                  | t <sub>CK(avg)</sub> | -    |
| Average low pulse width                                | t <sub>CL(avg)</sub>       | 0.47                                                  | 0.53                                                  | 0.47                                                  | 0.53                                                  | 0.47                                                  | 0.53                                                  | 0.47                                                  | 0.53                                                  | t <sub>CK(avg)</sub> | -    |
| Absolute clock period                                  | t <sub>CK(abs)</sub>       | t <sub>CK(avg)min</sub><br>+ t <sub>JIT(per)min</sub> | t <sub>CK(avg)max</sub><br>+ t <sub>JIT(per)max</sub> | t <sub>CK(avg)min</sub><br>+ t <sub>JIT(per)min</sub> | t <sub>CK(avg)max</sub><br>+ t <sub>JIT(per)max</sub> | t <sub>CK(avg)min</sub><br>+ t <sub>JIT(per)min</sub> | t <sub>CK(avg)max</sub><br>+ t <sub>JIT(per)max</sub> | t <sub>CK(avg)min</sub><br>+ t <sub>JIT(per)min</sub> | t <sub>CK(avg)max</sub><br>+ t <sub>JIT(per)max</sub> | ps                   | -    |
| Absolute clock high pulse width                        | t <sub>CH(abs)</sub>       | 0.43                                                  | -                                                     | 0.43                                                  | -                                                     | 0.43                                                  | -                                                     | 0.43                                                  | -                                                     | t <sub>CK(avg)</sub> | 25   |
| Absolute clock low pulse width                         | t <sub>CL(abs)</sub>       | 0.43                                                  | -                                                     | 0.43                                                  | -                                                     | 0.43                                                  | -                                                     | 0.43                                                  | -                                                     | t <sub>CK(avg)</sub> | 26   |
| Clock period jitter                                    | J <sub>IT(per)</sub>       | -100                                                  | 100                                                   | -90                                                   | 90                                                    | -80                                                   | 80                                                    | -70                                                   | 70                                                    | ps                   | -    |
| Clock period jitter during DLL locking period          | t <sub>JIT(per, lck)</sub> | -90                                                   | 90                                                    | -80                                                   | 80                                                    | -70                                                   | 70                                                    | -60                                                   | 60                                                    | ps                   | -    |
| Cycle to cycle period jitter                           | t <sub>JIT(cc)</sub>       | 200                                                   |                                                       | 180                                                   |                                                       | 160                                                   |                                                       | 140                                                   |                                                       | ps                   | -    |
| Cycle to cycle period jitter during DLL locking period | t <sub>JIT(cc, lck)</sub>  | 180                                                   |                                                       | 160                                                   |                                                       | 140                                                   |                                                       | 120                                                   |                                                       | ps                   | -    |
| Duty cycle jitter                                      | t <sub>JIT(duty)</sub>     | -                                                     | -                                                     | -                                                     | -                                                     | -                                                     | -                                                     | -                                                     | -                                                     | -                    | -    |
| Cumulative error across 2 cycles                       | t <sub>ERR(2per)</sub>     | -147                                                  | 147                                                   | -132                                                  | 132                                                   | -118                                                  | 118                                                   | -103                                                  | 103                                                   | ps                   | -    |
| Cumulative error across 3 cycles                       | t <sub>ERR(3per)</sub>     | -175                                                  | 175                                                   | -157                                                  | 157                                                   | -140                                                  | 140                                                   | -122                                                  | 122                                                   | ps                   | -    |
| Cumulative error across 4 cycles                       | t <sub>ERR(4per)</sub>     | -194                                                  | 194                                                   | -175                                                  | 175                                                   | -155                                                  | 155                                                   | -136                                                  | 136                                                   | ps                   | -    |
| Cumulative error across 5 cycles                       | t <sub>ERR(5per)</sub>     | -209                                                  | 209                                                   | -188                                                  | 188                                                   | -168                                                  | 168                                                   | -147                                                  | 147                                                   | ps                   | -    |
| Cumulative error across 6 cycles                       | t <sub>ERR(6per)</sub>     | -222                                                  | 222                                                   | -200                                                  | 200                                                   | -177                                                  | 177                                                   | -155                                                  | 155                                                   | ps                   | -    |
| Cumulative error across 7 cycles                       | t <sub>ERR(7per)</sub>     | -232                                                  | 232                                                   | -209                                                  | 209                                                   | -186                                                  | 186                                                   | -163                                                  | 163                                                   | ps                   | -    |
| Cumulative error across 8 cycles                       | t <sub>ERR(8per)</sub>     | -241                                                  | 241                                                   | -217                                                  | 217                                                   | -193                                                  | 193                                                   | -169                                                  | 169                                                   | ps                   | -    |
| Cumulative error across 9 cycles                       | t <sub>ERR(9per)</sub>     | -249                                                  | 249                                                   | -224                                                  | 224                                                   | -200                                                  | 200                                                   | -175                                                  | 175                                                   | ps                   | -    |
| Cumulative error across 10 cycles                      | t <sub>ERR(10per)</sub>    | -257                                                  | 257                                                   | -231                                                  | 231                                                   | -205                                                  | 205                                                   | -180                                                  | 180                                                   | ps                   | -    |

| Speed                                                                                       |                              | DDR3L/DDR3-800                                                                   |         | DDR3L/DDR3-1066 |         | DDR3L/DDR3-1333 |         | DDR3L/DDR3-1600 |         | Unit                 | Note    |
|---------------------------------------------------------------------------------------------|------------------------------|----------------------------------------------------------------------------------|---------|-----------------|---------|-----------------|---------|-----------------|---------|----------------------|---------|
| Parameter                                                                                   | Symbol                       | Min                                                                              | Max     | Min             | Max     | Min             | Max     | Min             | Max     |                      |         |
| Cumulative error across 11 cycles                                                           | t <sub>ERR(11per)</sub>      | 263                                                                              | 263     | -237            | 237     | -210            | 210     | -184            | 184     | ps                   | -       |
| Cumulative error across 12 cycles                                                           | t <sub>ERR(12per)</sub>      | -269                                                                             | 269     | -242            | 242     | -215            | 215     | -188            | 188     | ps                   | -       |
| Cumulative error across n = 13, 14 . . . 49, 50 cycles                                      | t <sub>ERR(nper)</sub>       | t <sub>ERR(nper)min</sub> = ((1 + 0.68ln(n)) × t <sub>JIT(per)_total min</sub> ) |         |                 |         |                 |         |                 |         | ps                   | 24      |
|                                                                                             |                              | t <sub>ERR(nper)max</sub> = ((1 + 0.68ln(n)) × t <sub>JIT(per)_total max</sub> ) |         |                 |         |                 |         |                 |         |                      |         |
| Data Timing                                                                                 |                              |                                                                                  |         |                 |         |                 |         |                 |         |                      |         |
| DQS,DQS# to DQ skew, per group, per access                                                  | t <sub>DQSQ</sub>            | -                                                                                | 200     | -               | 150     | -               | 125     | -               | 100     | ps                   | 13      |
| DQ output hold time from DQS, DQS#                                                          | t <sub>QH</sub>              | 0.38                                                                             | -       | 0.38            | -       | 0.38            | -       | 0.38            | -       | t <sub>CK(avg)</sub> | 13, g   |
| DQ low impedance time from CK, CK#                                                          | t <sub>LZ(DQ)</sub>          | -800                                                                             | 400     | -600            | 300     | -500            | 250     | -450            | 225     | ps                   | 13,14,f |
| DQ high impedance time from CK, CK#                                                         | t <sub>HZ(DQ)</sub>          | -                                                                                | 400     | -               | 300     | -               | 250     | -               | 225     | ps                   | 13,14,f |
| Data setup time to DQS, DQS# referenced to V <sub>IH(AC)</sub> /V <sub>IL(AC)</sub> levels  | 1.5V                         |                                                                                  |         |                 |         |                 |         |                 |         |                      |         |
|                                                                                             | t <sub>DS(base, AC175)</sub> | 75                                                                               | -       | 25              | -       | -               | -       | -               | -       | ps                   | d,17    |
|                                                                                             | t <sub>DS(base, AC150)</sub> | 125                                                                              | -       | 75              | -       | 30              | -       | 10              | -       | ps                   | d,17    |
|                                                                                             | 1.35V                        |                                                                                  |         |                 |         |                 |         |                 |         |                      |         |
|                                                                                             | t <sub>DS(base, AC160)</sub> | 90                                                                               | -       | 40              | -       | -               | -       | -               | -       | ps                   | d,17    |
|                                                                                             | t <sub>DS(base, AC135)</sub> | 140                                                                              | -       | 90              | -       | 45              | -       | 25              | -       | ps                   | d,17    |
| Data hold time from DQS, DQS# referenced to V <sub>IH(DC)</sub> /V <sub>IL(DC)</sub> levels | 1.5V                         |                                                                                  |         |                 |         |                 |         |                 |         |                      |         |
|                                                                                             | t <sub>DH(base, DC100)</sub> | 150                                                                              | -       | 100             | -       | 65              | -       | 45              | -       | ps                   | d,17    |
|                                                                                             | 1.35V                        |                                                                                  |         |                 |         |                 |         |                 |         |                      |         |
|                                                                                             | t <sub>DH(base, DC90)</sub>  | 160                                                                              | -       | 110             | -       | 75              | -       | 55              | -       | ps                   | d,17    |
| DQ and DM Input pulse width for each input                                                  | t <sub>DIPW</sub>            | 600                                                                              | -       | 490             | -       | 400             | -       | 360             | -       | ps                   | 28      |
| Data Strobe Timing                                                                          |                              |                                                                                  |         |                 |         |                 |         |                 |         |                      |         |
| DQS, DQS# differential READ preamble                                                        | t <sub>RPRE</sub>            | 0.9                                                                              | Note 19 | 0.9             | Note 19 | 0.9             | Note 19 | 0.9             | Note 19 | t <sub>CK(avg)</sub> | 13,19,g |
| DQS, DQS# differential READ postamble                                                       | t <sub>RPST</sub>            | 0.3                                                                              | Note 11 | 0.3             | Note 11 | 0.3             | Note 11 | 0.3             | Note 11 | t <sub>CK(avg)</sub> | 11,13,g |
| DQS, DQS# differential output high time                                                     | t <sub>QSH</sub>             | 0.38                                                                             | -       | 0.38            | -       | 0.40            | -       | 0.40            | -       | t <sub>CK(avg)</sub> | 13,g    |
| DQS, DQS# differential output low time                                                      | t <sub>QSL</sub>             | 0.38                                                                             | -       | 0.38            | -       | 0.40            | -       | 0.40            | -       | t <sub>CK(avg)</sub> | 13,g    |
| DQS, DQS# differential WRITE preamble                                                       | t <sub>WPRE</sub>            | 0.9                                                                              | -       | 0.9             | -       | 0.9             | -       | 0.9             | -       | t <sub>CK(avg)</sub> | 1       |
| DQS, DQS# differential WRITE postamble                                                      | t <sub>WPST</sub>            | 0.3                                                                              | -       | 0.3             | -       | 0.3             | -       | 0.3             | -       | t <sub>CK(avg)</sub> | 1       |

| Speed                                                                   |                      | DDR3L/DDR3-800          |      | DDR3L/DDR3-1066  |      | DDR3L/DDR3-1333  |      | DDR3L/DDR3-1600  |      | Unit                 | Note    |
|-------------------------------------------------------------------------|----------------------|-------------------------|------|------------------|------|------------------|------|------------------|------|----------------------|---------|
| Parameter                                                               | Symbol               | Min                     | Max  | Min              | Max  | Min              | Max  | Min              | Max  |                      |         |
| DQS, DQS# rising edge output access time from rising CK, CK#            | t <sub>DQSK</sub>    | -400                    | 400  | -300             | 300  | -255             | 255  | -225             | 225  | ps                   | 13,f    |
| DQS and DQS# low-impedance time (Referenced from RL-- 1)                | t <sub>LZ(DQS)</sub> | -800                    | 400  | -600             | 300  | -500             | 250  | -450             | 225  | ps                   | 13,14,f |
| DQS and DQS# high-impedance time (Referenced from RL + BL/2)            | t <sub>HZ(DQS)</sub> | -                       | 400  | -                | 300  | -                | 250  | -                | 225  | ps                   | 13,14,f |
| DQS and DQS# differential input low pulse width                         | t <sub>DQSL</sub>    | 0.45                    | 0.55 | 0.45             | 0.55 | 0.45             | 0.55 | 0.45             | 0.55 | t <sub>CK(avg)</sub> | 29,31   |
| DQS and DQS# differential input high pulse width                        | t <sub>DQSH</sub>    | 0.45                    | 0.55 | 0.45             | 0.55 | 0.45             | 0.55 | 0.45             | 0.55 | t <sub>CK(avg)</sub> | 30,31   |
| DQS, DQS# rising edge to CK, CK# rising edge                            | t <sub>DQSS</sub>    | -0.25                   | 0.25 | -0.25            | 0.25 | -0.25            | 0.25 | -0.27            | 0.27 | t <sub>CK(avg)</sub> | c       |
| DQS, DQS# falling edge setup time to CK, CK# rising edge                | t <sub>DSS</sub>     | 0.2                     | -    | 0.2              | -    | 0.2              | -    | 0.18             | -    | t <sub>CK(avg)</sub> | c,32    |
| DQS, DQS# falling edge hold time from CK, CK# rising edge               | t <sub>DSH</sub>     | 0.2                     | -    | 0.2              | -    | 0.2              | -    | 0.18             | -    | t <sub>CK(avg)</sub> | c,32    |
| Command and Address Timing                                              |                      |                         |      |                  |      |                  |      |                  |      |                      |         |
| DLL locking time                                                        | t <sub>DLLK</sub>    | 512                     | -    | 512              | -    | 512              | -    | 512              | -    | nCK                  | -       |
| Internal READ command to PRECHARGE command delay                        | t <sub>RTP</sub>     | Max (4nCK,7.5ns)        | -    | Max (4nCK,7.5ns) | -    | Max (4nCK,7.5ns) | -    | Max (4nCK,7.5ns) | -    | nCK                  | e       |
| Delay from start of internal write transaction to internal READ command | t <sub>WTR</sub>     | Max (4nCK, 7.5ns)       | -    | Max (4nCK,7.5ns) | -    | Max (4nCK,7.5ns) | -    | Max (4nCK,7.5ns) | -    | nCK                  | e,18    |
| WRITE recovery time                                                     | t <sub>WR</sub>      | 15                      | -    | 15               | -    | 15               | -    | 15               | -    | ns                   | e,18    |
| Mode register set command cycle time                                    | t <sub>MRD</sub>     | 4                       | -    | 4                | -    | 4                | -    | 4                | -    | nCK                  | -       |
| Mode register set command update delay                                  | t <sub>MOD</sub>     | Max (12nCK,15ns)        | -    | Max (12nCK,15ns) | -    | Max (12nCK,15ns) | -    | Max (12nCK,15ns) | -    | nCK                  | -       |
| ACT to internal READ or WRITE delay time                                | t <sub>RCD</sub>     | See Standard Speed Bins |      |                  |      |                  |      |                  |      | -                    | e       |
| PRE command period                                                      | t <sub>RP</sub>      | See Standard Speed Bins |      |                  |      |                  |      |                  |      | -                    | e       |
| ACT to ACT or REF command period                                        | t <sub>RC</sub>      | See Standard Speed Bins |      |                  |      |                  |      |                  |      | -                    | e       |
| CAS# to CAS# command delay                                              | t <sub>CCD</sub>     | 4                       | -    | 4                | -    | 4                | -    | 4                | -    | nCK                  | -       |

| Speed                                                                                   |                       | DDR3L/DDR3-800                         |     | DDR3L/DDR3-1066  |     | DDR3L/DDR3-1333  |     | DDR3L/DDR3-1600  |     | Unit | Note    |
|-----------------------------------------------------------------------------------------|-----------------------|----------------------------------------|-----|------------------|-----|------------------|-----|------------------|-----|------|---------|
| Parameter                                                                               | Symbol                | Min                                    | Max | Min              | Max | Min              | Max | Min              | Max |      |         |
| Auto-Precharge write recovery precharge time                                            | $t_{DALmin}$          | WR + round up ( $t_{RP}/t_{CK(avg)}$ ) |     |                  |     |                  |     |                  |     | nCK  | -       |
| Multi-Purpose register recovery Time                                                    | $t_{MPRR}$            | 1                                      | -   | 1                | -   | 1                | -   | 1                | -   | nCK  | 22      |
| ACTIVE to PRECHARGE command period                                                      | $t_{RAS}$             | See Standard Speed Bins                |     |                  |     |                  |     |                  |     | -    | e       |
| ACTIVE to ACTIVE command period for 1KB page size                                       | $t_{RRD}$             | Max (4nCK,10ns)                        | -   | Max (4nCK,7.5ns) | -   | Max (4nCK,6ns)   | -   | Max (4nCK,6ns)   | -   | nCK  | e       |
| ACTIVE to ACTIVE command period for 2KB page size                                       | $t_{RRD}$             | Max (4nCK,10ns)                        | -   | Max (4nCK,10ns)  | -   | Max (4nCK,7.5ns) | -   | Max (4nCK,7.5ns) | -   | nCK  | e       |
| Four activate window for 1KB page size                                                  | $t_{FAW}$             | 40                                     | -   | 37.5             | -   | 30               | -   | 30               | -   | ns   | e       |
| Four activate window for 2KB page size                                                  | $t_{FAW}$             | 50                                     | -   | 50               | -   | 45               | -   | 40               | -   | ns   | e       |
| Command and address setup time to CK, CK# referenced to $V_{IH(AC)}/V_{IL(AC)}$ levels  | 1.5V                  |                                        |     |                  |     |                  |     |                  |     |      |         |
|                                                                                         | $t_{IS(base, AC175)}$ | 200                                    | -   | 125              | -   | 65               | -   | 45               | -   | ps   | b,16    |
|                                                                                         | $t_{IS(base, AC150)}$ | 350                                    | -   | 275              | -   | 190              | -   | 170              | -   | ps   | b,16,27 |
|                                                                                         | 1.35V                 |                                        |     |                  |     |                  |     |                  |     |      |         |
|                                                                                         | $t_{IS(base, AC160)}$ | 215                                    | -   | 140              | -   | 80               | -   | 60               | -   | ps   | b,16    |
|                                                                                         | $t_{IS(base, AC135)}$ | 365                                    | -   | 290              | -   | 205              | -   | 185              | -   | ps   | b,16,27 |
| Command and Address hold time from CK, CK# referenced to $V_{IH(DC)}/V_{IL(DC)}$ levels | 1.5V                  |                                        |     |                  |     |                  |     |                  |     |      |         |
|                                                                                         | $t_{IH(base, DC100)}$ | 275                                    | -   | 200              | -   | 140              | -   | 120              | -   | ps   | b,16    |
|                                                                                         | 1.35V                 |                                        |     |                  |     |                  |     |                  |     |      |         |
|                                                                                         | $t_{IH(base, DC90)}$  | 285                                    | -   | 210              | -   | 150              | -   | 130              | -   | ps   | b,16    |
| Control and Address input pulse width for each input                                    | $t_{IPW}$             | 900                                    | -   | 780              | -   | 620              | -   | 560              | -   | ps   | 28      |
| Calibration Timing                                                                      |                       |                                        |     |                  |     |                  |     |                  |     |      |         |

| Speed                                                                                                                              |              | DDR3L/DDR3-800                      |     | DDR3L/DDR3-1066                     |     | DDR3L/DDR3-1333                     |     | DDR3L/DDR3-1600                     |     | Unit | Note |
|------------------------------------------------------------------------------------------------------------------------------------|--------------|-------------------------------------|-----|-------------------------------------|-----|-------------------------------------|-----|-------------------------------------|-----|------|------|
| Parameter                                                                                                                          | Symbol       | Min                                 | Max | Min                                 | Max | Min                                 | Max | Min                                 | Max |      |      |
| Power-up and RESET calibration time                                                                                                | $t_{zQinit}$ | 512                                 | -   | 512                                 | -   | 512                                 | -   | 512                                 | -   | nCK  | -    |
| Normal operation full calibration time                                                                                             | $t_{zQoper}$ | 256                                 | -   | 256                                 | -   | 256                                 | -   | 256                                 | -   | nCK  | -    |
| Normal operation short calibration time                                                                                            | $t_{zQCS}$   | 64                                  | -   | 64                                  | -   | 64                                  | -   | 64                                  | -   | nCK  | 23   |
| Reset Timing                                                                                                                       |              |                                     |     |                                     |     |                                     |     |                                     |     |      |      |
| Exit Reset from CKE HIGH to a valid command                                                                                        | $t_{XPR}$    | Max<br>(5nCK, $t_{RFCmin} + 10ns$ ) | -   | Max<br>(5nCK, $t_{RFCmin} + 10ns$ ) | -   | Max<br>(5nCK, $t_{RFCmin} + 10ns$ ) | -   | Max<br>(5nCK, $t_{RFCmin} + 10ns$ ) | -   | nCK  | -    |
| Self Refresh Timing                                                                                                                |              |                                     |     |                                     |     |                                     |     |                                     |     |      |      |
| Exit Self Refresh to commands not requiring a locked DLL                                                                           | $t_{XS}$     | Max<br>(5nCK, $t_{RFCmin} + 10ns$ ) | -   | Max<br>(5nCK, $t_{RFCmin} + 10ns$ ) | -   | Max<br>(5nCK, $t_{RFCmin} + 10ns$ ) | -   | Max<br>(5nCK, $t_{RFCmin} + 10ns$ ) | -   | nCK  | -    |
| Exit Self Refresh to commands requiring a locked DLL                                                                               | $t_{XSDLL}$  | $t_{DLLKmin}$                       | -   | $t_{DLLKmin}$                       | -   | $t_{DLLKmin}$                       | -   | $t_{DLLKmin}$                       | -   | nCK  | -    |
| Minimum CKE low width for Self refresh entry to exit timing                                                                        | $t_{CKESR}$  | $t_{CKEmin} + 1nCK$                 | -   | $t_{CKEmin} + 1nCK$                 | -   | $t_{CKEmin} + 1nCK$                 | -   | $t_{CKEmin} + 1nCK$                 | -   | nCK  | -    |
| Valid Clock Requirement after Self Refresh Entry (SRE) or Power-Down Entry (PDE)                                                   | $t_{CKSRE}$  | Max<br>(5nCK, 10ns)                 | -   | Max<br>(5nCK, 10ns)                 | -   | Max<br>(5nCK, 10ns)                 | -   | Max<br>(5nCK, 10ns)                 | -   | nCK  | -    |
| Valid Clock Requirement before Self Refresh Exit (SRX) or Power Down Exit (PDX) or Reset Exit                                      | $t_{CKSRX}$  | Max<br>(5nCK, 10ns)                 | -   | Max<br>(5nCK, 10ns)                 | -   | Max<br>(5nCK, 10ns)                 | -   | Max<br>(5nCK, 10ns)                 | -   | nCK  | -    |
| 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 | $t_{XP}$     | Max<br>(3nCK, 7.5ns)                | -   | Max<br>(3nCK, 7.5ns)                | -   | Max<br>(3nCK, 6ns)                  | -   | Max<br>(3nCK, 6ns)                  | -   | nCK  | -    |
| Exit Precharge Power Down with DLL frozen to commands requiring a locked DLL                                                       | $t_{XPDLL}$  | Max<br>(10nCK, 24ns)                | -   | Max<br>(10nCK, 24ns)                | -   | Max<br>(10nCK, 24ns)                | -   | Max<br>(10nCK, 24ns)                | -   | nCK  | 2    |
| CKE minimum pulse width                                                                                                            | $t_{CKE}$    | Max<br>(3nCK, 7.5ns)                | -   | Max<br>(3nCK, 5.625 ns)             | -   | Max<br>(3nCK, 5.625 ns)             | -   | Max<br>(3nCK, 5ns)                  | -   | nCK  | -    |

| Speed                                                              |               | DDR3L/DDR3-800                              |                     | DDR3L/DDR3-1066                 |                     | DDR3L/DDR3-1333                 |                     | DDR3L/DDR3-1600                 |                     | Unit | Note  |
|--------------------------------------------------------------------|---------------|---------------------------------------------|---------------------|---------------------------------|---------------------|---------------------------------|---------------------|---------------------------------|---------------------|------|-------|
| Parameter                                                          | Symbol        | Min                                         | Max                 | Min                             | Max                 | Min                             | Max                 | Min                             | Max                 |      |       |
| Command pass disable delay                                         | $t_{CPDED}$   | 1                                           | -                   | 1                               | -                   | 1                               | -                   | 1                               | -                   | nCK  | -     |
| Power Down Entry to Exit Timing                                    | $t_{PD}$      | $t_{CKEmin}$                                | $9 \times t_{REFI}$ | $t_{CKEmin}$                    | $9 \times t_{REFI}$ | $t_{CKEmin}$                    | $9 \times t_{REFI}$ | $t_{CKEmin}$                    | $9 \times t_{REFI}$ | nCK  | 15    |
| Timing of ACT command to Power Down entry                          | $t_{ACTPDEN}$ | 1                                           | -                   | 1                               | -                   | 1                               | -                   | 1                               | -                   | nCK  | 20    |
| Timing of PRE or PREA command to Power Down entry                  | $t_{PRPDEN}$  | 1                                           | -                   | 1                               | -                   | 1                               | -                   | 1                               | -                   | nCK  | 20    |
| Timing of RD/RDA command to Power Down entry                       | $t_{RDPDEN}$  | $RL + 4 + 1$                                | -                   | $RL + 4 + 1$                    | -                   | $RL + 4 + 1$                    | -                   | $RL + 4 + 1$                    | -                   | nCK  | -     |
| Timing of WR command to Power Down entry (BL8OTF, BL8MRS, BC4OTF)  | $t_{WRPDEN}$  | $WL + 4 + (t_{WR}/t_{CK(avg)})$             | -                   | $WL + 4 + (t_{WR}/t_{CK(avg)})$ | -                   | $WL + 4 + (t_{WR}/t_{CK(avg)})$ | -                   | $WL + 4 + (t_{WR}/t_{CK(avg)})$ | -                   | nCK  | 9     |
| Timing of WRA command to Power Down entry (BL8OTF, BL8MRS, BC4OTF) | $t_{WRAPDEN}$ | $WL + 4 + WR + 1$                           | -                   | $WL + 4 + WR + 1$               | -                   | $WL + 4 + WR + 1$               | -                   | $WL + 4 + WR + 1$               | -                   | nCK  | 10    |
| Timing of WR command to Power Down entry (BC4MRS)                  | $t_{WRPDEN}$  | $WL + 2 + (t_{WR}/t_{CK(avg)})$             | -                   | $WL + 2 + (t_{WR}/t_{CK(avg)})$ | -                   | $WL + 2 + (t_{WR}/t_{CK(avg)})$ | -                   | $WL + 2 + (t_{WR}/t_{CK(avg)})$ | -                   | nCK  | 9     |
| Timing of WRA command to Power Down entry (BC4MRS)                 | $t_{WRAPDEN}$ | $WL + 2 + WR + 1$                           | -                   | $WL + 2 + WR + 1$               | -                   | $WL + 2 + WR + 1$               | -                   | $WL + 2 + WR + 1$               | -                   | nCK  | 10    |
| Timing of REF command to Power Down entry                          | $t_{REFPDEN}$ | 1                                           | -                   | 1                               | -                   | 1                               | -                   | 1                               | -                   | nCK  | 20,21 |
| Timing of MRS command to Power Down entry                          | $t_{MRSPDEN}$ | $t_{MODmin}$                                | -                   | $t_{MODmin}$                    | -                   | $t_{MODmin}$                    | -                   | $t_{MODmin}$                    | -                   | nCK  | -     |
| ODT Timing                                                         |               |                                             |                     |                                 |                     |                                 |                     |                                 |                     |      |       |
| ODT turn on Latency                                                | ODTLon        | $WL \rightarrow 2 = CWL + AL \rightarrow 2$ |                     |                                 |                     |                                 |                     |                                 |                     | nCK  | -     |
| ODT turn off Latency                                               | ODTLoff       | $WL \rightarrow 2 = CWL + AL \rightarrow 2$ |                     |                                 |                     |                                 |                     |                                 |                     | nCK  | -     |
| ODT high time without WRITE command or with WRITE command and BC4  | ODTH4         | 4                                           | -                   | 4                               | -                   | 4                               | -                   | 4                               | -                   | nCK  | -     |
| ODT high time with WRITE command and BL8                           | ODTH8         | 6                                           | -                   | 6                               | -                   | 6                               | -                   | 6                               | -                   | nCK  | -     |
| Asynchronous $R_{TT}$ turn-on delay (Power-Down with DLL frozen)   | $t_{AONPD}$   | 2                                           | 8.5                 | 2                               | 8.5                 | 2                               | 8.5                 | 2                               | 8.5                 | ns   | -     |

| Speed                                                                              |                      | DDR3L/DDR3-800 |     | DDR3L/DDR3-1066 |     | DDR3L/DDR3-1333 |     | DDR3L/DDR3-1600 |     | Unit                 | Note |
|------------------------------------------------------------------------------------|----------------------|----------------|-----|-----------------|-----|-----------------|-----|-----------------|-----|----------------------|------|
| Parameter                                                                          | Symbol               | Min            | Max | Min             | Max | Min             | Max | Min             | Max |                      |      |
| Asynchronous R <sub>TT</sub> turn-off delay (Power-Down with DLL frozen)           | t <sub>AOFPD</sub>   | 2              | 8.5 | 2               | 8.5 | 2               | 8.5 | 2               | 8.5 | ns                   | -    |
| R <sub>TT</sub> turn-on                                                            | t <sub>AON</sub>     | -400           | 400 | -300            | 300 | -250            | 250 | -225            | 225 | ps                   | 7, f |
| R <sub>TT,Nom</sub> and R <sub>TT(WR)</sub> turn-off time from ODTL off reference  | t <sub>AOF</sub>     | 0.3            | 0.7 | 0.3             | 0.7 | 0.3             | 0.7 | 0.3             | 0.7 | t <sub>CK(avg)</sub> | 8, f |
| R <sub>TT</sub> dynamic change skew                                                | t <sub>ADC</sub>     | 0.3            | 0.7 | 0.3             | 0.7 | 0.3             | 0.7 | 0.3             | 0.7 | t <sub>CK(avg)</sub> | f    |
| Write Leveling Timing                                                              |                      |                |     |                 |     |                 |     |                 |     |                      |      |
| First DQS/DQS# rising edge after write leveling mode is programmed                 | t <sub>WLMRD</sub>   | 40             | -   | 40              | -   | 40              | -   | 40              | -   | nCK                  | 3    |
| DQS/DQS# delay after write leveling mode is programmed                             | t <sub>WLDQSEN</sub> | 25             | -   | 25              | -   | 25              | -   | 25              | -   | nCK                  | 3    |
| Write leveling setup time from rising CK, CK# crossing to rising DQS/DQS# crossing | t <sub>WLS</sub>     | 325            | -   | 245             | -   | 195             | -   | 165             | -   | ps                   | -    |
| Write leveling hold time from rising DQS/DQS# crossing to rising CK, CK# crossing  | t <sub>WLH</sub>     | 325            | -   | 245             | -   | 195             | -   | 165             | -   | ps                   | -    |
| Write leveling output delay                                                        | t <sub>WLO</sub>     | 0              | 9   | 0               | 9   | 0               | 9   | 0               | 7.5 | ns                   | -    |
| Write leveling output error                                                        | t <sub>WLOE</sub>    | 0              | 2   | 0               | 2   | 0               | 2   | 0               | 2   | ns                   | -    |

## 12.2 Timing Parameters for DDR3L-1866 and DDR3L-2133 Speed Bins

Table- 46 Timing Parameters by Speed Bin

| Speed                                                                                       |                              | DDR3L/DDR3-1866                                                                                                                                                      |                                                    | DDR3L/DDR3-2133                                    |                                                    | Unit                 | Note    |
|---------------------------------------------------------------------------------------------|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|----------------------------------------------------|----------------------------------------------------|----------------------|---------|
| Parameter                                                                                   | Symbol                       | Min                                                                                                                                                                  | Max                                                | Min                                                | Max                                                |                      |         |
| Clock Timing                                                                                |                              |                                                                                                                                                                      |                                                    |                                                    |                                                    |                      |         |
| Minimum clock cycle time (DLL off mode)                                                     | t <sub>CK(DLL_OFF)</sub>     | 8                                                                                                                                                                    | -                                                  | 8                                                  | -                                                  | ns                   | 6       |
| Average clock period                                                                        | t <sub>CK(avg)</sub>         | See Standard Speed Bins                                                                                                                                              |                                                    |                                                    |                                                    | -                    | -       |
| Average high pulse width                                                                    | t <sub>CH(avg)</sub>         | 0.47                                                                                                                                                                 | 0.53                                               | 0.47                                               | 0.53                                               | t <sub>CK(avg)</sub> | -       |
| Average low pulse width                                                                     | t <sub>CL(avg)</sub>         | 0.47                                                                                                                                                                 | 0.53                                               | 0.47                                               | 0.53                                               | t <sub>CK(avg)</sub> | -       |
| Absolute clock period                                                                       | t <sub>CK(abs)</sub>         | t <sub>CK(avg)min</sub> + t <sub>JIT(per)min</sub>                                                                                                                   | t <sub>CK(avg)max</sub> + t <sub>JIT(per)max</sub> | t <sub>CK(avg)min</sub> + t <sub>JIT(per)min</sub> | t <sub>CK(avg)max</sub> + t <sub>JIT(per)max</sub> | ps                   | -       |
| Absolute clock HIGH pulse width                                                             | t <sub>CH(abs)</sub>         | 0.43                                                                                                                                                                 | -                                                  | 0.43                                               | -                                                  | t <sub>CK(avg)</sub> | 25      |
| Absolute clock LOW pulse width                                                              | t <sub>CL(abs)</sub>         | 0.43                                                                                                                                                                 | -                                                  | 0.43                                               | -                                                  | t <sub>CK(avg)</sub> | 26      |
| Clock period jitter                                                                         | t <sub>JIT(per)</sub>        | -60                                                                                                                                                                  | 60                                                 | -50                                                | 50                                                 | ps                   | -       |
| Clock period jitter during DLL locking period                                               | t <sub>JIT(per, lck)</sub>   | -50                                                                                                                                                                  | 50                                                 | -40                                                | 40                                                 | ps                   | -       |
| Cycle to cycle period jitter                                                                | t <sub>JIT(cc)</sub>         | 120                                                                                                                                                                  |                                                    | 100                                                |                                                    | ps                   | -       |
| Cycle to cycle period jitter during DLL locking period                                      | t <sub>JIT(cc, lck)</sub>    | 100                                                                                                                                                                  |                                                    | 80                                                 |                                                    | ps                   | -       |
| Duty cycle jitter                                                                           | t <sub>JIT(duty)</sub>       | -                                                                                                                                                                    | -                                                  | -                                                  | -                                                  | -                    | -       |
| Cumulative error across 2 cycles                                                            | t <sub>ERR(2per)</sub>       | -88                                                                                                                                                                  | 88                                                 | -74                                                | 74                                                 | ps                   | -       |
| Cumulative error across 3 cycles                                                            | t <sub>ERR(3per)</sub>       | -105                                                                                                                                                                 | 105                                                | -87                                                | 87                                                 | ps                   | -       |
| Cumulative error across 4 cycles                                                            | t <sub>ERR(4per)</sub>       | -117                                                                                                                                                                 | 117                                                | -97                                                | 97                                                 | ps                   | -       |
| Cumulative error across 5 cycles                                                            | t <sub>ERR(5per)</sub>       | -126                                                                                                                                                                 | 126                                                | -105                                               | 105                                                | ps                   | -       |
| Cumulative error across 6 cycles                                                            | t <sub>ERR(6per)</sub>       | -133                                                                                                                                                                 | 133                                                | -111                                               | 111                                                | ps                   | -       |
| Cumulative error across 7 cycles                                                            | t <sub>ERR(7per)</sub>       | -139                                                                                                                                                                 | 139                                                | -116                                               | 116                                                | ps                   | -       |
| Cumulative error across 8 cycles                                                            | t <sub>ERR(8per)</sub>       | -145                                                                                                                                                                 | 145                                                | -121                                               | 121                                                | ps                   | -       |
| Cumulative error across 9 cycles                                                            | t <sub>ERR(9per)</sub>       | -150                                                                                                                                                                 | 150                                                | -125                                               | 125                                                | ps                   | -       |
| Cumulative error across 10 cycles                                                           | t <sub>ERR(10per)</sub>      | -154                                                                                                                                                                 | 154                                                | -128                                               | 128                                                | ps                   | -       |
| Cumulative error across 11 cycles                                                           | t <sub>ERR(11per)</sub>      | -158                                                                                                                                                                 | 158                                                | -132                                               | 132                                                | ps                   | -       |
| Cumulative error across 12 cycles                                                           | t <sub>ERR(12per)</sub>      | -161                                                                                                                                                                 | 161                                                | -134                                               | 134                                                | ps                   | -       |
| Cumulative error across n = 13, 14 . . . 49, 50 cycles                                      | t <sub>ERR(nper)</sub>       | t <sub>ERR(nper)min</sub> = ((1 + 0.68ln(n)) × t <sub>JIT(per)_total min</sub> )<br>t <sub>ERR(nper)max</sub> = ((1 + 0.68ln(n)) × t <sub>JIT(per)_total max</sub> ) |                                                    |                                                    |                                                    | ps                   | 24      |
| Data Timing                                                                                 |                              |                                                                                                                                                                      |                                                    |                                                    |                                                    |                      |         |
| DQS,DQS# to DQ skew, per group, per access                                                  | t <sub>DQSQ</sub>            | -                                                                                                                                                                    | 85                                                 | -                                                  | 75                                                 | ps                   | 13      |
| DQ output hold time from DQS, DQS#                                                          | t <sub>QH</sub>              | 0.38                                                                                                                                                                 | -                                                  | 0.38                                               | -                                                  | t <sub>CK(avg)</sub> | 13, g   |
| DQ low impedance time from CK, CK#                                                          | t <sub>LZ</sub> (DQ)         | -390                                                                                                                                                                 | 195                                                | -360                                               | 180                                                | ps                   | 13,14,f |
| DQ high impedance time from CK, CK#                                                         | t <sub>HZ</sub> (DQ)         | -                                                                                                                                                                    | 195                                                | -                                                  | 180                                                | ps                   | 13,14,f |
| Data setup time to DQS, DQS# referenced to V <sub>IH(AC)</sub> /V <sub>IL(AC)</sub> levels  | 1.5V                         |                                                                                                                                                                      |                                                    |                                                    |                                                    |                      |         |
|                                                                                             | t <sub>DS(base, AC150)</sub> | -                                                                                                                                                                    | -                                                  | -                                                  | -                                                  | ps                   | d,17    |
|                                                                                             | t <sub>DS(base, AC135)</sub> | 68                                                                                                                                                                   | -                                                  | 53                                                 | -                                                  | ps                   | d,17    |
|                                                                                             | 1.35V                        |                                                                                                                                                                      |                                                    |                                                    |                                                    |                      |         |
|                                                                                             | t <sub>DS(base, AC130)</sub> | 70                                                                                                                                                                   | -                                                  | 55                                                 | -                                                  | ps                   | d,17    |
| Data hold time from DQS, DQS# referenced to V <sub>IH(AC)</sub> /V <sub>IL(AC)</sub> levels | 1.5V                         |                                                                                                                                                                      |                                                    |                                                    |                                                    |                      |         |
|                                                                                             | t <sub>DH(base, DC100)</sub> | -                                                                                                                                                                    | -                                                  | -                                                  | -                                                  | ps                   | d,17    |
|                                                                                             | 1.35V                        |                                                                                                                                                                      |                                                    |                                                    |                                                    |                      |         |
|                                                                                             | t <sub>DH(base, DC90)</sub>  | 75                                                                                                                                                                   | -                                                  | 60                                                 | -                                                  | ps                   | d,17    |

| Speed                                                                                  |                       | DDR3L/DDR3-1866                         |         | DDR3L/DDR3-2133  |         | Unit          | Note    |
|----------------------------------------------------------------------------------------|-----------------------|-----------------------------------------|---------|------------------|---------|---------------|---------|
| Parameter                                                                              | Symbol                | Min                                     | Max     | Min              | Max     |               |         |
| DQ and DM Input pulse width for each input                                             | $t_{DIPW}$            | 320                                     | -       | 280              | -       | ps            | 28      |
| Data Strobe Timing                                                                     |                       |                                         |         |                  |         |               |         |
| DQS, DQS# differential READ preamble                                                   | $t_{RPRE}$            | 0.9                                     | Note 19 | 0.9              | Note 19 | $t_{CK(avg)}$ | 13,19,g |
| DQS, DQS# differential READ postamble                                                  | $t_{RPST}$            | 0.3                                     | Note 11 | 0.3              | Note 11 | $t_{CK(avg)}$ | 11,13,g |
| DQS, DQS# differential output high time                                                | $t_{QSH}$             | 0.4                                     | -       | 0.38             | -       | $t_{CK(avg)}$ | 13,g    |
| DQS, DQS# differential output low time                                                 | $t_{QSL}$             | 0.4                                     | -       | 0.38             | -       | $t_{CK(avg)}$ | 13,g    |
| DQS, DQS# differential WRITE preamble                                                  | $t_{WPRE}$            | 0.9                                     | -       | 0.9              | -       | $t_{CK(avg)}$ | 1       |
| DQS, DQS# differential WRITE postamble                                                 | $t_{WPST}$            | 0.3                                     | -       | 0.3              | -       | $t_{CK(avg)}$ | 1       |
| DQS, DQS# rising edge output access time from rising CK, CK#                           | $t_{DQSCK}$           | -195                                    | 195     | -180             | 180     | ps            | 13,f    |
| DQS and DQS# low-impedance time (Referenced from RL-- 1)                               | $t_{LZ(DQS)}$         | -390                                    | 195     | -360             | 180     | ps            | 13,14,f |
| DQS and DQS# high-impedance time (Referenced from RL + BL/2)                           | $t_{HZ(DQS)}$         | -                                       | 195     | -                | 180     | ps            | 13,14,f |
| DQS and DQS# differential input low pulse width                                        | $t_{DQSL}$            | 0.45                                    | 0.55    | 0.45             | 0.55    | $t_{CK(avg)}$ | 29,31   |
| DQS and DQS# differential input high pulse width                                       | $t_{DQSH}$            | 0.45                                    | 0.55    | 0.45             | 0.55    | $t_{CK(avg)}$ | 30,31   |
| DQS, DQS# rising edge to CK, CK# rising edge                                           | $t_{DQSS}$            | -0.27                                   | 0.27    | -0.27            | 0.27    | $t_{CK(avg)}$ | c       |
| DQS, DQS# falling edge setup time to CK, CK# rising edge                               | $t_{DSS}$             | 0.18                                    | -       | 0.18             | -       | $t_{CK(avg)}$ | c,32    |
| DQS, DQS# falling edge hold time from CK, CK# rising edge                              | $t_{DSH}$             | 0.18                                    | -       | 0.18             | -       | $t_{CK(avg)}$ | c,32    |
| Command and Address Timing                                                             |                       |                                         |         |                  |         |               |         |
| DLL locking time                                                                       | $t_{DLLK}$            | 512                                     | -       | 512              | -       | nCK           | -       |
| Internal READ command to PRECHARGE command delay                                       | $t_{RTP}$             | Max (4nCK,7.5ns)                        | -       | Max (4nCK,7.5ns) | -       | nCK           | e       |
| Delay from start of internal WRITE transaction to internal READ command                | $t_{WTR}$             | Max (4nCK,7.5ns)                        | -       | Max (4nCK,7.5ns) | -       | nCK           | e,18    |
| Write recovery time                                                                    | $t_{WR}$              | 15                                      | -       | 15               | -       | ns            | e,18    |
| MODE REGISTER SET command cycle time                                                   | $t_{MRD}$             | 4                                       | -       | 4                | -       | nCK           | -       |
| MODE REGISTER SET command update delay                                                 | $t_{MOD}$             | Max (12nCK,15ns)                        | -       | Max (12nCK,15ns) | -       | nCK           | -       |
| ACT to internal READ or WRITE delay time                                               | $t_{RCD}$             | See Standard Speed Bins                 |         |                  |         | -             | e       |
| PRE command period                                                                     | $t_{RP}$              | See Standard Speed Bins                 |         |                  |         | -             | e       |
| ACT to ACT or REF command period                                                       | $t_{RC}$              | See Standard Speed Bins                 |         |                  |         | -             | e       |
| CAS# to CAS# command delay                                                             | $t_{CCD}$             | 4                                       | -       | 4                | -       | nCK           | -       |
| Auto-precharge write recovery precharge time                                           | $t_{DALmin}$          | WR + roundup ( $t_{RP} / t_{CK(avg)}$ ) |         |                  |         | nCK           | -       |
| Multi-Purpose register recovery time                                                   | $t_{MPRR}$            | 1                                       | -       | 1                | -       | nCK           | 22      |
| ACTIVE to PRECHARGE command period                                                     | $t_{RAS}$             | See Standard Speed Bins                 |         |                  |         | -             | e       |
| ACTIVE to ACTIVE command period for 1KB page size                                      | $t_{RRD}$             | Max (4nCK,5.0ns)                        | -       | Max (4nCK,5.0ns) | -       | nCK           | e       |
| ACTIVE to ACTIVE command period for 2KB page size                                      | $t_{RRD}$             | Max (4nCK,6.0ns)                        | -       | Max (4nCK,6.0ns) | -       | nCK           | e       |
| Four activate window for 1KB page size                                                 | $t_{FAW}$             | 27                                      | -       | 25               | -       | ns            | e       |
| Four activate window for 2KB page size                                                 | $t_{FAW}$             | 35                                      | -       | 35               | -       | ns            | e       |
| Command and address setup time to CK, CK# referenced to $V_{IH(AC)}/V_{IL(AC)}$ levels | 1.5V                  |                                         |         |                  |         |               |         |
|                                                                                        | $t_{IS(base, AC150)}$ | -                                       | -       | -                | -       | ps            | b,16    |
|                                                                                        | $t_{IS(base, AC125)}$ | 150                                     | -       | 135              | -       | ps            | b,16,27 |
|                                                                                        | 1.35V                 |                                         |         |                  |         |               |         |

| Speed                                                                                                                              |                       | DDR3L/DDR3-1866                     |                     | DDR3L/DDR3-2133                     |                     | Unit | Note    |
|------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-------------------------------------|---------------------|-------------------------------------|---------------------|------|---------|
| Parameter                                                                                                                          | Symbol                | Min                                 | Max                 | Min                                 | Max                 |      |         |
|                                                                                                                                    | $t_{IS}(base, AC135)$ | 65                                  | -                   | 60                                  | -                   | ps   | b,16    |
|                                                                                                                                    | $t_{IS}(base, AC125)$ | 150                                 | -                   | 135                                 | -                   | ps   | b,16,27 |
| Command and Address hold time from CK, CK# referenced to $V_{IH(DC)}/V_{IL(DC)}$ levels                                            | 1.5V                  |                                     |                     |                                     |                     |      |         |
|                                                                                                                                    | $t_{IH}(base, DC100)$ | 100                                 | -                   | 95                                  | -                   | ps   | b,16    |
|                                                                                                                                    | 1.35V                 |                                     |                     |                                     |                     |      |         |
|                                                                                                                                    | $t_{IH}(base, DC90)$  | 110                                 | -                   | 95                                  | -                   | ps   | b,16    |
| Control and address Input pulse width for each input                                                                               | $t_{IPW}$             | 535                                 | -                   | 470                                 | -                   | ps   | 28      |
| Calibration Timing                                                                                                                 |                       |                                     |                     |                                     |                     |      |         |
| Power-up and Reset calibration time                                                                                                | $t_{zQinit}$          | 512                                 | -                   | 512                                 | -                   | nCK  | -       |
| Normal operation Full calibration time                                                                                             | $t_{zQoper}$          | 256                                 | -                   | 256                                 | -                   | nCK  | -       |
| Normal operation short calibration time                                                                                            | $t_{zQCS}$            | 64                                  | -                   | 64                                  | -                   | nCK  | 23      |
| Reset Timing                                                                                                                       |                       |                                     |                     |                                     |                     |      |         |
| Exit Reset from CK High to a valid command                                                                                         | $t_{XPR}$             | Max<br>(5nCK, $t_{RFCmin} + 10ns$ ) | -                   | Max<br>(5nCK, $t_{RFCmin} + 10ns$ ) | -                   | nCK  | -       |
| Self Refresh Timing                                                                                                                |                       |                                     |                     |                                     |                     |      |         |
| Exit Self Refresh to commands not requiring a locked DLL                                                                           | $t_{XS}$              | Max<br>(5nCK, $t_{RFCmin} + 10ns$ ) | -                   | Max<br>(5nCK, $t_{RFCmin} + 10ns$ ) | -                   | nCK  | -       |
| Exit Self Refresh to commands requiring a locked DLL                                                                               | $t_{XSDLL}$           | $t_{DLLKmin}$                       | -                   | $t_{DLLKmin}$                       | -                   | nCK  | -       |
| Minimum CK low width for Self refresh entry to exit timing                                                                         | $t_{CKESR}$           | $t_{CKEmin} + 1nCK$                 | -                   | $t_{CKEmin} + 1nCK$                 | -                   | nCK  | -       |
| Valid Clock Requirement after Self Refresh Entry (SRE) or Power-Down Entry (PDE)                                                   | $t_{CKSRE}$           | Max<br>(5nCK, 10ns)                 | -                   | Max<br>(5nCK, 10ns)                 | -                   | nCK  | -       |
| Valid Clock Requirement before Self Refresh Exit (SRX) or Power-Down Exit (PDX) or Reset Exit                                      | $t_{CKSRX}$           | Max<br>(5nCK, 10ns)                 | -                   | Max<br>(5nCK, 10ns)                 | -                   | nCK  | -       |
| 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 | $t_{XP}$              | Max<br>(3nCK, 6ns)                  | -                   | Max<br>(3nCK, 6ns)                  | -                   | nCK  | -       |
| Exit Precharge Power Down with DLL frozen to commands requiring a locked DLL                                                       | $t_{XPDLL}$           | Max<br>(10nCK, 24ns)                | -                   | Max<br>(10nCK, 24ns)                | -                   | nCK  | 2       |
| CKE minimum pulse width                                                                                                            | $t_{CKE}$             | Max<br>(3nCK, 5ns)                  | -                   | Max<br>(3nCK, 5ns)                  | -                   | nCK  | -       |
| Command pass disable delay                                                                                                         | $t_{CPDED}$           | 2                                   | -                   | 2                                   | -                   | nCK  | -       |
| Power Down Entry to Exit Timing                                                                                                    | $t_{PD}$              | $t_{CKEmin}$                        | $9 \times t_{REFI}$ | $t_{CKEmin}$                        | $9 \times t_{REFI}$ | nCK  | 15      |
| Timing of ACT command to Power Down entry                                                                                          | $t_{ACTPDEN}$         | 1                                   | -                   | 2                                   | -                   | nCK  | 20      |
| Timing of PRE or PREA command to Power Down entry                                                                                  | $t_{PRPDEN}$          | 1                                   | -                   | 2                                   | -                   | nCK  | 20      |

| Speed                                                                              |               | DDR3L/DDR3-1866                   |     | DDR3L/DDR3-2133                 |     | Unit          | Note   |
|------------------------------------------------------------------------------------|---------------|-----------------------------------|-----|---------------------------------|-----|---------------|--------|
| Parameter                                                                          | Symbol        | Min                               | Max | Min                             | Max |               |        |
| Timing of RD/RDA command to Power Down entry                                       | $t_{RDPDEN}$  | $RL + 4 + 1$                      | -   | $RL + 4 + 1$                    | -   | nCK           | -      |
| Timing of WR command to Power Down entry (BL8OTF, BL8MRS, BC4OTF)                  | $t_{WRPDEN}$  | $WL + 4 + (t_{WR}/t_{CK(avg)})$   | -   | $WL + 4 + (t_{WR}/t_{CK(avg)})$ | -   | nCK           | 9      |
| Timing of WRA command to Power Down entry (BL8OTF, BL8MRS, BC4OTF)                 | $t_{WRAPDEN}$ | $WL + 4 + WR + 1$                 | -   | $WL + 4 + WR + 1$               | -   | nCK           | 10     |
| Timing of WR command to Power Down entry (BC4MRS)                                  | $t_{WRPDEN}$  | $WL + 2 + (t_{WR}/t_{CK(avg)})$   | -   | $WL + 2 + (t_{WR}/t_{CK(avg)})$ | -   | nCK           | 9      |
| Timing of WRA command to Power Down entry (BC4MRS)                                 | $t_{WRAPDEN}$ | $WL + 2 + WR + 1$                 | -   | $WL + 2 + WR + 1$               | -   | nCK           | 10     |
| Timing of REF command to Power Down entry                                          | $t_{REFPDEN}$ | 1                                 | -   | 2                               | -   | nCK           | 20,21s |
| Timing of MRS command to Power Down entry                                          | $t_{MRSPDEN}$ | $t_{MODmin}$                      | -   | $t_{MODmin}$                    | -   | -             | -      |
| 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                                 | -   | 4                               | -   | nCK           | -      |
| ODT high time with WRITE command and BL8                                           | ODTH8         | 6                                 | -   | 6                               | -   | nCK           | -      |
| Asynchronous $R_{TT}$ turn-on delay (Power-Down with DLL frozen)                   | $t_{AONPD}$   | 2                                 | 8.5 | 2                               | 8.5 | ns            | -      |
| Asynchronous $R_{TT}$ turn-off delay (Power-Down with DLL frozen)                  | $t_{AOFPD}$   | 2                                 | 8.5 | 2                               | 8.5 | ns            | -      |
| $R_{TT}$ turn-on                                                                   | $t_{AON}$     | -195                              | 195 | -180                            | 180 | ps            | 7, f   |
| $R_{TT, Nom}$ and $R_{TT(WR)}$ turn-off time from ODTL off reference               | $t_{AOF}$     | 0.3                               | 0.7 | 0.3                             | 0.7 | $t_{CK(avg)}$ | 8, f   |
| $R_{TT}$ dynamic change skew                                                       | $t_{ADC}$     | 0.3                               | 0.7 | 0.3                             | 0.7 | $t_{CK(avg)}$ | f      |
| Write Leveling Timing                                                              |               |                                   |     |                                 |     |               |        |
| First DQS/DQS# rising edge after write leveling mode is programmed                 | $t_{WLMRD}$   | 40                                | -   | 40                              | -   | nCK           | 3      |
| DQS/DQS# delay after write leveling mode is programmed                             | $t_{WLDQSEN}$ | 25                                | -   | 25                              | -   | nCK           | 3      |
| Write leveling setup time from rising CK, CK# crossing to rising DQS/DQS# crossing | $t_{WLS}$     | 140                               | -   | 125                             | -   | ps            | -      |
| Write leveling hold time from rising DQS/DQS# crossing to rising CK, CK#           | $t_{WLH}$     | 140                               | -   | 125                             | -   | ps            | -      |
| Write leveling output delay                                                        | $t_{WLO}$     | 0                                 | 7.5 | 0                               | 7.5 | ns            | -      |
| Write leveling output error                                                        | $t_{WLOE}$    | 0                                 | 2   | 0                               | 2   | ns            | -      |

## 12.3 Jitter Notes

Note:

- Unit ' $t_{CK(avg)}$ ' represents the actual  $t_{CK(avg)}$  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  $T_m$ , another MODE REGISTER SET command may be registered at  $T_m + 4$ , even if  $(T_m + 4 - T_m)$  is  $4 \times t_{CK(avg)} + t_{ERR(4per)min}$ .
- These parameters are measured from a command/address signal (CKE, CS#, RAS#, CAS#, WE#, ODT, BA0, A0, A1, etc.) transition edge to its respective clock signal (CK/CK#) crossing. The spec values are not affected by the amount of clock jitter applied (i.e.  $t_{JIT(per)}$ ,  $t_{JIT(cc)}$ , etc.), as 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.
- These parameters are measured from a data strobe signal (DQS(L/U), DQS(L/U)#) crossing to its respective clock signal (CK, CK#) crossing. The spec values are not affected by the amount of clock jitter applied (i.e.  $t_{JIT(per)}$ ,  $t_{JIT(cc)}$ , etc.), as these are relative to the clock signal crossing. That is, these parameters should be met whether clock jitter is present or not.
- These parameters are measured from a data signal (DM(L/U), DQ(L/U)0, DQ(L/U)1, etc.) transition edge to its respective data strobe signal (DQS(L/U), DQS(L/U) #) crossing.
- For these parameters, the DDR3 SDRAM device supports  $t_{nPARAM} [nCK] = RU \{t_{PARAM} [ns]/t_{CK(avg)} [ns]\}$ , which is in clock cycles, assuming all input clock jitter specifications are satisfied. For example, the device will support  $t_{nRP} = RU \{t_{RP}/t_{CK(avg)}\}$ , which is in clock cycles, if all input clock jitter specifications are met. This means: For DDR3L/DDR3-800 6-6-6, of which  $t_{RP} = 15ns$ , the device will support  $t_{nRP} = RU \{t_{RP}/t_{CK(avg)}\} = 6$ , as long as the input clock jitter specifications are met, i.e. PRECHARGE command at  $T_m$  and ACTIVE command at  $T_m+6$  is valid even if  $(T_m + 6 - T_m)$  is less than 15ns due to input clock jitter.
- When the device is operated with input clock jitter, this parameter needs to be derated by the actual  $t_{ERR(mper)}$ , act of the input clock, where  $2 \leq m \leq 12$ . (output deratings are relative to the SDRAM input clock.)

For example, if the measured jitter into a DDR3L/DDR3-800 SDRAM has  $t_{ERR(mper),act,min} = -172ps$  and  $t_{ERR(mper),act,max} = +193ps$ , then  $t_{DQSK,min(derated)} = t_{DQSK,min} - t_{ERR(mper),act,max} = -400ps - 193ps = -593ps$  and  $t_{DQSK,max(derated)} = t_{DQSK,max} - t_{ERR(mper),act,min} = 400ps + 172ps = +572ps$ . Similarly,  $t_{LZ(DQ)}$  for DDR3L-800 derates to  $t_{LZ(DQ),min(derated)} = -800ps - 193ps = -993ps$  and  $t_{LZ(DQ),max(derated)} = 400ps + 172ps = +572ps$ . (Caution on the min/max usage).

Note that  $t_{ERR(mper),act,min}$  is the minimum measured value of  $t_{ERR(nper)}$  where  $2 \leq n \leq 12$ , and  $t_{ERR(mper),act,max}$  is the maximum measured value of  $t_{ERR(nper)}$  where  $2 \leq n \leq 12$ .

- When the device is operated with input clock jitter, this parameter needs to be derated by the actual  $t_{JIT(per)}$ , act of the input clock. (output deratings are relative to the SDRAM input clock) For example, if the measured jitter into a DDR3L/DDR3-800 SDRAM has  $t_{CK(avg),act} = 2500ps$ ,  $t_{JIT(per),act,min} = -72ps$  and  $t_{JIT(per),act,max} = +93ps$ , then  $t_{RPRE,min(derated)} = t_{RPRE,min} + t_{JIT(per),act,min} = 0.9 \times t_{CK(avg),act} + t_{JIT(per),act,min} = 0.9 \times 2500ps - 72ps = +2178ps$ . Similarly,  $t_{QH,min(derated)} = t_{QH,min} + t_{JIT(per),act,min} = 0.38 \times t_{CK(avg),act} + t_{JIT(per),act,min} = 0.38 \times 2500ps - 72ps = +878ps$ . (Cautionle min/max usage.)

## 12.4 Timing Parameter Notes

Note:

1. Actual value dependant upon measurement level definitions. See "Method for calculating  $t_{WPRE}$  transitions and endpoints" and "Method for calculating  $t_{WPST}$  transitions and endpoints".
2. Commands requiring a locked DLL are: READ (and RAP) and synchronous ODT commands.
3. The max values are system dependent.
4. WR as programmed in mode register.
5. Value must be rounded-up to next higher integer value.
6. There is no maximum cycle time limit besides the need to satisfy the refresh interval,  $t_{REFI}$ .
7. For definition of  $R_{TT}$  turn-on time  $t_{AON}$ .
8. For definition of  $R_{TT}$  turn-off time  $t_{AOF}$ .
9.  $t_{WR}$  is defined in ns, for calculation of  $t_{WRPDEN}$  it is necessary to round up  $t_{WR}/t_{CK}$  to the next integer.
10. WR in clock cycles as programmed in MR0.
11. The maximum READ postamble is bound by  $t_{DQSKmin}$  plus  $t_{QSHmin}$  on the left side and  $t_{HZ(DQS)max}$  on the right side. See "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 t.b.d.
13. Value is only valid for  $R_{ON34}$ .
14. Single-ended signal parameter.
15.  $t_{REFI}$  depends on  $T_{OPER}$ .
16.  $t_{IS(base)}$  and  $t_{IH(base)}$  values are for 1V/ns CMD/ADD single-ended slew rate and 2V/ns CK, CK# differential slew rate. Note for DQ and DM signals,  $V_{REF(DC)} = V_{REFDQ(DC)}$ . For input only pins except RESET#,  $V_{REF(DC)} = V_{REFCA(DC)}$ . See "Address/ Command Setup, Hold and Derating" in Section 12.5.
17.  $t_{DS(base)}$  and  $t_{DH(base)}$  values are for 1V/ns DQ single-ended slew rate and 2V/ns DQS, DQS# differential slew rate. Note for DQ and DM signals,  $V_{REF(DC)} = V_{REFDQ(DC)}$ . For input only pins except RESET#,  $V_{REF(DC)} = V_{REFCA(DC)}$ . See "Data Setup, Hold and Slew Rate Derating" in Section 12.6.
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  $t_{LZ(DQS)min}$  on the left side and  $t_{DQSKmax}$  on the right side.
20. CKE is allowed to be registered LOW while operations such as row activation, precharge, auto-precharge or refresh are in progress, but power-down  $I_{DD}$  spec will not be applied until finishing those operations.
21. Although CKE is allowed to be registered LOW after a REFRESH command once  $t_{REFPDENmin}$  is satisfied, there are cases where additional time such as  $t_{XPDLLmin}$  is also required.
22. Defined between end of MPR read burst and MRS which reloads MPR or disables MPR function.
23. One ZQCS command can effectively correct a minimum of 0.5% (ZQ Correction) of  $R_{ON}$  and  $R_{TT}$  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 ( $T_{driftrate}$ ) and voltage ( $V_{driftrate}$ ) drift rates that the SDRAM is subject to in the application, is illustrated. The interval could be defined by the following formula:

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

where  $TSens = \max(dR_{TTdT}, dR_{ONdTM})$  and  $VSens = \max(dR_{TTdV}, dR_{ONdVM})$  define the SDRAM temperature and voltage sensitivities.

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

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

24.  $n$  = from 13 cycles to 50 cycles. This row defines 38 parameters.
25.  $t_{CH(ABS)}$  is the absolute instantaneous clock high pulse width, as measured from one rising edge to the following falling edge.
26.  $t_{CL(ABS)}$  is the absolute instantaneous clock low pulse width, as measured from one falling edge to the following rising edge.
27. The  $t_{IS(base, AC150)}$  specifications are adjusted from the  $t_{IS(base)}$  specification by adding an additional 100 ps of derating to accommodate for the lower alternate threshold of 150mV and another 25ps to account for the earlier reference point [(1–5 mv - 150mV)/1V/ns].
28. Pulse width of an input signal is defined as the width between the first crossing of  $V_{REF(DC)}$  and the consecutive crossing of  $V_{REF(DC)}$ .
29.  $t_{DQSL}$  describes the instantaneous differential input low pulse width o– DQS - DQS#, as measured from one falling edge to the next consecutive rising edge.
30.  $t_{DQSH}$  describes the instantaneous differential input high pulse width o– DQS - DQS#, as measured from one rising edge to the next consecutive falling edge.
31.  $t_{DQSH, act} + t_{DQSL, act} = 1t_{CK, act}$  with  $t_{XYZ, act}$  being the actual measured value of the respective timing parameter in the application.
32.  $t_{DQSH, act} + t_{DSS, act} = 1t_{CK, act}$  with  $t_{XYZ, act}$  being the actual measured value of the respective timing parameter in the application.

## 12.5 Address/Command Setup, Hold and Derating

For all input signals the total  $t_{IS}$  (setup time) and  $t_{IH}$  (hold time) required is calculated by adding the datasheet  $t_{IS(base)}$  and  $t_{IH(base)}$  value (see Table- 47) to the  $\Delta t_{IS}$  and  $\Delta t_{IH}$  derating value (see Table- 49) respectively.

Example:  $t_{IS} \text{ (total setup time)} = t_{IS(base)} + \Delta t_{IS}$ .

Setup ( $t_{IS}$ ) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of  $V_{REF(DC)}$  and the first crossing of  $V_{IH(AC)min}$ . Setup ( $t_{IS}$ ) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of  $V_{REF(DC)}$  and the first crossing of  $V_{IL(AC)max}$ . If the actual signal is always earlier than the nominal slew rate line between shaded ' $V_{REF(DC)}$  to AC region', use nominal slew rate for derating value (see Figure- 22). If the actual signal is later than the nominal slew rate line anywhere between shaded ' $V_{REF(DC)}$  to AC region', the slew rate of a tangent line to the actual signal from the AC level to  $V_{REF(DC)}$  level is used for derating value (see Figure- 24).

Hold ( $t_{IH}$ ) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of  $V_{IL(DC)max}$  and the first crossing of  $V_{REF(DC)}$ . Hold ( $t_{IH}$ ) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of  $V_{IH(DC)min}$  and the first crossing of  $V_{REF(DC)}$ . If the actual signal is always later than the nominal slew rate line between shaded ' $DC$  to  $V_{REF(DC)}$  region', use nominal slew rate for derating value (see Figure- 22). If the actual signal is earlier than the nominal slew rate line anywhere between shaded ' $DC$  to  $V_{REF(DC)}$  region', the slew rate of a tangent line to the actual signal from the DC level to  $V_{REF(DC)}$  level is used for derating value (see Figure- 24).

For a valid transition the input signal has to remain above/below  $V_{IH/IL(AC)}$  for some time  $t_{VAC}$  (see Table- 56). Although for slow slew rates the total setup time might be negative (i.e. a valid input signal will not have reached  $V_{IH/IL(AC)}$  at the time of the rising clock transition), a valid input signal is still required to complete the transition and reach  $V_{IH/IL(AC)}$ . For slew rates in between the values listed in Table Table- 49, the derating values may obtain by linear interpolation. These values are typically not subject to production test. They are verified by design and characterization.

**Table- 47 ADD/CMD Setup and Hold Base-Values for 1V/ns (1.35V)**

| Symbol                | Reference      | DDR3L-800 | DDR3L-1066 | DDR3L-1333 | DDR3L-1600 | DDR3L-1866 | DDR3L-2133 | Unit |
|-----------------------|----------------|-----------|------------|------------|------------|------------|------------|------|
| $t_{IS(base, AC160)}$ | $V_{IH/L(AC)}$ | 215       | 140        | 80         | 60         | -          | -          | ps   |
| $t_{IS(base, AC135)}$ | $V_{IH/L(AC)}$ | 365       | 290        | 205        | 185        | 65         | 60         | ps   |
| $t_{IS(base, AC125)}$ | $V_{IH/L(AC)}$ | -         | -          | -          | -          | 150        | 135        | ps   |
| $t_{IH(base, DC90)}$  | $V_{IH/L(DC)}$ | 285       | 210        | 150        | 130        | 110        | 105        | ps   |

Note:

- AC/DC referenced for 1V/ns Address/Command slew rate and 2V/ns differential CK-CK# slew rate.
- The  $t_{IS(base, AC135)}$  specifications are adjusted from the  $t_{IS(base, AC160)}$  specification by adding an additional 125ps for DDR3L-800/1066 or 100ps for DDR3L-1333/1600 of derating to accommodate for the lower alternate threshold of 135mV and another 25ps to account for the earlier reference point  $[(-60mV - 135mV)/1V/ns]$ .
- The  $t_{IS(base, AC125)}$  specifications are adjusted from the  $t_{IS(base, AC135)}$  specification by adding an additional 75ps for DDR3L-1866 and 65ps for DDR3L-2133 to accommodate for the lower alternate threshold of 125mV and another 10ps to account for the earlier reference point  $[(-35mV - 125mV)/1V/ns]$ .

**Table- 48 ADD/CMD Setup and Hold Base-Values for 1V/ns (1.5V)**

| Symbol                       | Reference      | DDR3-800 | DDR3-1066 | DDR3-1333 | DDR3-1600 | DDR3-1866 | DDR3-2133 | Unit |
|------------------------------|----------------|----------|-----------|-----------|-----------|-----------|-----------|------|
| $t_{IS}(\text{base, AC175})$ | $V_{IH/L(AC)}$ | 200      | 125       | 65        | 45        | -         | -         | ps   |
| $t_{IS}(\text{base, AC150})$ | $V_{IH/L(AC)}$ | 350      | 275       | 190       | 170       | -         | -         | ps   |
| $t_{IS}(\text{base, AC135})$ | $V_{IH/L(AC)}$ | -        | -         | -         | -         | 65        | 60        | ps   |
| $t_{IS}(\text{base, AC125})$ | $V_{IH/L(AC)}$ | -        | -         | -         | -         | 150       | 135       | ps   |
| $t_{IH}(\text{base, DC100})$ | $V_{IH/L(DC)}$ | 275      | 200       | 140       | 120       | 100       | 95        | ps   |

Note:

- AC/DC referenced for 1V/ns Address/Command slew rate and 2V/ns differential-I CK - CK# slew rate.
- The  $t_{IS}(\text{base, AC135})$  specifications are adjusted from the  $t_{IS}(\text{base, AC160})$  specification by adding an additional 125ps for DDR3L-800/1066 or 100ps for DDR3L-1333/1600 of derating to accommodate for the lower alternate threshold of 135mV and another 25ps to account for the earlier reference point  $[(-60\text{mV} - 135\text{mV})/1\text{V/ns}]$ .
- The  $t_{IS}(\text{base, AC125})$  specifications are adjusted from the  $t_{IS}(\text{base, AC135})$  specification by adding an additional 75ps for DDR3L-1866 and 65ps for DDR3L-2133 to accommodate for the lower alternate threshold of 125mV and another 10ps to account for the earlier reference point  $[(-35\text{mV} - 125\text{mV})/1\text{V/ns}]$ .

**Table- 49 Derating value DDR3L-800/1066/1333/1600  $t_{IS}/t_{IH}$  – AC/DC based AC160 Threshold (1.35V)**

| <div><math>\Delta t_{IS}, \Delta t_{IH}</math> derating in [ps] AC/DC based</div> <div>AC160 Threshold -&gt; <math>V_{IH(AC)} = V_{REF(DC)} + 160mV</math>, <math>V_{IL(AC)} = V_{RE-(DC)} - 160mV</math></div> |     |                                |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|--------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                                                                                                                                                                                                 |     | CK, CK# Differential Slew Rate |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|                                                                                                                                                                                                                 |     | 4.0V/ns                        |                 | 3.0V/ns         |                 | 2.0V/ns         |                 | 1.8V/ns         |                 | 1.6V/ns         |                 | 1.4V/ns         |                 | 1.2V/ns         |                 | 1.0V/ns         |                 |
|                                                                                                                                                                                                                 |     | $\Delta t_{IS}$                | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ |
| CMD/ADD<br>Slew Rate<br>V/ns                                                                                                                                                                                    | 2.0 | 80                             | 45              | 80              | 45              | 80              | 45              | 88              | 53              | 96              | 61              | 104             | 69              | 112             | 79              | 120             | 95              |
|                                                                                                                                                                                                                 | 1.5 | 53                             | 30              | 53              | 30              | 53              | 30              | 61              | 38              | 69              | 46              | 77              | 54              | 85              | 64              | 93              | 80              |
|                                                                                                                                                                                                                 | 1.0 | 0                              | 0               | 0               | 0               | 0               | 0               | 8               | 8               | 16              | 16              | 24              | 24              | 32              | 34              | 40              | 50              |
|                                                                                                                                                                                                                 | 0.9 | -1                             | -3              | -1              | -3              | -1              | -3              | 7               | 5               | 15              | 13              | 23              | 21              | 31              | 31              | 39              | 47              |
|                                                                                                                                                                                                                 | 0.8 | -3                             | -8              | -3              | -8              | -3              | -8              | 5               | 1               | 13              | 9               | 21              | 17              | 29              | 27              | 37              | 43              |
|                                                                                                                                                                                                                 | 0.7 | -5                             | -13             | -5              | -13             | -5              | -13             | 3               | -5              | 11              | 3               | 19              | 11              | 27              | 21              | 35              | 37              |
|                                                                                                                                                                                                                 | 0.6 | -8                             | -20             | -8              | -20             | -8              | -20             | 0               | -12             | 8               | -4              | 16              | 4               | 24              | 14              | 32              | 30              |
|                                                                                                                                                                                                                 | 0.5 | -20                            | -30             | -20             | -30             | -20             | -30             | -12             | -22             | -4              | -14             | 4               | -6              | 12              | 4               | 20              | 20              |
|                                                                                                                                                                                                                 | 0.4 | -40                            | -45             | -40             | -45             | -40             | -45             | -32             | -37             | -24             | -29             | -16             | -21             | -8              | -11             | 0               | 5               |

Table- 50 Derating value DDR3L-800/1066/1333/1600  $t_{IS}/t_{IH}$  – AC/DC based Alternate AC135 Threshold (1.35V)

| $\Delta t_{IS}, \Delta t_{IH}$ derating in [ps] AC/DC based<br>Alternate AC135 Threshold $\rightarrow V_{IH(AC)} = V_{REF(DC)} + 135mV, V_{IL(AC)} = V_{RE-(DC)} - 135mV$ |     |                                |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|--------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                                                                                                                                                           |     | CK, CK# Differential Slew Rate |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|                                                                                                                                                                           |     | 4.0V/ns                        |                 | 3.0V/ns         |                 | 2.0V/ns         |                 | 1.8V/ns         |                 | 1.6V/ns         |                 | 1.4V/ns         |                 | 1.2V/ns         |                 | 1.0V/ns         |                 |
|                                                                                                                                                                           |     | $\Delta t_{IS}$                | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ |
| CMD/ADD<br>Slew Rate<br>V/ns                                                                                                                                              | 2.0 | 68                             | 45              | 68              | 45              | 68              | 45              | 76              | 53              | 84              | 61              | 92              | 69              | 100             | 79              | 108             | 95              |
|                                                                                                                                                                           | 1.5 | 45                             | 30              | 45              | 30              | 45              | 30              | 53              | 38              | 61              | 46              | 69              | 54              | 77              | 64              | 85              | 80              |
|                                                                                                                                                                           | 1.0 | 0                              | 0               | 0               | 0               | 0               | 0               | 8               | 8               | 16              | 16              | 24              | 24              | 32              | 34              | 40              | 50              |
|                                                                                                                                                                           | 0.9 | 2                              | -3              | 2               | -3              | 2               | -3              | 10              | 5               | 18              | 13              | 26              | 21              | 34              | 31              | 42              | 47              |
|                                                                                                                                                                           | 0.8 | 3                              | -8              | 3               | -8              | 3               | -8              | 11              | 1               | 19              | 9               | 27              | 17              | 35              | 27              | 43              | 43              |
|                                                                                                                                                                           | 0.7 | 6                              | -13             | 6               | -13             | 6               | -13             | 14              | -5              | 22              | 3               | 30              | 11              | 38              | 21              | 46              | 37              |
|                                                                                                                                                                           | 0.6 | 9                              | -20             | 9               | -20             | 9               | -20             | 17              | -12             | 25              | -4              | 33              | 4               | 41              | 14              | 49              | 30              |
|                                                                                                                                                                           | 0.5 | 5                              | -30             | 5               | -30             | 5               | -30             | 13              | -22             | 21              | -14             | 29              | -6              | 37              | 4               | 45              | 20              |
|                                                                                                                                                                           | 0.4 | -3                             | -45             | -3              | -45             | -3              | -45             | 6               | -37             | 14              | -29             | 22              | -21             | 30              | -11             | 38              | 5               |

Table- 51 Derating value DDR3L-1866/2133  $t_{IS}/t_{IH}$  – AC/DC based Alternate AC125 Threshold (1.35V)

| $\Delta t_{IS}, \Delta t_{IH}$ derating in [ps] AC/DC based<br>Alternate AC125 Threshold $\rightarrow V_{IH(AC)} = V_{REF(DC)} + 125mV, V_{IL(AC)} = V_{RE-(DC)} - 125mV$ |     |                                |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|--------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                                                                                                                                                           |     | CK, CK# Differential Slew Rate |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|                                                                                                                                                                           |     | 4.0V/ns                        |                 | 3.0V/ns         |                 | 2.0V/ns         |                 | 1.8V/ns         |                 | 1.6V/ns         |                 | 1.4V/ns         |                 | 1.2V/ns         |                 | 1.0V/ns         |                 |
|                                                                                                                                                                           |     | $\Delta t_{IS}$                | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ |
| CMD/ADD<br>Slew Rate<br>V/ns                                                                                                                                              | 2.0 | 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               | 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              | -30             | 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               |

Table- 52 Derating value DDR3-800/1066/1333/1600  $t_{IS}/t_{IH}$  – AC/DC based AC175 Threshold (1.5V)

| $\Delta t_{IS}, \Delta t_{IH}$ derating in [ps] AC/DC based<br>AC175 Threshold $\rightarrow V_{IH(AC)} = V_{REF(DC)} + 175mV, V_{IL(AC)} = V_{RE-(DC)} - 175mV$ |     |                                |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|--------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                                                                                                                                                 |     | CK, CK# Differential Slew Rate |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|                                                                                                                                                                 |     | 4.0V/ns                        |                 | 3.0V/ns         |                 | 2.0V/ns         |                 | 1.8V/ns         |                 | 1.6V/ns         |                 | 1.4V/ns         |                 | 1.2V/ns         |                 | 1.0V/ns         |                 |
|                                                                                                                                                                 |     | $\Delta t_{IS}$                | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ |
| CMD/ADD<br>Slew Rate<br>V/ns                                                                                                                                    | 2.0 | 88                             | 50              | 88              | 50              | 88              | 50              | 96              | 58              | 104             | 66              | 112             | 74              | 120             | 84              | 128             | 100             |
|                                                                                                                                                                 | 1.5 | 59                             | 34              | 59              | 34              | 59              | 34              | 67              | 42              | 75              | 50              | 83              | 58              | 91              | 68              | 99              | 84              |
|                                                                                                                                                                 | 1.0 | 0                              | 0               | 0               | 0               | 0               | 0               | 8               | 8               | 16              | 16              | 24              | 24              | 32              | 34              | 40              | 50              |
|                                                                                                                                                                 | 0.9 | -2                             | -4              | -2              | -4              | -2              | -4              | 6               | 4               | 14              | 12              | 22              | 20              | 30              | 30              | 38              | 46              |
|                                                                                                                                                                 | 0.8 | -6                             | -10             | -6              | -10             | -6              | -10             | 2               | -2              | 10              | 6               | 18              | 14              | 26              | 24              | 34              | 40              |
|                                                                                                                                                                 | 0.7 | -11                            | -16             | -11             | -16             | -11             | -16             | -3              | -8              | 5               | 0               | 13              | 8               | 21              | 18              | 29              | 34              |
|                                                                                                                                                                 | 0.6 | -17                            | -26             | -17             | -26             | -17             | -26             | -9              | -18             | -1              | -10             | 7               | -2              | 15              | 8               | 23              | 24              |
|                                                                                                                                                                 | 0.5 | -35                            | -40             | -35             | -40             | -35             | -40             | -27             | -32             | -19             | -24             | -11             | -16             | -2              | -6              | 5               | 10              |
|                                                                                                                                                                 | 0.4 | -62                            | -60             | -62             | -60             | -62             | -60             | -54             | -52             | -46             | -44             | -38             | -36             | -30             | -26             | -22             | -10             |

Table- 53 Derating value DDR3-800/1066/1333/1600  $t_{IS}/t_{IH}$  – AC/DC based AC150 Threshold (1.5V)

| $\Delta t_{IS}, \Delta t_{IH}$ derating in [ps] AC/DC based<br>Alternate AC150 Threshold $\rightarrow V_{IH(AC)} = V_{REF(DC)} + 150mV, V_{IL(AC)} = V_{RE-(DC)} - 150mV$ |     |                                |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|--------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                                                                                                                                                           |     | CK, CK# Differential Slew Rate |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|                                                                                                                                                                           |     | 4.0V/ns                        |                 | 3.0V/ns         |                 | 2.0V/ns         |                 | 1.8V/ns         |                 | 1.6V/ns         |                 | 1.4V/ns         |                 | 1.2V/ns         |                 | 1.0V/ns         |                 |
|                                                                                                                                                                           |     | $\Delta t_{IS}$                | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ |
| CMD/ADD<br>Slew Rate<br>V/ns                                                                                                                                              | 2.0 | 75                             | 50              | 75              | 50              | 75              | 50              | 83              | 58              | 91              | 66              | 99              | 74              | 107             | 84              | 115             | 100             |
|                                                                                                                                                                           | 1.5 | 50                             | 34              | 50              | 34              | 50              | 34              | 58              | 42              | 66              | 50              | 74              | 58              | 82              | 68              | 90              | 84              |
|                                                                                                                                                                           | 1.0 | 0                              | 0               | 0               | 0               | 0               | 0               | 8               | 8               | 16              | 16              | 24              | 24              | 32              | 34              | 40              | 50              |
|                                                                                                                                                                           | 0.9 | 0                              | -4              | 0               | -4              | 0               | -4              | 8               | 4               | 16              | 12              | 24              | 20              | 32              | 30              | 40              | 46              |
|                                                                                                                                                                           | 0.8 | 0                              | -10             | 0               | -10             | 0               | -10             | 8               | -2              | 16              | 6               | 24              | 14              | 32              | 24              | 40              | 40              |
|                                                                                                                                                                           | 0.7 | 0                              | -16             | 0               | -16             | 0               | -16             | 8               | -8              | 16              | 0               | 24              | 8               | 32              | 18              | 40              | 34              |
|                                                                                                                                                                           | 0.6 | -1                             | -26             | -1              | -26             | -1              | -26             | 7               | -18             | 15              | -10             | 23              | -2              | 31              | 8               | 39              | 24              |
|                                                                                                                                                                           | 0.5 | -10                            | -40             | -10             | -40             | -10             | -40             | -2              | -32             | 6               | -24             | 14              | -16             | 22              | -6              | 30              | 10              |
|                                                                                                                                                                           | 0.4 | -25                            | -60             | -25             | -60             | -25             | -60             | -17             | -52             | -9              | -44             | -1              | -36             | 7               | -26             | 15              | -10             |

Table- 54 Derating value DDR3-1866/2133  $t_{IS}/t_{IH}$  – AC/DC based AC135 Threshold (1.5V)

| $\Delta t_{IS}, \Delta t_{IH}$ derating in [ps] AC/DC based<br>Alternate AC135 Threshold $\rightarrow V_{IH(AC)} = V_{REF(DC)} + 135mV, V_{IL(AC)} = V_{RE-(DC)} - 135mV$ |     |                                |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|--------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                                                                                                                                                           |     | CK, CK# Differential Slew Rate |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|                                                                                                                                                                           |     | 4.0V/ns                        |                 | 3.0V/ns         |                 | 2.0V/ns         |                 | 1.8V/ns         |                 | 1.6V/ns         |                 | 1.4V/ns         |                 | 1.2V/ns         |                 | 1.0V/ns         |                 |
|                                                                                                                                                                           |     | $\Delta t_{IS}$                | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ |
| CMD/ADD<br>Slew Rate<br>V/ns                                                                                                                                              | 2.0 | 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               | 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             |

Table- 55 Derating value DDR3-1866/2133  $t_{IS}/t_{IH}$  – AC/DC based AC125 Threshold (1.5V)

| $\Delta t_{IS}, \Delta t_{IH}$ derating in [ps] AC/DC based<br>Alternate AC125 Threshold $\rightarrow V_{IH(AC)} = V_{REF(DC)} + 125mV, V_{IL(AC)} = V_{RE-(DC)} - 125mV$ |     |                                |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|--------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                                                                                                                                                           |     | CK, CK# Differential Slew Rate |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|                                                                                                                                                                           |     | 4.0V/ns                        |                 | 3.0V/ns         |                 | 2.0V/ns         |                 | 1.8V/ns         |                 | 1.6V/ns         |                 | 1.4V/ns         |                 | 1.2V/ns         |                 | 1.0V/ns         |                 |
|                                                                                                                                                                           |     | $\Delta t_{IS}$                | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ | $\Delta t_{IS}$ | $\Delta t_{IH}$ |
| CMD/ADD<br>Slew Rate<br>V/ns                                                                                                                                              | 2.0 | 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               | 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             |

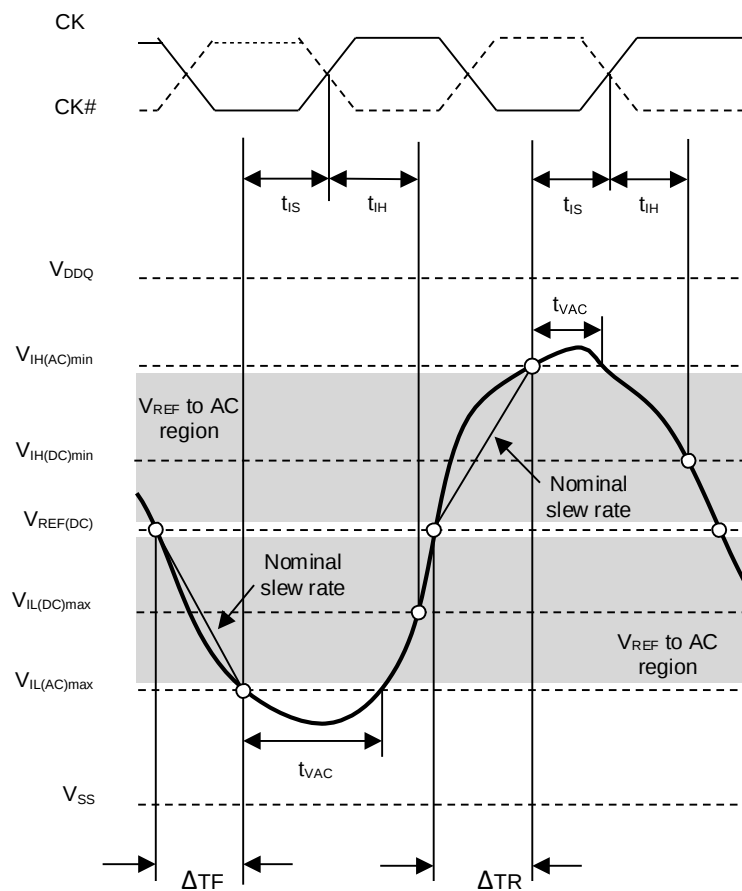
**Table- 56 Required minimum time  $t_{VAC}$  above  $V_{IH(AC)}$  {below  $V_{IL(AC)}$ } for valid ADD/CMD transition (1.35V)**

| Slew Rate [V/ns] | DDR3               |            |            |            | DDR3L              |            |            |            |
|------------------|--------------------|------------|------------|------------|--------------------|------------|------------|------------|
|                  | 800/1066/1333/1600 |            | 1866/2133  |            | 800/1066/1333/1600 |            | 1866/2133  |            |
|                  | 175mV [ps]         | 150mV [ps] | 135mV [ps] | 125mV [ps] | 160mV [ps]         | 135mV [ps] | 135mV [ps] | 125mV [ps] |
| >2.0             | 75                 | 175        | 168        | 173        | 200                | 213        | 200        | 205        |
| 2.0              | 57                 | 170        | 168        | 173        | 200                | 213        | 200        | 205        |
| 1.5              | 50                 | 167        | 145        | 152        | 173                | 190        | 178        | 184        |
| 1.0              | 38                 | 130        | 100        | 110        | 120                | 145        | 133        | 143        |
| 0.9              | 34                 | 113        | 85         | 96         | 102                | 130        | 118        | 129        |
| 0.8              | 29                 | 93         | 66         | 79         | 80                 | 111        | 99         | 111        |
| 0.7              | 22                 | 66         | 42         | 56         | 51                 | 87         | 75         | 89         |
| 0.6              | Note               | 30         | 10         | 27         | 13                 | 55         | 43         | 59         |
| 0.5              | Note               | Note       | Note       | Note       | Note               | 10         | Note       | 18         |
| <0.5             | Note               | Note       | Note       | Note       | Note               | 10         | Note       | 18         |

Note:

1. Rising input signal shall become equal to or greater than  $V_{IH(AC)}$  level and falling input signal shall become equal to or less than  $V_{IL(AC)}$  level.

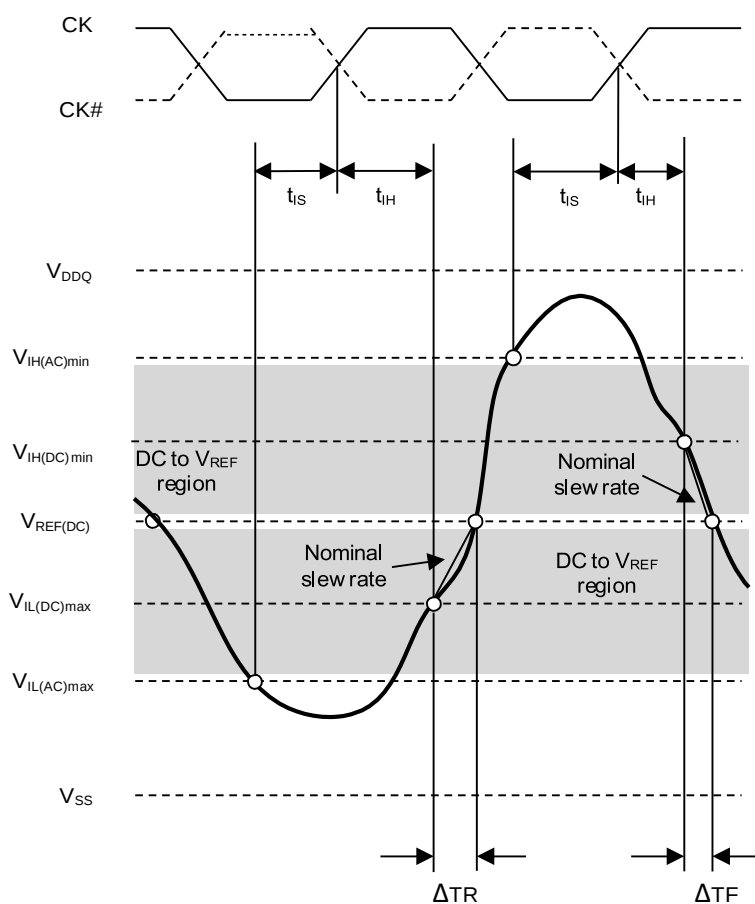
Figure- 22 Illustration of nominal slew rate and  $t_{VAC}$  for setup time  $t_{IS}$  (for ADD/CMD with respect to clock)



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

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

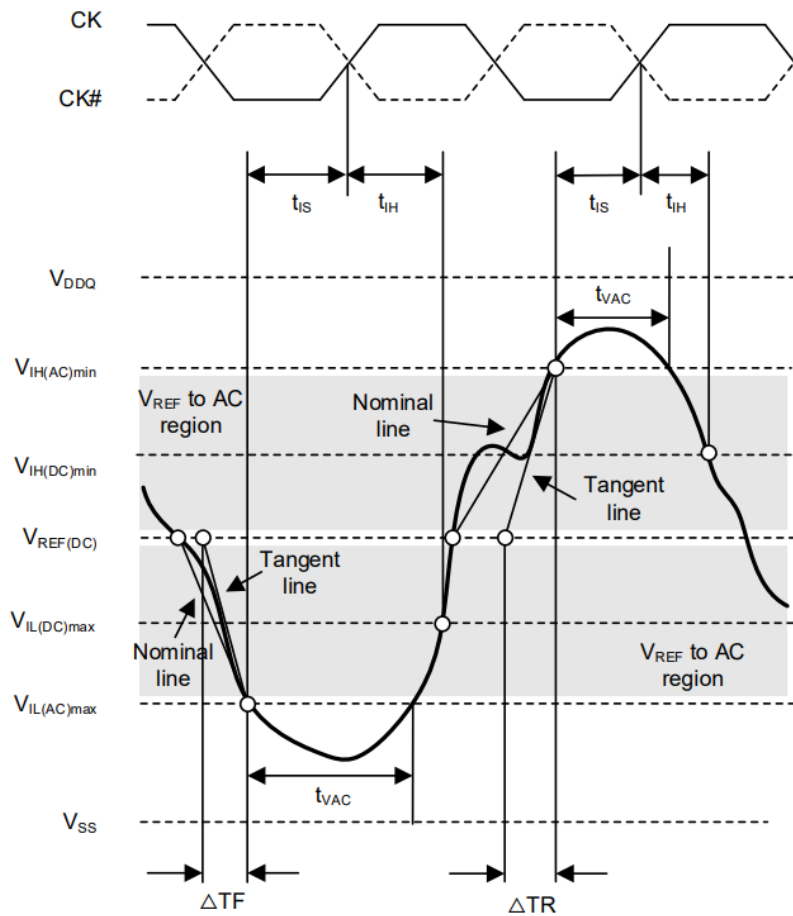
Figure- 23 Illustration of nominal slew rate for hold time  $t_{IH}$  (for ADD/CMD with respect to clock)



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

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

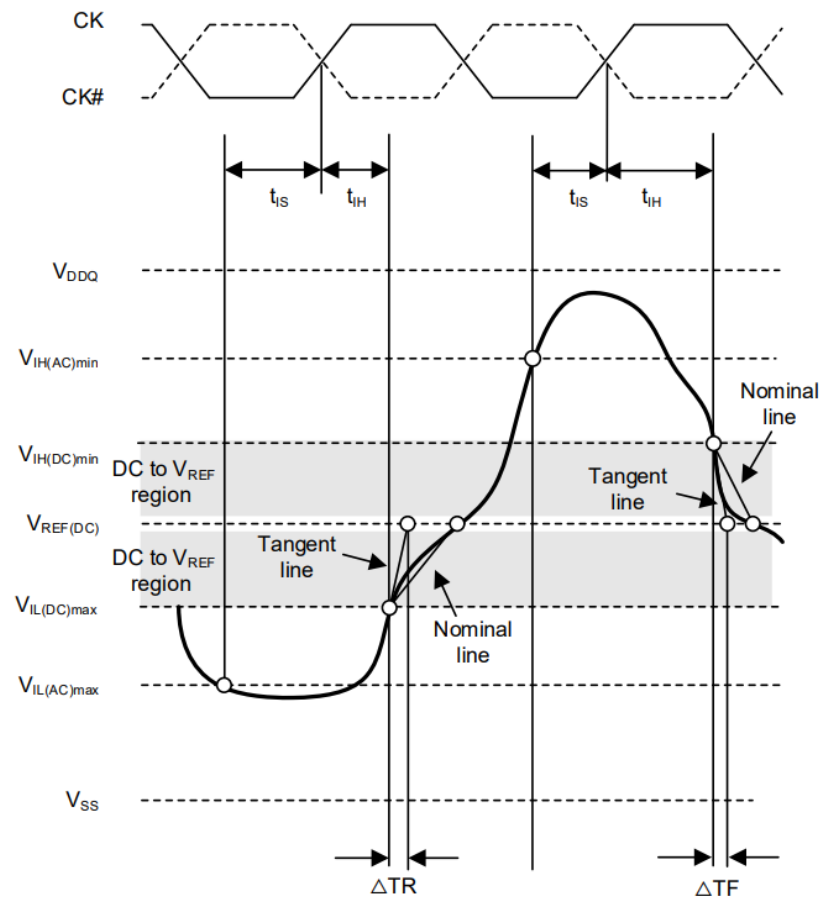
Figure- 24 Illustration of tangent line for setup time t<sub>IS</sub> (for ADD/CMD with respect to clock)



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

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

Figure- 25 Illustration of tangent line for hold time t<sub>lH</sub> (for ADD/CMD with respect to clock)



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

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

## 12.6 Data Setup, Hold and Slew Rate Derating

For all input signals the total  $t_{DS}$  (setup time) and  $t_{DH}$  (hold time) required is calculated by adding the data sheet  $t_{DS(base)}$  and  $t_{DH(base)}$  values to the  $\Delta t_{DS}$  and  $\Delta t_{DH}$  derating value respectively.

Example:  $t_{DS} \text{ (total setup time)} = t_{DS(base)} + \Delta t_{DS}$ .

Setup ( $t_{DS}$ ) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of  $V_{REF(DC)}$  and the first crossing of  $V_{IH(AC)min}$ . Setup ( $t_{DS}$ ) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of  $V_{REF(DC)}$  and the first crossing of  $V_{IL(AC)max}$  (see Figure- 26). If the actual signal is always earlier than the nominal slew rate line between shaded ' $V_{REF(DC)}$  to AC region', use nominal slew rate for derating value. If the actual signal is later than the nominal slew rate line anywhere between shaded ' $V_{REF(DC)}$  to AC region', the slew rate of a tangent line to the actual signal from the AC level to DC level is used for derating value (see Figure- 28).

Hold ( $t_{DH}$ ) nominal slew rate for a rising signal is defined as the slew rate between the last crossing of  $V_{IL(DC)max}$  and the first crossing of  $V_{REF(DC)}$ . Hold ( $t_{DH}$ ) nominal slew rate for a falling signal is defined as the slew rate between the last crossing of  $V_{IH(DC)min}$  and the first crossing of  $V_{REF(DC)}$  (see Figure- 27). If the actual signal is always later than the nominal slew rate line between shaded 'DC level to  $V_{REF(DC)}$  region', use nominal slew rate for derating value. If the actual signal is earlier than the nominal slew rate line anywhere between shaded 'DC to  $V_{REF(DC)}$  region', the slew rate of a tangent line to the actual signal from the DC level to  $V_{REF(DC)}$  level is used for derating value (see Figure- 29).

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

For slew rates in between the values listed in the tables the derating values may obtained by linear interpolation. These values are typically not subject to production test. They are verified by design and characterization.

**Table- 57 Data Setup and Hold Base-Values (1.35V)**

| Symbol                | Reference                     | DDR3L-800 | DDR3L-1066 | DDR3L-1333 | DDR3L-1600 | DDR3L-1866 | DDR3L-2133 | Unit | Note |
|-----------------------|-------------------------------|-----------|------------|------------|------------|------------|------------|------|------|
| $t_{DS(base, AC160)}$ | $V_{IH/IL(AC)}$<br>SR = 1V/ns | 90        | 40         | -          | -          | -          | -          | ps   | 2    |
| $t_{DS(base, AC135)}$ | $V_{IH/IL(AC)}$<br>SR = 1V/ns | 140       | 90         | 45         | 25         | -          | -          | ps   | 2    |
| $t_{DS(base, AC130)}$ | $V_{IH/IL(AC)}$<br>SR = 2V/ns | -         | -          | -          | -          | 70         | 55         | ps   | 1    |
| $t_{DH(base, DC90)}$  | $V_{IH/IL(DC)}$<br>SR = 2V/ns | -         | -          | -          | -          | 75         | 60         | ps   | 2    |
| $t_{DH(base, DC90)}$  | $V_{IH/IL(DC)}$<br>SR = 1V/ns | 160       | 110        | 75         | 55         | -          | -          | ps   | 1    |

**Table- 58 Data Setup and Hold Base-Values (1.5V)**

| Symbol                | Reference                     | DDR3-800 | DDR3-1066 | DDR3-1333 | DDR3-1600 | DDR3-1866 | DDR3-2133 | Unit | Note |
|-----------------------|-------------------------------|----------|-----------|-----------|-----------|-----------|-----------|------|------|
| $t_{DS(base, AC175)}$ | $V_{IH/IL(AC)}$<br>SR = 1V/ns | 75       | 25        | -         | -         | -         | -         | ps   | 2    |
| $t_{DS(base, AC150)}$ | $V_{IH/IL(AC)}$<br>SR = 1V/ns | 125      | 75        | 30        | 10        | -         | -         | ps   | 2    |
| $t_{DS(base, AC135)}$ | $V_{IH/IL(AC)}$<br>SR = 1V/ns | 165      | 115       | 60        | 40        | -         | -         | ps   | 2,3  |
| $t_{DS(base, AC135)}$ | $V_{IH/IL(AC)}$<br>SR = 2V/ns | -        | -         | -         | -         | 68        | 53        | ps   | 1    |
| $t_{DH(base, DC100)}$ | $V_{IH/IL(DC)}$<br>SR = 1V/ns | 150      | 100       | 65        | 45        | -         | -         | ps   | 2    |
| $t_{DH(base, DC100)}$ | $V_{IH/IL(DC)}$<br>SR = 2V/ns | -        | -         | -         | -         | 70        | 55        | ps   | 1    |

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.
3. Optional in DDR3L SDRAM.

**Table- 59 Derating values for DDR3L-800/1066 t<sub>D</sub>-/t<sub>DH</sub> - (AC160) (1.35V)**

| AC160 Threshold-> V <sub>IH(AC)</sub> = V <sub>REF(DC)</sub> + 160mV, V <sub>IL(AC)</sub> = V <sub>RE-(DC)</sub> - 160mV |     |                                  |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |
|--------------------------------------------------------------------------------------------------------------------------|-----|----------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| DDR3L                                                                                                                    |     | DQS, DQS# Differential Slew Rate |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |
|                                                                                                                          |     | 4.0V/ns                          |                   | 3.0V/ns           |                   | 2.0V/ns           |                   | 1.8V/ns           |                   | 1.6V/ns           |                   | 1.4V/ns           |                   | 1.2V/ns           |                   | 1.0V/ns           |                   |
|                                                                                                                          |     | Δ t <sub>DS</sub>                | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> |
| DQ Slew Rate V/ns                                                                                                        | 2.0 | 80                               | 45                | 80                | 45                | 80                | 45                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 |
|                                                                                                                          | 1.5 | 53                               | 30                | 53                | 30                | 53                | 30                | 61                | 38                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 |
|                                                                                                                          | 1.0 | 0                                | 0                 | 0                 | 0                 | 0                 | 0                 | 8                 | 8                 | 16                | 16                | -                 | -                 | -                 | -                 | -                 | -                 |
|                                                                                                                          | 0.9 | -                                | -                 | -1                | -3                | -1                | -3                | 7                 | 5                 | 15                | 13                | 23                | 21                | -                 | -                 | -                 | -                 |
|                                                                                                                          | 0.8 | -                                | -                 | -                 | -                 | -3                | -8                | 5                 | 1                 | 13                | 9                 | 21                | 17                | 29                | 27                | -                 | -                 |
|                                                                                                                          | 0.7 | -                                | -                 | -                 | -                 | -                 | -                 | 3                 | -5                | 11                | 3                 | 19                | 11                | 27                | 21                | 35                | 37                |
|                                                                                                                          | 0.6 | -                                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | 8                 | -4                | 16                | 4                 | 24                | 14                | 32                | 30                |
|                                                                                                                          | 0.5 | -                                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | 4                 | -6                | 12                | 4                 | 20                | 20                |
|                                                                                                                          | 0.4 | -                                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -8                | -11               | 0                 | 5                 |

Note:

1. Cell contents which is '-' are defined as 'not supported'.

**Table- 60 Derating values for DDR3L-800/1066/1333/1600 t<sub>D</sub>-/t<sub>DH</sub> - (AC135) (1.35V)**

| AC135 Threshold-> V <sub>IH(AC)</sub> = V <sub>REF(DC)</sub> + 135mV, V <sub>IL(AC)</sub> = V <sub>RE-(DC)</sub> - 135mV |     |                                  |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |
|--------------------------------------------------------------------------------------------------------------------------|-----|----------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| DDR3L                                                                                                                    |     | DQS, DQS# Differential Slew Rate |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |
|                                                                                                                          |     | 4.0V/ns                          |                   | 3.0V/ns           |                   | 2.0V/ns           |                   | 1.8V/ns           |                   | 1.6V/ns           |                   | 1.4V/ns           |                   | 1.2V/ns           |                   | 1.0V/ns           |                   |
|                                                                                                                          |     | Δ t <sub>DS</sub>                | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> |
| DQ Slew Rate V/ns                                                                                                        | 2.0 | 68                               | 45                | 68                | 45                | 68                | 45                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 |
|                                                                                                                          | 1.5 | 45                               | 30                | 45                | 30                | 45                | 30                | 53                | 38                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 |
|                                                                                                                          | 1.0 | 0                                | 0                 | 0                 | 0                 | 0                 | 0                 | 8                 | 8                 | 16                | 16                | -                 | -                 | -                 | -                 | -                 | -                 |
|                                                                                                                          | 0.9 | -                                | -                 | 2                 | -3                | 2                 | -3                | 10                | 5                 | 18                | 13                | 26                | 21                | -                 | -                 | -                 | -                 |
|                                                                                                                          | 0.8 | -                                | -                 | -                 | -                 | 3                 | -8                | 11                | 1                 | 19                | 9                 | 27                | 17                | 35                | 27                | -                 | -                 |
|                                                                                                                          | 0.7 | -                                | -                 | -                 | -                 | -                 | -                 | 14                | -5                | 22                | 3                 | 30                | 11                | 38                | 21                | 46                | 37                |
|                                                                                                                          | 0.6 | -                                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | 25                | -4                | 33                | 4                 | 41                | 14                | 49                | 30                |
|                                                                                                                          | 0.5 | -                                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | 29                | -6                | 37                | 4                 | 45                | 20                |
|                                                                                                                          | 0.4 | -                                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | 30                | -11               | 38                | 5                 |

Note:

1. Cell contents which is '-' are defined as 'not supported'.

Table- 61 Derating values for DDR3L-1866  $t_D$ -/ $t_{DH}$  - (AC130) (1.35V)

| AC130 Threshold-> $V_{IH(AC)} = V_{REF(DC)} + 130mV$ , $V_{IL(AC)} = V_{RE-(DC)} - 130mV$ |     |                                  |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|-------------------------------------------------------------------------------------------|-----|----------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| DDR3L                                                                                     |     | DQS, DQS# Differential Slew Rate |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|                                                                                           |     | 8.0V/ns                          |                 | 7.0V/ns         |                 | 6.0V/ns         |                 | 5.0V/ns         |                 | 4.0V/ns         |                 | 3.0V/ns         |                 | 2.0V/ns         |                 | 1.8V/ns         |                 | 1.6V/ns         |                 | 1.4V/ns         |                 | 1.2V/ns         |                 | 1.0V/ns         |                 |
|                                                                                           |     | $\Delta t_{DS}$                  | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ |
| DQ Slew Rate V/ns                                                                         | 4.0 | 33                               | 23              | 33              | 23              | 33              | 23              | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               |
|                                                                                           | 3.5 | 28                               | 19              | 28              | 19              | 28              | 19              | 28              | 19              | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               |
|                                                                                           | 3.0 | 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               | 0               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               |
|                                                                                           | 1.5 | -                                | -               | -               | -               | -               | -               | -22             | -15             | -22             | -15             | -22             | -15             | -22             | -15             | -14             | -7              | -               | -               | -               | -               | -               | -               | -               | -               |
|                                                                                           | 1.0 | -                                | -               | -               | -               | -               | -               | -               | -               | -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:

1. Cell contents which is '-' are defined as 'not supported'.

Table- 62 Derating values for DDR3-800/1066 t<sub>D</sub>-/t<sub>DH</sub> - (AC175) (1.5V)

| AC175 Threshold-> V <sub>IH(AC)</sub> = V <sub>REF(DC)</sub> + 175mV, V <sub>IL(AC)</sub> = V <sub>RE-(DC)</sub> - 175mV |     |                                  |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |
|--------------------------------------------------------------------------------------------------------------------------|-----|----------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| DDR3                                                                                                                     |     | DQS, DQS# Differential Slew Rate |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |
|                                                                                                                          |     | 4.0V/ns                          |                   | 3.0V/ns           |                   | 2.0V/ns           |                   | 1.8V/ns           |                   | 1.6V/ns           |                   | 1.4V/ns           |                   | 1.2V/ns           |                   | 1.0V/ns           |                   |
|                                                                                                                          |     | Δ t <sub>DS</sub>                | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> |
| DQ Slew Rate V/ns                                                                                                        | 2.0 | 88                               | 50                | 88                | 50                | 88                | 50                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 |
|                                                                                                                          | 1.5 | 59                               | 34                | 59                | 34                | 59                | 34                | 67                | 42                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 |
|                                                                                                                          | 1.0 | 0                                | 0                 | 0                 | 0                 | 0                 | 0                 | 8                 | 8                 | 16                | 16                | -                 | -                 | -                 | -                 | -                 | -                 |
|                                                                                                                          | 0.9 | -                                | -                 | -2                | -4                | -2                | -4                | 6                 | 4                 | 14                | 12                | 22                | 20                | -                 | -                 | -                 | -                 |
|                                                                                                                          | 0.8 | -                                | -                 | -                 | -                 | -6                | -10               | 2                 | -2                | 10                | 6                 | 18                | 14                | 26                | 24                | -                 | -                 |
|                                                                                                                          | 0.7 | -                                | -                 | -                 | -                 | -                 | -                 | -3                | -8                | 5                 | 0                 | 13                | 8                 | 21                | 18                | 29                | 34                |
|                                                                                                                          | 0.6 | -                                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -1                | -10               | 7                 | -2                | 15                | 8                 | 23                | 24                |
|                                                                                                                          | 0.5 | -                                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -11               | -16               | -2                | -6                | 5                 | 10                |
|                                                                                                                          | 0.4 | -                                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -30               | -26               | -22               | -10               |

Table- 63 Derating values for DDR3-800/1066/1333/1600 t<sub>D</sub>-/t<sub>DH</sub> - (AC150) (1.5V)

| AC150 Threshold-> V <sub>IH(AC)</sub> = V <sub>REF(DC)</sub> + 150mV, V <sub>IL(AC)</sub> = V <sub>RE-(DC)</sub> - 150mV |     |                                  |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |
|--------------------------------------------------------------------------------------------------------------------------|-----|----------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| DDR3                                                                                                                     |     | DQS, DQS# Differential Slew Rate |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |
|                                                                                                                          |     | 4.0V/ns                          |                   | 3.0V/ns           |                   | 2.0V/ns           |                   | 1.8V/ns           |                   | 1.6V/ns           |                   | 1.4V/ns           |                   | 1.2V/ns           |                   | 1.0V/ns           |                   |
|                                                                                                                          |     | Δ t <sub>DS</sub>                | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> | Δ t <sub>DS</sub> | Δ t <sub>DH</sub> |
| DQ Slew Rate V/ns                                                                                                        | 2.0 | 75                               | 50                | 75                | 50                | 75                | 50                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 |
|                                                                                                                          | 1.5 | 50                               | 34                | 50                | 34                | 50                | 34                | 58                | 42                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 |
|                                                                                                                          | 1.0 | 0                                | 0                 | 0                 | 0                 | 0                 | 0                 | 8                 | 8                 | 16                | 16                | -                 | -                 | -                 | -                 | -                 | -                 |
|                                                                                                                          | 0.9 | -                                | -                 | 0                 | -4                | 0                 | -4                | 8                 | 4                 | 16                | 12                | 24                | 20                | -                 | -                 | -                 | -                 |
|                                                                                                                          | 0.8 | -                                | -                 | -                 | -                 | 0                 | -10               | 8                 | -2                | 16                | 6                 | 24                | 14                | 32                | 24                | -                 | -                 |
|                                                                                                                          | 0.7 | -                                | -                 | -                 | -                 | -                 | -                 | 8                 | -8                | 16                | 0                 | 24                | 8                 | 32                | 18                | 40                | 34                |
|                                                                                                                          | 0.6 | -                                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | 15                | -10               | 23                | -2                | 31                | 8                 | 39                | 24                |
|                                                                                                                          | 0.5 | -                                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | 14                | -16               | 22                | -6                | 30                | 10                |
|                                                                                                                          | 0.4 | -                                | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | -                 | 7                 | -26               | 15                | -10               |

Table- 64 Derating values for DDR3-800/1066/1333/1600  $t_D$ -/ $t_{DH}$  - (AC135) (1.5V)

| AC150 Threshold-> $V_{IH(AC)} = V_{REF(DC)} + 150mV$ , $V_{IL(AC)} = V_{RE-(DC)} - 150mV$ |     |                                  |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|-------------------------------------------------------------------------------------------|-----|----------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| DDR3                                                                                      |     | DQS, DQS# Differential Slew Rate |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|                                                                                           |     | 4.0V/ns                          |                 | 3.0V/ns         |                 | 2.0V/ns         |                 | 1.8V/ns         |                 | 1.6V/ns         |                 | 1.4V/ns         |                 | 1.2V/ns         |                 | 1.0V/ns         |                 |
|                                                                                           |     | $\Delta t_{DS}$                  | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ |
| DQ<br>Slew<br>Rate<br>V/ns                                                                | 2.0 | 68                               | 50              | 68              | 50              | 68              | 50              | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               |
|                                                                                           | 1.5 | 45                               | 34              | 45              | 34              | 45              | 34              | 53              | 42              | -               | -               | -               | -               | -               | -               | -               | -               |
|                                                                                           | 1.0 | 0                                | 0               | 0               | 0               | 0               | 0               | 8               | 8               | 16              | 16              | -               | -               | -               | -               | -               | -               |
|                                                                                           | 0.9 | -                                | -               | 2               | -4              | 2               | -4              | 10              | 4               | 18              | 12              | 26              | 20              | -               | -               | -               | -               |
|                                                                                           | 0.8 | -                                | -               | -               | -               | 3               | -10             | 11              | -2              | 19              | 6               | 27              | 14              | 35              | 24              | -               | -               |
|                                                                                           | 0.7 | -                                | -               | -               | -               | -               | -               | 14              | -8              | 22              | 0               | 30              | 8               | 38              | 18              | 46              | 34              |
|                                                                                           | 0.6 | -                                | -               | -               | -               | -               | -               | -               | -               | 25              | -10             | 33              | -2              | 41              | 8               | 49              | 24              |
|                                                                                           | 0.5 | -                                | -               | -               | -               | -               | -               | -               | -               | -               | -               | 29              | -16             | 37              | -6              | 45              | 10              |
|                                                                                           | 0.4 | -                                | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | 30              | -26             | 38              | -10             |

Table- 65 Derating values for DDR3-1866/2133  $t_D$ -/ $t_{DH}$  - (AC135) (1.5V)

| AC135Threshold -> $V_{IH(AC)} = V_{REF(DC)} + 135mV$ , $V_{IL(AC)} = V_{RE-(DC)} - 135mV$<br>DC100Threshold -> $V_{IH(DC)} = V_{REF(DC)} + 100mV$ , $V_{IL(DC)} = V_{RE-(DC)} - 100mV$ |     |                                  |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|----------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                                                                                                                                                                        |     | DQS, DQS# Differential Slew Rate |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|                                                                                                                                                                                        |     | 8.0V/ns                          |                 | 7.0V/ns         |                 | 6.0V/ns         |                 | 5.0V/ns         |                 | 4.0V/ns         |                 | 3.0V/ns         |                 | 2.0V/ns         |                 | 1.8V/ns         |                 | 1.6V/ns         |                 | 1.4V/ns         |                 | 1.2V/ns         |                 | 1.0V/ns         |                 |
|                                                                                                                                                                                        |     | $\Delta t_{DS}$                  | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ | $\Delta t_{DS}$ | $\Delta t_{DH}$ |
| DQ Slew Rate V/ns                                                                                                                                                                      | 4.0 | 34                               | 25              | 34              | 25              | 34              | 25              | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               |
|                                                                                                                                                                                        | 3.5 | 29                               | 21              | 29              | 21              | 29              | 21              | 29              | 21              | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               |
|                                                                                                                                                                                        | 3.0 | 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               | 0               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               |
|                                                                                                                                                                                        | 1.5 | -                                | -               | -               | -               | -               | -               | -23             | -17             | -23             | -17             | -23             | -17             | -23             | -17             | -15             | -9              | -               | -               | -               | -               | -               | -               | -               | -               |
|                                                                                                                                                                                        | 1.0 | -                                | -               | -               | -               | -               | -               | -               | -               | -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 | -                                | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -               | -36             | -76             | -30             | -60             |

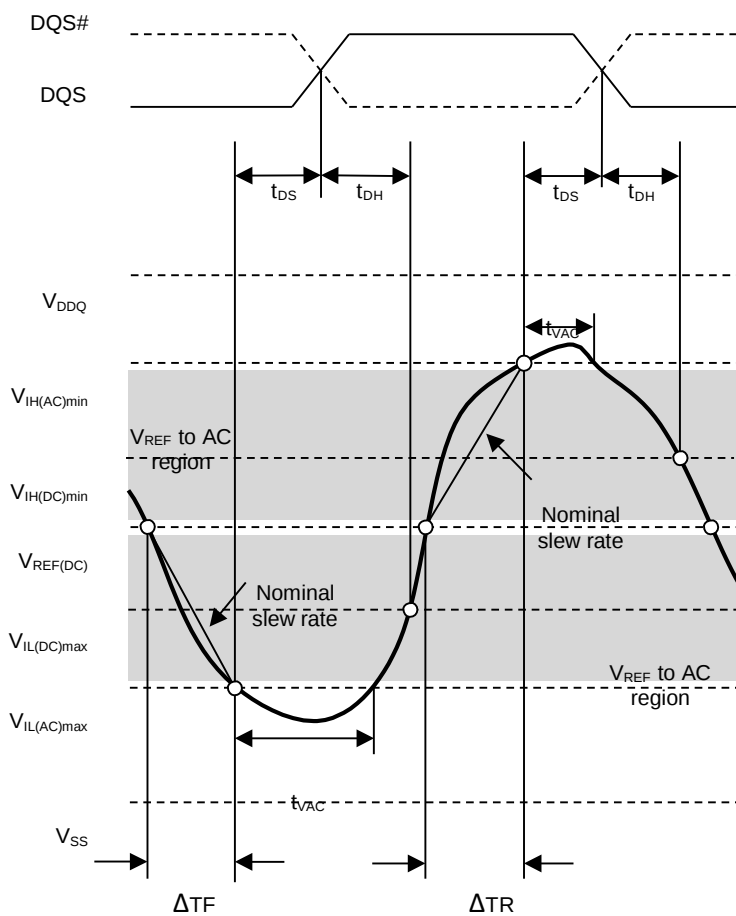
Table- 66 Required minimum time  $t_{VAC}$  above  $V_{IH(AC)}$  {below  $V_{IL(AC)}$ } for valid DQ transition

| Slew Rate [V/ns] | DDR3 (1.5V) |                        |                        |      |      | DDR3L (1.35V) |                        |       |       | Unit |
|------------------|-------------|------------------------|------------------------|------|------|---------------|------------------------|-------|-------|------|
|                  | 800/1066    | 800/1066/<br>1333/1600 | 800/1066/<br>1333/1600 | 1866 | 2133 | 800/1066      | 800/1066/<br>1333/1600 | 1866  | 2133  |      |
|                  | AC175       | AC150                  | AC135                  |      |      | AC160         | AC135                  | AC130 | AC130 |      |
| >2.0             | 75          | 105                    | 113                    | 93   | 73   | 165           | 113                    | 95    | 73    | ps   |
| 2.0              | 57          | 105                    | 113                    | 93   | 73   | 165           | 113                    | 95    | 73    | ps   |
| 1.5              | 50          | 80                     | 90                     | 70   | 50   | 138           | 90                     | 73    | 50    | ps   |
| 1.0              | 38          | 30                     | 45                     | 25   | 5    | 85            | 45                     | 30    | 5     | ps   |
| 0.9              | 34          | 13                     | 30                     | Note | Note | 67            | 30                     | 16    | Note  | ps   |
| 0.8              | 29          | Note                   | 11                     | Note | Note | 45            | 11                     | Note  | Note  | ps   |
| 0.7              | Note        | Note                   | Note                   | -    | -    | 16            | Note                   | -     | -     | ps   |
| 0.6              | Note        | Note                   | Note                   | -    | -    | Note          | Note                   | -     | -     | ps   |
| 0.5              | Note        | Note                   | Note                   | -    | -    | Note          | Note                   | -     | -     | ps   |
| <0.5             | Note        | Note                   | Note                   | -    | -    | Note          | Note                   | -     | -     | ps   |

Note:

1. Rising input signal shall become equal to or greater than  $V_{IH(AC)}$  level and falling input signal shall become equal to or less than  $V_{IL(AC)}$  level.

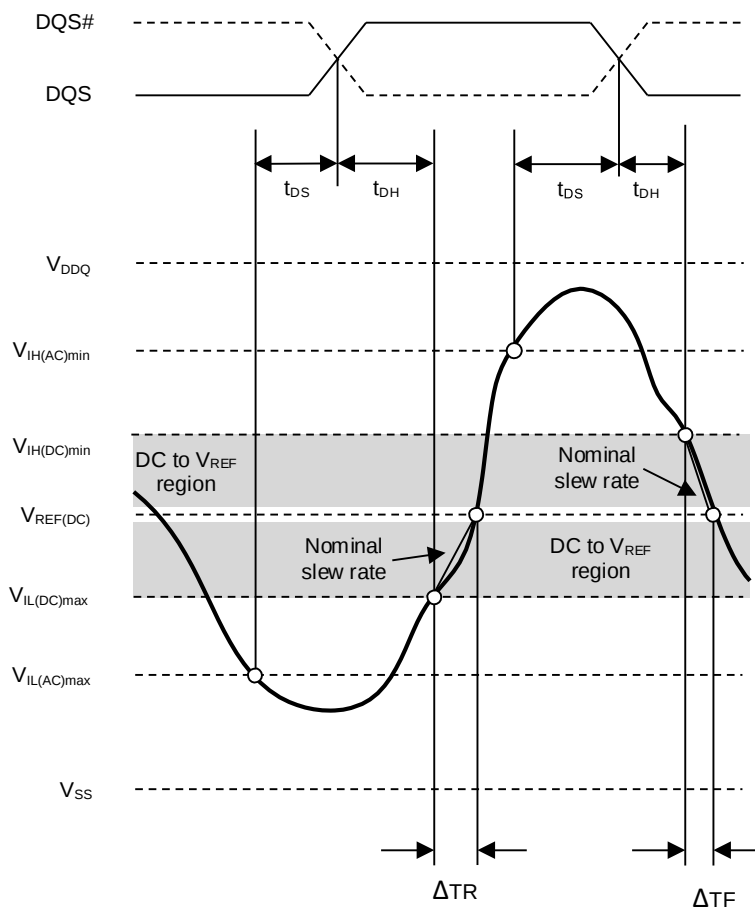
Figure- 26 Illustration of nominal slew rate and t<sub>VAC</sub> for setup time t<sub>DS</sub> (for DQ with respect to strobe)



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

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

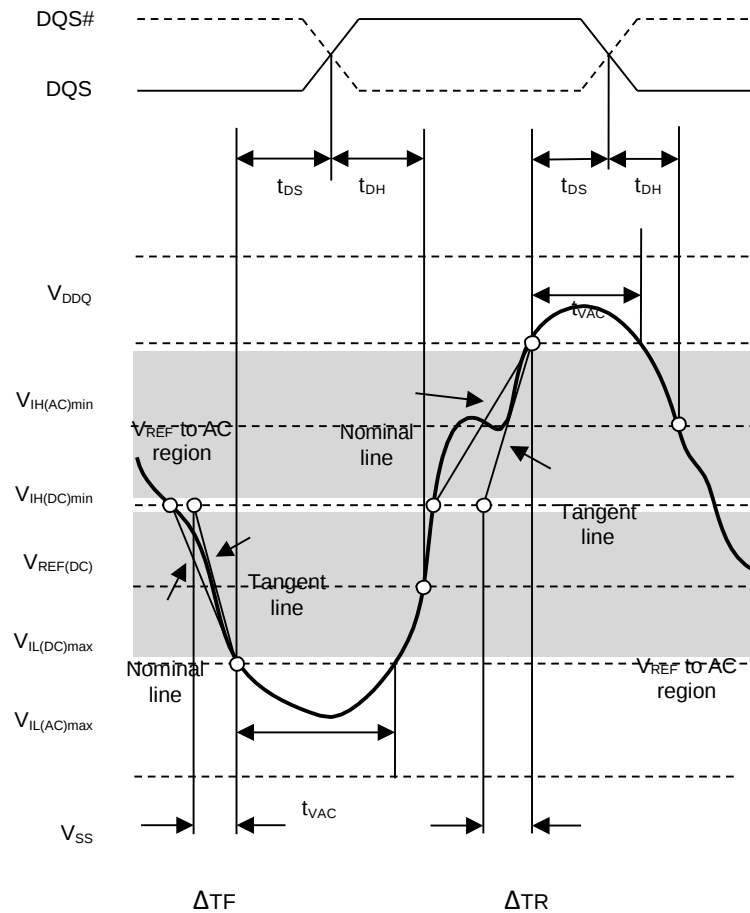
Figure- 27 Illustration of nominal slew rate for hold time  $t_{DH}$  (for DQ with respect to strobe)



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

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

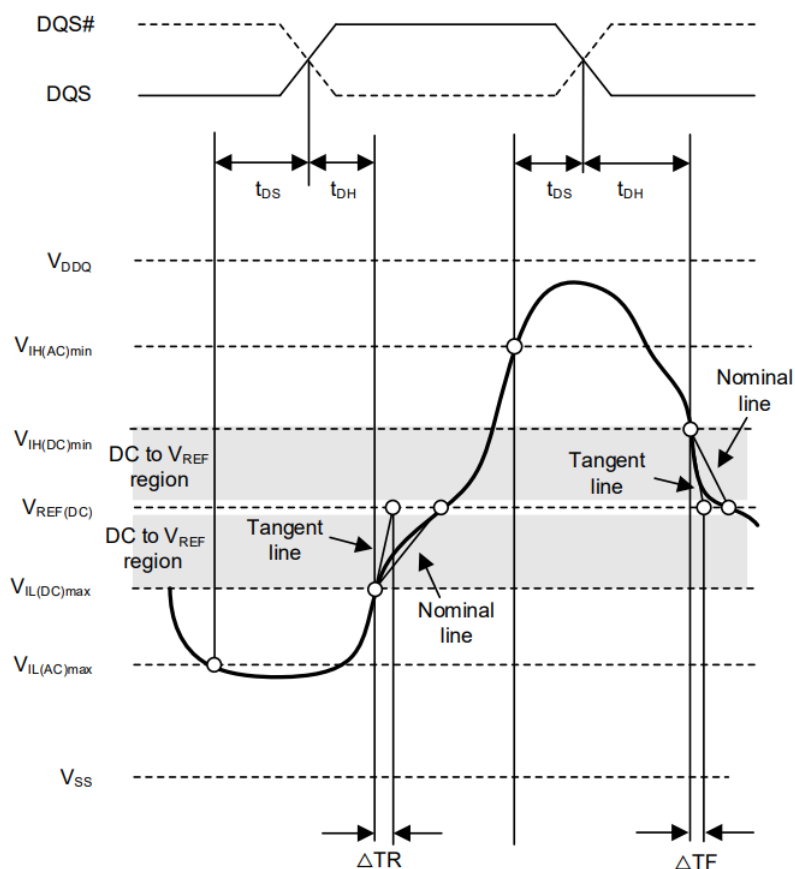
Figure- 28 Illustration of tangent line for setup time  $t_{DS}$  (for DQ with respect to strobe)



$$\text{Setup Slew Rate Rising Signal} = \frac{\text{tangent line}[V_{IH(AC)min} - V_{REF(dc)}]}{\Delta TR}$$

$$\text{Setup Slew Rate Falling Signal} = \frac{\text{tangent line}[V_{REF(dc)min} - V_{IL(AC)max}]}{\Delta TF}$$

Figure- 29 Illustration of tangent line for hold time  $t_{DH}$  (for DQ with respect to strobe)



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

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

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